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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Bing		Dai	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Fremont	State/Province	CA	Country of Residence [i]	US

Citizenship under 37 CFR 1.41(b) [i]	CN

Mailing Address of Applicant:

Address 1	4987 Central Avenue, #237
Address 2	

City	Fremont	State/Province	CA

Postal Code	94536	Country [i]	US

Applicant 2 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Xianglong		Yuan	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Fremont	State/Province	CA	Country of Residence [i]	US

Citizenship under 37 CFR 1.41(b) [i]	CN

Mailing Address of Applicant:

Address 1	360 Escobar Street
Address 2	

City	Fremont	State/Province	CA

Postal Code	94539	Country [i]	US

Applicant 3 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Gang		Wang	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Milpitas	State/Province	CA	Country of Residence [i]	US

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	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Citizenship under 37 CFR 1.41(b) i	CN				
Mailing Address of Applicant:					
Address 1	416 Capella Way				
Address 2					
City	Milpitas	**State/Province**	CA		
Postal Code	95035	**Country**i	US		

Applicant 4 Remove

Applicant Authority (•) Inventor ( ) Legal Representative under 35 U.S.C. 117 ( ) Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Charles		Edwards	

Residence Information (Select One) (•) US Residency ( ) Non US Residency ( ) Active US Military Service

City	Pleasanton	**State/Province**	CA	**Country of Residence** i	US
Citizenship under 37 CFR 1.41(b) i	US				
Mailing Address of Applicant:					
Address 1	4380 Entrada Drive				
Address 2					
City	Pleasanton	**State/Province**	CA		
Postal Code	94566	**Country**i	US		

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	84561		
Email Address	pcm@viplawgroup.com	Add Email	Remove Email

Application Information:

Title of the Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER		
Attorney Docket Number	ITMX-VISTA-00318US1	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		**Sub Class (if any)**	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	25	**Suggested Figure for Publication (if any)**	

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S. C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	84561		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61427411	2010-12-27
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation in part of	13253031	2011-10-04
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
13253031	non provisional of	61390091	2010-10-05

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

Remove

Application Number	Country [i]	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			◉ Yes ○ No

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	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.

Assignee 1 Remove

If the Assignee is an Organization check here. ☒

Organization Name	Intematix Corporation		
Mailing Address Information:			
Address 1	46430 Fremont Blvd.		
Address 2			
City	Fremont	**State/Province**	CA
Country [i]	US	Postal Code	94538
Phone Number		Fax Number	
Email Address			

Additional Assignee Data may be generated within this form by selecting the **Add** button. Add

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Peter C. Mei/			Date (YYYY-MM-DD)	2011-10-13
First Name	Peter C.	Last Name	Mei	Registration Number	39768

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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CLAIMS

What is claimed is:

1. A wavelength conversion component for a light emitting device comprising:

a wavelength conversion layer comprising particles of at least one photoluminescence material; and

a light diffusing layer comprising particles of a light scattering material.

2. The component of Claim 1, wherein the wavelength conversion layer and the light diffusing layer are in direct contact with each other.

3. The component of Claim 1, wherein the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder.

4. The component of Claim 3, wherein the wavelength conversion layer further comprises a second light scattering material.

5. The component of Claim 4, wherein the light scattering material and the second light scattering material have different material properties.

6. The component of Claim 3, wherein the light transmissive binder comprises a curable liquid polymer selected from the group consisting of: a polymer resin, a monomer resin, an

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acrylic, an epoxy, a silicone and a fluorinated polymer.

7. The component of Claim 2, wherein the weight loading of light scattering material to binder selected from the group consisting of: 7% to 35% and 10% to 20%.

8. The component of Claim 1, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

9. The component of Claim 1, wherein the wavelength conversion and light diffusing layers are deposited using a method selected from the group consisting of: screen printing, slot die coating, spin coating, roller coating, drawdown coating and doctor blading.

10. The component of Claim 1, wherein the light scattering material is selected from the group consisting of: titanium dioxide, barium sulfate, magnesium oxide, silicon dioxide and aluminum oxide.

11. The component of Claim 1, wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material.

12. The component of Claim 11, wherein the light scattering material scatters the excitation light at least twice as much as light generated by the at least one photoluminescence material.

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13. The component of Claim 11, wherein the excitation light comprises blue light.

14. The component of Claim 13, wherein the light scattering material has an average particle size that is less than about 150nm.

15. The component of Claim 1, wherein the light diffusing layer is deposited on a light transmissive substrate, and the light transmissive substrate is selected from the group consisting of: a polycarbonate, an acrylic and a glass.

16. The component of Claim 1 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

17. The component of Claim 1 in which the light diffusing layer comprises a dome or elongated dome shape.

18. The component of claim 17 in which the wavelength conversion layer fills a volume formed beneath the dome or elongated dome shapes.

19. A light emitting device, comprising:

at least one solid-state light emitter operable to generate excitation light;

a wavelength conversion layer excitable by the excitation light, wherein the wavelength conversion layer comprises particles of at least one photoluminescence material; and

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a light diffusing layer comprising particles of a light scattering material.

20. The device of claim 19, wherein the light emitting device is selected from the group consisting of: downlights, light bulbs, linear lamps, lanterns, wall lamps, pendant lamps, chandeliers, recessed lights, track lights, accent lights, stage lighting, movie lighting, street lights, flood lights, beacon lights, security lights, traffic lights, headlamps, taillights, and signs.

21. The device of claim 19 in which the light scattering material within the light diffusing layer corresponds to an average particle size that improves an OFF state white appearance of the light emitting device.

22. The device of claim 19 in which the light diffusing layer is configured to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a $\pm 60^{o}$ range from an emission axis.

23. The device of claim 22, wherein a weight loading of the light scattering material to a binder selected from the group consisting of: 7% to 35% and 10% to 20%.

24. The device of Claim 19, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

25. The device of Claim 19 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

26. The device of Claim 19 in which the light diffusing layer comprises a dome or elongated

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dome shape.

27. A linear lamp comprising:

an elongate housing;

a plurality of solid-state light emitters housed within the housing and configured along the length of the housing; and

an elongate wavelength conversion component remote to the plurality of solid-state light emitters and configured to in part at least define a light mixing chamber,

wherein the elongate wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material.

28. A downlight comprising:

a body comprising one or more solid-state light emitters, wherein the body is configured to be positioned within a downlighting fixture such that the downlight emits light in a downward direction; and

a wavelength conversion component remote to the one or more solid-state light emitters and configured to in part at least define a light mixing chamber,

wherein the wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material.

29. A light bulb comprising:

a connector base configured to be inserted in a socket to form an electrical connection for the light bulb;

a body comprising one or more solid-state light emitters;

a wavelength conversion component having a three dimensional shape that is configured to enclose the one or more solid-state light emitters and to in part at least define a light mixing chamber,

wherein the wavelength conversion component comprises a wavelength conversion layer

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comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material.

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ABSTRACT

A light emitting device comprises at least one solid-state light source (LED) operable to generate excitation light and a wavelength conversion component located remotely to the at least one source and operable to convert at least a portion of the excitation light to light of a different wavelength. The wavelength conversion component comprises a light transmissive substrate having a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light diffractive material. This approach of using the light diffusing layer in combination with the wavelength conversion layer solves the problem of variations or non-uniformities in the color of emitted light with emission angle. In addition, the color appearance of the lighting apparatus in its OFF state can be improved by implementing the light diffusing layer in combination with the wavelength conversion layer. Moreover, significant reductions can be achieved in the amount phosphor materials required to implement phosphor-based LED devices.

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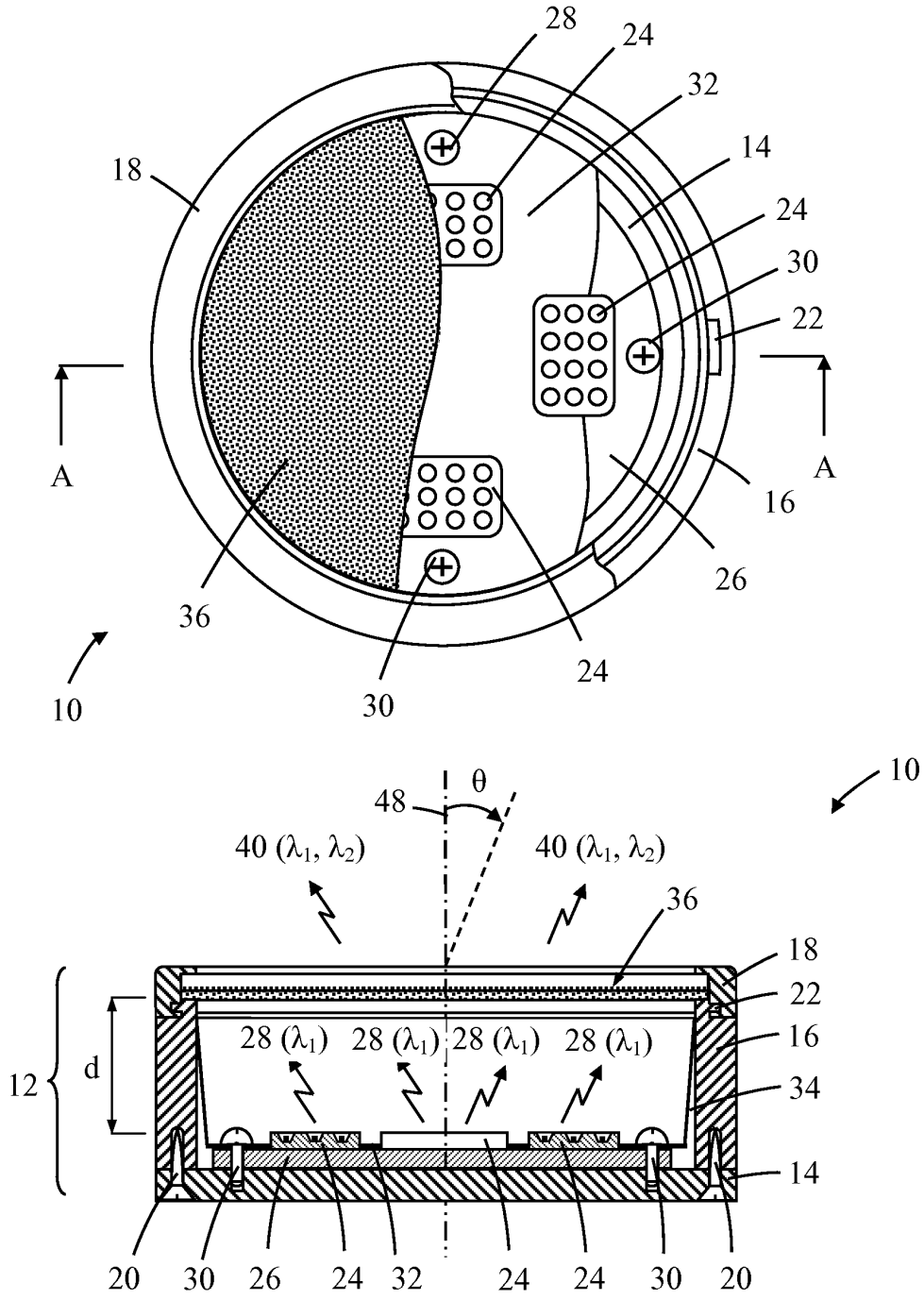

28
24
32
14
18
24
30
22
A
A
16
26
36
24
10
30
10
θ
48
40 (λ1, λ2)
40 (λ1, λ2)
36
18
22
28 (λ1)
28 (λ1)
28 (λ1)
28 (λ1)
16
12
d
34
14
20
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26
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24
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30
20

FIG. 1

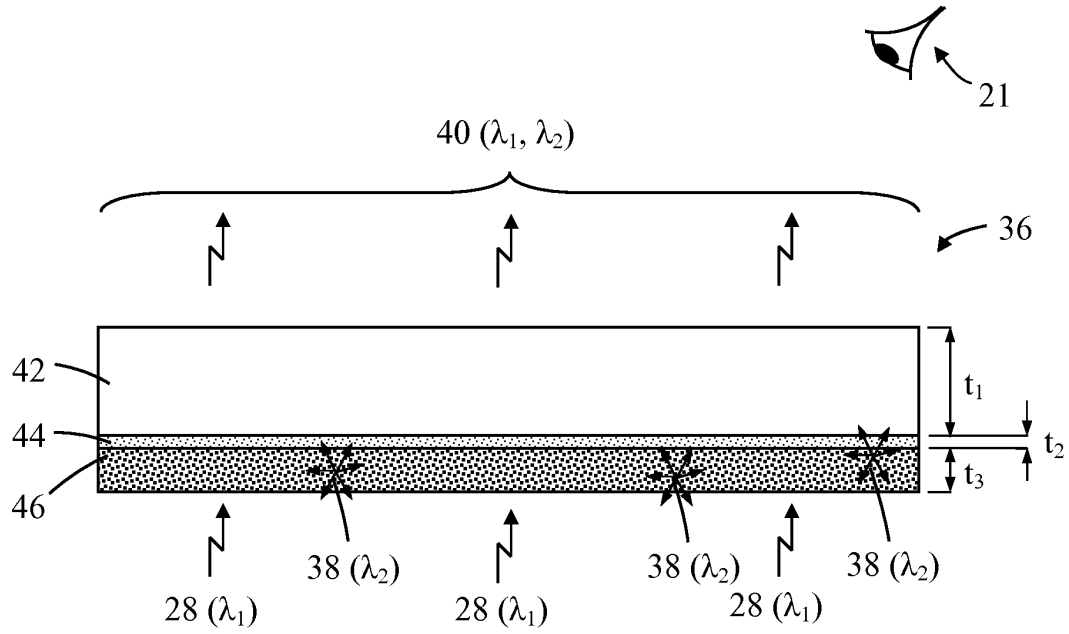

21
40 (λ1, λ2)
36
42
44
46
t1
t2
t3
38 (λ2)
38 (λ2)
38 (λ2)
28 (λ1)
28 (λ1)
28 (λ1)

FIG. 2

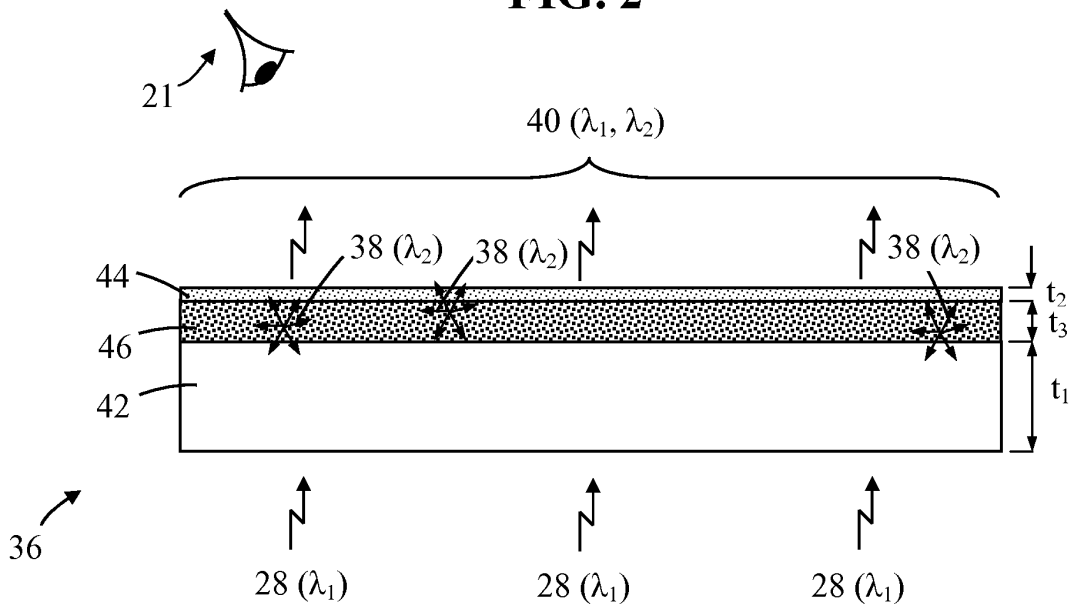

21
40 (λ1, λ2)
38 (λ2)
38 (λ2)
38 (λ2)
44
46
42
t2
t3
t1
36
28 (λ1)
28 (λ1)
28 (λ1)

FIG. 3

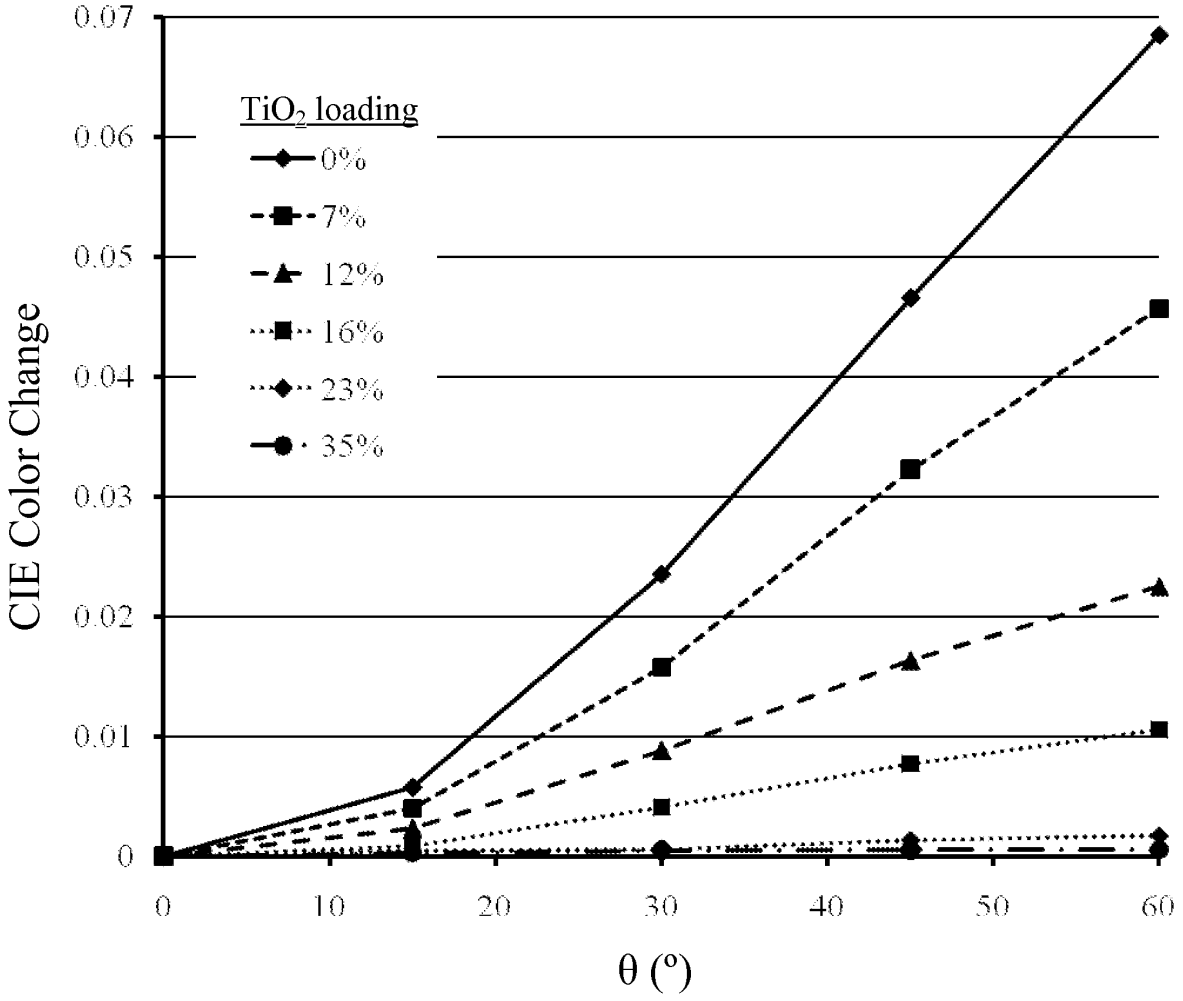

0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
CIE Color Change
TiO2 loading
0%
7%
12%
16%
23%
35%
0
10
20
30
40
50
60
θ (°)

FIG. 4

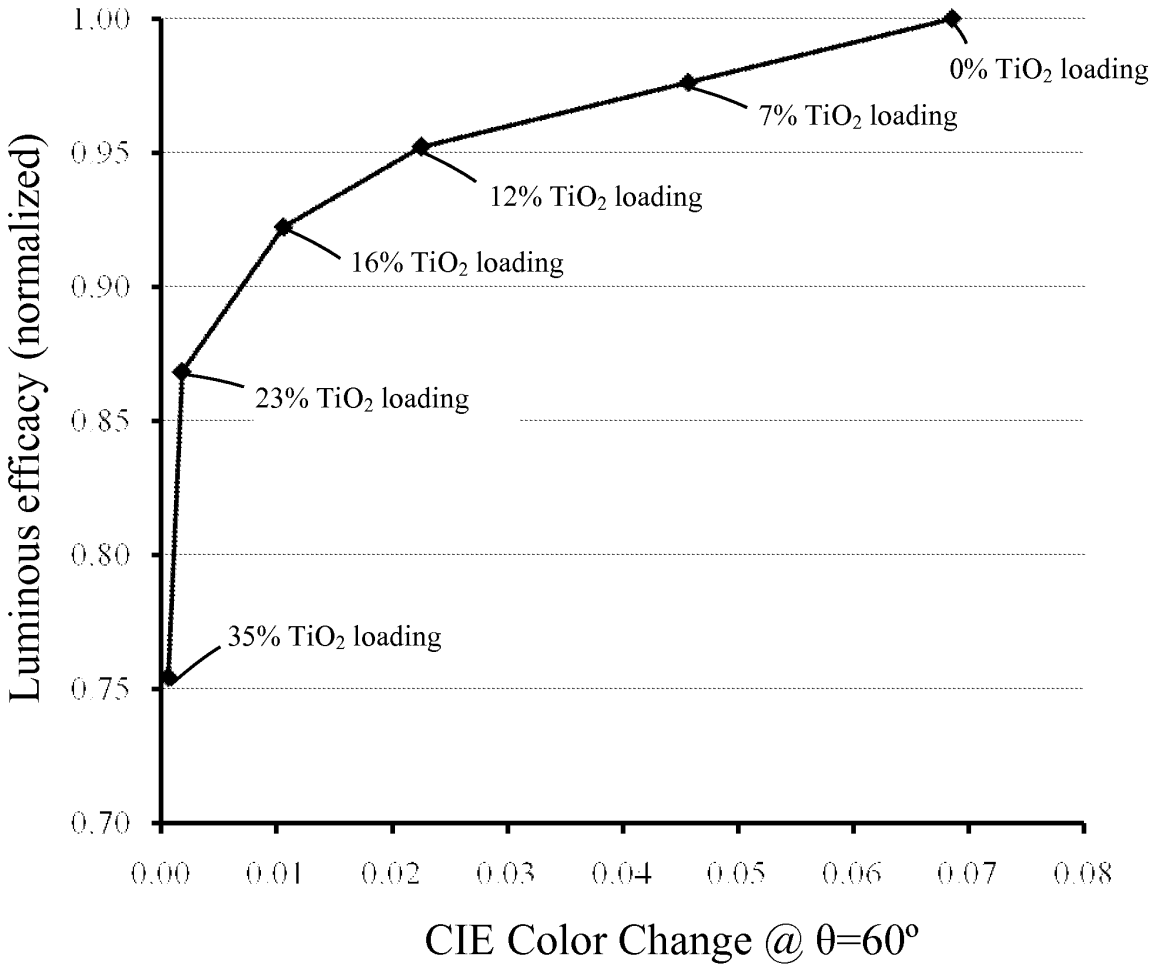

1.00
0.95
0.90
0.85
0.80
0.75
0.70
Luminous efficacy (normalized)
0% TiO2 loading
7% TiO2 loading
12% TiO2 loading
16% TiO2 loading
23% TiO2 loading
35% TiO2 loading
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
CIE Color Change @ θ=60º

FIG. 5

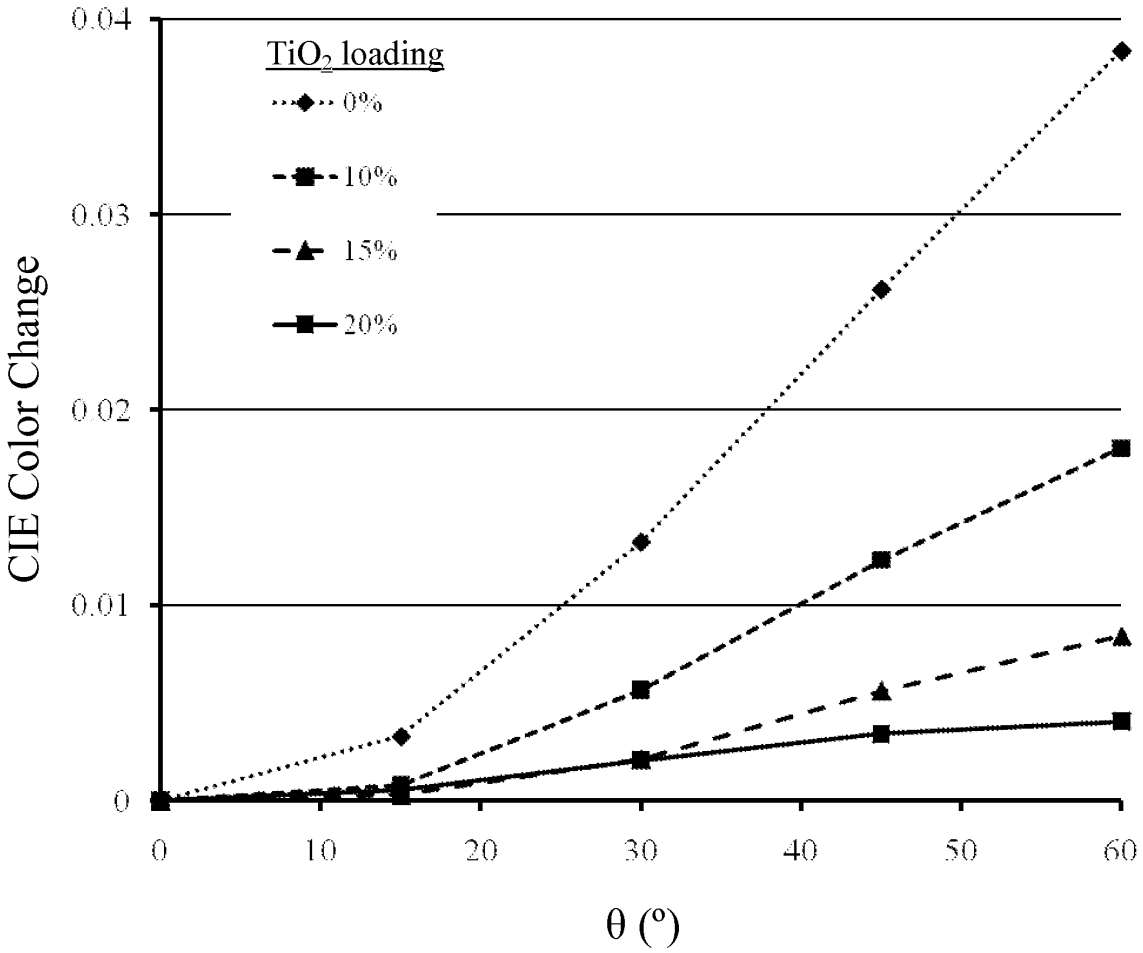

0.04
0.03
0 02
0.01
0
CIE Color Change
TiO2 loading
0%
10%
15%
20%
0
10
20
30
40
50
60
θ (°)

FIG. 6

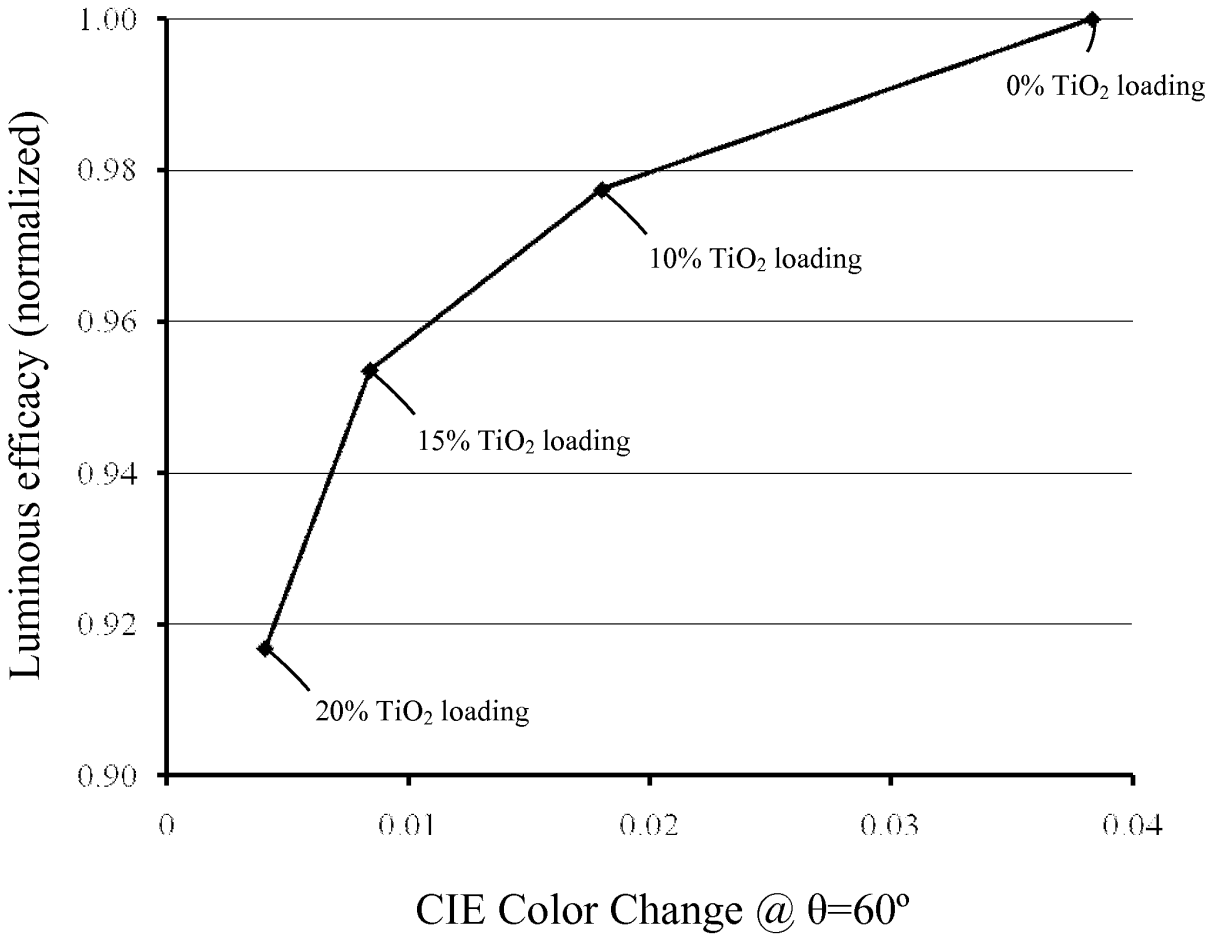

1.00
0.98
0.96
0.94
0.92
0.90
Luminous efficacy (normalized)
0% TiO2 loading
10% TiO2 loading
15% TiO2 loading
20% TiO2 loading
0
0.01
0.02
0.03
0.04
CIE Color Change @ θ=60º

FIG. 7

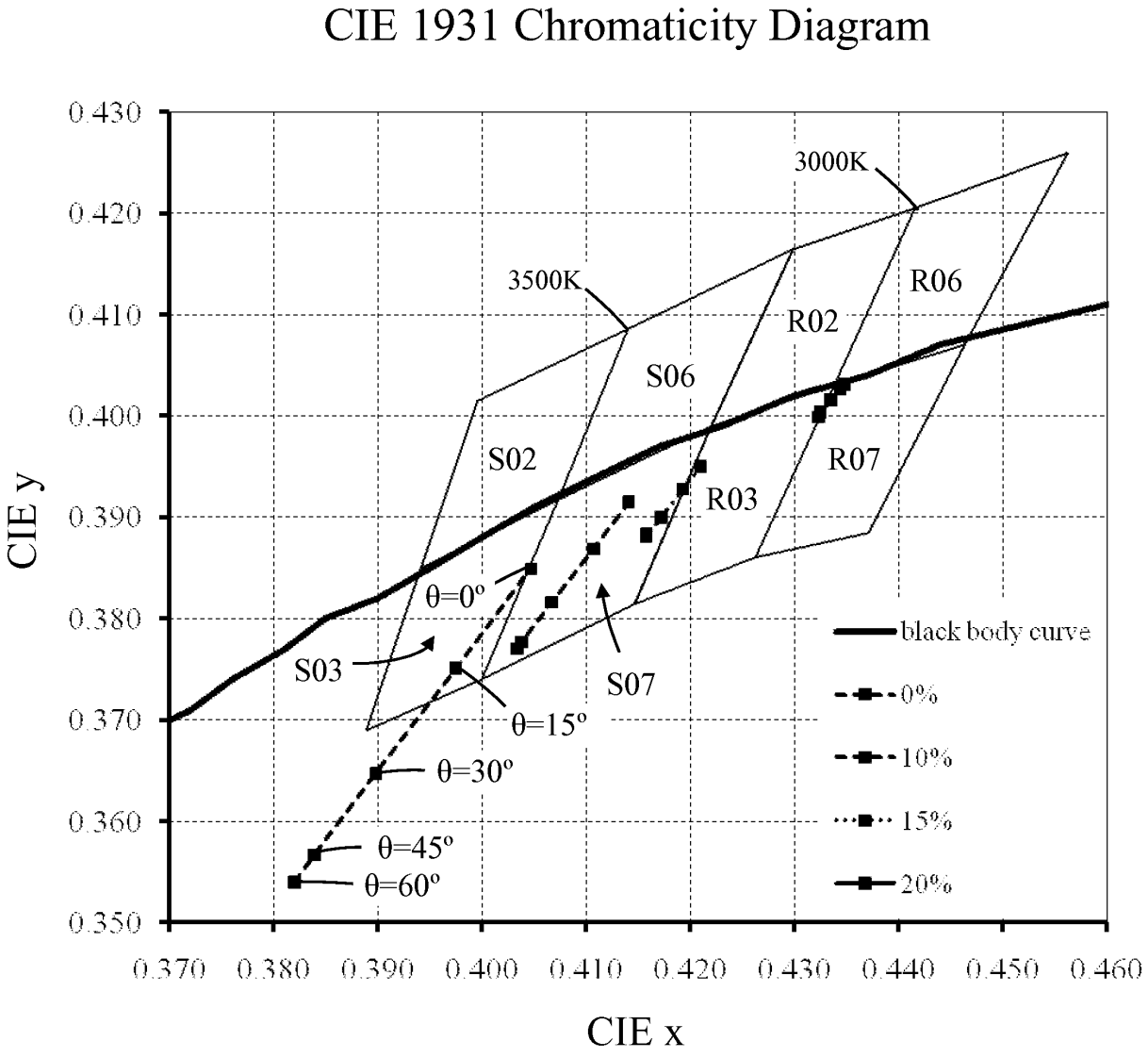

CIE 1931 Chromaticity Diagram
CIE y
CIE x
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0.420
0.410
0.400
0.390
0.380
0.370
0.360
0.350
0.370
0.380
0.390
0.400
0.410
0.420
0.430
0.440
0.450
0.460
3000K
3500K
R06
R02
S06
S02
R07
R03
S03
S07
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θ=15º
θ=30º
θ=45º
θ=60º
black body curve
0%
10%
15%
20%

FIG. 8

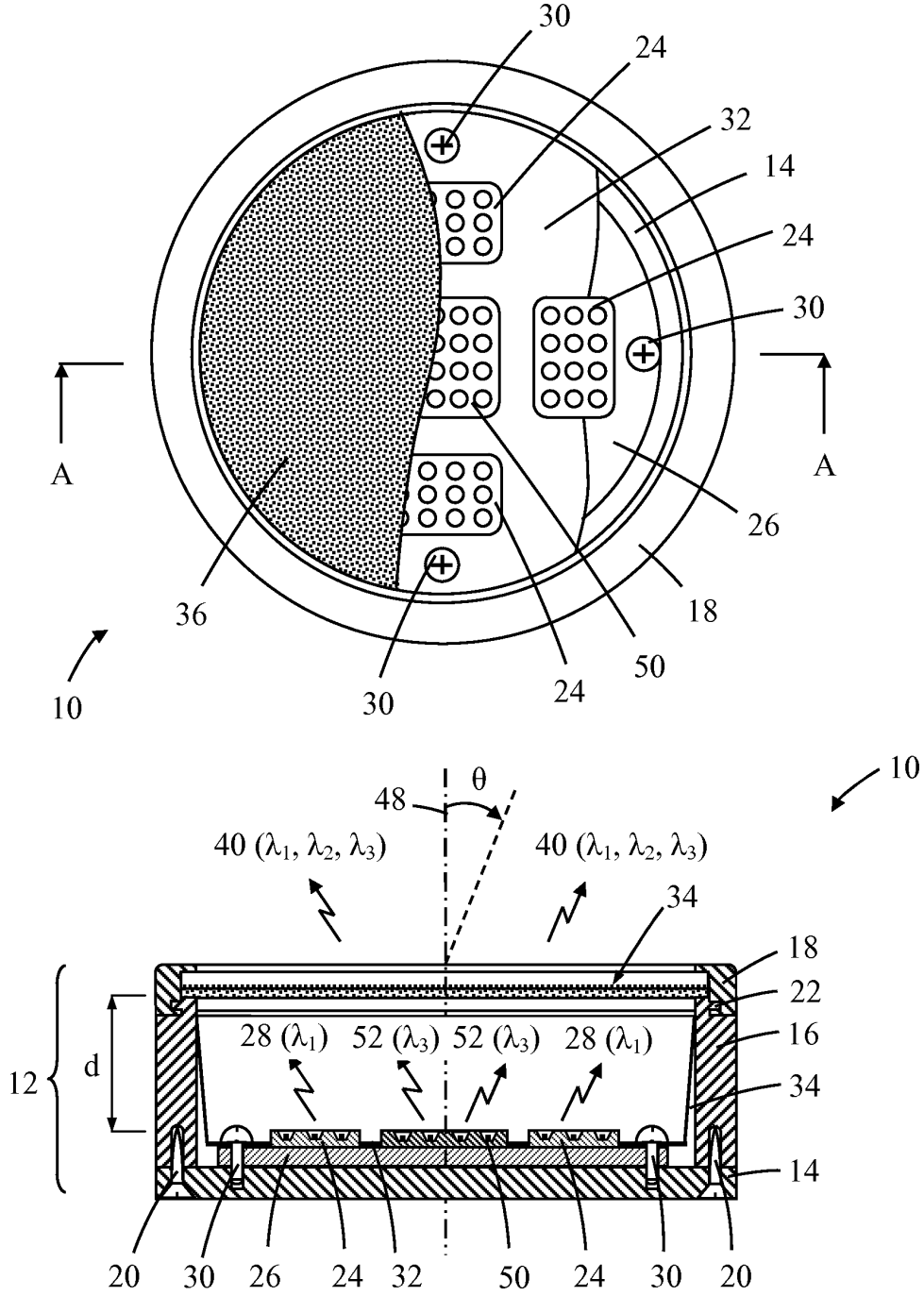

30
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A
A
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10
θ
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40 (λ1, λ2, λ3)
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18
22
16
34
14
12
d
28 (λ1)
52 (λ3)
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28 (λ1)
20
30
26
24
32
50
24
30
20

FIG. 9

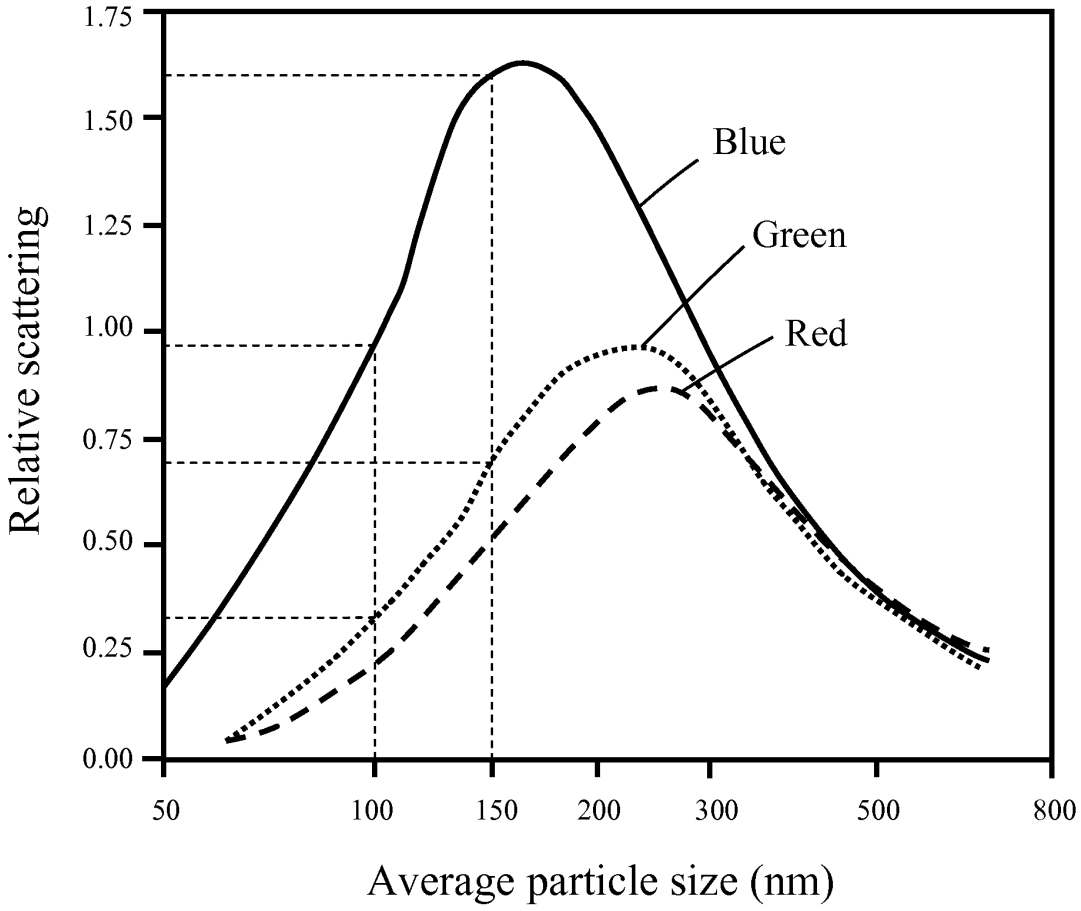
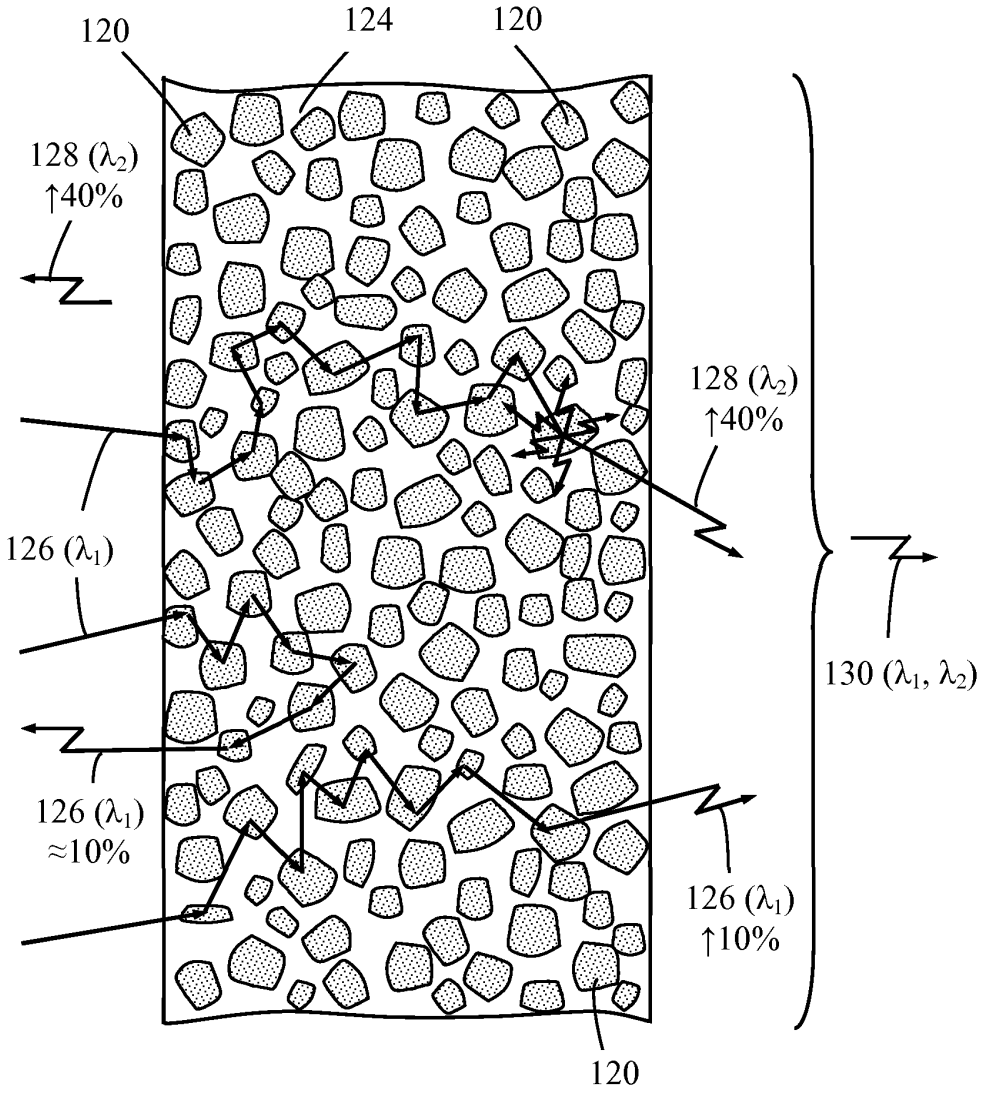

1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Relative scattering
Blue
Green
Red
50
100
150
200
300
500
800
Average particle size (nm)

FIG. 10



PRIOR ART

FIG. 11

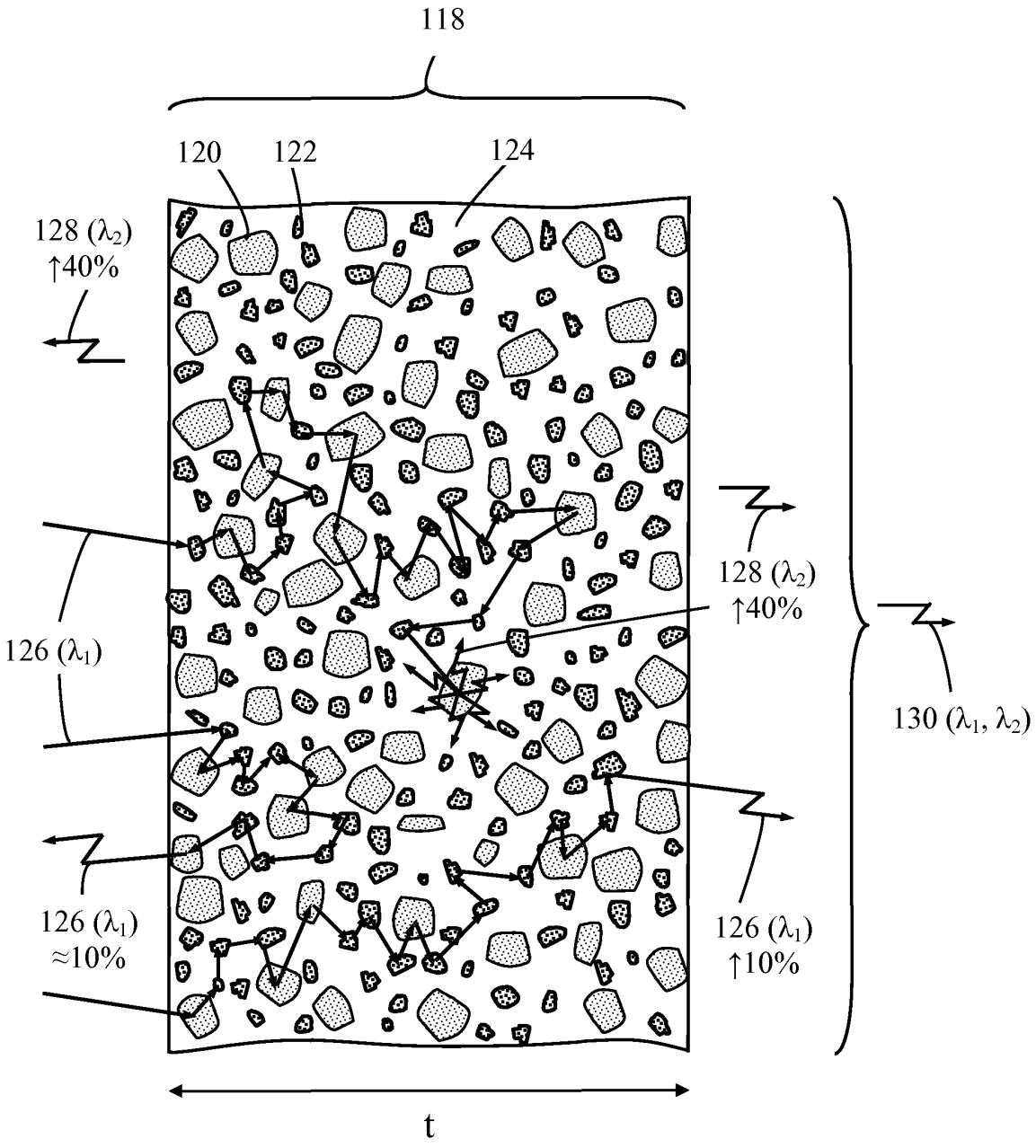

118
120
122
124
128 (λ_2)
↑40%
126 (λ_1)
126 (λ_1)
≈10%
128 (λ_2)
↑40%
126 (λ_1)
↑10%
130 (λ_1, λ_2)
t

FIG. 12

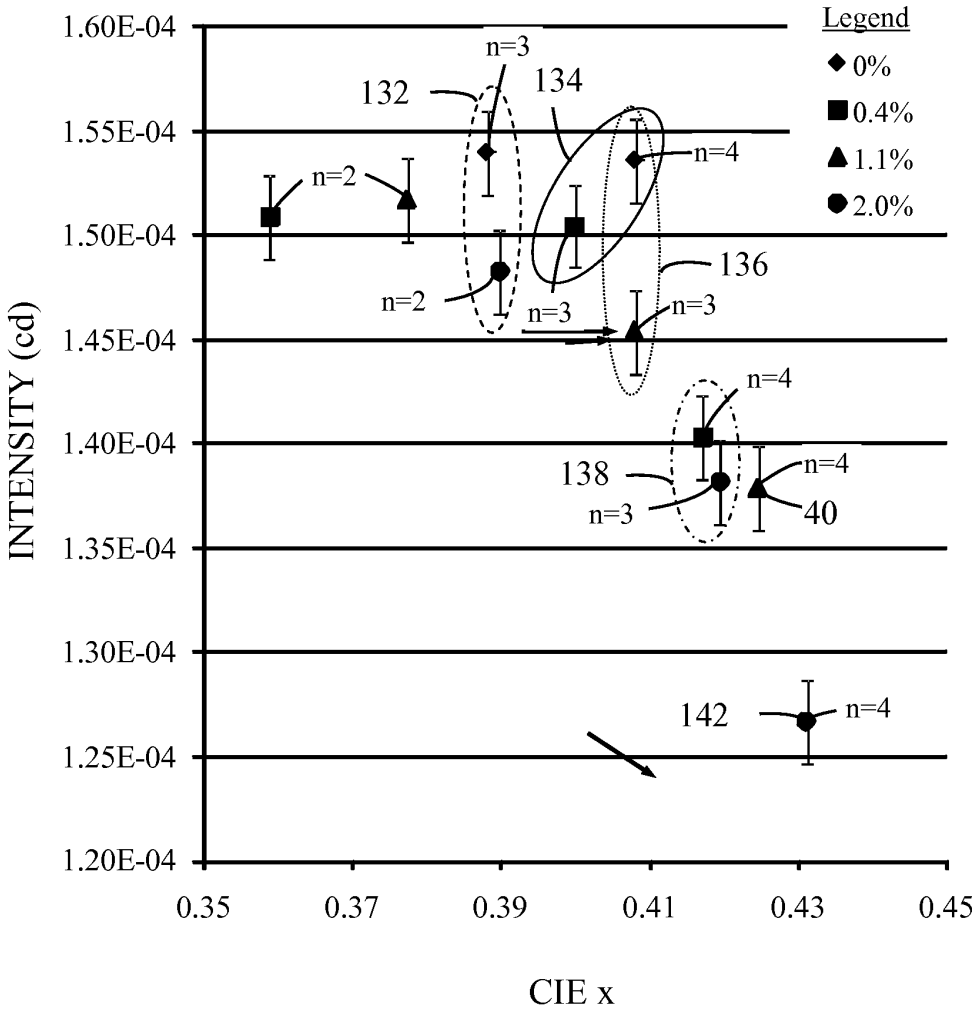

Legend
0%
0.4%
1.1%
2.0%
INTENSITY (cd)
1.60E-04
1.55E-04
1.50E-04
1.45E-04
1.40E-04
1.35E-04
1.30E-04
1.25E-04
1.20E-04
0.35
0.37
0.39
0.41
0.43
0.45
CIE x
132
134
136
138
140
142
n=2
n=3
n=4

FIG. 13

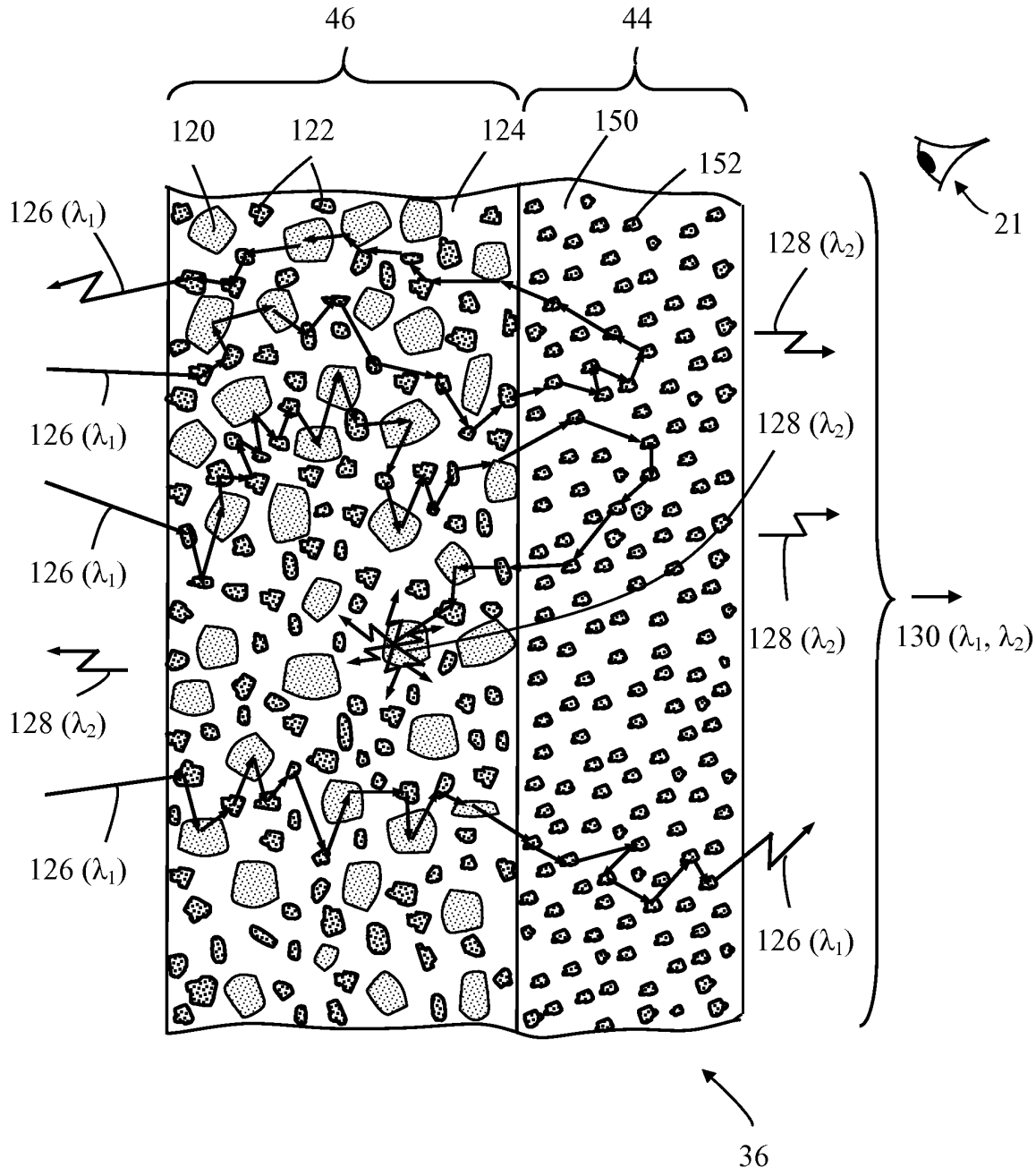

46
44
120
122
124
150
152
21
126 (λ_1)
126 (λ_1)
126 (λ_1)
128 (λ_2)
126 (λ_1)
128 (λ_2)
128 (λ_2)
128 (λ_2)
126 (λ_1)
130 (λ_1, λ_2)
36

FIG. 14

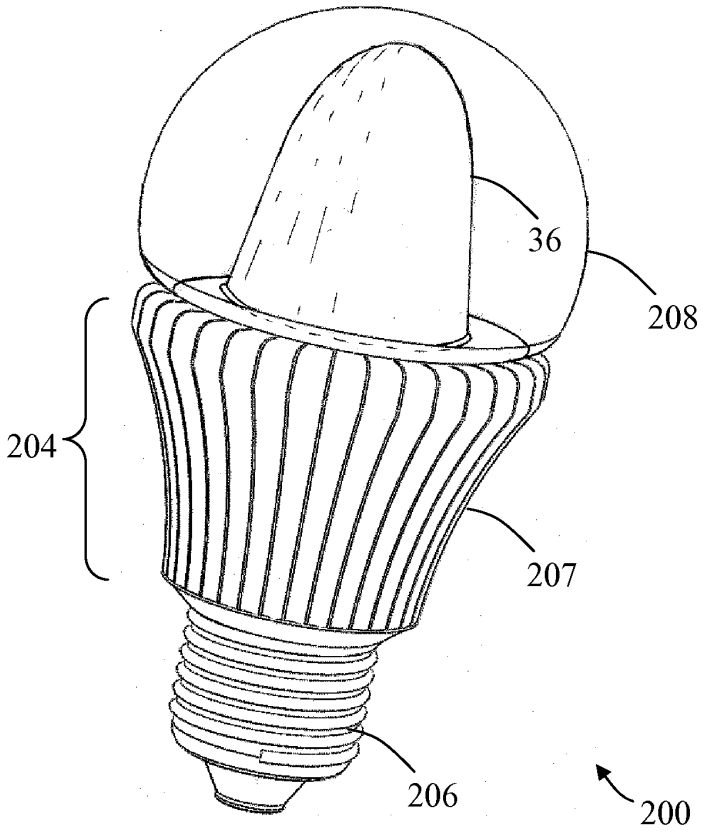


FIG. 15

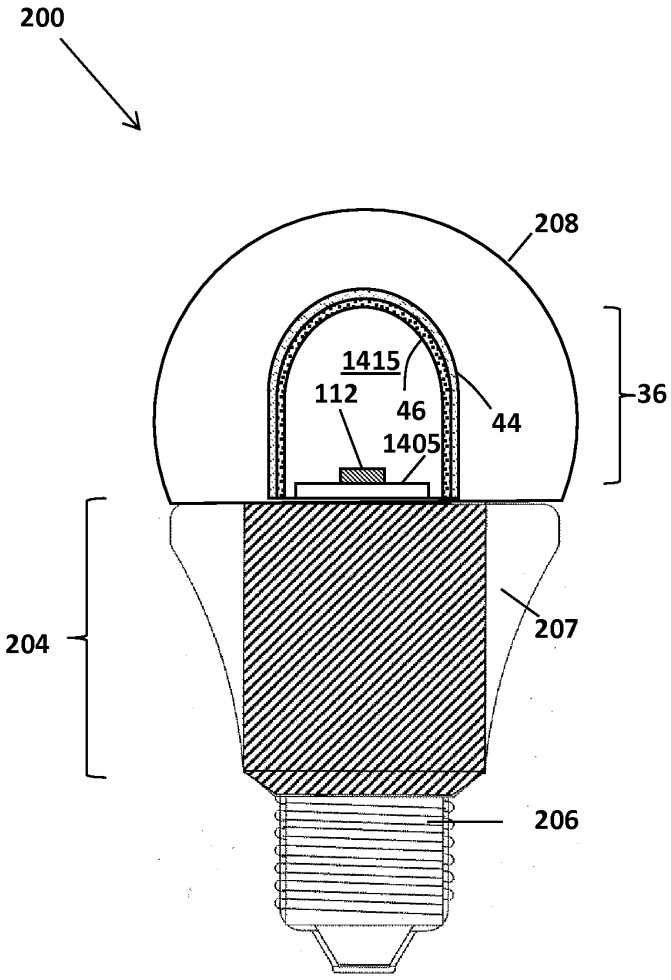


FIG. 16

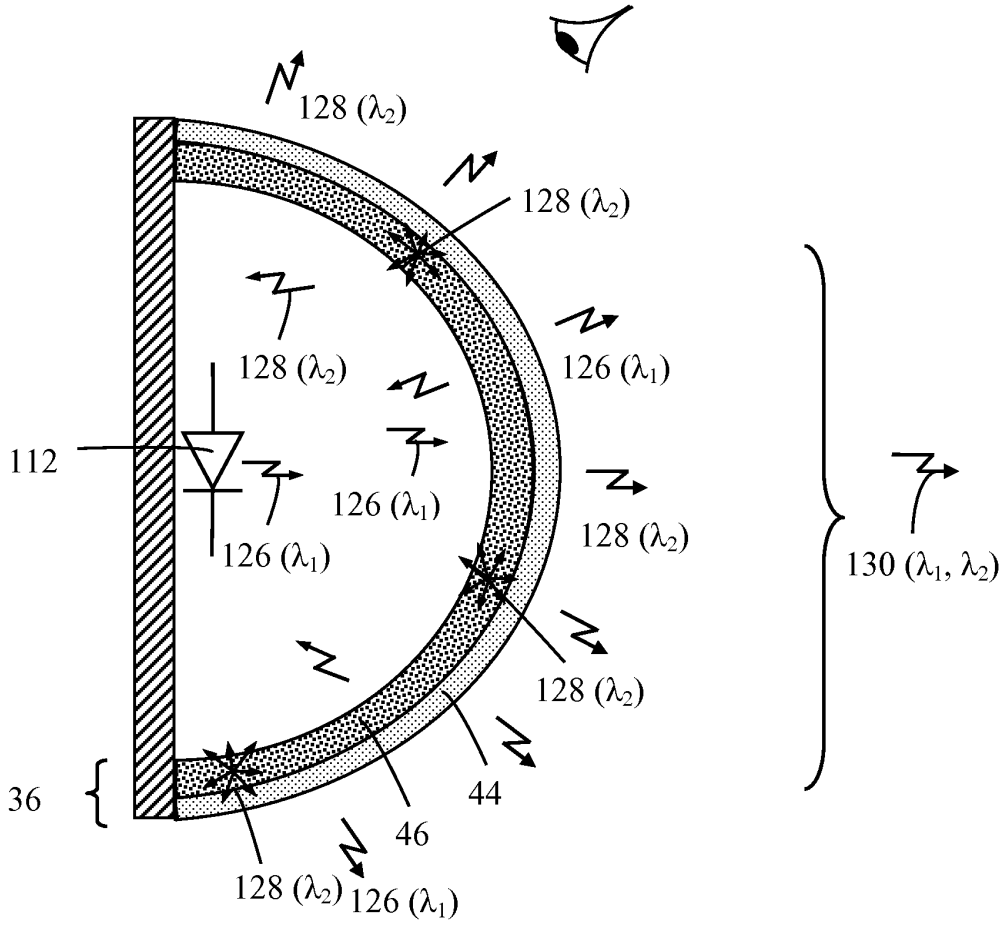


FIG. 17

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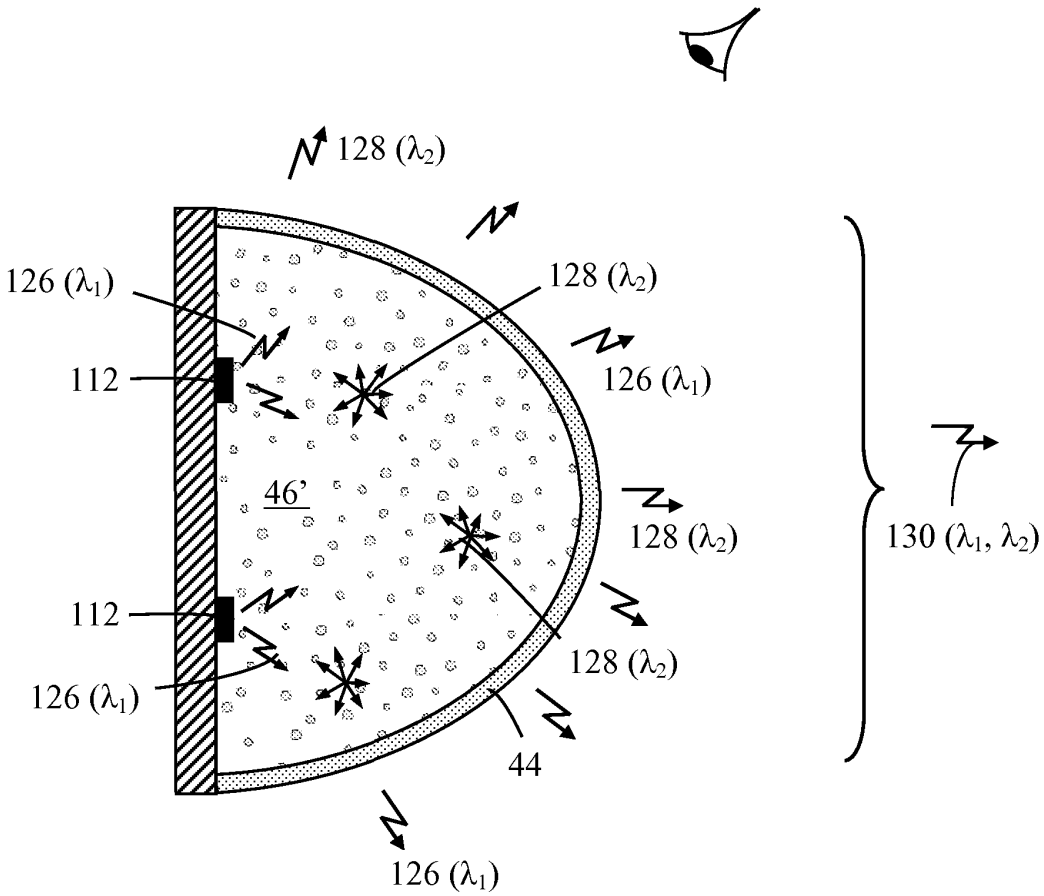

128 (λ2)
126 (λ1)
128 (λ2)
112
126 (λ1)
46'
128 (λ2)
130 (λ1, λ2)
112
128 (λ2)
126 (λ1)
44
126 (λ1)

FIG. 18

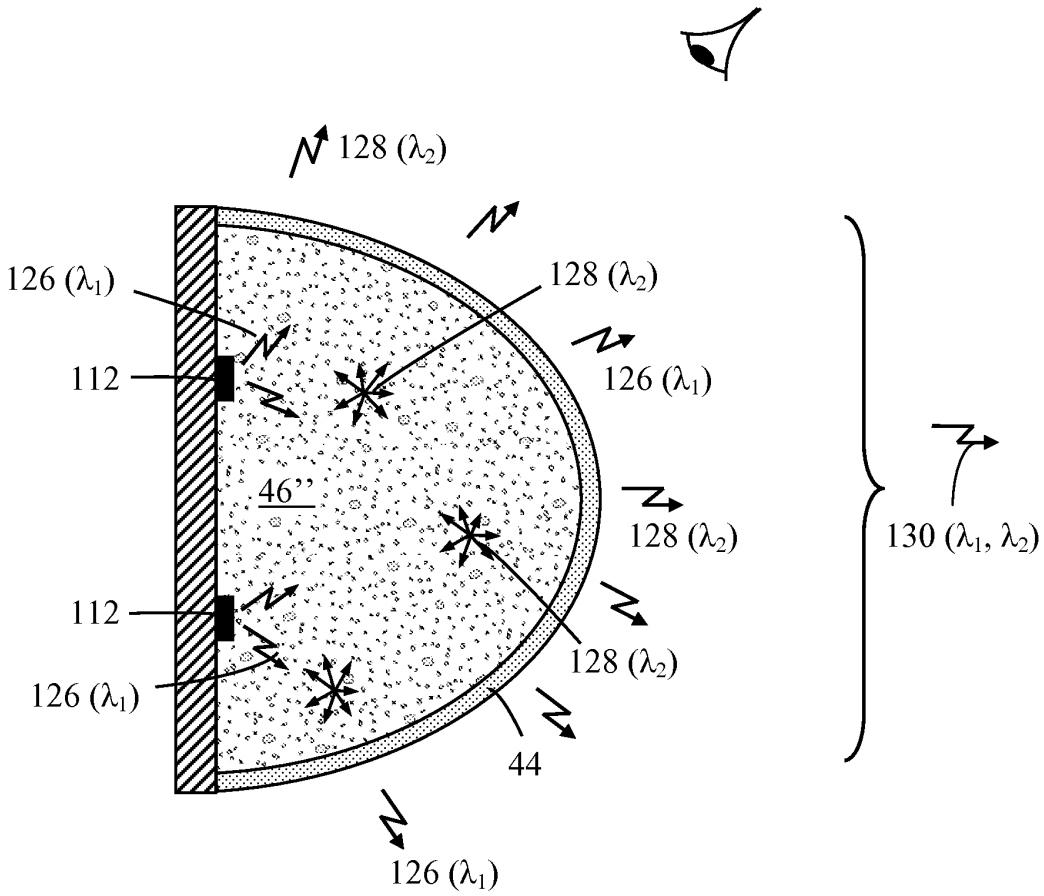

128 (λ2)
126 (λ1)
128 (λ2)
112
126 (λ1)
46''
128 (λ2)
130 (λ1, λ2)
112
128 (λ2)
126 (λ1)
44
126 (λ1)

FIG. 19

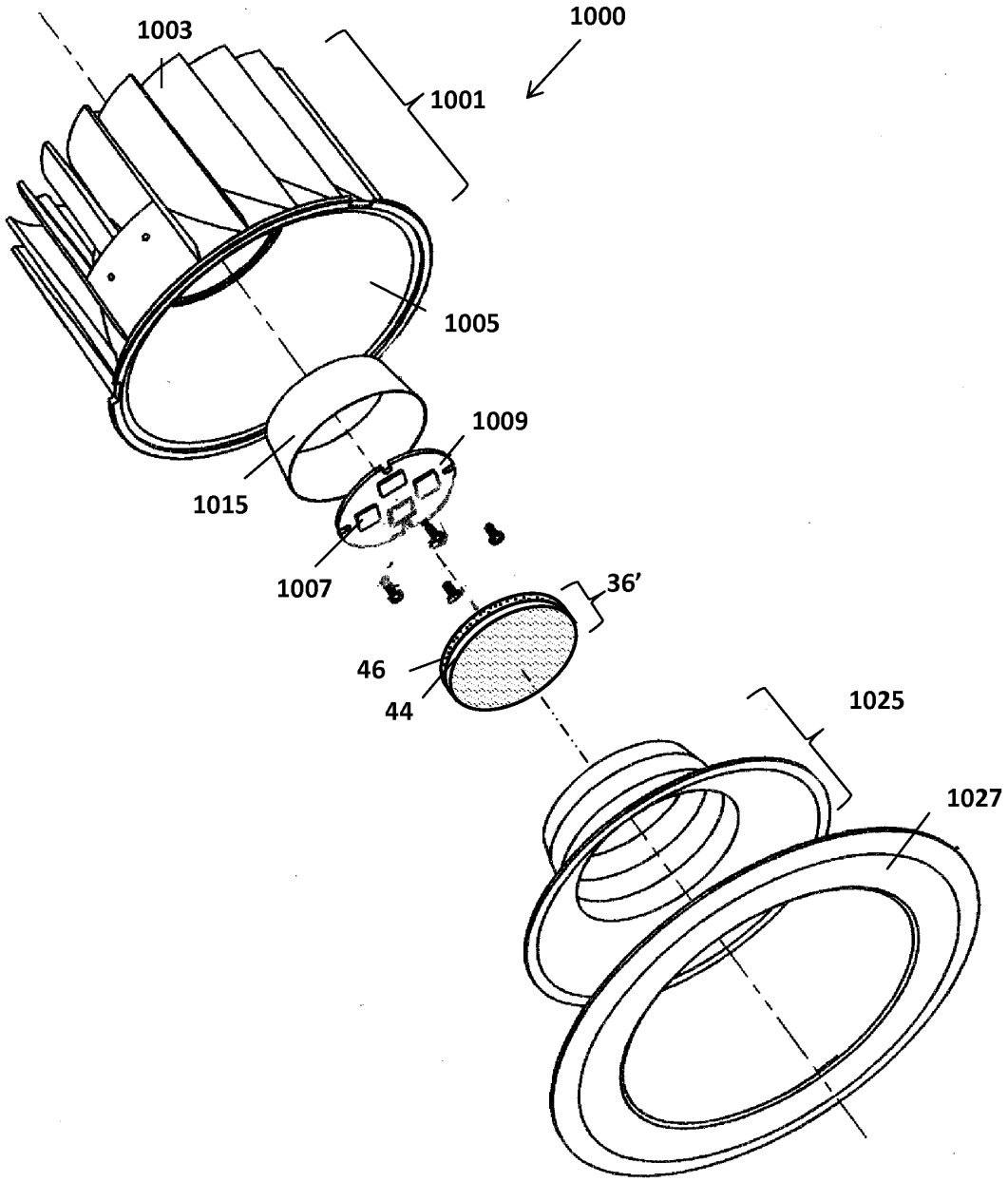


FIG. 20A

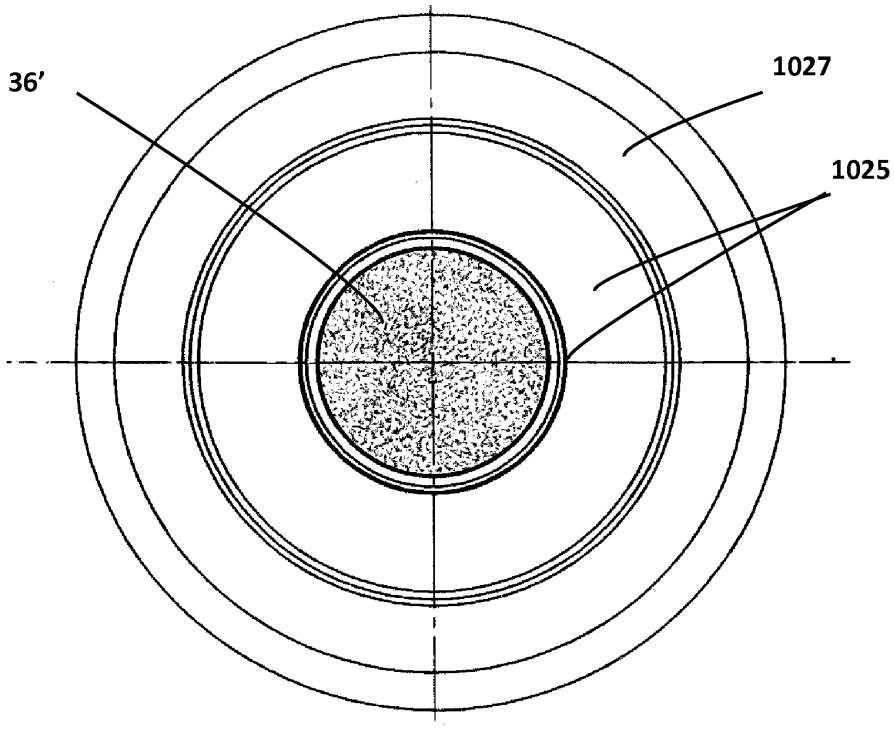


FIG. 20B

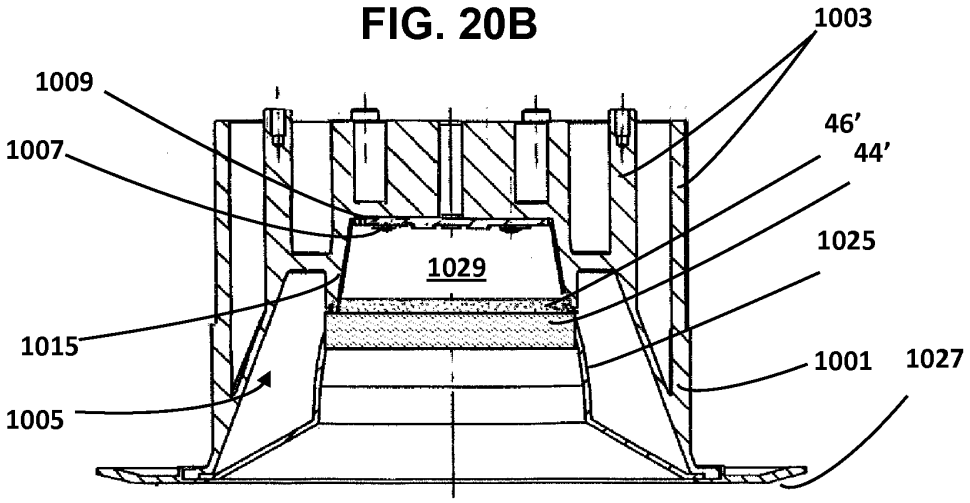


FIG. 20C

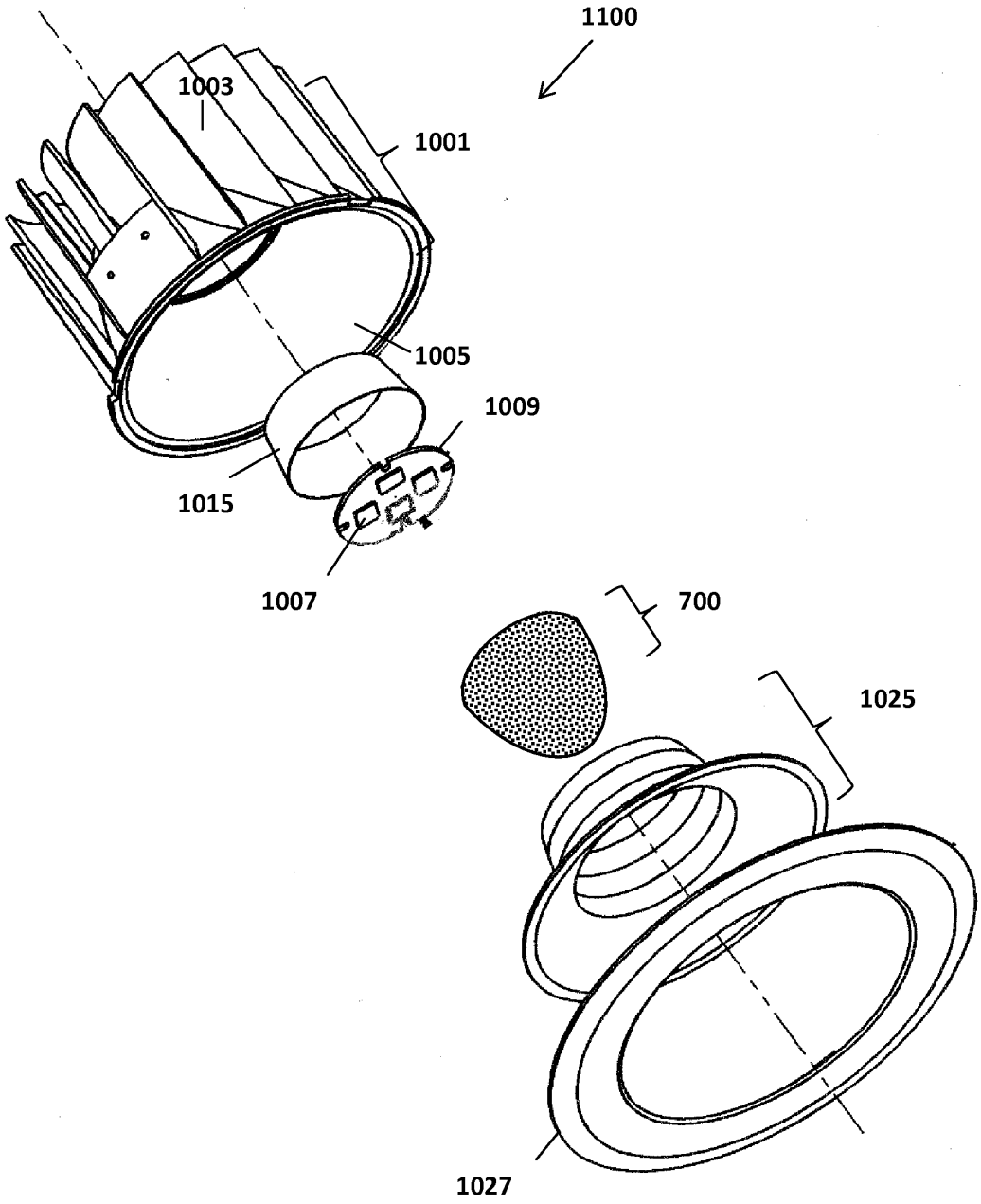


FIG. 21A

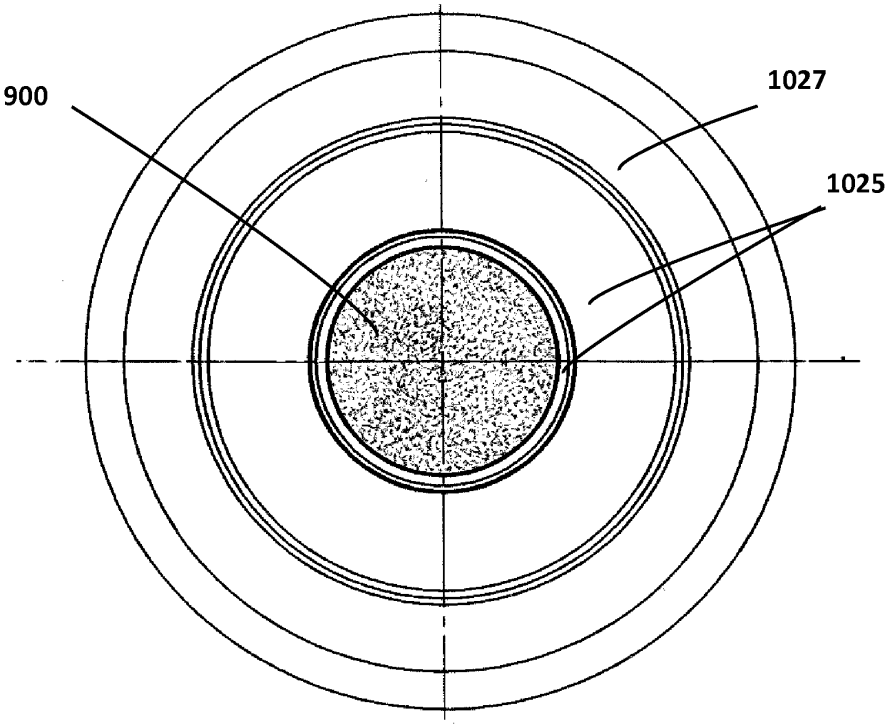


FIG. 21B

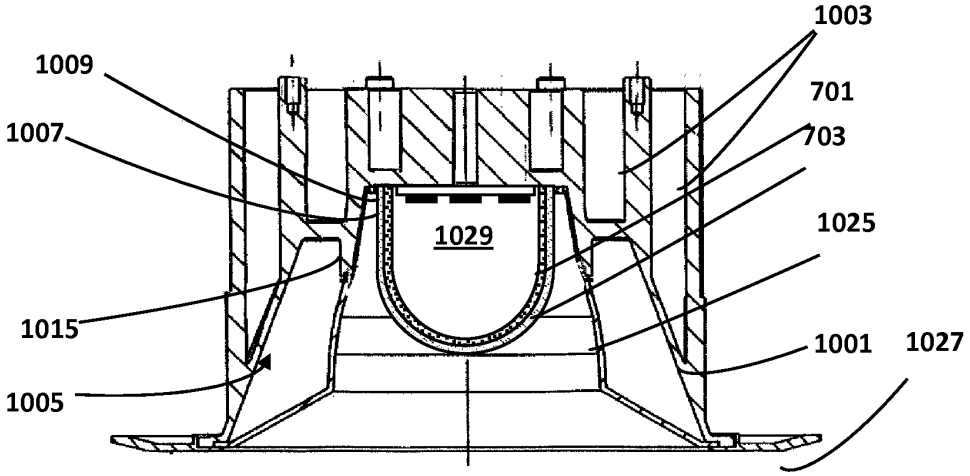


FIG. 21C

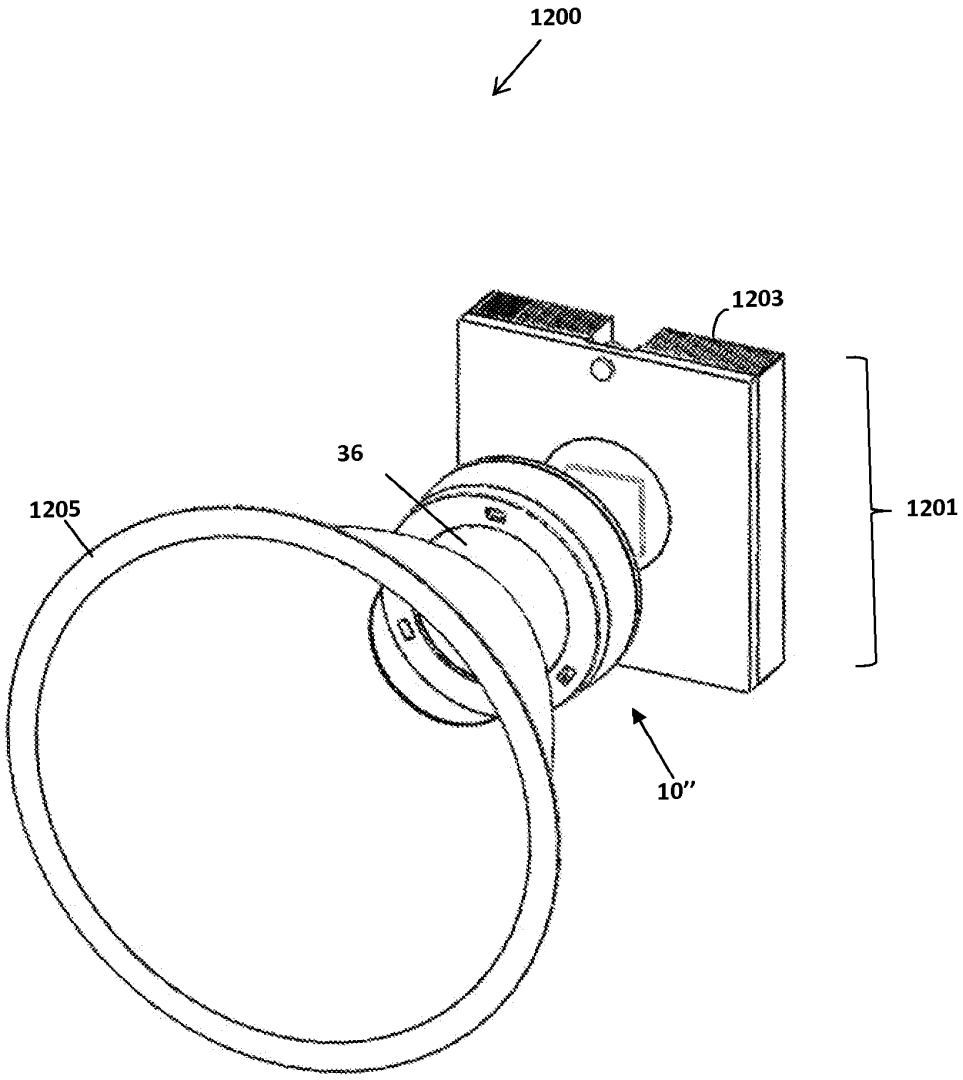


FIG. 22

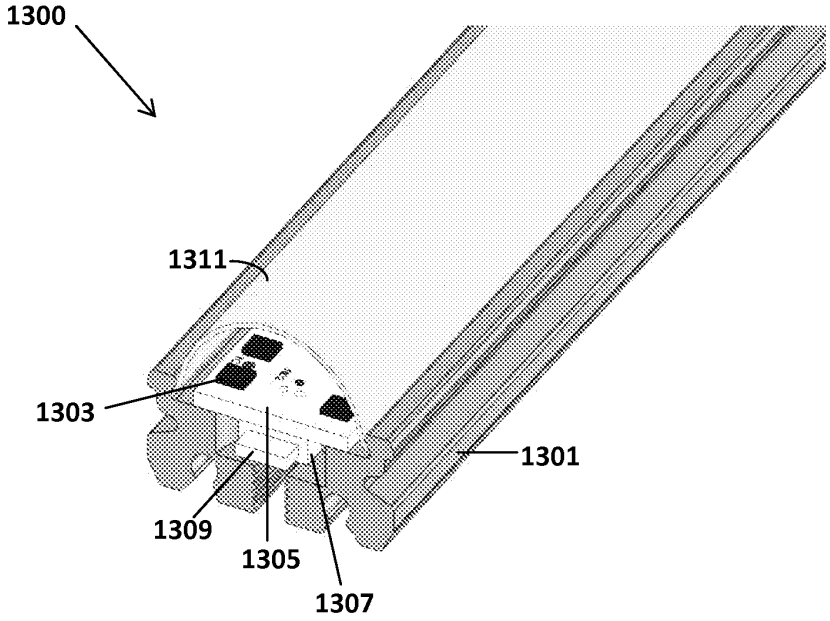


FIG. 23A

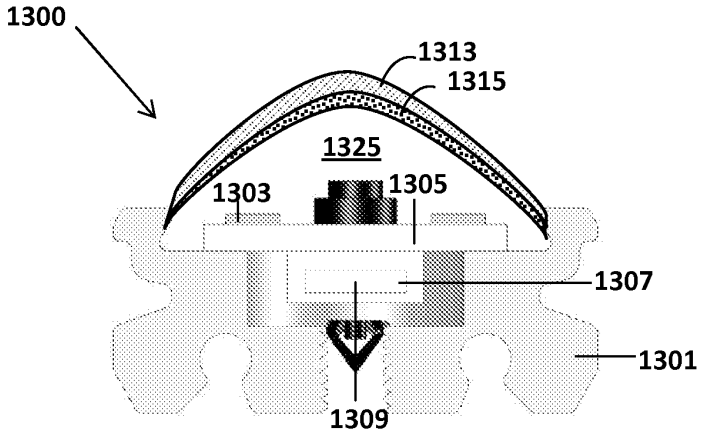


FIG. 23B

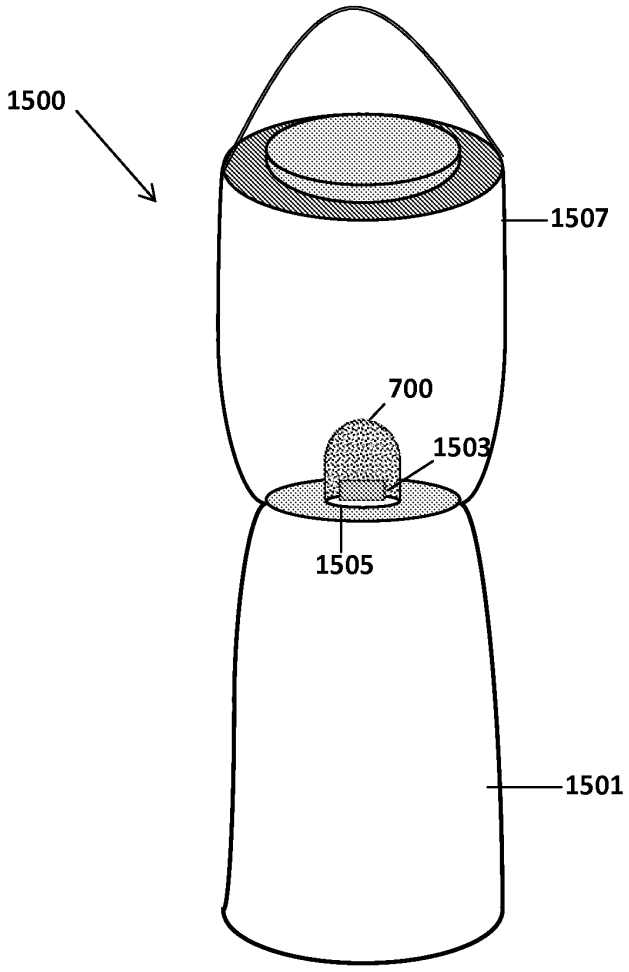


FIG. 24

Electronic Acknowledgement Receipt

EFS ID:	11185533
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH SCATTERING PARTICLES
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-VISTA-00318US1
Receipt Date:	13-OCT-2011
Filing Date:	
Time Stamp:	23:27:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	ITMX-VISTA-00318US1_ADS.pdf	1421505 0fcc318f4f638edf2816cb5d1425275ae2781ad6	no	5

Warnings:	
Information:	

2		ITMX-VISTA-00318US1_Specification.pdf	347192 7692cf45943bc373c6db7baeb7232177536 2fed4	yes	56

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Specification	1	49
Claims	50	55
Abstract	56	56

Warnings:

Information:

3	Drawings-only black and white line drawings	ITMX-VISTA-00318US1_Drawings-final.pdf	747904 f399510f58dac9daa34df9a218b667ec0595 c33f	no	25

Warnings:

Information:

Total Files Size (in bytes):	2516601

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority to United States Provisional Patent Application Serial No. 61/427,411, entitled "Solid-State Light Emitting Devices with Remote Phosphor Wavelength Conversion Component", filed December 27, 2010, which is hereby incorporated by reference in its entirety. This application is also a continuation-in-part of United States Application Serial No. 13/253,031, entitled "Solid-State Light Emitting Devices and Signage with Photoluminescence Wavelength Conversion," filed on October 4, 2011, which claims the benefit of United States Provisional Patent Application Serial No. 61/390,091, entitled "Solid-State Light Emitting Devices and Signage with Photoluminescence Wavelength Conversion," filed on October 5, 2010, which is hereby incorporated by reference in its entirety.

FIELD

[0002] This disclosure relates to solid-state light emitting devices that use a remotely positioned phosphor wavelength conversion component to generate a desired color of light.

BACKGROUND

[0003] White light emitting LEDs ("white LEDs") are known and are a relatively recent innovation. It was not until LEDs emitting in the blue/ultraviolet part of the electromagnetic spectrum were developed that it became practical to develop white light sources based on LEDs. As taught, for example in US 5,998,925, white LEDs include one or more one or more photoluminescent materials (e.g., phosphor materials), which absorb a portion of the radiation

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emitted by the LED and re-emit light of a different color (wavelength). Typically, the LED chip or die generates blue light and the phosphor(s) absorbs a percentage of the blue light and re-emits yellow light or a combination of green and red light, green and yellow light, green and orange or yellow and red light. The portion of the blue light generated by the LED that is not absorbed by the phosphor material combined with the light emitted by the phosphor provides light which appears to the eye as being nearly white in color. Alternatively, the LED chip or die may generate ultraviolet (UV) light, in which phosphor(s) to absorb the UV light to re-emit a combination of different colors of photoluminescent light that appear white to the human eye.

[0004] Due to their long operating life expectancy (>50,000 hours) and high luminous efficacy (70 lumens per watt and higher) high brightness white LEDs are increasingly being used to replace conventional fluorescent, compact fluorescent and incandescent light sources.

[0005] Typically the phosphor material is mixed with light transmissive materials, such as silicone or epoxy material, and the mixture applied to the light emitting surface of the LED die. It is also known to provide the phosphor material as a layer on, or incorporate the phosphor material within, an optical component, a phosphor wavelength conversion component, that is located remotely to the LED die ("remote phosphor" LED devices).

[0006] One issue with remote phosphor devices is the non-white color appearance of the device in its OFF state. During the ON state of the LED device, the LED chip or die generates blue light and the phosphor(s) absorbs a percentage of the blue light and re-emits yellow light or a combination of green and red light, green and yellow light, green and orange, or yellow and red light. The portion of the blue light generated by the LED that is not absorbed by the phosphor combined with the light emitted by the phosphor provides light which appears to the human eye as being nearly white in color. However, for a remote phosphor device in its OFF state, the

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absence of the blue light that would otherwise be produced by the LED in the ON state causes the device to have a yellowish, yellow-orange, or orange-color appearance. A potential consumer or purchaser of such devices that is seeking a white-appearing light may be quite confused by the yellowish, yellow-orange, or orange-color appearance of such devices in the marketplace, since the device on a store shelf is in its OFF state. This may be off-putting or undesirable to the potential purchasers and hence cause loss of sales to target customers.

[0007] Another problem with remote phosphor devices can be the variation in color of emitted light with emission angle. In particular, such devices are subject to perceptible non-uniformity in color when viewed from different angles. Such visually distinctive color differences are unacceptable for many commercial uses, particularly for the high-end lighting that often employ LED lighting devices.

[0008] Yet another problem with using phosphor materials is that they are relatively costly, and hence correspond to a significant portion of the costs for producing phosphor-based LED devices. For a non-remote phosphor device, the phosphor material in a LED light is typically mixed with a light transmissive material such as a silicone or epoxy material and the mixture directly applied to the light emitting surface of the LED die. This results in a relatively small layer of phosphor materials placed directly on the LED die, that is nevertheless still costly to produce in part because of the significant costs of the phosphor materials. A remote phosphor device typically uses a much larger layer of phosphor materials as compared to the non-remote phosphor device. Because of its larger size, a much greater amount of phosphor is normally required to manufacture such remote phosphor LED devices. As a result, the costs are correspondingly greater as well to provide the increased amount of phosphor materials needed for such remote phosphor LED devices.

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[0009] Therefore, there is a need for improved approaches to implement LED lighting apparatuses that maintains the desired color properties of the devices, but without requiring the large quantities of photoluminescent materials (e.g. phosphor materials) that are required in the prior approaches. In addition, there is a need for an improved approach to implement LED lighting apparatuses which addresses perceptible variations in color of emitted light with emission angle, and which also addresses the non-white color appearance of the LED lighting apparatuses while in an OFF state.

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SUMMARY OF THE INVENTION

[0010] Embodiments of the invention concern light emitting devices comprising one or more solid-state light sources, typically LEDs, that are operable to generate excitation radiation (typically blue light) and a remote wavelength conversion component, containing one or more excitable photoluminescence materials (e.g., phosphor materials), that is operable to convert at least a portion of the excitation radiation to light of a different wavelength. When using a blue light radiation source, the emission product of the device comprises the combined light generated by the source and the wavelength conversion component and is typically configured to appear white in color. When using an UV source, the wavelength conversion component(s) may include a blue wavelength conversion component and a yellow wavelength conversion component with the outputs of these components combining to form the emission product. The wavelength conversion component comprises a light transmissive substrate such as a polymer or glass having a wavelength conversion layer comprising particles of the excitable photoluminescence material (such as phosphor) and a light diffusing layer comprising particles of a light diffractive material (such as titanium dioxide). In accordance with some embodiments of the invention, the wavelength conversion and light diffusing layers are in direct contact with each other and are preferably deposited by screen printing or slot die coating. As used herein, "direct contact" means that there are no intervening layers or air gaps.

[0011] One benefit of this approach is that by selecting an appropriate particle size and concentration per unit area of the light diffractive material, an improvement is obtained in the white color appearance of a LED device in its OFF state. Another benefit is an improvement to the color uniformity of emitted light from an LED device for emission angles over a ±60° range from the emission axis. Moreover the use of a light diffusing layer having an appropriate particle

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size and concentration per unit area of the light diffractive material can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light, since the light diffusing layer increases the probability that a photon will result in the generation of photoluminescence light by directing light back into the wavelength conversion layer. Therefore, inclusion of a diffusing layer in direct contact with the wavelength conversion layer can reduce the quantity of phosphor material required to generate a given color emission product, e.g., by up to 40%. In one embodiment the particle size of the light diffractive material is selected such that excitation radiation generated by the source is scattered more than light generated by the one or more phosphor materials.

[0012] According to some embodiments of the invention a wavelength conversion component for a light emitting device comprising at least one light emitting solid-state radiation source, comprises a light transmissive substrate having a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light diffractive material; and wherein the layers are in direct contact with each other. Preferably the wavelength conversion layer comprises a mixture of at least one phosphor material and a light transmissive binder while the light diffusing layer comprises a mixture of the light diffractive material and a light transmissive binder. To minimize optical losses at the interface of the layers it is preferred that the layers comprise the same transmissive binder. The binder can comprise a curable liquid polymer such as a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone or a fluorinated polymer. The binder is preferably UV or thermally curable.

[0013] To reduce the variation in emitted light color with emission angle the weight loading of light diffractive material to binder is in a range 7% to 35% and more preferably in a range

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10% to 20%. The wavelength conversion and light diffusing layers are preferably deposited by screen printing though they can be deposited using other deposition techniques such as spin coating or doctor blading. The light diffractive material preferably comprises titanium dioxide (TiO_2) though it can comprise other materials such as barium sulfate ($BaSO_4$), magnesium oxide (MgO), silicon dioxide (SiO_2) or aluminum oxide (Al_2O_3).

[0014] In one arrangement the light diffractive material has an average particle size in a range 1μm to 50μm and more preferably in a range 10μm to 20μm. In other arrangements the light diffractive material has a particle size that is selected such that the particles will scatter excitation radiation relatively more than they will scatter light generated by the at least one photoluminescence material. For example, for blue light radiation sources, the light diffractive particle size can be selected such that the particles will scatter blue light relatively at least twice as much as they will scatter light generated by the at least one phosphor material. Such a light diffusing layer ensures that a higher proportion of the blue light emitted from the wavelength conversion layer will be scattered and directed by the light diffractive material back into the wavelength conversion layer increasing the probability of the photon interacting with a phosphor material particle and resulting in the generation of photoluminescent light. At the same time, phosphor generated light can pass through the diffusing layer with a lower probability of being scattered. Since the diffusing layer increases the probability of blue photons interacting with a phosphor material particle, less phosphor material can be used to generate a selected emission color. Such an arrangement can also increase luminous efficacy of the wavelength conversion component/device. Preferably the light diffractive material has an average particle size of less than about 150nm where the excitation radiation comprises blue light. When the excitation radiation comprises UV light, the light diffractive material may have an average particle size of

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less than about 100nm.

[0015] The light transmissive substrate can comprise any material that is substantially transmissive to visible light (380nm to 740nm) and typically comprises a polymer material such as a polycarbonate or an acrylic. Alternatively the substrate can comprise a glass.

[0016] The concept of a wavelength conversion component having a light diffusing layer composed of light diffractive particles that preferentially scatter light corresponding to wavelengths generated by the LEDs compared with light of wavelengths generated by the phosphor material is considered inventive in its own right. According to a further aspect of the invention a wavelength conversion component for a light emitting device comprising at least one blue light emitting solid-state light source, comprises a wavelength layer comprising particles of at least one phosphor material and a light diffusing layer comprising particles of a light diffractive material; wherein the light diffractive particle size is selected such that the particles will scatter excitation radiation relatively more than they will scatter light generated by the at least one phosphor material.

[0017] To increase the CRI (Color Rendering Index) of light generated by the device the device can further comprise at least one solid-state light source operable to generate red light.

[0018] Further details of aspects, objects, and advantages of the invention are described below in the detailed description, drawings, and claims. Both the foregoing general description and the following detailed description are exemplary and explanatory, and are not intended to be limiting as to the scope of the invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0019] In order that the present invention is better understood LED-based light emitting devices and phosphor wavelength conversion components in accordance with the invention will now be described, by way of example only, with reference to the accompanying drawings in which like reference numerals are used to denote like parts, and in which:

[0020] FIG. **1** shows schematic partial cutaway plan and sectional views of a solid-state light emitting device in accordance with an embodiment of the invention;

[0021] FIG. **2** is a schematic of a phosphor wavelength conversion component in accordance with an embodiment of the invention;

[0022] FIG. **3** is a schematic of a phosphor wavelength conversion component in accordance with another embodiment of the invention;

[0023] FIG. **4** shows plots of emission color change versus emission angle for the device of FIG. **1** for phosphor wavelength conversion components containing 0%, 7%, 12%, 16%, 23% and 35% weight loadings of light diffractive material;

[0024] FIG. **5** is a plot of luminous efficacy (normalized) versus emission color change at an emission angle θ=60° for the device of FIG. **1**;

[0025] FIG. **6** shows plots of emission color change versus emission angle for a warm white (≈3000K) solid-state light emitting device in accordance with the invention for wavelength conversion components containing different 0%, 10%, 15% and 20% weight loadings of light diffractive material;

[0026] FIG. **7** is a plot of luminous efficacy (normalized) versus emission color change at an emission angle θ=60° for the warm white light emitting device for wavelength conversion components containing different 0%, 10%, 15% and 20% weight loadings of light diffractive

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material;

[0027] FIG. **8** is a 1931 C.I.E. (Commission Internationale de l'Eclairage) chromaticity diagram showing emission color at emission angles θ=0°, 15°, 30°, 45° and 60° for the warm white light emitting device for wavelength conversion components containing 0%, 10%, 15% and 20% weight loadings of light diffractive material;

[0028] FIG. **9** shows schematic partial cutaway plan and sectional views of a high CRI solid-state light emitting device in accordance with another embodiment of the invention;

[0029] FIG. **10** shows plots of relative light scattering versus light diffractive particle size (nm) for red, green and blue light.

[0030] FIG. **11** is a schematic illustrating the principle of operation of a known light emitting device;

[0031] FIG. **12** is a schematic illustrating the principle of operation of the light emitting device having scattering particles mixed with phosphor particles in accordance with an embodiment of the invention;

[0032] FIG. **13** is a plot of emission intensity versus chromaticity CIE x for an LED-based light emitting device in accordance with the invention for different weight percent loadings of light reflective material;

[0033] FIG. **14** is a schematic illustrating a light emitting device having scattering particles within both a wavelength conversion layer and a diffusing layer according to an embodiment of the invention;

[0034] FIGs. **15** and **16** illustrate, respectively, a perspective view and a cross-sectional view of an application of a wavelength conversion component in accordance with some embodiments;

[0035] FIG. **17** is a schematic illustrating a light emitting device having a diffusing layer

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formed as a dome-shaped shell, in which a wavelength conversion layer forms an inner layer on an interior surface of the dome-shaped diffusing layer, according to an embodiment of the invention;

[0036] FIG. **18** is a schematic illustrating a light emitting device having a diffusing layer formed as a dome-shaped shell, in which a wavelength conversion layer substantially fills an interior volume formed by the interior surface of the dome-shaped diffusing layer, according to an embodiment of the invention;

[0037] FIG. **19** is a schematic illustrating a light emitting device having a diffusing layer formed as a dome-shaped shell, in which a wavelength conversion layer having scattering particles substantially fills an interior volume formed by the interior surface of the dome-shaped diffusing layer, according to an embodiment of the invention;

[0038] FIGs. **20A**, **20B**, and **20C** illustrate an example of an application of a wavelength conversion component in accordance with some embodiments;

[0039] FIGs. **21A**, **21B**, and **21C** illustrate another example of an application of a wavelength conversion component in accordance with some embodiments;

[0040] FIG **22** illustrates another example of an application of a wavelength conversion component in accordance with some embodiments;

[0041] FIGs. **23A** and **23B** illustrate another example of an application of a wavelength conversion component in accordance with some embodiments; and

[0042] FIG. **24** illustrates a perspective of another application of a wavelength conversion component in accordance with some embodiments.

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DETAILED DESCRIPTION OF THE INVENTION

[0043] Some embodiments of the invention are directed to light emitting devices comprising one or more solid-state light emitters, typically LEDs, that is/are operable to generate excitation light (typically blue or UV) which is used to excite a wavelength conversion component containing particles of a photoluminescence materials (e.g. phosphor materials), such as a blue light excitable phosphor material or an UV excitable phosphor material. Additionally the wavelength conversion component comprises a light diffusing layer comprising particles of a light diffractive material (also referred to herein as "light scattering material"). One benefit of this arrangement is that by selecting an appropriate particle size and concentration per unit area of the light diffractive material, it is possible to make a device having an emission product color that is virtually uniform with emission angle over a ±60° range from the emission axis. Moreover the use of a light diffusing layer can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. In addition, the light diffusing layer can significantly improve the white appearance of the light emitting device in its OFF state.

[0044] For the purposes of illustration only, the following description is made with reference to photoluminescence material embodied specifically as phosphor materials. However, the invention is applicable to any type of any type of photoluminescence material, such as either phosphor materials or quantum dots. A quantum dot is a portion of matter (e.g. semiconductor) whose excitons are confined in all three spatial dimensions that may be excited by radiation energy to emit light of a particular wavelength or range of wavelengths. In addition, the following description is made with reference to radiation sources embodied specifically as blue light sources. However, the invention is applicable any type of radiation source, including blue light sources and UV light sources.

Savant Technologies LLC - 1004.051

[0045] A solid-state light emitting device **10** in accordance with an embodiment of the invention will now be described with reference to FIG. **1** which shows schematic partial cutaway plan and sectional views of the device. The device **10** is configured to generate warm white light with a CCT (Correlated Color Temperature) of approximately 3000K and a luminous flux of approximately 1000 lumens.

[0046] The device **10** comprises a hollow cylindrical body **12** composed of a circular disc-shaped base **14**, a hollow cylindrical wall portion **16** and a detachable annular top **18**. To aid in the dissipation of heat the base **14** is preferably fabricated from aluminum, an alloy of aluminum or any material with a high thermal conductivity (preferably $\geq 200 Wm^{-1}K^{-1}$) such as for example copper, a magnesium alloy or a metal loaded plastics material. For low cost production the wall **16** and top **18** are preferably fabricated from a thermoplastics material such as HDPP (High Density Polypropylene), nylon or PMA (polymethyl acrylate). Alternatively they can be fabricated from a thermally conductive material such as aluminum or an aluminum alloy. As indicated in FIG. **1** the base **14** can be attached to the wall portion **16** by screws or bolts **20** or by other fasteners or by means of an adhesive. As further shown in FIG. **1** the top **18** can be detachably mounted to the wall portion **16** using a bayonet-type mount in which radially extending tabs **22** engage in a corresponding annular groove in the top **18**.

[0047] The device **10** further comprises a plurality (four in the example illustrated) of blue light emitting LEDs **24** (blue LEDs) that are mounted in thermal communication with a circular-shaped MCPCB (metal core printed circuit board) **26**. The blue LEDs **24** can comprise 4.8W Cetus™ C1109 chip on ceramic devices from Intematix Corporation of Fremont, California in which each device comprises a ceramic packaged array of twelve 0.4W GaN-based (gallium nitride-based) blue LED chips that are configured as a rectangular array 3 rows by 4 columns.

Savant Technologies LLC - 1004.052

Each blue LED **24** is operable to generate blue light **28** having a peak wavelength λ_1 in a wavelength range 400nm to 480nm (typically 450nm to 470nm). As is known an MCPCB comprises a layered structure composed of a metal core base, typically aluminum, a thermally conductive/electrically insulating dielectric layer and a copper circuit layer for electrically connecting electrical components in a desired circuit configuration. The metal core base of the MCPCB **26** is mounted in thermal communication with the base **14** with the aid of a thermally conductive compound such as for example an adhesive containing a standard heat sink compound containing beryllium oxide or aluminum nitride. As shown in FIG. **1** the MCPCB can be attached to the base using screws or bolts **30**.

[0048] To maximize the emission of light, the device **10** can further comprise light reflective surfaces **32**, **34** that respectively cover the face of the MCPCB **26** and the inner curved surface of the top **18**. Typically the light reflective surfaces **32**, **34** can comprise a highly light reflective sheet material such as WhiteOptics™ "White 97" (A high-density polyethylene fiberbased composite film) from A.L.P. lighting Components, Inc of Niles, Illinois, USA. As indicated in FIG. **1** a circular disc **32** of the material can used to cover the face of the MCPCB and a strip of the light reflective material configured as a cylindrical sleeve **34** that is inserted in the housing and is configured to cover the inner surface of the housing wall portion **16**.

[0049] The device **10** further comprises a phosphor wavelength conversion component **36** that is operable to absorb a proportion of the blue light **28** (λ_1) generated by the LEDs **24** and convert it to light **38** of a different wavelength (λ_2) by a process of photoluminescence **36**. The emission product **40** of the device **10** comprises the combined light of wavelengths λ_1, λ_2 generated by the LEDs **24** and the phosphor wavelength conversion component **36**. The wavelength conversion component is positioned remotely to the LEDs **24** and is spatially

Savant Technologies LLC - 1004.053

separated from the LEDs a distance **d** that is typically at least 1cm. In this patent specification "remotely" and "remote" means in a spaced or separated relationship. The wavelength conversion component **36** is configured to completely cover the housing **12** opening such that all light emitted by the lamp passes through the component **36**. As shown the wavelength conversion component **36** can be detachably mounted to the top of the wall portion **16** using the top **18** enabling the component and emission color of the lamp to be readily changed.

[0050] As shown in FIG. **2**, the wavelength conversion component **36** comprises, in order, a light transmissive substrate **42,** a light diffusing layer **44** containing light diffractive particles and a wavelength conversion layer **46** containing one or more photoluminescent (e.g., phosphor) materials. As can be seen in FIG. **2** the wavelength conversion component **36** is configured such that in operation the wavelength conversion layer **46** faces the LEDs.

[0051] The light transmissive substrate **42** can be any material that is substantially transmissive to light in a wavelength range 380nm to 740nm and can comprise a light transmissive polymer such as a polycarbonate or acrylic or a glass such as a borosilicate glass. For the lamp **10** of FIG. **1** the substrate **42** comprises a planar circular disc of diameter φ= 62mm and thickness t_1 which is typically 0.5mm to 3mm. In other embodiments the substrate can comprise other geometries such as being convex or concave in form such as for example being dome shaped or cylindrical.

[0052] The diffusing layer **44** comprises a uniform thickness layer of particles of a light diffractive material, preferably titanium dioxide (TiO_2). In alternative arrangements the light diffractive material can comprise barium sulfate ($BaSO_4$), magnesium oxide (MgO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) or a powdered material with as high a reflectivity as possible, typically a reflectance of 0.9 or higher. The light diffractive material powder is

Savant Technologies LLC - 1004.054

thoroughly mixed in known proportions with a light transmissive liquid binder material to form a suspension and the resulting mixture deposited onto the face of the substrate **42** preferably by screen printing to form a uniform layer of thickness t_2 (typically in a range 10μm to 75μm) that covers the entire face of the substrate. The quantity of light diffracting material per unit area in the light diffusing layer **44** will typically in a range $10\mu g.cm^{-2}$ to $5mg.cm^{-2}$.

[0053] Whilst screen printing is a preferred method for depositing the light diffractive diffusing layer **44**, it can be deposited using other techniques such as for example slot die coating, spin coating, roller coating, drawdown coating or doctor blading. The binder material can comprise a curable liquid polymer such as a polymer resin, a monomer resin, an acrylic, an epoxy (polyepoxide), a silicone or a fluorinated polymer. It is important that the binder material is, in its cured state, substantially transmissive to all wavelengths of light generated by the phosphor material(s) and the LEDs **24** and preferably has a transmittance of at least 0.9 over the visible spectrum (380nm to 800nm). The binder material is preferably U.V. curable though it can be thermally curable, solvent based or a combination thereof. U.V. or thermally curable binders can be preferable because, unlike solvent-based materials, they do not "outgas" during polymerization. In one arrangement the average particle size of the light diffractive material is in a range 5μm to 15μm though as will be described it can be in a nanometer range (nm) and is advantageously in a range 100nm to 150nm. The weight percent loading of light diffractive material to liquid binder is typically in a range 7% to 35%.

[0054] The wavelength conversion layer **46** is deposited in direct contact with the light diffusing layer **44** without any intervening layers or air gaps. The phosphor material, which is in powder form, is thoroughly mixed in known proportions with a liquid light transmissive binder material to form a suspension and the resulting phosphor composition, "phosphor ink", deposited

Savant Technologies LLC - 1004.055

directly onto the diffusing layer **44**. The wavelength conversion layer is preferably deposited by screen printing though other deposition techniques such as slot die coating, spin coating or doctor blading can be used. To eliminate an optical interface between the wavelength conversion and diffusing layers **46**, **44** and to maximize the transmission of light between layers, the same liquid binder material is preferably used to fabricate both layers; that is, a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone or a fluorinated polymer.

[0055] The phosphor wavelength conversion layer **46** is preferably deposited by screen printing though other deposition techniques such as for example slot die coating, spin coating, roller coating, drawdown coating or doctor blading can be used. The binder material is preferably U.V. or thermally curable rather than being solvent-based. When a solvent evaporates the volume and viscosity of the composition will change and this can result in a higher concentration of phosphor material which will affect the emission product color of the device. With U.V. curable polymers, the viscosity and solids ratios are more stable during the deposition process with U.V. curing being used to polymerize and solidify the layer after deposition is completed. Moreover since in the case of screen printing of the phosphor ink multiple-pass printing may be required to achieve a required layer thickness, the use of a U.V. curable binder is preferred since each layer can be cured virtually immediately after printing prior to printing of the next layer.

[0056] The color of the emission product produced by the wavelength conversion component depends on the phosphor material composition and the quantity of phosphor material per unit area in the wavelength conversion layer **46**. It will be appreciated that the quantity of phosphor material per unit area is dependent on the thickness t_3 of the wavelength conversion layer **46** and the weight loading of phosphor material to binder in the phosphor ink. In applications in which the emission product is white or in applications in which the emission product has a high

Savant Technologies LLC - 1004.056

saturation color (i.e. the emission product comprises substantially all photoluminescence generated light) the quantity of phosphor material per unit area in the wavelength conversion layer **46** will typically be between $10mg.cm^{-2}$ and $40mg.cm^{-2}$. To enable printing of the wavelength conversion layer **46** in a minimum number of print passes the phosphor ink preferably has as high a solids loading of phosphor material to binder material as possible and preferably has a weight loading of phosphor material to binder in a range 40% to 75%. For weight loadings below about 40% it is found that five or more print passes may be necessary to achieve a required phosphor material per unit area. The phosphor material comprises particles with an average particle size of 10μm to 20μm and typically of order 15μm.

[0057] In general lighting applications the emission product **40** will typically be white light and the phosphor material can comprise one or more blue light excitable phosphor materials that emit green (510nm to 550 nm), yellow-green (550nm to 570nm), yellow (570nm to 590nm), orange (590nm to 630nm) or red (630nm to 740nm) light. The thickness t_3 of the wavelength conversion layer, phosphor material composition and the density (weight loading) of phosphor material per unit area will determine the color of light emitted by the lamp.

[0058] The phosphor material can comprise an inorganic or organic phosphor such as for example silicate-based phosphor of a general composition $A_3Si(O,D)_5$ or $A_2Si(O,D)_4$ in which Si is silicon, O is oxygen, A comprises strontium (Sr), barium (Ba), magnesium (Mg) or calcium (Ca) and D comprises chlorine (Cl), fluorine (F), nitrogen (N) or sulfur (S). Examples of silicate-based phosphors are disclosed in United States patents US 7,575,697 B2 *"Silicate-based green phosphors"*, US 7,601,276 B2 *"Two phase silicate-based yellow phosphors"*, US 7,655,156 B2 *"Silicate-based orange phosphors"* and US 7,311,858 B2 *"Silicate-based yellow-green phosphors"*. The phosphor can also comprise an aluminate-based material such as

Savant Technologies LLC - 1004.057

is taught in co-pending patent application US2006/0158090 A1 *"Novel aluminate-based green phosphors"* and patent US 7,390,437 B2 *"Aluminate-based blue phosphors"*, an aluminum-silicate phosphor as taught in co-pending application US2008/0111472 A1 *"Aluminum-silicate orange-red phosphor"* or a nitride-based red phosphor material such as is taught in co-pending United States patent application US2009/0283721 A1 *"Nitride-based red phosphors"* and International patent application WO2010/074963 A1 *"Nitride-based red-emitting in RGB (red-green-blue) lighting systems"*. It will be appreciated that the phosphor material is not limited to the examples described and can comprise any phosphor material including nitride and/or sulfate phosphor materials, oxy-nitrides and oxy-sulfate phosphors or garnet materials (YAG).

[0059] A further example of a phosphor wavelength conversion component **36** in accordance with the invention is illustrated in FIG. **3**. In common with the wavelength conversion component of FIG. **2** the component comprises a light transmissive substrate **42**, a light diffusing layer **44** and a wavelength conversion layer **46**. In accordance with the invention the light diffusing and wavelength conversion layers **44**, **46** are deposited in direct contact with one another. Again in operation the component is configured such that the wavelength conversion component is configured such that the light diffusing layer **44** faces the LEDs **24**.

[0060] In operation blue light **28** generated by the LEDs **24** travels through the wavelength conversion layer **46** until it strikes a particle of phosphor material. It is believed that on average as little as 1 in 1000 interactions of a photon with a phosphor material particle results in absorption and generation of photo luminescence light **38**. The majority, about 99.9%, of interactions of photons with a phosphor particle result in scattering of the photon. Due to the isotropic nature of the scattering process on average half of the photons will scattered in a direction back towards the LEDs. Tests indicate that typically about 10% of the total incident

Savant Technologies LLC - 1004.058

blue light **28** is scattered and emitted from the wavelength conversion component **36** in a direction back towards the LEDs. For a cool white light emitting device the amount of phosphor material is selected to allow approximately 10% of the total incident blue light to be emitted from the wavelength conversion component and contribute to the emission product **40** that is viewed by an observer **21**. The majority, approximately 80%, of the incident light is absorbed by the phosphor material and re-emitted as photo luminescence light **38**. Due to the isotropic nature of photo luminescence light generation, approximately half of the light **38** generated by the phosphor material will be emitted in a direction towards the LED. As a result only up to about 40% of the total incident light will be emitted as light **38** of wavelength λ_2 and contributes to the emission product **38** with the remaining (up to about 40%) of the total incident light being emitted as light **38** of wavelength λ_2 in a direction back towards the LED. Light emitted towards the LEDs from the wavelength conversion component **36** is re-directed by the light diffractive surfaces **32, 34** to contribute to the emission product and to increase the overall efficiency of the device.

[0061] One problem associated with a conventional LED lighting device that is addressed by embodiments of the invention is the non-white color appearance of the device in an OFF state. As discussed, during an ON state, the LED chip or die generates blue light and some portion of the blue light is thereafter absorbed by the phosphor(s) to re-emit yellow light (or a combination of green and red light, green and yellow light, green and orange or yellow and red light). The portion of the blue light generated by the LED that is not absorbed by the phosphor combined with the light emitted by the phosphor provides light which appears to the human eye as being nearly white in color.

[0062] However, in an OFF state, the LED chip or die does not generate any blue light.

Savant Technologies LLC - 1004.059

Instead, light that is produced by the remote phosphor lighting apparatus is based at least in part upon external light (e.g., sunlight or room lights) that excites the phosphor material in the wavelength conversion component, and which therefore generates a yellowish, yellow-orange or orange color in the photoluminescence light. Since the LED chip or die is not generating any blue light, this means that there will not be any residual blue light to combine with the yellow/orange light from the photoluminescence light of the wavelength conversion component to generate white appearing light. As a result, the lighting device will appear to be yellowish, yellow-orange or orange in color. This may be undesirable to the potential purchaser or customer that is seeking a white-appearing light.

[0063] According to some embodiments, the light diffusing layer **44** provides the additional benefit of addressing this problem by improving the visual appearance of the device in an OFF state to an observer **21**. In part, this is because the light diffusing layer **44** includes particles of a light diffractive material that can substantially reduce the passage of external excitation light that would otherwise cause the wavelength conversion component to re-emit light of a wavelength having a yellowish/orange color.

[0064] The particles of a light diffractive material in the light diffusing layer **44** are selected, for example, to have a size range that increases its probability of scattering blue light, which means that less of the external blue light passes through the light diffusing layer **44** to excite the wavelength conversion layer **46**. Therefore, the remote phosphor lighting apparatus will have more of a white appearance in an OFF state since the wavelength conversion component is emitting less yellow/red light.

[0065] The light diffractive particle size can be selected such that the particles will scatter blue light relatively at least twice as much as they will scatter light generated by the phosphor

Savant Technologies LLC - 1004.060

material. Such a light diffusing layer **44** ensures that during an OFF state, a higher proportion of the external blue light received by the device will be scattered and directed by the light diffractive material away from the wavelength conversion layer **46**, decreasing the probability of externally originated photons interacting with a phosphor material particle and minimizing the generation of the yellowish/orange photoluminescent light. However, during an ON state, phosphor generated light caused by excitation light from the LED light source can nevertheless pass through the diffusing layer **44** with a lower probability of being scattered. Preferably, to enhance the white appearance of the lighting device in an OFF state, the light diffractive material within the light diffusing layer **44** is a "nano-particle" having an average particle size of less than about 150nm. For light sources that emit lights having other colors, the nano-particle may correspond to other average sizes. For example, the light diffractive material within the light diffusing layer **44** for an UV light source may have an average particle size of less than about 100nm.

[0066] Therefore, by appropriate selection of the average particle size of the light scattering material, it is possible to configure the light diffusing layer such that it scatters excitation light (e.g., blue light) more readily than other colors, namely green and red as emitted by the photoluminescence materials. FIG. **10** shows plots of relative light scattering versus TiO_2 average particle size (nm) for red, green and blue light. As can be seen from FIG. **10**, TiO_2 particles with an average particle size of 100nm to 150nm are more than twice as likely to scatter blue light (450nm to 480nm) than they will scatter green light (510nm to 550nm) or red light (630nm to 740nm). For example TiO_2 particles with an average particle size of 100nm will scatter blue light nearly three times (2.9=0.97/0.33) more than it will scatter green or red light. For TiO_2 particles with an average particle size of 200nm these will scatter blue light over twice

Savant Technologies LLC - 1004.061

(2.3=1.6/0.7) as much as they will scatter green or red light. In accordance with some embodiments of the invention, the light diffractive particle size is preferably selected such that the particles will scatter blue light relatively at least twice as much as light generated by the phosphor material(s).

[0067] Another problem with remote phosphor devices that can be addressed by embodiments of the invention is the variation in color of emitted light with emission angle. In particular, remote phosphor devices are often subject to perceptible non-uniformity in color when viewed from different angles.

[0068] Embodiments of the invention correct for this problem, since the addition of a light diffusing layer **44** in direct contact with the wavelength conversion layer **46** significantly increases the uniformity of color of emitted light with emission angle θ. The emission angle θ is measured with respect to an emission axis **48** (FIG. **1**). FIG. **4** shows plots of measured CIE color change versus emission angle θ for the lamp of FIG. **1** for wavelength conversion components **36** comprising diffusing layer **44** with percentage (%) weight loadings of light diffractive material to binder material of 0%, 7%, 12%, 16%, 23% and 35%, according to some example implementations of the invention. All emission color measurements were measured at a distance of 10m from the lamp **10** for wavelength conversion components in which the light diffusing layer comprises light diffractive particles of TiO_2 with an average particle size ≈5μm. For comparison the data for a 0% percentage loading of $Ti0_2$ correspond to a wavelength conversion component that does not include a light diffusing layer.

[0069] The measured color change is derived from the relationship:

$$\text{CIE change} = \sqrt{(\text{CIE } x_{\theta^\circ} - \text{CIE } x_{0^\circ})^2 + (\text{CIE } y_{\theta^\circ} - \text{CIE } y_{0^\circ})^2}$$

Savant Technologies LLC - 1004.062

where CIE x_{θ° is the measured CIE chromaticity x value at an emission angle of θ°, CIE x_{0° is the measured CIE chromaticity x value for an emission angle of $\theta=0^\circ$, CIE y_{θ° is the measured CIE chromaticity y value at an emission angle of θ° and CIE y_{0° is the measured CIE chromaticity y value at an emission angle of $\theta=0^\circ$. It will be appreciated that the CIE change is normalized to the light color at an emission angle $\theta=0^\circ$ (i.e. the CIE change is always 0 for $\theta=0^\circ$).

[0070] As can be seen in FIG. **4** for a wavelength conversion component with no light diffusing layer (i.e. 0% $Ti0_2$ loading), the color of light generated by such a lamp can alter by a CIE change of nearly 0.07 for emission angles up to $\theta=60^\circ$. In comparison for a wavelength conversion component **36** in accordance with the invention that includes a light diffusing layer **44** with a percentage weight loading of TiO_2 of only 7% the change in emission color over a 60° range drops to about 0.045. As can be seen from this figure, increasing the percentage weight loading of TiO_2 decreases the change in emission color over a 60° angular range. For example for a 35% TiO_2 percentage weight loading the CIE color change is less than 0.001. Although the change in emission color with emission angle decreases with increasing TiO_2 loading the total emission intensity will also decrease.

[0071] FIG. **5** shows measured luminous efficacy versus CIE color change at an emission angle $\theta=60^\circ$ for wavelength conversion components **36** comprising diffusing layer **44** with percentage (%) weight loadings of TiO_2 to binder material of 0%, 7%, 12%, 16%, 23% and 35% for an example implementation of the invention. The luminous efficacy values are normalized relative to a lamp that does not include a light diffusing layer (i.e. 0% TiO_2 loading). The CIE color change @ $\theta=60^\circ$ is determined from the relationship:

Savant Technologies LLC - 1004.063

$$\sqrt{(\text{CIE } x_{60^\circ} - \text{CIE } x_{0^\circ})^2 + (\text{CIE } y_{60^\circ} - \text{CIE } y_{0^\circ})^2}$$

where CIE x_{60° is the measured CIE chromaticity x value at an emission angle of 60°, CIE x_{0° is the measured CIE chromaticity x value for an emission angle of 0°, CIE y_{60° is the measured CIE chromaticity y value at an emission angle of 60° and CIE y_{0° is the measured CIE chromaticity y value at an emission angle of 0°. As can be seen from FIG. **5**, there can be as much as a 25% decrease in luminous efficacy for a wavelength conversion component with a light diffusing layer containing a 35% weight loading of TiO_2. It will be appreciated when selecting the weight loading of light diffractive material in light diffusing layer a balance should be struck between improving emission color uniformity with emission angle and the decrease in luminous efficacy of the lamp. Wavelength conversion component in accordance with some embodiments of the invention preferably has a light diffusing layer with percentage weight loading of light diffractive material to binder material in a range 10% to 20%.

[0072] FIG. **6** shows plots of measured CIE color change versus emission angle θ for an example implementation of a 3000K white light emitting lamp **10** for conversion components **36** comprising diffusing layer **44** with percentage (%) weight loadings of TiO_2 to binder material of 0%, 10%, 15% and 20% whilst FIG. **7** shows corresponding measured luminous efficacy versus CIE color change at an emission angle θ=60°.

[0073] FIG. **8** is a 1931 chromaticity diagram showing the color CIE x, CIE y) of emitted light at emission angles θ=0°, 15°, 30°, 45° and 60° for a an example 3000K white light emitting LED-based lamp in accordance with the invention for wavelength conversion components containing 0%, 10%, 15% and 20% weight loadings of TiO_2. For comparison FIG. **8** also includes the black body radiation curve and ANSI C78.377A *"Specification for chromaticity of*

Savant Technologies LLC - 1004.064

white solid state lighting products" S and R quadrangles for white light of 3500K and 3000K respectively. Each quadrangle is equivalent to approximately seven MacAdam ellipses whilst each sub quadrangle (S02, S03, S06, S07, R02, R03, R06, R07) is equivalent to approximately four McAdam ellipses. As is known a MacAdam ellipse is a region on a chromaticity diagram which contains all colors which are indistinguishable, to the average human eye **21**, from the color at the center of the ellipse. As can be seen from FIG. **8** for a lamp without a light diffusing layer (0% TiO_2), the variation in emission color for emission angles of over a range θ=0° to 60° is approximately three MacAdam ellipses. For a lamp including a light diffusing layer with a 10% weight loading of TiO_2, the variation in emission color with emission angle is less than two MacAdam ellipses with a corresponding decrease in luminous efficacy of about 2% (FIG. 7). For a lamp including a light diffusing layer with a 15% weight loading of TiO_2, the variation in emission color with emission angle is approximately one MacAdam ellipse with a corresponding decrease in luminous efficacy of about 5% (FIG. 7). For such a lamp, an average person **21** would be unable to perceive the variation in emission color with emission angle. For a lamp including a light diffusing layer with a 20% weight loading of TiO_2 the variation in emission color with emission angle is less than one MacAdam ellipse with a corresponding decrease in luminous efficacy of about 9% (FIG. 7). It will be appreciated the inclusion of a light diffusing layer **44** in accordance with the invention can virtually eliminate the effects of emission color variation with emission angle whilst maintaining an acceptable luminous efficacy.

[0074] Embodiments of the present invention can also be used to reduce the amount of phosphor materials that is required to manufacture an LED lighting product, thereby reducing the cost of manufacturing such products given the relatively costly nature of the phosphor materials. In particular, the addition of a light diffusing layer **44** composed of particles of a light diffractive

Savant Technologies LLC - 1004.065

material can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. This means that relatively less phosphor is required to manufacture a wavelength conversion component as compared to comparable prior art approaches. As a result, it will be much less costly to manufacture lighting apparatuses that employ such wavelength conversion components, particularly for remote phosphor lighting devices.

[0075] In operation, the diffusing layer **44** increases the probability that a photon will result in the generation of photoluminescence light by reflecting light back into the wavelength conversion layer **46**. Therefore, inclusion of a diffusing layer with the wavelength conversion layer can reduce the quantity of phosphor material required to generate a given color emission product, e.g., by up to 40%.

[0076] As previously noted, the light diffusing layer **44** can be configured such that it selectively scatters excitation light generated by the LEDs (e.g., blue light) more than it scatters light generated by the phosphor material. Such a light diffusing layer **44** ensures that a higher proportion of the blue light emitted from the wavelength conversion layer will be scattered and directed by the light diffractive material back into the wavelength conversion layer increasing the probability of the photon interacting with a phosphor material particle and resulting in the generation of photoluminescence light. At the same time phosphor generated light can pass through the diffusing layer with a lower probability of being scattered. Since the diffusing layer increases the probability of blue photons interacting with a phosphor material particle less phosphor material can be used to generate a selected emission color. Such an arrangement can also increase luminous efficacy of the wavelength conversion component/device.

[0077] The light diffusing layer **44** can be used in combination with additional scattering (or

Savant Technologies LLC - 1004.066

reflective/diffractive) particles in the wavelength conversion component to further reduce the amount of phosphor material that is required to generate a selected color of emitted light. As disclosed in U.S. Application Ser. No. 13/253,031 (which is hereby incorporated by reference in its entirety), a wavelength conversion component comprises particles of a light scattering material (also referred to herein as "light reflecting material") that is incorporated with the phosphor material to enhance photoluminescence light generation by the phosphor material. The enhanced light generation results from the light reflective material increasing the number of collisions of light generated by the light emitter(s) with particles of the phosphor material. The net result is a decrease in phosphor material usage for the light emitting devices.

[0078] To explain this aspect of the current embodiment, it is helpful to first provide an explanation of the prior art approach that does not mix phosphors with scattering particles. FIG. **11** shows a schematic of an LED-based light emitting device that utilizes phosphor wavelength conversion without scattering particles mixed in with phosphors. The known device of FIG. **11** includes a wavelength conversion component that includes phosphor material particles **120** homogeneously distributed throughout the volume of a light transmissive binder **124**. Unlike the device of the invention, the known devices do not include particles of a light scattering material. In operation blue light **126** from the LED is transmitted by the light transmissive binder **124** until it strikes a particle of phosphor material. It is believed that on average as little as 1 in a 10,000 interactions of a photon with a phosphor material particle results in absorption and generation of photoluminescence light. The majority, about 99.99%, of interactions of photons with a phosphor particle result in scattering of the photon. Due to the isotropic nature of the scattering process on average half the scattered photons will be in a direction back towards the LED. Tests indicate that typically about 10% of the total incident blue light is scattered and emitted from the

Savant Technologies LLC - 1004.067

wavelength conversion component in a direction back towards the LED. For a cool white light emitting device the amount of phosphor material is selected to allow approximately 10% of the total incident blue light to be emitted through the window and contribute to the emission product. The majority, approximately 80%, of the incident light is absorbed by the phosphor material and re-emitted as photoluminescence light **128**. Due to the isotropic nature of photoluminescence light generation, approximately half of the light **128** generated by the phosphor material will be emitted in a direction towards the LED. As a result up to (↑) 40% of the total incident light will be emitted as light **128** of wavelength λ_2 and contributes to the emission product **130** whilst up to (↑) 40% of the total incident light will be emitted as light **128** of wavelength λ_2 in a direction back towards the LED. Typically light that is emitted towards the LED is re-directed by a reflector (not shown) to increase the overall efficacy of the device.

[0079] FIG. **12** shows a schematic of operation of a device that is similar to that of FIG. **11** but additionally includes reflection or scattering of light (of wavelengths λ_1 and λ_2) by the particles of the light reflective/scattering material. By including particles of a light reflective material with the phosphor material, this can reduce the amount of phosphor material required to generate a given color emission product, e.g. by up to 33% in some embodiments. The particles of light reflective material increase the probability of photons striking a particle of phosphor material and thus for an emission product of a given color less phosphor material is required.

[0080] FIG. **13** is a plot of emission intensity versus chromaticity CIE x for a light emitting device in accordance with some embodiments of the invention for weight percent loadings of light reflective material of ♦- 0%, ■- 0.4%, ▲- 1.1% and ●- 2%. The data are for screen printed phosphor conversion layers in which the binder material comprises Nazdar's® UV curable litho clear overprint PSLC-294 and the phosphor material comprises Intematix Corporation's

Savant Technologies LLC - 1004.068

phosphor EY4453 with an average particle size of 15μm. The ratio of phosphor material to clear ink is in a proportion of 2:1 by weight. The light reflective material comprises Norcote International Inc's super white ink GN-027SA. The figures for loading of light reflective material refer to weight percent of super white ink to clear ink. The smaller reference numerals associated with each data point indicate the number 'n' of print passes used to form the phosphor layer.

[0081] The phosphor material and light scattering material, which can be in powder form, are thoroughly mixed in known proportions with the light transmissive binder material, such as a polymer material (for example a thermally or UV curable silicone or an epoxy material) or a clear ink such as for example Nazdar's® UV curable litho clear overprint PSLC-294. The mixture is applied to the face of a substrate as one or more layers of uniform thickness. In a preferred embodiment the mixture is applied to the light transmissive window by screen printing and the thickness **t** of the layer controlled by the number of printing passes. The phosphor/reflective material mixture can be applied using other methods including inkjet printing, spin coating or sweeping the mixture over the surface using a blade such as a squeegee (e.g. doctor blading).

[0082] It will be appreciated that the number of print passes is directly proportional to the thickness of the phosphor layer **118** and quantity of phosphor. The ovals **132, 134, 136, 138** are used to group data points for emission products that have substantially the same intensity and CIE x values. For example oval **132** indicates that an emission product of similar intensity and color can be produced for a phosphor conversion layers **118** comprising i) 3 print passes without light reflective material and ii) 2 print passes with a 2% loading of light reflective material. These data indicate that by the inclusion of a 2% weight loading of light reflective material it is

Savant Technologies LLC - 1004.069

possible to generate the same color and intensity of light using a phosphor conversion layer **118** that comprises about 33% less phosphor material. Oval **134** indicates that the same intensity and color of emission product is produced for a phosphor conversion layer comprising i) 4 print passes without light reflective material and ii) 3 print passes with a 0.4% loading of light reflective material. These data indicate that for this embodiment, by the inclusion of a 0.4% weight loading of light reflective material, the same color and intensity of light can be produced using a phosphor conversion layer comprising about 25% less phosphor. Oval **136** indicates that the same intensity and color of emission product is produced for a phosphor conversion layer comprising i) 4 print passes without light reflective material and ii) 3 print passes with a 1.1% loading of light reflective material. These data indicate that by the inclusion of a 1.1% weight loading of light reflective material the same color and intensity of light can be produced using a phosphor conversion layer comprising about 25% less phosphor. Oval **138** indicates that the same intensity and color of emission product is produced for a phosphor conversion layer comprising i) 4 print passes with a 0.4% weight loading of light reflective material and ii) 3 print passes with a 2% weight loading of light reflective material. These data indicate by the inclusion of a 0.4% weight loading of light reflective material that the same color and intensity of light can be produced using a phosphor conversion layer comprising about 25% less phosphor. Points **140** (n=4, 1.1% loading) and **142** (n=4, 2% loading) suggest that a saturation point exists above which an increase in light reflective material loading results in a decrease in emission intensity with little effect on the color.

[0083] It is envisioned in further embodiments to incorporate the mixture of phosphor and light reflective material mixture within a light transmissive window. For example the phosphor and light reflective material mixture can be mixed with a light transmissive polymer and the

Savant Technologies LLC - 1004.070

polymer/phosphor mixture extruded or injection molded to form the wavelength conversion component **36** with the phosphor and light reflective material homogeneously distributed throughout the volume of the component.

[0084] The light scattering material **122** comprises a powdered material with a high reflectivity typically a reflectance of 0.9 or higher. The particle size of the light reflective material is typically in a range 0.1μm to 10μm and in a preferred embodiment is within a range 0.1μm to 10μm. The weight percent loading of light reflective material to phosphor material is in a range 0.1% to 10% and in a preferred embodiment in a range 1% to 2%. Examples of light reflective materials include magnesium oxide (MgO), titanium dioxide (TiO_2), barium sulfate ($BaSO_4$) and combinations thereof. The light reflective material can also comprise a white ink such as for example Norcote International Inc's super white ink GN-027SA which already includes particles of a highly light reflective material, typically TiO_2.

[0085] FIG. **14** illustrates a representation of a LED-based white light emitting device in accordance with an embodiment of the invention, which includes a wavelength conversion component **36** having a wavelength conversion layer **46** that includes a mixture of phosphor material particles **120** and light scattering particles **122** distributed throughout the volume of a light transmissive binder material **124**. The particles of light scattering particles **122** increase the probability of photons striking phosphor material particles **120,** and thus for an emission product of a given color less phosphor material is required.

[0086] Wavelength conversion component **36** also includes a diffusing layer **44** that comprises light scattering particles **152** within a binder material **150**. The light scattering particles **152** within the light diffusing layer **44** selectively scatters blue light **126** generated by the LEDs more than it scatters light **128** generated by the phosphor material **120**. Such a light

Savant Technologies LLC - 1004.071

diffusing layer **44** ensures that a higher proportion of the blue light **126** emitted from the wavelength conversion layer **46** will be scattered and directed by the light scattering material **152** back into the wavelength conversion layer **46** increasing the probability of the photon interacting with a phosphor material particle **120** and resulting in the generation of photoluminescence light. At the same time phosphor generated light can pass through the diffusing layer **44** with a lower probability of being scattered. Since the diffusing layer **44** increases the probability of blue photons interacting with a phosphor material particle **120**, less phosphor material can be used to generate an emitted light **130** of a selected emission color that is visible to an observer **21**.

[0087] Therefore, the combination of a diffusing layer **44** having scattering particles **152** and a wavelength conversion layer **46** that also includes light scattering particles **122** results in a wavelength conversion component that requires much less phosphor materials **120** to generate a given color emission product. Both sets of scattering particles **122** and **152** act in combination to increase the probability of photons striking a particle of phosphor material **120**, and thus require less phosphor material for a given color.

[0088] The two sets of scattering particles **122** and **152** can have different material properties. For example, the scattering particles **122** within the wavelength conversion layer **46** can be selected to have a relatively larger average particle size. On the other hand, the scattering particles **152** within the diffusing layer **44** can be selected to be nano-particles having a relatively smaller average particle size that is selected such that the particles **152** will scatter excitation (typically blue) light relatively more than they will scatter light generated by the photoluminescence (phosphor) material(s). Therefore, some embodiments employ a light scattering material **152** that has an average particle size of less than about 150nm and typically has an average particle size in a range of 100nm to 150nm. Alternative embodiments can

Savant Technologies LLC - 1004.072

implement both sets of scattering particles **122** and **152** having the same or substantially the same particle size, e.g., to employ nano-particles in both the wavelength conversion layer **46** and the diffusing layer **44**.

[0089] The inventive concepts disclosed herein may be applied to wavelength conversion components that encompass any suitable shape. For example, consider the LED light bulb **200** illustrated in FIGS. **15** and **16** which illustrate a perspective view and a cross-sectional view of an application of an LED light bulb that utilizes a wavelength conversion component in accordance with some embodiments. The LED light bulb **200** is intended to be used as an energy efficient replacement for a conventional incandescent or fluorescent light bulb.

[0090] The light bulb **200** comprises a screw base **206** that is configured to fit within standard light bulb sockets, e.g. implemented as a standard Edison screw base. The light bulb **200** may further comprise a thermally conductive body **204** fabricated from, for example, die cast aluminum. The body **204** functions as a heat sink and dissipates heat generated by the light emitters **112**, which are mounted on a MCPCB (Metal Core Printed Circuit Board). To increase heat radiation from the light bulb **200** and thereby increase cooling of the light bulb **200**, the body **204** can include a series of latitudinal radially extending heat radiating fins **207**.

[0091] The light bulb **200** further comprises a wavelength conversion component **36** having a three-dimensional shape, e.g., elongated dome shape shell having an interior volume defined by its inner surface that encloses the light emitters **112** within the interior volume. The three dimensional wavelength conversion component **36** includes a three-dimensional light transmissive thermally conductive substrate **703** in thermal contact with a three-dimensional wavelength conversion layer **701.**

Savant Technologies LLC - 1004.073

[0092] An envelope **208** extends around the upper portion of the LED light bulb **200**, enclosing the LEDs **112** and the wavelength conversion component **36**. The envelope **208** is a light-transmissive material (e.g. glass or plastic) that provides protective and/or diffusive properties for the LED light bulb **200**.

[0093] The blue LED device **112** resides on the top surface of the lighting base **204**, beneath the wavelength conversion component **36**, which comprises both a light diffusing layer **44** and a wavelength conversion layer **46**. The three-dimensional nature of the wavelength conversion component **36** creates a relatively large shape that surrounds the interior volume around and above the LEDs **112**. Using three-dimensional shapes for the wavelength conversion component **36** in a lighting device **200** allows for certain functional advantages, such as the ability to perform light shaping for the light emitted by the lighting device **200**.

[0094] However, these types of three-dimensional shapes for the wavelength conversion component **36** also correspond to a relatively large volume for the wavelength conversion component which needs to be populated with adequate amounts of the phosphor materials. With prior art approaches, a significantly large amount of phosphor material would therefore be required to manufacture such wavelength conversion components **36**.

[0095] Embodiments of the invention may be employed to reduce the amount of phosphor needed to manufacture such wavelength conversion components **36**. In particular, the wavelength conversion component **36** comprises a light diffusing layer **44** that is adjacent to a wavelength conversion layer **46**, where either or both of these layers may include a light scattering material. Since the scattering material within the wavelength conversion component **36** has the property of scattering light, this reduces the amount of phosphor material that is needed for the wavelength conversion component **36**.

Savant Technologies LLC - 1004.074

[0096] In addition, the light diffusing layer **44** also serves to improve the OFF state color appearance of the LED lighting device **200** based at least in part on the properties of the particles of diffracting materials within the diffusing layer **44**.

[0097] FIG. **17** illustrates an embodiment of the invention comprising a dome-shaped wavelength conversion component **36** that includes a light diffusing layer **44** adjacent to a wavelength conversion layer **46**, where either or both the light diffusing layer **44** and the wavelength conversion layer **46** comprise light scattering particles. As with the other described embodiments, the light scattering particles within the light diffusing layer **44** scatters blue light **126** generated by the LEDs **112** more than it scatters light **128** generated by the phosphor material within the wavelength conversion layer **46**, which ensures that a higher proportion of the blue light **126** emitted from the wavelength conversion layer **46** will be scattered and directed by the light scattering material **152** back into the wavelength conversion layer **46** increasing the probability of the photon interacting with a phosphor material particles and resulting in the generation of photoluminescence light. At the same time phosphor generated light can pass through the diffusing layer **44** with a lower probability of being scattered. Since the diffusing layer **44** increases the probability of blue photons interacting with a phosphor material particle, less phosphor material can be used to generate an emitted light **130** of a selected emission color that is visible to an observer **21**.

[0098] The three-dimensional wavelength conversion components of FIGs. **15-17** can be manufactured using any suitable means. For example, a molding process (e.g., injection molding) can be used to manufacture the two layers of the light diffusing layer **44** and the wavelength conversion layer **46**. For the light diffusing layer **44**, light diffractive material may be mixed with a solid light-transmissive polymer material, in which the phosphor material and

Savant Technologies LLC - 1004.075

the light-transmissive polymer material undergo a heating process that melts and mixes the phosphor material with the polymer material into a liquid, which is then injected into a mold and then cooled to form the final shape of the light diffusing layer **44**. For the wavelength conversion layer **46**, a similar molding process may be utilized, in which the phosphor material and the light-transmissive polymer material are heated and drawn into a mold (e.g., the light diffusing layer **44**). A heating process will melt and mix the phosphor material with the polymer material, which is then cooled to form the final shape of the wavelength conversion layer **46**. Hot runners may be employed to ensure efficient usage of the constituent components for the molding process. Vacuum molding may also be employed to manufacture the three-dimensional wavelength conversion components. In addition, light scattering particles may be introduced into the materials of the wavelength conversion layer **46**, thereby reducing the amount of phosphor material that is required.

[0099] FIG. **18** illustrates an alternative embodiment of the invention, comprising a three-dimensional wavelength conversion component **36** that includes a dome-shaped light diffusing layer **44**. In this embodiment, the wavelength conversion layer **46'** fills a substantial portion of the volume defined by the interior surface of the light diffusing layer **44**, rather than being embodied as a thin layer directly adjacent to the light diffusing layer **44** as described in FIG. **17**. One possible advantage of the approach of FIG. **17** over the approach of FIG. **18** is the increased conversion efficiency for converting the blue light **126** generated by the LEDs **112** into the light **128** generated by the phosphor material within the wavelength conversion layer **46'**. However, a possible disadvantage is the negative performance that may result from excessive heating of the phosphor material within the wavelength conversion layer **46'** due to its close proximity to the LEDs **112**.

Savant Technologies LLC - 1004.076

[00100] FIG. **19** illustrates another embodiment of the invention that comprises a wavelength conversion component **36** with a dome-shaped light diffusing layer **44**. In this embodiment, the wavelength conversion layer **46''** fills a substantial portion of the volume defined by the light diffusing layer **44**, but in which scattering particles are also distributed within the wavelength conversion layer **46''**. The scattering particles within the wavelength conversion layer **46''** has the property of scattering light, which reduces the amount of phosphor material that is needed for the wavelength conversion component **36**. In addition, the light diffractive material within the light diffusing layer **44** serves to improve the OFF state color appearance of the LED lighting device **200**, while also reducing the amount of phosphor material required for the wavelength conversion layer **46''**.

[00101] The wavelength conversion components of FIGs. **18** and **19** can be manufactured using any suitable means. For example, a molding process (e.g., injection molding or vacuum molding) can be used to manufacture the light diffusing layer **44**. For the light diffusing layer **44**, light diffractive material may be mixed with a solid light-transmissive polymer material (e.g., in the form of polymer pellets), which are heated and injected into a mold in the desired shape for the light diffusing layer **44**. The heating process will melt and mix the light diffractive material with the polymer material in the mold, which is then cooled to form the final shape of the light diffusing layer **44**. For the wavelength conversion layer, the phosphor material may be mixed with a liquid binder material, with the resulting mixture poured into the interior volume formed by the inner surfaces of the light diffusing layer **44**. A curing process is then employed to cure the wavelength conversion layer not its final form. Scattering particles may also be placed into the phosphor/binder mixture to reduce the amount of phosphor that is required.

[00102] A high CRI solid-state light emitting device **10** in accordance with another

Savant Technologies LLC - 1004.077

embodiment of the invention will now be described with reference to FIG. **9** which shows schematic partial cutaway plan and sectional views of the device. The device **10** is configured to generate warm white light with a CCT of ≈3000K, a luminous flux of about 1100 lumens and a CRI (Color Rendering Index) greater than 90. The device **10** is essentially the same as that of FIG. **1** and additionally comprises one or more red light emitting LEDs (red LEDs) **50**. As shown in FIG. **9** the red LED(s) can comprise a packaged array of red LED chips. The red LED chips can comprise AlGaAs (aluminum gallium arsenic), GaAsP (gallium arsenic phosphide), AlGaInP (aluminum gallium indium phosphide) or GaP (gallium phosphide) LED that are operable to generate red light **52** having a peak wavelength λ_3 in a wavelength range 610nm to 670nm. The emission product **38** of the device **10** comprises the combined blue **28** (λ_1) and red **52** (λ_3) light by generated by the LEDs **24**, **50** and photoluminescence light **38** generated by the phosphor wavelength conversion component **36**. Operation of the device **10** of FIG. **9** is analogous to that of the device of FIG. **1** and is not described further. Initial tests of the device of FIG. **9** indicate that the light diffusing layer **44** increases the angular emission color uniformity of the device by blending the red, blue and phosphor generated light.

[00103] FIGs. **20A**, **20B**, and **20C** illustrate an example of an application of a wavelength conversion component in accordance with some embodiments of the invention. FIG. **20A**, **20B**, and **20C** illustrates an LED downlight **1000** that utilizes remote wavelength conversion in accordance with some embodiments. FIG. **20A** is an exploded perspective view of the LED downlight **1000**, FIG. **20B** is an end view of the downlight **1000**, and FIG. **20C** is a sectional view of the downlight **1000**. The downlight **1000** is configured to generate light with an emission intensity of 650-700 lumens and a nominal beam spread of 60° (wide flood). It is intended to be used as an energy efficient replacement for a conventional incandescent six inch downlight.

Savant Technologies LLC - 1004.078

[00104] The downlight **1000** comprises a hollow generally cylindrical thermally conductive body **1001** fabricated from, for example, die cast aluminum. The body **1001** functions as a heat sink and dissipates heat generated by the LEDs **1007**. To increase heat radiation from the downlight **1000** and thereby increase cooling of the light emitting device **1000**, the body **1001** can include a series of latitudinal spirally extending heat radiating fins **1003** located towards the base of the body **1001**. To further increase the radiation of heat, the outer surface of the body can be treated to increase its emissivity such as for example painted black or anodized. The body **1001** further comprises a generally frustoconical (i.e. a cone whose apex is truncated by a plane that is parallel to the base) axial chamber **1005** that extends from the front of the body a depth of approximately two thirds of the length of the body. The form factor of the body **1001** is configured to enable the downlight to be retrofitted directly in a standard six inch downlighting fixture (can) as are commonly used in the United States.

[00105] Four solid state light emitters **1007** are mounted as a square array on a circular shaped MCPCB **1009**. As is known an MCPCB comprises a layered structure composed of a metal core base, typically aluminum, a thermally conducting/electrically insulating dielectric layer and a copper circuit layer for electrically connecting electrical components in a desired circuit configuration. With the aid of a thermally conducting compound such as for example a standard heat sink compound containing beryllium oxide or aluminum nitride the metal core base of the MCPCB **1009** is mounted in thermal communication with the body via the floor of the chamber **1005**. The MCPCB **1009** can be mechanically fixed to the body floor by one or more screws, bolts or other mechanical fasteners.

[00106] The downlight **1000** further comprises a hollow generally cylindrical light reflective chamber wall mask **1015** that surrounds the array of light emitters **1007**. The chamber wall mask

Savant Technologies LLC - 1004.079

1015 can be made of a plastics material and preferably has a white or other light reflective finish. A wavelength conversion component **36** may be mounted overlying the front of the chamber wall mask **1015** using, for example, an annular steel clip that has resiliently deformable barbs that engage in corresponding apertures in the body. The wavelength conversion component **36** is remote to the light emitting devices **1007**.

[00107] The wavelength conversion component **36** comprises a light diffusing layer **44** adjacent to a wavelength conversion layer **46** as described above. By placing the wavelength conversion layer **46** adjacent to a light diffusing layer **44**, the light scattering particles within the light diffusing layer **44** scatters blue light generated by the light emitters **1007** more than it scatters light generated by the phosphor material within the wavelength conversion layer **46**. This ensures that a higher proportion of the blue light emitted from the wavelength conversion layer **46** will be scattered and directed by the light scattering material back into the wavelength conversion layer **46** increasing the probability of the photon interacting with a phosphor material particles and resulting in the generation of photoluminescence light. At the same time phosphor generated light can pass through the diffusing layer **44** with a lower probability of being scattered. Since the diffusing layer **44** increases the probability of blue photons interacting with a phosphor material particle, less phosphor material can be used to generate an emitted light of a selected emission color. In addition, during its OFF state, the diffusing layer **44** also serves to improve the white color of the light **1000**.

[00108] The downlight **1000** further comprises a light reflective hood **1025** which is configured to define the selected emission angle (beam spread) of the downlight (i.e. 60° in this example). The hood **1025** comprises a generally cylindrical shell with three contiguous (conjoint) inner light reflective frustoconical surfaces. The hood **1025** is preferably made of

Savant Technologies LLC - 1004.080

Acrylonitrile butadiene styrene (ABS) with a metallization layer. Finally the downlight **1025** can comprise an annular trim (bezel) **1027** that can also be fabricated from ABS.

[00109] FIGs. **21A**, **21B**, and **21C** illustrate another example of an application of a wavelength conversion component in accordance with some embodiments. FIGs. **21A**, **21B**, and **21C** illustrate an LED downlight **1100** that utilizes remote wavelength conversion in accordance with some embodiments. FIG. **21A** is an exploded perspective view of the LED downlight **1100**, FIG. **21B** is an end view of the downlight **1100**, and FIG. **21C** is a sectional view of the downlight **1100**. The downlight **1100** is configured to generate light with an emission intensity of 650-700 lumens and a nominal beam spread of 60° (wide flood). It is intended to be used as an energy efficient replacement for a conventional incandescent six inch downlight.

[00110] The downlight **1100** of FIGs. **21A**, **21B**, and **21C** is substantially the same as the downlight **1000** of FIGs. **20A**, **20B**, and **20C**. For purposes of discussion, only features of the downlight **1100** that are new relative to the embodiments of FIGs. **20A**, **20B**, and **20C** will be described.

[00111] Whereas the wavelength conversion component **36** of FIGs. **20A**, **20B**, and **20C** has a two-dimensional shape (e.g., is substantially planar), the wavelength conversion component **700** of FIGs. **21A**, **21B**, and **21C** has a three-dimensional shape (e.g., elongated dome shaped shell). The three dimensional wavelength conversion component **700** includes a three-dimensional light transmissive thermally conductive substrate **703** in thermal contact with a three-dimensional wavelength conversion layer **701**, such as the wavelength conversion component **700** described above in FIG. 7. The wavelength conversion component may also be mounted enclosing the front of the chamber wall mask **1015**.

[00112] As discussed above, by placing the wavelength conversion layer **701** adjacent to a

Savant Technologies LLC - 1004.081

light diffusing layer **703**, the light scattering particles within the light diffusing layer **703** scatters blue light generated by the light emitters **1007** more than it scatters light generated by the phosphor material within the wavelength conversion layer **701**. This ensures that a higher proportion of the blue light emitted from the wavelength conversion layer **701** will be scattered and directed by the light scattering material back into the wavelength conversion layer **700** increasing the probability of the photon interacting with a phosphor material particles and resulting in the generation of photoluminescence light. Therefore, less phosphor material is required to generate an emitted light of a selected emission color. In addition, during its OFF state, the diffusing layer **703** also improves the white color of the light **1100**.

[00113] FIG. **22** illustrates another example of an application of a wavelength conversion component in accordance with some embodiments, showing an exploded perspective view of a reflector lamp **1200** that utilizes remote wavelength conversion in accordance with some embodiments. The reflector lamp **1200** is configured to generate light with an emission intensity of 650-700 lumens and a nominal beam spread of 60° (wide flood). It is intended to be used as an energy efficient replacement for a conventional incandescent six inch downlight.

[00114] The reflector lamp **1200** comprises a generally rectangular thermally conductive body **1201** fabricated from, for example, die cast aluminum. The body **1201** functions as a heat sink and dissipates heat generated by the light emitting device **10"** To increase heat radiation from the reflector lamp **1000** and thereby increase cooling of the light emitting device **10''**, the body **1201** can include a series of heat radiating fins **1203** located on the sides of the body **1201**. The form factor of the body **1201** is configured to enable the reflector lamp to be retrofitted directly in a standard six inch downlighting fixture (a "can") as are commonly used in the United States.

[00115] The wavelength conversion component 36 may be implemented to have a wavelength

Savant Technologies LLC - 1004.082

conversion layer that is adjacent to a light diffusing layer, such that the light scattering particles within the light diffusing layer scatters blue light more than it scatters light generated by the phosphor material within the wavelength conversion layer. Therefore, less phosphor material is required to generate an emitted light of a selected emission color. In addition, during its OFF state, the diffusing layer also improves the white color of the light **1200**.

[00116] The reflector lamp **1200** further comprises a generally frustroconical light reflector **1205** having a paraboloidal light reflective inner surface which is configured to define the selected emission angle (beam spread) of the downlight (i.e. 60° in this example). The reflector **1205** is preferably made of Acrylonitrile butadiene styrene (ABS) with a metallization layer.

[00117] FIGs. **23A** and **23B** illustrate another example of an application of a wavelength conversion component in accordance with some embodiments. FIGs. **23A** and **23B** illustrate an LED linear lamp **1300** that utilizes remote wavelength conversion in accordance with some embodiments. FIG. **23A** is a three-dimensional perspective view of the linear lamp **1300** and FIG. **23B** is a cross-sectional view of the linear lamp **1300**. The LED linear lamp **1300** is intended to be used as an energy efficient replacement for a conventional incandescent or fluorescent tube lamp.

[00118] The linear lamp **1300** comprises an elongated thermally conductive body **1301** fabricated from, for example, extruded aluminum. The form factor of the body **1301** can be configured to be mounted with a standard linear lamp housing. The body **1301** further comprises a first recessed channel **1304**, wherein a rectangular tube-like case **1307** containing some electrical components (e.g., electrical wires) of the linear lamp **1300** may be situated. The case **1307** may further comprise an electrical connector **1309** (e.g., plug) extending past the length of the body **1301** on one end, and a recessed complimentary socket (not shown) configured to

Savant Technologies LLC - 1004.083

receive a connector on another end. This allows several linear lamps **1300** to be connected in series to cover a desired area. Individual linear lamps **1300** may range from 1 foot to 6 feet in length.

[00119] The body **1301** functions as a heat sink and dissipates heat generated by the light emitters **1303**. To increase heat radiation from the linear lamp **1300** and thereby increase cooling of the light emitters **1303**, the body **1301** can include a series of heat radiating fins **1302** located on the sides of the body **1301**. To further increase heat radiation from the linear lamp **1300**, the outer surface of the body **1301** can be treated to increase its emissivity such as for example painted black or anodized.

[00120] Light emitters **1303** are mounted on a strip (rectangular shaped) MCPCB **1305** configured to sit above the first recessed channel **1304**. The under surface of the MCPCB **1305** sits in thermal contact with a second recessed channel **1306** that includes inclined walls **1302**.

[00121] A generally hemi-spherical elongate wavelength conversion component **1311** may be positioned remote to the light emitters **1303**. The wavelength conversion component **1311** may be secured within the second recessed channel **1306** by sliding the wavelength conversion component **1311** under the inclined walls **1308** such that the wavelength conversion component **1311** engages with inclined walls **1308**.

[00122] The wavelength conversion component **1311** may include a hemi-spherical elongate light diffusing layer **1313** and a hemi-spherical elongate wavelength conversion layer **1315**. As discussed above, less phosphor material is required to generate an emitted light of a selected emission color. In addition, during its OFF state, the diffusing layer also improves the white color of the light **1300**.

[00123] In alternative embodiments, the wavelength conversion component of the linear lamp

Savant Technologies LLC - 1004.084

may be configured in the shape of a generally planar strip. In such embodiments, it will be appreciated that the second recessed channel may instead have vertical walls that extend to allow the wavelength conversion component to be received by the second recessed channel.

[00124] FIG. **24** illustrates a perspective of another application of a wavelength conversion component in accordance with some embodiments. FIG. **24** illustrates an LED lantern **1500** that utilizes remote wavelength conversion. The LED light lantern **1500** is intended to be used as an energy efficient replacement for conventional gas and fluorescent lanterns (e.g., camping lanterns).

[00125] The lantern **1500** comprises a generally cylindrical thermally conductive body **1501** fabricated from, for example, plastic material or pressed metal. The body **1501** further includes an internal heat sink which dissipates heat generated by the light emitters **1503**, which are mounted on a circular shaped MCPCB **1505**. The MCPCB **1505** may be in thermal contact with the body **1501**.

[00126] The lantern **1500** comprises a three-dimensional (e.g., elongated dome shaped shell) wavelength conversion component **700**, such as the one described above in FIG. **17**, **18** or **19**, that extends from the MCPCB **1505**. While only an exterior surface of the wavelength conversion component **700** is depicted, it is important to note that the three dimensional wavelength conversion component **700** may include a three-dimensional light diffusing layer adjacent to a three-dimensional wavelength conversion layer. As discussed above, this configuration permits less phosphor material to be used to generate an emitted light of a selected emission color. In addition, during its OFF state, the diffusing layer also improves the white color of the light.

[00127] A light transmissive cover (e.g., plastic) **1507** may extend around the upper portion of

Savant Technologies LLC - 1004.085

the lantern, surrounding the LEDs **1503** and the wavelength conversion component **900**. The light transmissive cover **1507** comprises a light-transmissive material (e.g. glass or plastic) that provides protective and/or diffusive properties for the LED lantern **1500**. The lantern **1500** may further comprise a lid that sits on top of the glass receptacle to enclose the light emitters **1503** and the wavelength conversion component **700**.

[00128] The above applications of light emitting devices describe a remote wavelength conversion configuration, wherein a wavelength conversion component is remote to one or more light emitters. The wavelength conversion component and body of those light emitting devices define an interior volume wherein the light emitters are located. The interior volume may also be referred to as a light mixing chamber. For example, in the downlight **1000, 1100** of FIGs. 20A, 20B, 20C, 21A, 21B, and 21C, an interior volume **1029** is defined by the wavelength conversion component **36', 700**, the light reflective chamber mask **1015**, and the body of the downlight **1001**. In the linear lamp **1300** of FIGs. 23A and 23B, an interior volume **1325** is defined by the wavelength conversion component **1311** and the body of the linear lamp **1301**. In the light bulb **200** of FIGs. 15 and 16, an interior volume **1415** is defined by the wavelength conversion component **36** and the body of the light bulb **204**. Such an interior volume provides a physical separation (air gap) of the wavelength conversion component from the light emitters that improves the thermal characteristics of the light emitting device. Due to the isotropic nature of photoluminescence light generation, approximately half of the light generated by the phosphor material can be emitted in a direction towards the light emitters and can end up in the light mixing chamber. It is believed that on average as little as 1 in a 10,000 interactions of a photon with a phosphor material particle results in absorption and generation of photoluminescence light. The majority, about 99.99%, of interactions of photons with a phosphor particle result in

Savant Technologies LLC - 1004.086

scattering of the photon. Due to the isotropic nature of the scattering process on average half the scattered photons will be in a direction back towards the light emitters. As a result up to half of the light generated by the light emitters that is not absorbed by the phosphor material can also end up back in the light mixing chamber. To maximize light emission from the device and to improve the overall efficiency of the light emitting device the interior volume of the mixing chamber includes light reflective surfaces to redirect - light in- the interior volume towards the wavelength conversion component and out of the device. The light mixing chamber may be operated to mix light within the chamber. The light mixing chamber can be defined by the wavelength conversion component in conjunction with another component of the device such a device body or housing (e.g., dome-shaped wavelength conversion component encloses light emitters located on a base of device body to define light mixing chamber, or planar wavelength conversion component placed on a chamber shaped component to enclose light emitters located on a base of device body and surrounded by the chamber shaped component to define light mixing chamber). For example, the downlight **1000, 1100** of FIGs. 20A, 20B, 20C, 21A, 21B, and 21C, includes an MCPCB **1009**, on which the light emitters **1007** are mounted, comprising light reflective material and a light reflective chamber wall mask **1015** to facilitate the redirection of light reflected back into the interior volume towards the wavelength conversion component **36', 700**. The linear lamp **1300** of FIGs. 23A and 23B includes an MCPCB **1305**, on which the light emitters **1303** are mounted, comprising light reflective material to facilitate the redirection of light reflected back into the interior volume towards the wavelength conversion component **1311**. The light bulb **200** of FIGs. 12A and 12B also includes an MCPCB **1405** on which the light emitters **112** are mounted, to facilitate the redirection of light reflected back into the interior volume towards the wavelength conversion component **36**.

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[00129] The above applications of light emitting devices describe only a few embodiments with which the claimed invention may be applied. It is important to note that the claimed invention may be applied to other types of light emitting device applications, including but not limited to, wall lamps, pendant lamps, chandeliers, recessed lights, track lights, accent lights, stage lighting, movie lighting, street lights, flood lights, beacon lights, security lights, traffic lights, headlamps, taillights, signs, etc.

[00130] Therefore, what has been described is a novel wavelength conversion component that comprises a light diffusing layer. Light diffractive particles within the light diffusing layer are selected to have a size such that the particles will scatter blue light generated by the LED relatively more than they will scatter light generated by a wavelength conversion layer, e.g., where the particles have an average particle size that is less than about 150nm. This approach of using the light diffusing layer in combination with the wavelength conversion layer solves the problem of variations or non-uniformities in the color of emitted light with emission angle. In addition, the color appearance of the lighting apparatus in its OFF state can be improved by implementing the light diffusing layer in combination with the wavelength conversion layer. Moreover, significant reductions can be achieved in the amount phosphor materials that is required to implement phosphor-based LED devices.

[00131] It will be appreciated that the invention is not limited to the exemplary embodiments described and that variations can be made within the scope of the invention. For example whilst the devices of the invention have been described as comprising one or more LEDs the devices can comprise other solid-state light sources such as a laser diode or laser.

Savant Technologies LLC - 1004.088

SCORE Placeholder Sheet for IFW Content

Application Number: 13273212 Document Date: 10/13/2011

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

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- Examiners may access SCORE content via the eDAN interface.
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Form Revision Date: February 8, 2006

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/273,212

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	29 minus 20 =	* 9	x 30 =	270	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	5 minus 3 =	* 2	x 125 =	250			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1050		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/273,212	10/13/2011	2811	0.00	ITMX-VISTA-00318US1	29	5

CONFIRMATION NO. 8795

84561
Vista IP Law Group, LLP
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

FILING RECEIPT

OC000000050630920

Date Mailed: 10/27/2011

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Bing Dai, Fremont, CA;
Xianglong Yuan, Fremont, CA;
Gang Wang, Milpitas, CA;
Charles Edwards, Pleasanton, CA;

Assignment For Published Patent Application

INTEMATIX CORPORATION, Fremont, CA

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/427,411 12/27/2010
and is a CIP of 13/253,031 10/04/2011
which claims benefit of 61/390,091 10/05/2010

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 10/26/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/273,212**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
** **SMALL ENTITY** **

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Title

WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

Preliminary Class

257

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

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set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/273,212	10/13/2011	Bing Dai	ITMX-VISTA-00318US1

CONFIRMATION NO. 8795

84561
Vista IP Law Group, LLP
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

FORMALITIES LETTER

OC000000050630921

Date Mailed: 10/27/2011

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  *Applicant must submit $**95** to complete the basic filing fee for a small entity.*
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A replacement abstract not exceeding 150 words in length and commencing on a separate sheet in compliance with 37 CFR 1.72(b) and 37 CFR 1.121 is required.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of $**520** as a small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.

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- A surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $**65** for a small entity in compliance with 37 CFR 1.27, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is $**1115** for a small entity

- $**95** Statutory basic filing fee.
- $**65** Surcharge.
- The application search fee has not been paid. Applicant must submit $**310** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**125** to complete the examination fee for a small entity in compliance with 37 CFR 1.27.
- Total additional claim fee(s) for this application is $**520**
  - $**250** for **2** independent claims over 3.
  - $**270** for **9** total claims over 20.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
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/bzewdie/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	Group Art Unit: 2811
Bing Dai, et al.	Examiner: Not Yet Assigned
Serial No.: 13/273,212	Confirmation No.: 8795
Filed: October 13, 2011	
For: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

RESPONSE TO NOTICE TO FILE MISSING PARTS

Mail Stop: Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This paper is in response to the Notice to File Missing Parts mailed on October 27, 2011. Prior to substantive examination of the application, Applicants respectfully request entry of the present amendment in accordance with the following sheets.

Amendments to the Specification begin on page 2.

Remarks begin on page 3.

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AMENDMENTS TO THE SPECIFICATION

The Abstract of the application is currently being amended. Please make this amendment by deleting the entire section identified by the heading "ABSTRACT" on page 56 of the application, and replacing that deleted section with the following replacement section:

ABSTRACT

A light emitting device comprises at least one solid-state light source (LED) operable to generate excitation light and a wavelength conversion component located remotely to the at least one source and operable to convert at least a portion of the excitation light to light of a different wavelength. The wavelength conversion component [[comprises]] includes a light transmissive substrate having a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light diffractive material. This approach of using the light diffusing layer in combination with the wavelength conversion layer solves the problem of variations or non-uniformities in the color of emitted light with emission angle. ~~In addition, the color appearance of the lighting apparatus in its OFF state can be improved by implementing the light diffusing layer in combination with the wavelength conversion layer. Moreover, significant reductions can be achieved in the amount phosphor materials required to implement phosphor-based LED devices.~~

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REMARKS

The Notice to File Missing Parts mailed on October 27, 2011 required the application to be amended to include a replacement Abstract not exceeding 150 words in length. In response, the current amendment has provided a replacement Abstract in compliance with 37 CFR section 1.72.

The Notice to File Missing Parts also requires submission of the Oath/Declaration and payment of required fees. Submitted herewith is an executed Declaration and payment of the required fees.

The Commissioner is authorized to charge any fees due in connection with the filing of this document to Vista IP Law Group's Deposit Account No. **50-1105**, referencing billing number **ITMX-VISTA-00318US1**. The Commissioner is authorized to credit any overpayment or to charge any underpayment to Vista IP Law Group's Deposit Account No. **50-1105**, referencing billing number **ITMX-VISTA-00318US1**.

Respectfully submitted,

Dated: December 27, 2011

By: /Peter C. Mei/
Peter C. Mei
Registration No.: 39,768

VISTA IP LAW GROUP LLP
2160 Lundy Ave., Suite 230
San Jose, CA 95131
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Facsimile: (408) 877-1662

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PTO/SB/14 (11-08)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Bing		Dai	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Fremont	State/Province	CA	Country of Residence [i]	US

Citizenship under 37 CFR 1.41(b) [i]	CN

Mailing Address of Applicant:

Address 1	4987 Central Avenue, #237
Address 2	

City	Fremont	State/Province	CA

Postal Code	94536	Country [i]	US

Applicant 2 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Xianglong		Yuan	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Fremont	State/Province	CA	Country of Residence [i]	US

Citizenship under 37 CFR 1.41(b) [i]	CN

Mailing Address of Applicant:

Address 1	360 Escobar Street
Address 2	

City	Fremont	State/Province	CA

Postal Code	94539	Country [i]	US

Applicant 3 Remove

Applicant Authority	◉ Inventor	○ Legal Representative under 35 U.S.C. 117	○ Party of Interest under 35 U.S.C. 118

Prefix	Given Name	Middle Name	Family Name	Suffix
	Gang		Wang	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Milpitas	State/Province	CA	Country of Residence [i]	US

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Citizenship under 37 CFR 1.41(b) i	CN				
Mailing Address of Applicant:					
Address 1	416 Capella Way				
Address 2					
City	Milpitas	**State/Province**	CA		
Postal Code	95035	**Country**i	US		

Applicant 4 Remove

Applicant Authority (•) Inventor	( ) Legal Representative under 35 U.S.C. 117	( ) Party of Interest under 35 U.S.C. 118	
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	Charles		Edwards	

Residence Information (Select One) (•) US Residency ( ) Non US Residency ( ) Active US Military Service

City	Pleasanton	**State/Province**	CA	**Country of Residence** i	US
Citizenship under 37 CFR 1.41(b) i	US				
Mailing Address of Applicant:					
Address 1	4380 Entrada Drive				
Address 2					
City	Pleasanton	**State/Province**	CA		
Postal Code	94566	**Country**i	US		

Applicant 5 Remove

Applicant Authority (•) Inventor	( ) Legal Representative under 35 U.S.C. 117	( ) Party of Interest under 35 U.S.C. 118	
Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	James		Caruso	

Residence Information (Select One) (•) US Residency ( ) Non US Residency ( ) Active US Military Service

City	Albuquerque	**State/Province**	NM	**Country of Residence** i	US
Citizenship under 37 CFR 1.41(b) i	US				
Mailing Address of Applicant:					
Address 1	7721 Cedar Canyon Ct NE				
Address 2					
City	Albuquerque	**State/Province**	NM		
Postal Code	87122	**Country**i	US		

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	101130

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Email Address	pcm@viplawgroup.com	Add Email	Remove Email

Application Information:

Title of the Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER		
Attorney Docket Number	ITMX-VISTA-00318US1	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	25	Suggested Figure for Publication (if any)	

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S. C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	101130		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	non provisional of	61427411	2010-12-27
Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation in part of	13253031	2011-10-04
Prior Application Status	Expired		Remove

PTO/SB/14 (11-08)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
13253031	non provisional of	61390091	2010-10-05

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).

Remove

Application Number	Country [i]	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
			◉ Yes ○ No

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.

Assignee 1 Remove

If the Assignee is an Organization check here. ☒			
Organization Name	Intematix Corporation		
Mailing Address Information:			
Address 1	46430 Fremont Blvd.		
Address 2			
City	Fremont	**State/Province**	CA
Country [i]	US	Postal Code	94538
Phone Number		Fax Number	
Email Address			

Additional Assignee Data may be generated within this form by selecting the **Add** button. Add

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Peter C. Mei/			Date (YYYY-MM-DD)	2011-12-27
First Name	Peter C.	Last Name	Mei	Registration Number	39768

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PTO/SB/14 (11-08)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	ITMX-VISTA-00318US1
	Application Number	
Title of Invention	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Electronic Patent Application Fee Transmittal

Application Number:	13273212
Filing Date:	13-Oct-2011
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Filer:	Peter C. Mei/Tony Nguyen
Attorney Docket Number:	ITMX-VISTA-00318US1

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	95	95
Utility Search Fee	2111	1	310	310
Utility Examination Fee	2311	1	125	125
Pages:				
Claims:				
Claims in excess of 20	2202	9	30	270
Independent claims in excess of 3	2201	2	125	250
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Late filing fee for oath or declaration	2051	1	65	65
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1115**

Electronic Acknowledgement Receipt	
EFS ID:	11714246
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	84561
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-VISTA-00318US1
Receipt Date:	27-DEC-2011
Filing Date:	13-OCT-2011
Time Stamp:	19:02:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$1115
RAM confirmation Number	4790
Deposit Account	501105
Authorized User	VISTA IP LAW GR
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees) Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	ITMX-VISTA-00318US1_Declaration-executed.pdf	3485978 df3dd5bf19f2a7fc3340d115a2125ec2daea8696	no	7
Warnings:					
Information:					
2	Miscellaneous Incoming Letter	ITMX-VISTA-00318US1_Response-to-Missing-Parts.pdf	68537 8a1f6c6fe964affbf553547ff4de20598849f7b7	no	3
Warnings:					
Information:					
3	Application Data Sheet	ITMX-VISTA-00318US1_ADS.pdf	1421641 6f7505f1d053755f3b65057efcd53d76dcbc0447	no	6
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	40168 98259b1712e5a4ed3b570c2af7b79bbf85a575e6	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	5016324		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

DECLARATION
Utility Application

As a below named inventors, I hereby declare that:

Our residence, post office addresses and citizenships are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER** the specification of which

☐ is attached hereto OR
☒ was filed on **October 13, 2011** as United States Application Serial No. **13/273,212**.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment(s) referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Date of Filing	Priority Claimed Yes	No

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date
61/427,411	December 27, 2010
61/390,091	October 5, 2010

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to

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patentability as defined in Title 37, Code of Federal Regulations § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application Number	PCT Parent Number	Parent Filing Date	Status-Patented, Pending or Abandoned
13/253,031		October 4, 2011	Pending

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Title 18, United States Code, § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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1	FULL NAME OF INVENTOR	FIRST Name **Bing**	MIDDLE Initial	LAST Name **Dai**	
	RESIDENCE & CITIZENSHIP	City **Fremont**	State or Foreign Country **California**	Country of Citizenship **CN**	
	POST OFFICE ADDRESS	**4987 Central Avenue, #237**	City **Fremont**	State or Country **California**	Zip Code **94536**

INVENTOR'S SIGNATURE _____ DATE 12/20/2011

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2	FULL NAME OF INVENTOR	FIRST Name **Xianglong**	MIDDLE Initial	LAST Name **Yuan**	
	RESIDENCE & CITIZENSHIP	City **Fremont**	State or Foreign Country **California**	Country of Citizenship **CN**	
	POST OFFICE ADDRESS	~~**109 Linmore Drive**~~ 360 Escobar St	City **Fremont**	State or Country **California**	Zip Code **94539**

XLY

INVENTOR'S SIGNATURE _____ DATE 12/20/2011

Savant Technologies LLC - 1004.112

3	FULL NAME OF INVENTOR	FIRST Name **Gang**	MIDDLE Initial	LAST Name **Wang**	
	RESIDENCE & CITIZENSHIP	City **Milpitas**	State or Foreign Country **California**	Country of Citizenship **CN**	
	POST OFFICE ADDRESS	**416 Capella Way**	City **Milpitas**	State or Country **California**	Zip Code **95035**

INVENTOR'S SIGNATURE _____ DATE 12/20/11

Savant Technologies LLC - 1004.113

4	FULL NAME OF INVENTOR	FIRST Name **Charles**	MIDDLE Initial	LAST Name **Edwards**	
	RESIDENCE & CITIZENSHIP	City **Pleasanton**	State or Foreign Country **California**	Country of Citizenship **US**	
	POST OFFICE ADDRESS	**4380 Entrada Drive**	City **Pleasanton**	State or Country **California**	Zip Code **94566**

INVENTOR'S SIGNATURE _____ DATE 20 Dec 2011

Savant Technologies LLC - 1004.114

5	FULL NAME OF INVENTOR	FIRST Name **James**	MIDDLE Initial	LAST Name **Caruso**	
	RESIDENCE & CITIZENSHIP	City **Albuquerque**	State or Foreign Country **New Mexico**	Country of Citizenship **US**	
	POST OFFICE ADDRESS	**7721 Cedar Canyon Ct. NE**	City **Albuquerque**	State or Country **New Mexico**	Zip Code **87122**

INVENTOR'S SIGNATURE _____ DATE 12/23/11

Savant Technologies LLC - 1004.115

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/273,212

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE($)	FEE($)		RATE($)	FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	29 minus 20 =	* 9	x 30 =	270	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	5 minus 3 =	* 2	x 125 =	250			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	1050		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1)		(Column 2)	(Column 3)					
		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/273,212	10/13/2011	2811	1115	ITMX-VISTA-00318US1	29	5

CONFIRMATION NO. 8795

UPDATED FILING RECEIPT

101130
Vista IP Law Group, LLP (Intematix)
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

OC000000051795624

Date Mailed: 01/04/2012

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Bing Dai, Fremont, CA;
Xianglong Yuan, Fremont, CA;
Gang Wang, Milpitas, CA;
Charles Edwards, Pleasanton, CA;
James Caruso, Albuquerque, NM;

Assignment For Published Patent Application

INTEMATIX CORPORATION, Fremont, CA

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/427,411 12/27/2010
and is a CIP of 13/253,031 10/04/2011
which claims benefit of 61/390,091 10/05/2010

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 10/26/2011

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/273,212**

Projected Publication Date: 04/12/2012

Non-Publication Request: No

Early Publication Request: No

** **SMALL ENTITY** **

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Title

WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

Preliminary Class

257

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as

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set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/273,212	10/13/2011	Bing Dai	ITMX-VISTA-00318US1

CONFIRMATION NO. 8795

101130
Vista IP Law Group, LLP (Intematix)
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

PUBLICATION NOTICE



Title:WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

Publication No.US-2012-0087103-A1
Publication Date:04/12/2012

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Savant Technologies LLC - 1004.120

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/273,212	10/13/2011	Bing Dai	ITMX-VISTA-00318US1	8795

101130 7590 09/24/2012

Vista IP Law Group, LLP (Intematix)
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

EXAMINER	
BOWMAN, MARY ELLEN	
ART UNIT	**PAPER NUMBER**
2879	

MAIL DATE	DELIVERY MODE
09/24/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Savant Technologies LLC - 1004.121

Office Action Summary	Application No.	Applicant(s)	
	13/273,212	DAI ET AL.	
	Examiner	Art Unit	
	MARY ELLEN BOWMAN	2879	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *13 October 2011*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *1-29* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-29* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *13 October 2011* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

Savant Technologies LLC - 1004.122

DETAILED ACTION

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

Claims 1-6, 9-14, 16-19, 21, 22, 25 and 26 are rejected under 35 U.S.C. 102(b) as being anticipated by McNulty et al., US 2002/0180351 A1, published December 5, 2002 (hereinafter referred to as "McNulty").

Regarding claim 1, McNulty teaches a wavelength conversion component for a light emitting device comprising a wavelength conversion layer comprising particles of at least one photoluminescence material; and a light diffusing layer comprising particles of a light scattering material (Abstract, [0022-0024] and claim 5).

Regarding claim 2, McNulty further teaches the wavelength conversion layer and the light diffusing layer are in direct contact with each other ([0022] and Figure 2, layers 40 and 42).

Regarding claim 3, McNulty further teaches the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder ([0021-0022]).

Regarding claims 4 and 5, McNulty further teaches the wavelength conversion layer further comprises a second light scattering material ([0022-0024], one scattering material in the

wavelength conversion layer and one in a separate layer), and wherein the first and second light scattering material have different properties ([0026]).

Regarding claim 6, McNulty further teaches the light transmissive binder comprises a curable liquid polymer selected from the group consisting of a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone and a fluorinated polymer ([0021]).

Regarding claim 9, McNulty teaches the invention as explained above. Further, the process limitations of claim 9 lend weight to the claim only in so far as they affect the structure of the device. It is the position of the Examiner that the structure of McNulty is capable of being manufactured by said method, and therefore meets the limitations of the claim.

Regarding claim 10, McNulty further teaches the light scattering material is silica ([0023-0024] and Table 1).

Regarding claims 11 and 12, McNulty further teaches a light scattering material wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light from a radiation source relatively more, at least twice as much as the light scattering material will scatter light generated by the at least one photoluminescence material (Abstract, [0022-0024] and claim 5; Note: The average particle size of the scattering material is around 1/10 of the wavelength of the light emitted from the LED light source, which is within the range taught by Applicant, therefore the particles would perform in the same manner).

Regarding claim 13, McNulty further teaches the excitation light comprises blue light ([0002]).

Regarding claim 14, McNulty further teaches the light scattering material has an average particle size that is less than about 150 nm (Abstract and [0022-0024]; Average particle size of between 30-42nm).

Regarding claim 19, McNulty teaches the invention as explained above regarding claim 1 and further teaches a light emitting device comprising a solid state light emitter operable to generate excitation light (LED 20, Figure 2).

Regarding claims 16 and 25, McNulty further teaches the wavelength conversion layer and the light diffusing layer comprises planar shapes (Figure 2 and [0022]).

Regarding claims 17 and 26, McNulty further teaches the light diffusing layer comprises a dome or elongated dome shape (Figure 2 and [0022]).

Regarding claim 18, McNulty further teaches the wavelength conversion layer fills a volume formed beneath the dome or elongated dome shape (Figure 2 and [0022]).

Regarding claims 21 and 22, McNulty further teaches the average particle size of the light scattering material is selected to improve an OFF state white appearance of the light emitting device and to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a 60 degree range from an emission axis (see explanation regarding claim 1 above, the scattering particles are of the same material and same size as those used by Applicant, therefore it is the position of the Examiner that the light scattering layer would function in a similar manner).

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 7 and 23 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Cairns et al., US 4191943, published March 4, 1980 (hereinafter referred to as "Cairns").

Regarding claims 7 and 23, McNulty teaches the inventions as explained above, but is silent as to the loading of scattering material into the transmissive binder.

In the same field of endeavor of LEDs, Cairns teaches a light scattering material should be employed in the amount claimed in order to achieve optimum light scattering (col 3, lines 60-62). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the light scattering particles of McNulty in the amount taught by Cairns in order to achieve optimum light scattering without loss due to absorption.

Claims 8, 15 and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Chakraborty et al., US 2009/0272996, filed May 2, 2008 (hereinafter referred to as "Chakraborty").

Regarding claims 8 and 24, McNulty teaches the invention as explained above but is silent as to the particles being from 1 to 50 micrometers in size.

However, in the same field of endeavor of LEDs, Chakraborty teaches light scattering particles of the claimed size in a light transmissive binder ([0084]). Chakraborty further teaches that said particle size optimizes the light scattering effect of the layer (id). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to

utilize light scattering particles in the claimed range in order to optimize the light scattering effect of the layer.

Regarding claim 15, McNulty teaches the invention as explained above but is silent as to the substrate upon which the LED and phosphor layer are formed.

In the same field of endeavor of LEDs, Chakraborty teaches the LED and phosphor layer are formed on a substrate having a reflective film thereon ([0097-0098]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that materials such as glass make excellent device substrates due to their electrical insulation properties and ease of manufacturing. Therefore, in light of the state of the art as well as the teaching in Chakraborty, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize a light transmissive substrate such as glass in order to form the LED and phosphor layers of an LED lighting device.

Claims 20 and 27 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Robertson et al., US 6860628 B2, published March 1, 2005 (hereinafter referred to as "Robertson").

Regarding claim 20, McNulty teaches the invention as explained above but is silent as to the myriad of uses for an LED.

In the same field of endeavor of LEDs, Robertson teaches an LED may be used in a linear lamp as a replacement for a fluorescent bulb (Figure 3A). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time

the invention was made to utilize the LED taught by McNulty in several different ways, including as a linear lamp, such as the lighting device in Robertson.

Regarding claim 27, McNulty teaches the invention as explained above, but is silent as to the LED being used in a linear lamp.

In the same field of endeavor of LEDs, Robertson teaches a linear lamp comprising an elongate housing and a plurality of LEDs housed within the housing and configured along the length of the housing and an elongate wavelength conversion component (Figure 3A). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including as a linear lamp, such as the lighting device in Robertson.

Claim 28 is rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Soules et al, US 2007/0120135 A1, published May 31, 2007 (hereinafter referred to as "Soules").

Regarding claim 28, McNulty teaches the invention as explained above but is silent as to the LED being used in a downlight.

In the same field of endeavor of LEDs, Soules teaches a downlight comprising a body comprising one or more LEDs, and the body is configured within a downlighting fixture ([0052]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of

ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including in a downlight, such as the lighting device in Soules.

Claim 29 is rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Negley et al., US 2008/0130285 A1, published June 5, 2008 (hereinafter referred to as "Negley").

Regarding claim 29, McNulty teaches the invention as explained above but is silent as to the LED being used in a light bulb.

In the same field of endeavor of LEDs, Negley teaches a light bulb comprising a connector base and a body comprising one or more LEDs ([0022]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including in a light bulb, such as the lighting device in Negley.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference

claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

Claims 1-29 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over the claims of copending Application No. 13/253031, 13/273215 and 13/272217. Although the conflicting claims are not identical, they are not patentably distinct from each other because they teach each of the limitations of the present claims.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to MARY ELLEN BOWMAN whose telephone number is (571)270-5383. The examiner can normally be reached on Monday-Friday, 5:30-8:30a.m. and 12:00-5:00 p.m. EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nimesh Patel can be reached on (571) 272-2457. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MARY ELLEN BOWMAN/
Examiner, Art Unit 2879

Notice of References Cited	Application/Control No. 13/273,212	Applicant(s)/Patent Under Reexamination DAI ET AL.	
	Examiner MARY ELLEN BOWMAN	Art Unit 2879	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-4,191,943 A	03-1980	Cairns et al.	340/815.42
*	B	US-2002/0180351 A1	12-2002	McNulty et al.	313/512
*	C	US-6,860,628 B2	03-2005	Robertson et al.	362/555
*	D	US-2007/0120135 A1	05-2007	Soules et al.	257/098
*	E	US-2008/0130285 A1	06-2008	Negley et al.	362/257
*	F	US-2009/0272996 A1	11-2009	Chakraborty, Arpan	257/98
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Savant Technologies LLC - 1004.132

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BIB DATA SHEET

CONFIRMATION NO. 8795

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/273,212	10/13/2011 RULE	313	2879	ITMX-VISTA-00318US1

APPLICANTS

Bing Dai, Fremont, CA;
Xianglong Yuan, Fremont, CA;
Gang Wang, Milpitas, CA;
Charles Edwards, Pleasanton, CA;
James Caruso, Albuquerque, NM;

**** CONTINUING DATA ***************************

This appln claims benefit of 61/427,411 12/27/2010
and is a CIP of 13/253,031 10/04/2011
which claims benefit of 61/390,091 10/05/2010

**** FOREIGN APPLICATIONS ***************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
10/26/2011

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☑ No Verified and Acknowledged /MARY ELLEN BOWMAN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		CA	25	29	5

ADDRESS

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2160 Lundy Avenue, Suite 230
San Jose, CA 95131
UNITED STATES

TITLE

WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

FILING FEE RECEIVED		
1115	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Savant Technologies LLC - 1004.133

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13273212	DAI ET AL.
	Examiner	Art Unit
	MARY ELLEN BOWMAN	2879

SEARCHED			
Class	Subclass	Date	Examiner
313	112, 498, 501, 512	9/18/12	MB
257	98	9/18/12	MB
438	27	9/18/12	MB

SEARCH NOTES		
Search Notes	Date	Examiner
inventor search in eDan	9/18/12	MB

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

/MARY ELLEN BOWMAN/ Examiner.Art Unit 2879	

Savant Technologies LLC - 1004.134

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13273212	DAI ET AL.
	Examiner	Art Unit
	MARY ELLEN BOWMAN	2879

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	09/18/2012								
	1	✓								
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	29	✓								

Savant Technologies LLC - 1004.135

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	"20090272996"	US-PGPUB; USPAT; USOCR	OR	OFF	2012/09/17 14:20
L2	2	"20070240346"	US-PGPUB; USPAT; USOCR	OR	OFF	2012/09/17 14:28
L3	356	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and ((scatter$3 reflect$3) with particle with (size nanometer micrometer))	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 14:34
L4	215	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and ((scatter$3 reflect$3) with particle with (concentration weight percent$3 amount))	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 15:37
L5	9	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and (down$light) and (base near4 socket)	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 16:20
L6	2	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and (down$light) and ((housing envelope bulb) with (elongat$2 linear))	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 16:30
L7	46	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and ((housing envelope bulb) with (elongat$2 linear))	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 16:31
L8	50	(257/98.ccls. 438/27.ccls. 313/498,501,512,112.ccls.) and ("light emitting diode" LED.U/C.) and (downlight)	US-PGPUB; USPAT; USOCR	OR	ON	2012/09/17 16:33

EAST Search History (Interference)

<This search history is empty>

9/17/2012 5:16:15 PM
C:\Users\mbowman\Documents\EAST\Workspaces\13273212.wsp

Savant Technologies LLC - 1004.136

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99**)		
	Application Number	13273212
	Filing Date	2011-10-13
	First Named Inventor	Bing Dai
	Art Unit	2879
	Examiner Name	Bowman, Mary Ellen
	Attorney Docket Number	ITMX-00318US1

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13273212
	Filing Date	2011-10-13
	First Named Inventor	Bing Dai
	Art Unit	2879
	Examiner Name	Bowman, Mary Ellen
	Attorney Docket Number	ITMX-00318US1

	1	Docket No. ITMX-00318US2; Non-Final Office Action dated Sep. 24, 2012 for U.S. Appln. No. 13/273,215	☐
	2	Docket No. ITMX-00318US3; Non-Final Office Action dated Sep. 24, 2012 for U.S. Appln. No. 13/273,217	☐

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13273212
	Filing Date	2011-10-13
	First Named Inventor	Bing Dai
	Art Unit	2879
	Examiner Name	Bowman, Mary Ellen
	Attorney Docket Number	ITMX-00318US1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Peter C. Mei/	Date (YYYY-MM-DD)	2012-11-16
Name/Print	Peter C. Mei	Registration Number	39768

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Electronic Acknowledgement Receipt

EFS ID:	14256397
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-00318US1
Receipt Date:	16-NOV-2012
Filing Date:	13-OCT-2011
Time Stamp:	20:37:46
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	ITMX-00318US1_IDS-transmittal-letter.pdf	50968 76768a2213fa9728fcbe7f6feaa1efc6035fd38b	no	1

Warnings:	
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2	Information Disclosure Statement (IDS) Form (SB08)	ITMX-00318US1_IDS-sb08.pdf	612436 8581ce93a238dc491d9a728c6f76961aa459b6f4	no	4
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A U.S. Patent Number Citation or a U.S. Publication Number Citation is required in the Information Disclosure Statement (IDS) form for autoloading of data into USPTO systems. You may remove the form to add the required data in order to correct the Informational Message if you are citing U.S. References. If you chose not to include U.S. References, the image of the form will be processed and be made available within the Image File Wrapper (IFW) system. However, no data will be extracted from this form. Any additional data such as Foreign Patent Documents or Non Patent Literature will be manually reviewed and keyed into USPTO systems.					
3	Non Patent Literature	ITMX-VISTA-00318US2_Non_Final_OA_09-24-12.pdf	469165 00fc1e2123a590aa4abd9e3e97cc8db2561c3fd2	no	13
Warnings:					
Information:					
4	Non Patent Literature	ITMX-VISTA-00318US3_Non_Final_OA_09-24-12.pdf	456811 ee90a666401a52d4673c2f8692f846fe38d2cae3	no	13
Warnings:					
Information:					
		Total Files Size (in bytes):	1589380		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT
Atty. Dkt. No.: ITMX-00318US1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	Group Art Unit: 2879
Bing Dai et al.	Confirmation No.: 8795
Serial No.: 13/273,212	Examiner: Bowman, Mary Ellen
Filed: Oct. 13, 2011	
For: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER	

COMMUNICATION RE: INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In connection with the Information Disclosure Statement (PTO/SB/08a) being filed herewith, and /or filed previously, Applicant(s) has/have identified certain information in the IDS(s). Citation of these information should/shall not be construed as:

1. an admission that the information are necessarily prior art with respect to the instant invention;
2. a representation that a search has been made, other than as described above; and
3. an admission that the information cited herein is, or is considered to be, material to patentability as defined in § 1.56(b).

Respectfully submitted,

DATE: Nov. 16, 2012

By: /Peter C. Mei/
Peter C. Mei
Reg. No. 39,768

VISTA IP LAW GROUP LLP
2160 Lundy Ave., Suite 230
San Jose, California 95131
Telephone: (408) 321-8663
Facsimile: (408) 877-1662

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of Bing Dai et al.	Group Art Unit: 2879
Application No.: 13/273,212	Examiner: Bowman, Mary Ellen
Filed: October 13, 2011	Confirmation No.: 8795
For: WAVELENGTH CONVERSION COMPONENTS WITH A DIFFUSING LAYER	Customer No.: 16650

RESPONSE TO OFFICE ACTION

Mail Stop **Amendment**
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In response to the Official Action sent on September 24, 2011, Applicants request that this application be amended in accordance with the following sheets.

Amendments to the Claims begin on page 2.

Remarks begin on page 8 of this paper.

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AMENDMENT TO THE CLAIMS

Claims 1-29 are pending. Claims 1, 11, 19, 21, 27, 28 and 29 have been amended without acquiescence in the Office Action's basis for rejections and without prejudice to pursue canceled subject matter in a related application. Support for these amendments can be found, for example, in at least paragraphs 60, 63 and 64 of the subject application. No new matter has been added. A complete listing of the pending claims is provided below and supersedes all previous claim lists.

1. (Currently Amended) A wavelength conversion component for a light emitting device comprising:

a wavelength conversion layer comprising particles of at least one photoluminescence material; and

a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product.

2. (Original) The component of Claim 1, wherein the wavelength conversion layer and the light diffusing layer are in direct contact with each other.

3. (Original) The component of Claim 1, wherein the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder.

4. (Original) The component of Claim 3, wherein the wavelength conversion layer further comprises a second light scattering material.

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5. (Original) The component of Claim 4, wherein the light scattering material and the second light scattering material have different material properties.

6. (Original) The component of Claim 3, wherein the light transmissive binder comprises a curable liquid polymer selected from the group consisting of: a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone and a fluorinated polymer.

7. (Original) The component of Claim 2, wherein the weight loading of light scattering material to binder selected from the group consisting of: 7% to 35% and 10% to 20%.

8. (Original) The component of Claim 1, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

9. (Original) The component of Claim 1, wherein the wavelength conversion and light diffusing layers are deposited using a method selected from the group consisting of: screen printing, slot die coating, spin coating, roller coating, drawdown coating and doctor blading.

10. (Original) The component of Claim 1, wherein the light scattering material is selected from the group consisting of: titanium dioxide, barium sulfate, magnesium oxide, silicon dioxide and aluminum oxide.

11. (Currently Amended) The component of Claim 1, wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter the excitation light relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material.

12. (Original) The component of Claim 11, wherein the light scattering material scatters the excitation light at least twice as much as light generated by the at least one photoluminescence material.

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13. (Original) The component of Claim 11, wherein the excitation light comprises blue light.

14. (Original) The component of Claim 13, wherein the light scattering material has an average particle size that is less than about 150nm.

15. (Original) The component of Claim 1, wherein the light diffusing layer is deposited on a light transmissive substrate, and the light transmissive substrate is selected from the group consisting of: a polycarbonate, an acrylic and a glass.

16. (Original) The component of Claim 1 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

17. (Original) The component of Claim 1 in which the light diffusing layer comprises a dome or elongated dome shape.

18. (Original) The component of claim 17 in which the wavelength conversion layer fills a volume formed beneath the dome or elongated dome shapes.

19. (Currently Amended) A light emitting device, comprising:

at least one solid-state light emitter operable to generate excitation light; and

a wavelength conversion component comprising:

a wavelength conversion layer excitable by the excitation light, wherein the wavelength conversion layer comprises particles of at least one photoluminescence material; and

a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an OFF state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light generated by the at least one solid-state light emitter is emitted through the wavelength conversion component to contribute to a final visible emission product.

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20. (Original) The device of claim 19, wherein the light emitting device is selected from the group consisting of: downlights, light bulbs, linear lamps, lanterns, wall lamps, pendant lamps, chandeliers, recessed lights, track lights, accent lights, stage lighting, movie lighting, street lights, flood lights, beacon lights, security lights, traffic lights, headlamps, taillights, and signs.

21. (Currently Amended) The device of claim 19 in which the light scattering material within the light diffusing layer corresponds to an average particle size that improves [[an]] the OFF state white appearance of the ~~light emitting device~~ wavelength conversion component.

22. (Original) The device of claim 19 in which the light diffusing layer is configured to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a $\pm 60^{o}$ range from an emission axis.

23. (Original) The device of claim 22, wherein a weight loading of the light scattering material to a binder selected from the group consisting of: 7% to 35% and 10% to 20%.

24. (Original) The device of Claim 19, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

25. (Original) The device of Claim 19 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

26. (Original) The device of Claim 19 in which the light diffusing layer comprises a dome or elongated dome shape.

27. (Currently Amended) A linear lamp comprising:

an elongate housing;

a plurality of solid-state light emitters housed within the housing and configured along the length of the housing; and

an elongate wavelength conversion component remote to the plurality of solid-state light emitters and configured to in part at least define a light mixing chamber,

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wherein the elongate wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the elongate wavelength conversion component;

wherein the elongate wavelength conversion component is configured such that in operation a portion of light generated by the plurality of solid-state light emitters is emitted through the wavelength conversion component to contribute to a visible final emission product.

28. (Currently Amended) A downlight comprising:

a body comprising one or more solid-state light emitters, wherein the body is configured to be positioned within a downlighting fixture such that the downlight emits light in a downward direction; and

a wavelength conversion component remote to the one or more solid-state light emitters and configured to in part at least define a light mixing chamber,

wherein the wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product.

29. (Currently Amended) A light bulb comprising:

a connector base configured to be inserted in a socket to form an electrical connection for the light bulb;

a body comprising one or more solid-state light emitters;

a wavelength conversion component having a three dimensional shape that is configured to enclose the one or more solid-state light emitters and to in part at least define a light mixing chamber,

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wherein the wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product.

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REMARKS

Claims 1-29 are pending. Claims 1, 11, 19, 21, 27, 28 and 29 have been amended without acquiescence in the Office Action's basis for rejections and without prejudice to pursue canceled subject matter in a related application. Support for these amendments can be found, for example, in at least paragraphs 60, 63 and 64 of the subject application. As such, no new matter has been added.

I. Double Patent Rejection

Claims 1-29 stand provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims of co-pending Application No. 13/253,031, 13/273,215 and 13/272,217. In response to these rejections, Applicants have provided herewith a Terminal Disclaimer over US Patent Application Nos. 13/253,031, 13/273,215 and 13/272,217. The filing of this Terminal Disclaimer in no way manifests an admission by the Patentee as to the propriety of the double patenting determination and serves simply to remove the issue of double patenting, and raises neither a presumption nor estoppel on the merits of the double patenting determination. MPEP §804.02 citing *Quad Environmental Technologies Corp. v. Union Sanitary District,* 946 F. 2d 870, 20 USPQ 2d 1392 (Fed Cir. 1991). In light of this submission, the double patenting rejections are now overcome.

II. Claim rejections under 35 U.S.C. §102(b)

Claims 1-6, 9-14, 16-19, 21, 22, 25 and 26 stand rejected under 35 U.S.C. §102(b) as allegedly being anticipated by Publication No. 2002/0180351 to McNulty et al. (hereinafter McNulty). Applicants respectfully traverse.

Claim 1 recites at least the following limitations.

> "wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;
> wherein the wavelength conversion component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product."

Savant Technologies LLC - 1004.151

Claim 19 recites similar limitations.

A. Applicants submit that McNulty fails to disclose "wherein the wavelength component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product"

McNulty discloses UV reflectors incorporated in a UV LED-based light source to reduce the amount of UV radiation emission into the surroundings and increase the efficiency of such light sources. *See abstract*. Figure 2 of McNulty illustrates an embodiment of a UV LED-based light source wherein a layer of phosphor material is applied to a surface of the UV LED and a layer of scattering material is applied on top of the phosphor layer. *See paragraph 22*. The UV radiation emitted by the UV LED is absorbed by the phosphor layer and converted into visible light. *See paragraph 22*. A portion of the UV radiation is not emitted through the phosphor layer and layer of scattering material to contribute to a final visible emission product. The UV radiation does not contribute to the final visible emission product because UV radiation is not visible. As such, McNulty fails to teach or suggest "wherein the wavelength component is configured such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product"

B. MPEP requires that "[a] prior art reference must be considered **in its entirety**, i.e., as a whole, including portions that would lead away from the claimed invention." MPEP §2141.03 citing *W.L. Gore & Associates, Inc. v. Garlock, Inc.*, 721 F. 2d 1540, 220 USPQ 303 (Fed. Cir. 1983), cert. denied, 469 U.S. 851 (1984) (emphasis added). The U.S. Court of Appeals for the Federal Circuit held that "[t]he Supreme Court went on to state that 'when a patent simply arranges old elements…the combination is obvious' (citation omitted)", and that "[t]he opposite conclusion would follow, however, if the prior art indicated that the invention would not have worked for its intended purpose or otherwise taught away from the invention. (Citation omitted.)" *DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.* 567 F. 3d 1314, ____ (Fed. Cir. 2009) (emphasis added).

Claim 1 recites at least the limitation "wherein the wavelength component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product".

Applicants respectfully submit that McNulty in fact teaches away from at least the claimed limitation "wherein the wavelength component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product".

McNulty discloses UV reflectors incorporated in a UV LED-based light source to reduce the amount of UV radiation emission into the surroundings and increase the efficiency of such light sources. *See abstract*. Figure 2 of McNulty illustrates an embodiment of a UV LED-based light source wherein a layer of phosphor material is applied to a surface of the UV LED and a layer of scattering material is applied on top of the phosphor layer. *See paragraph 22*. McNulty discloses that the scattering layer serves the purpose of reflecting UV radiation back into the layer of phosphor material for further absorption and conversion to visible light such that the amount of UV radiation leakage to the surroundings is significantly reduced. *See paragraph 22*. The UV radiation that leaks into the surroundings does not contribute a final visible emission product, as only the light converted from the layer of phosphor material is visible. *See paragraph 22*.

Thus, McNulty teaches a scattering layer that serves the purpose of reflecting UV radiation back into the layer of phosphor material for further absorption and conversion to visible light in order to significantly reduce the amount of UV radiation leakage to the surroundings. As such, McNulty clearly teaches away from configuring a wavelength conversion component such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product.

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Therefore, Applicants respectfully submit that McNulty cannot be combined with other references to support claim rejections under 35 U.S.C. §103(a) as mandated by MPEP §2143.01 and the current 35 U.S.C. §103 jurisdprudence.

C. MPEP requires that the proposed modification cannot change the principle of operation of a reference, and that the suggested combination may not require a change in the basic principle under which the [primary reference] construction was designed to operate." MPEP §2143.01 citing *In re Ratti*, 270 F. 2d 810, 813, 123 USPQ 349, 352 (CCPA 1959) (emphasis added).

Claim 1 recites at least the limitation "wherein the wavelength component is configured such that in operation a portion of excitation light generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product".

In contrast, McNulty teaches a UV LED-based light source wherein a layer of phosphor material is applied to a surface of the UV LED and a layer of scattering material is applied on top of the phosphor layer and the scattering layer serves the purpose of reflecting UV radiation back into the layer of phosphor material for further absorption and conversion to visible light such that the amount of UV radiation leakage to the surroundings is significantly reduced. *See paragraph 22*. The UV radiation that leaks into the surroundings does not contribute a final visible emission product, as only the light converted from the layer of phosphor material is visible. *See paragraph 22*.

That is, the principle of operation for McNulty's approach requires UV radiation to be reflected back into the layer of phosphor material in order to significantly reduce the amount of UV radiation leakage to the surroundings. Nonetheless, claim 1 recites "wherein the wavelength component is configured such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product".

It would therefore frustrate the principle or operation of McNulty, to permit a modification of the UV LED-based light source to possess the claimed aspect "wherein the

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wavelength component is configured such that in operation a portion of light generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product".

D. Applicants submit that McNulty fails to disclose "wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component".

McNulty discloses UV reflectors incorporated in a UV LED-based light source to reduce the amount of UV radiation emission into the surroundings and increase the efficiency of such light sources. *See abstract*. Figure 2 of McNulty illustrates an embodiment of a UV LED-based light source wherein a layer of phosphor material is applied to a surface of the UV LED and a layer of scattering material is applied on top of the phosphor layer. *See paragraph 22*. The Examiner asserts that the light diffusing layer is taught by the layer of scattering material in McNulty. However, nothing in McNulty teaches or suggests that the layer of scattering material improves an off-state white appearance of the wavelength conversion layer. In fact, McNulty never even mentions anything about an off-state white appearance of its UV LED-based light source. As such, McNulty fails to teach or suggest "wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component".

For at least these reasons, claim 1 and its dependent claims should be allowable over the cited art. For the reasons discussed, claim 19 and its dependent claims should also be allowable over the cited art.

III. Claim rejections under 35 U.S.C. §103(a)

Claims 7 and 23 stand rejected as allegedly being unpatentable over McNulty in view of US Patent No. 4,191,943 (Cairns). The Applicants respectfully traverse.

Regardless of whether or not Cairns discloses or suggests the additional limitations as embodied in these rejected claims, Applicants respectfully submit that McNulty cannot be combined to support claim rejections under 35 U.S.C. §103(a) for at least the reasons provided in sub-section II above. Therefore, Applicants respectfully submit that these claims are believed to be allowable over McNulty and Cairns because Cairns fails to cure McNulty's deficiencies, and

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further because the Office Action does not rely on Cairns in supporting the basis for rejection in claims 1 and 19 from which these rejected claims respectively depend.

IV. Claim rejections under 35 U.S.C. §103(a)

Claims 8, 15 and 24 stand rejected as allegedly being unpatentable over McNulty in view of US Publication No. 2009/0272996 (Chakraborty). The Applicants respectfully traverse.

Regardless of whether or not Chakraborty discloses or suggests the additional limitations as embodied in these rejected claims, Applicants respectfully submit that McNulty cannot be combined to support claim rejections under 35 U.S.C. §103(a) for at least the reasons provided in sub-section II above. Therefore, Applicants respectfully submit that these claims are believed to be allowable over McNulty and Chakraborty because Chakraborty fails to cure McNulty's deficiencies, and further because the Office Action does not rely on Chakraborty in supporting the basis for rejection in claims 1 and 19 from which these rejected claims respectively depend.

V. Claim rejections under 35 U.S.C. §103(a)

Claims 20 and 27 stand rejected as allegedly being unpatentable over McNulty in view of US Patent No. 6,860,628 (Robertson). The Applicants respectfully traverse.

Regardless of whether or not Robertson discloses or suggests the additional limitations as embodied in these rejected claims, Applicants respectfully submit that McNulty cannot be combined to support claim rejections under 35 U.S.C. §103(a) for at least the reasons provided in sub-section II above. Therefore, Applicants respectfully submit that these claims are believed to be allowable over McNulty and Robertson because Robertson fails to cure McNulty's deficiencies.

VI. Claim rejections under 35 U.S.C. §103(a)

Claim 28 stands rejected as allegedly being unpatentable over McNulty in view of US Publication No. 2007/0120135 (Soules). The Applicants respectfully traverse.

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Regardless of whether or not Soules discloses or suggests the additional limitations as embodied in these rejected claims, Applicants respectfully submit that McNulty cannot be combined to support claim rejections under 35 U.S.C. §103(a) for at least the reasons provided in sub-section II above. Therefore, Applicants respectfully submit that these claims are believed to be allowable over McNulty and Soules because Soules fails to cure McNulty's deficiencies.

VII. Claim rejections under 35 U.S.C. §103(a)

Claim 29 stands rejected as allegedly being unpatentable over McNulty in view of US Publication No. 2008/0130285 (Negley). The Applicants respectfully traverse.

Regardless of whether or not Negley discloses or suggests the additional limitations as embodied in these rejected claims, Applicants respectfully submit that McNulty cannot be combined to support claim rejections under 35 U.S.C. §103(a) for at least the reasons provided in sub-section II above. Therefore, Applicants respectfully submit that these claims are believed to be allowable over McNulty and Negley because Negley fails to cure McNulty's deficiencies.

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CONCLUSION

Based on the foregoing, all claims are believed allowable, and an allowance of the claims is respectfully requested. If the Examiner has any questions or comments, the Examiner is respectfully requested to contact the undersigned at the number listed below.

Applicant(s) hereby explicitly retracts and rescinds any and all of the arguments and disclaimers presented to distinguish the prior art of record during the prosecution of all parent and related application(s)/patent(s), and respectfully requests that the Examiner re-visit the prior art that such arguments and disclaimers were made to avoid.

The Commissioner is authorized to charge any fees due in connection with the filing of this document to Vista IP Law Group's Deposit Account No. **50-1105**, referencing billing number **ITMX-00318US1**. The Commissioner is authorized to credit any overpayment or to charge any underpayment to Vista IP Law Group's Deposit Account No. **50-1105**, referencing billing number **ITMX-00318US1**.

Respectfully submitted,

Dated: December 23, 2012

By: /Frederick Hsu/
Frederick Hsu
Reg. No. 65,375
For Peter C. Mei, Reg. No. 39,768

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PTO/SB/25 (08-11)
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TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION	Docket Number (Optional) ITMX-00318US1

In re Application of: Bing Dai et al.

Application No.: 13/273,212

Filed: 10-13-2011

For: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

The owner*, Intematix Corporation, of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending **reference** Application Number 13/273,217, filed 10-13-2011, as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the **reference** application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said **reference** application, "as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application," in the event that: any such patent: granted on the pending **reference** application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 39,768

/Peter C. Mei/ — Signature
Dec. 22, 2012 — Date

Peter C. Mei — Typed or printed name

408-321-8663 ext. 208 — Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) is included.

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The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
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9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Bing Dai et al.

Application No./Patent No.: 13/273,212 Filed/Issue Date: 10-13-2011

Titled: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

Intematix Corporation , a corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;

2. ☐ an assignee of less than the entire right, title, and interest in (The extent (by percentage) of its ownership interest is _____ %); or

3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

A. ☒ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 027448, Frame 0492, or for which a copy therefore is attached.

OR

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____

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☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (*i.e.*, a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Peter C. Mei/ Dec. 23, 2012

Signature Date

Peter C. Mei Attorney of Record

Printed or Typed Name Title

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
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6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
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POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

☑ Practitioners associated with the Customer Number: 101130

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

☑ The address associated with Customer Number: 101130

OR

☐ Firm or Individual Name			
Address			
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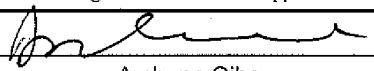
Assignee Name and Address:

Intematix Corporation,
46430 Fremont Blvd.,
Fremont, CA 94538

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	1-9-2012
Name	Archana Ojha	Telephone	510-933-3240
Title	Assistant General Counsel		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Electronic Patent Application Fee Transmittal	
Application Number:	13273212
Filing Date:	13-Oct-2011
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Filer:	Peter C. Mei/Tony Nguyen
Attorney Docket Number:	ITMX-00318US1
Filed as Small Entity	

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Statutory or terminal disclaimer	2814	3	80	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt	
EFS ID:	14553492
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-00318US1
Receipt Date:	23-DEC-2012
Filing Date:	13-OCT-2011
Time Stamp:	15:33:11
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$240
RAM confirmation Number	7771
Deposit Account	501105
Authorized User	VISTA IP LAW GR
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	ITMX-00318US1_Response-to-OA_122212.pdf	150798 2db39daaf3d1da2eabc5326d541b9ff790eb9557	no	15
Warnings:					
Information:					
2	Terminal Disclaimer Filed	ITMX-00318US1_sb0025-1.pdf	342112 0964c75d286719845cbb0d7a40b34e47681104a3	no	2
Warnings:					
Information:					
3	Terminal Disclaimer Filed	ITMX-00318US1_sb0025-2.pdf	342118 0b4d039aee11781cd5a06c525d30761783cf255e	no	2
Warnings:					
Information:					
4	Terminal Disclaimer Filed	ITMX-00318US1_sb0025-3.pdf	342118 1ebc94cd086f6381ac3ebc0ece9cf3327e572719	no	2
Warnings:					
Information:					
5	Assignee showing of ownership per 37 CFR 3.73.	ITMX-00318US1_373b.pdf	422661 3c98898caa18c92dcd6c0485c8efbd117c68f29c	no	2
Warnings:					
Information:					
6	Power of Attorney	Power_of_Attorney_to_Prosecute_Applns_PTO_SB_80_1-9-2012.pdf	75521 37360e7a2ef4eb360d01f198106ae674cfcbd504	no	1
Warnings:					
Information:					
7	Fee Worksheet (SB06)	fee-info.pdf	30135 06613faf341487b7a47ede468a9fd82b73a95cc0	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1705463		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/25 (08-11)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION	Docket Number (Optional) ITMX-00318US1

In re Application of: Bing Dai et al.

Application No.: 13/273,212

Filed: 10-13-2011

For: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

The owner*, Intematix Corporation, of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending **reference** Application Number 13/273,215, filed 10-13-2011, as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the **reference** application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said **reference** application, "as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application," in the event that: any such patent: granted on the pending **reference** application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 39,768

/Peter C. Mei/ — Signature
Dec. 22, 2012 — Date

Peter C. Mei — Typed or printed name

408-321-8663 ext. 208 — Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) is included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this statement. See MPEP § 324.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PTO/SB/25 (08-11)
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TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION	Docket Number (Optional) ITMX-00318US1

In re Application of: Bing Dai et al.

Application No.: 13/273,212

Filed: 10-13-2011

For: WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER

The owner*, Intematix Corporation, of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending **reference** Application Number 13/253,031, filed 10-04-2011, as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the **reference** application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

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Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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/Peter C. Mei/ — Signature
Dec. 22, 2012 — Date

Peter C. Mei — Typed or printed name

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PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
13/273,212	10/13/2011	

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY ☒ RATE ($)	SMALL ENTITY ☒ FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY FEE ($)
☒ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	95		TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT 12/23/2012	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 29	Minus	** 29	= 0	X $31 =	0	OR	X $ =	
Independent (37 CFR 1.16(h))	* 5	Minus	***5	= 0	X $125 =	0	OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE	0	OR	TOTAL ADD'L FEE	

AMENDMENT	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/FELICIA ALLEN-JENKINS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	13/273,212	DAI ET AL.	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 23 DEC 2012	This patent is subject to a Terminal Disclaimer	

Approved/Disapproved by:

THREE TDS FILED AND APPROVED.

JAB

U.S. Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/273,212	10/13/2011	Bing Dai	ITMX-00318US1

CONFIRMATION NO. 8795

101130
Vista IP Law Group, LLP (Intematix)
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

POA ACCEPTANCE LETTER

OC000000058433039

Date Mailed: 01/07/2013

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 12/23/2012.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

/snguyen/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Savant Technologies LLC - 1004.175

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/273,212	10/13/2011	Bing Dai	ITMX-00318US1	8795

101130 7590 03/06/2013

Vista IP Law Group, LLP (Intematix)
2160 Lundy Avenue, Suite 230
San Jose, CA 95131

EXAMINER	
BOWMAN, MARY ELLEN	
ART UNIT	PAPER NUMBER
2879	

NOTIFICATION DATE	DELIVERY MODE
03/06/2013	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@viplawgroup.com
ttn@viplawgroup.com

Savant Technologies LLC - 1004.176

Office Action Summary	Application No.	Applicant(s)	
	13/273,212	DAI ET AL.	
	Examiner	Art Unit	
	MARY ELLEN BOWMAN	2879	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *23 December 2012*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *1-29* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-29* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

Savant Technologies LLC - 1004.177

DETAILED ACTION

Response to Arguments

Applicant's arguments filed January 16, 2013 have been fully considered but they are not persuasive. Specifically, Applicant argues that McNulty fails to teach an LED emitting a light that contributes to the final visible emission. However, in light of the new rejection set forth below and necessitated by the amendment, Examiner demonstrates that McNulty at least makes obvious the use of a blue LED which would contribute to the final visible emission product of the device. Further, Applicant's argument that the reflective particles taught by McNulty would reflect all of the UV/blue light back into the phosphor layer and thereby prevent the blue light from contributing to the final emission product is not persuasive. The reflective particles of McNulty are the same size and in the same concentration as those taught in the current application, therefore the particles would reflect a similar amount of the blue light as in the current application. Although most of the final visible emission product would be a result of the photoluminescence material, at least a small portion of the light would be the UV/blue light emitted from the LED. Further, regarding the OFF state white appearance of the lamp, it is the position of the Examiner that the reflecting particles are of the same material and in the same concentration as the present application, therefore the McNulty reflective layer would also improve the OFF state white appearance of the lamp. Therefore, the rejection as set forth below is maintained and made final.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

Claims 1-6, 9-14, 16-19, 21, 22, 25 and 26 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty et al., US 2002/0180351 A1, published December 5, 2002 (hereinafter referred to as "McNulty").

Regarding claim 1, McNulty teaches a wavelength conversion component for a light emitting device comprising a wavelength conversion layer comprising particles of at least one photoluminescence material; and a light diffusing layer comprising particles of a light scattering material (Abstract, [0022-0024] and claim 5).

McNulty further teaches that one must balance the type of light emitted from an LED between UV and blue in order to prevent utilizing a UV light that would be dangerous upon emission and a blue LED that would contribute too heavily to the final emission product ([0004-0005]). Further, Applicant's specification teaches that the reflective particles help prevent most of the LED emitted light from passing through the photoluminescence layer without being converted. Therefore, in light of the Applicant's own disclosure, as well as McNulty's teaching that a UV/blue LED may be used, it is the position of the Examiner that it would have been obvious to one of ordinary skill in the art to have a small portion of the light emitted from the LED contribute to a final emission product of the device. McNulty further teaches the average particle size of the light scattering material is selected to improve an OFF state white appearance of the light emitting device and to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a 60 degree range from an emission axis (see explanation regarding claim 1 above, the scattering particles are of the same material and same

size as those used by Applicant, therefore it is the position of the Examiner that the light scattering layer would function in a similar manner).

Regarding claim 2, McNulty further teaches the wavelength conversion layer and the light diffusing layer are in direct contact with each other ([0022] and Figure 2, layers 40 and 42).

Regarding claim 3, McNulty further teaches the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder ([0021-0022]).

Regarding claims 4 and 5, McNulty further teaches the wavelength conversion layer further comprises a second light scattering material ([0022-0024], one scattering material in the wavelength conversion layer and one in a separate layer), and wherein the first and second light scattering material have different properties ([0026]).

Regarding claim 6, McNulty further teaches the light transmissive binder comprises a curable liquid polymer selected from the group consisting of a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone and a fluorinated polymer ([0021]).

Regarding claim 9, McNulty teaches the invention as explained above. Further, the process limitations of claim 9 lend weight to the claim only in so far as they affect the structure of the device. It is the position of the Examiner that the structure of McNulty is capable of being manufactured by said method, and therefore meets the limitations of the claim.

Regarding claim 10, McNulty further teaches the light scattering material is silica ([0023-0024] and Table 1).

Regarding claims 11 and 12, McNulty further teaches a light scattering material wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter excitation light from a radiation source relatively more, at least twice as much as the light scattering material will scatter light generated by the at least one photoluminescence material (Abstract, [0022-0024] and claim 5; Note: The average particle size of the scattering material is around 1/10 of the wavelength of the light emitted from the LED light source, which is within the range taught by Applicant, therefore the particles would perform in the same manner).

Regarding claim 13, McNulty further teaches the excitation light comprises blue light ([0002, 0004, 0005]; see explanation above).

Regarding claim 14, McNulty further teaches the light scattering material has an average particle size that is less than about 150 nm (Abstract and [0022-0024]; Average particle size of between 30-42nm).

Regarding claim 19, McNulty teaches the invention as explained above regarding claim 1 and further teaches a light emitting device comprising a solid state light emitter operable to generate excitation light (LED 20, Figure 2).

Regarding claims 16 and 25, McNulty further teaches the wavelength conversion layer and the light diffusing layer comprises planar shapes (Figure 2 and [0022]).

Regarding claims 17 and 26, McNulty further teaches the light diffusing layer comprises a dome or elongated dome shape (Figure 2 and [0022]).

Regarding claim 18, McNulty further teaches the wavelength conversion layer fills a volume formed beneath the dome or elongated dome shape (Figure 2 and [0022]).

Regarding claims 21 and 22, McNulty further teaches the average particle size of the light scattering material is selected to improve an OFF state white appearance of the light emitting device and to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a 60 degree range from an emission axis (see explanation regarding claim 1 above, the scattering particles are of the same material and same size as those used by Applicant, therefore it is the position of the Examiner that the light scattering layer would function in a similar manner).

Claims 7 and 23 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Cairns et al., US 4191943, published March 4, 1980 (hereinafter referred to as "Cairns").

Regarding claims 7 and 23, McNulty teaches the inventions as explained above, but is silent as to the loading of scattering material into the transmissive binder.

In the same field of endeavor of LEDs, Cairns teaches a light scattering material should be employed in the amount claimed in order to achieve optimum light scattering (col 3, lines 60-62). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the light scattering particles of McNulty in the amount taught by Cairns in order to achieve optimum light scattering without loss due to absorption.

Claims 8, 15 and 24 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Chakraborty et al., US 2009/0272996, filed May 2, 2008 (hereinafter referred to as "Chakraborty").

Regarding claims 8 and 24, McNulty teaches the invention as explained above but is silent as to the particles being from 1 to 50 micrometers in size.

However, in the same field of endeavor of LEDs, Chakraborty teaches light scattering particles of the claimed size in a light transmissive binder ([0084]). Chakraborty further teaches that said particle size optimizes the light scattering effect of the layer (id). Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize light scattering particles in the claimed range in order to optimize the light scattering effect of the layer.

Regarding claim 15, McNulty teaches the invention as explained above but is silent as to the substrate upon which the LED and phosphor layer are formed.

In the same field of endeavor of LEDs, Chakraborty teaches the LED and phosphor layer are formed on a substrate having a reflective film thereon ([0097-0098]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that materials such as glass make excellent device substrates due to their electrical insulation properties and ease of manufacturing. Therefore, in light of the state of the art as well as the teaching in Chakraborty, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize a light transmissive substrate such as glass in order to form the LED and phosphor layers of an LED lighting device.

Claims 20 and 27 are rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Robertson et al., US 6860628 B2, published March 1, 2005 (hereinafter referred to as "Robertson").

Regarding claim 20, McNulty teaches the invention as explained above but is silent as to the myriad of uses for an LED.

In the same field of endeavor of LEDs, Robertson teaches an LED may be used in a linear lamp as a replacement for a fluorescent bulb (Figure 3A). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including as a linear lamp, such as the lighting device in Robertson.

Regarding claim 27, McNulty teaches the invention as explained above, but is silent as to the LED being used in a linear lamp.

In the same field of endeavor of LEDs, Robertson teaches a linear lamp comprising an elongate housing and a plurality of LEDs housed within the housing and configured along the length of the housing and an elongate wavelength conversion component (Figure 3A). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including as a linear lamp, such as the lighting device in Robertson.

Claim 28 is rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Soules et al, US 2007/0120135 A1, published May 31, 2007 (hereinafter referred to as "Soules").

Regarding claim 28, McNulty teaches the invention as explained above but is silent as to the LED being used in a downlight.

In the same field of endeavor of LEDs, Soules teaches a downlight comprising a body comprising one or more LEDs, and the body is configured within a downlighting fixture ([0052]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including in a downlight, such as the lighting device in Soules.

Claim 29 is rejected under 35 U.S.C. 103(a) as being unpatentable over McNulty in view of Negley et al., US 2008/0130285 A1, published June 5, 2008 (hereinafter referred to as "Negley").

Regarding claim 29, McNulty teaches the invention as explained above but is silent as to the LED being used in a light bulb.

In the same field of endeavor of LEDs, Negley teaches a light bulb comprising a connector base and a body comprising one or more LEDs ([0022]). Further, it was well known to those of ordinary skill in the art at the time the invention was made that LEDs have many applications in the lighting field including several different types of bulbs with and without reflectors. Therefore, it would have been obvious for one of ordinary skill in the art at the time the invention was made to utilize the LED taught by McNulty in several different ways, including in a light bulb, such as the lighting device in Negley.

Conclusion

Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to MARY ELLEN BOWMAN whose telephone number is (571)270-5383. The examiner can normally be reached on Monday-Friday, 5:30-8:30a.m. and 12:00-5:00 p.m. EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Nimesh Patel can be reached on (571) 272-2457. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/MARY ELLEN BOWMAN/
Primary Examiner, Art Unit 2879

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13273212	DAI ET AL.
	Examiner	Art Unit
	MARY ELLEN BOWMAN	2879

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
313	112, 498, 501, 512	9/18/12	MB
257	98	9/18/12	MB
438	27	9/18/12	MB

SEARCH NOTES		
Search Notes	Date	Examiner
inventor search in eDan	9/18/12	MB

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

Savant Technologies LLC - 1004.188

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13273212	DAI ET AL.
	Examiner	Art Unit
	MARY ELLEN BOWMAN	2879

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	09/18/2012	02/25/2013							
	1	✓	✓							
	2	✓	✓							
	3	✓	✓							
	4	✓	✓							
	5	✓	✓							
	6	✓	✓							
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	26	✓	✓							
	27	✓	✓							
	28	✓	✓							
	29	✓	✓							

Savant Technologies LLC - 1004.189

Doc code: RCEX
Doc description: Request for Continued Examination (RCE)

PTO/SB/30EFS (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	13273212	Filing Date	2011-10-13	Docket Number (if applicable)	ITMX-00318US1	Art Unit	2879
First Named Inventor	Bing Dai			Examiner Name	Bowman, Mary Ellen		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ☐ Other _____

☒ Enclosed

- ☒ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☐ Other _____

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months _____ (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other _____

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 501105

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature

☐ Applicant Signature

Savant Technologies LLC - 1004.190

PTO/SB/30EFS (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Signature of Registered U.S. Patent Practitioner			
Signature	/Peter C. Mei/	Date (YYYY-MM-DD)	2013-06-05
Name	Peter C. Mei	Registration Number	39768

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Savant Technologies LLC - 1004.191

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

PATENT
Attorney Docket No.: ITMX-00318US1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	Group Art Unit: 2879
Bing Dai et al.	Examiner: Bowman, Mary Ellen
Serial No.: 13/273,212	Confirmation No.: 8795
Filed: October 13, 2011	
For: WAVELENGTH CONVERSION COMPONENT WITH DIFFUSING LAYER	

REQUEST FOR CONTINUED EXAMINATION UNDER 37 CFR §1.114 WITH AMENDMENT AND RESPONSE TO FINAL OFFICE ACTION

Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In response to the Office action dated March 6, 2013, Applicants request that this application be amended in accordance with the following sheets.

Amendment to the Claims begins on page 2.

Remarks begin on page 8.

Savant Technologies LLC - 1004.193

AMENDMENT TO THE CLAIMS

Claims 1-29 are pending. Claims 1, 19 and 27-29 have been amended without acquiescence in the Office Action's basis for rejections and without prejudice to pursue canceled subject matter in a related application. No new matter has been added. A complete listing of the pending claims is provided below and supersedes all previous claim lists.

1. (Currently Amended) A wavelength conversion component for a light emitting device comprising:

a wavelength conversion layer comprising particles of at least one photoluminescence material; and

a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of excitation light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product.

2. (Original) The component of Claim 1, wherein the wavelength conversion layer and the light diffusing layer are in direct contact with each other.

3. (Original) The component of Claim 1, wherein the wavelength conversion layer comprises a mixture of the at least one phosphor material and a light transmissive binder and the light diffusing layer comprises a mixture of the light scattering material and the light transmissive binder.

4. (Original) The component of Claim 3, wherein the wavelength conversion layer further comprises a second light scattering material.

5. (Original) The component of Claim 4, wherein the light scattering material and the

Savant Technologies LLC - 1004.194

second light scattering material have different material properties.

6. (Original) The component of Claim 3, wherein the light transmissive binder comprises a curable liquid polymer selected from the group consisting of: a polymer resin, a monomer resin, an acrylic, an epoxy, a silicone and a fluorinated polymer.

7. (Original) The component of Claim 2, wherein the weight loading of light scattering material to binder selected from the group consisting of: 7% to 35% and 10% to 20%.

8. (Original) The component of Claim 1, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

9. (Original) The component of Claim 1, wherein the wavelength conversion and light diffusing layers are deposited using a method selected from the group consisting of: screen printing, slot die coating, spin coating, roller coating, drawdown coating and doctor blading.

10. (Original) The component of Claim 1, wherein the light scattering material is selected from the group consisting of: titanium dioxide, barium sulfate, magnesium oxide, silicon dioxide and aluminum oxide.

11. (Currently Amended) The component of Claim 1, wherein the light scattering material has an average particle size that is selected such that the light scattering material will scatter the excitation light relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material.

12. (Original) The component of Claim 11, wherein the light scattering material scatters the excitation light at least twice as much as light generated by the at least one photoluminescence material.

13. (Original) The component of Claim 11, wherein the excitation light comprises blue light.

Savant Technologies LLC - 1004.195

14. (Original) The component of Claim 13, wherein the light scattering material has an average particle size that is less than about 150nm.

15. (Original) The component of Claim 1, wherein the light diffusing layer is deposited on a light transmissive substrate, and the light transmissive substrate is selected from the group consisting of: a polycarbonate, an acrylic and a glass.

16. (Original) The component of Claim 1 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

17. (Original) The component of Claim 1 in which the light diffusing layer comprises a dome or elongated dome shape.

18. (Original) The component of claim 17 in which the wavelength conversion layer fills a volume formed beneath the dome or elongated dome shapes.

19. (Currently Amended) A light emitting device, comprising:

at least one solid-state light emitter operable to generate excitation light; and

a wavelength conversion component comprising:

a wavelength conversion layer excitable by the excitation light, wherein the wavelength conversion layer comprises particles of at least one photoluminescence material; and

a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an OFF state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the at least one solid-state light emitter is emitted through the wavelength conversion component to contribute to a final visible emission product.

Savant Technologies LLC - 1004.196

20. (Original) The device of claim 19, wherein the light emitting device is selected from the group consisting of: downlights, light bulbs, linear lamps, lanterns, wall lamps, pendant lamps, chandeliers, recessed lights, track lights, accent lights, stage lighting, movie lighting, street lights, flood lights, beacon lights, security lights, traffic lights, headlamps, taillights, and signs.

21. (Previously Presented) The device of claim 19 in which the light scattering material within the light diffusing layer corresponds to an average particle size that improves the OFF state white appearance of the wavelength conversion component.

22. (Original) The device of claim 19 in which the light diffusing layer is configured to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a $\pm 60^{o}$ range from an emission axis.

23. (Original) The device of claim 22, wherein a weight loading of the light scattering material to a binder selected from the group consisting of: 7% to 35% and 10% to 20%.

24. (Original) The device of Claim 19, wherein the light scattering material has an average particle size in a range selected from the group consisting of: 1μm to 50μm and 10μm to 20μm.

25. (Original) The device of Claim 19 in which the wavelength conversion layer and the light diffusing layer comprises planar shapes.

26. (Original) The device of Claim 19 in which the light diffusing layer comprises a dome or elongated dome shape.

27. (Currently Amended) A linear lamp comprising:

an elongate housing;

a plurality of solid-state light emitters housed within the housing and configured along the length of the housing; and

an elongate wavelength conversion component remote to the plurality of solid-state light emitters and configured to in part at least define a light mixing chamber,

Savant Technologies LLC - 1004.197

wherein the elongate wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the elongate wavelength conversion component;

wherein the elongate wavelength conversion component is configured such that in operation a portion of light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the plurality of solid-state light emitters is emitted through the wavelength conversion component to contribute to a visible final emission product.

28. (Currently Amended) A downlight comprising:

a body comprising one or more solid-state light emitters, wherein the body is configured to be positioned within a downlighting fixture such that the downlight emits light in a downward direction; and

a wavelength conversion component remote to the one or more solid-state light emitters and configured to in part at least define a light mixing chamber,

wherein the wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product.

29. (Currently Amended) A light bulb comprising:

a connector base configured to be inserted in a socket to form an electrical connection for the light bulb;

a body comprising one or more solid-state light emitters;

Savant Technologies LLC - 1004.198

a wavelength conversion component having a three dimensional shape that is configured to enclose the one or more solid-state light emitters and to in part at least define a light mixing chamber,

wherein the wavelength conversion component comprises a wavelength conversion layer comprising particles of at least one photoluminescence material and a light diffusing layer comprising particles of a light scattering material,

wherein the light diffusing layer improves an off-state white appearance of the wavelength conversion component;

wherein the wavelength conversion component is configured such that in operation a portion of light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the one or more solid-state light emitters is emitted through the wavelength conversion component to contribute to a final visible emission product.

Savant Technologies LLC - 1004.199

REMARKS

Claims 1-29 are currently pending in the application. Claims 1, 19 and 27-29 have been amended without acquiescence to the basis of rejections set forth in the Office Action, and without prejudice to pursue the previously presented claims in related application(s). No new matter has been added.

I. Claim Rejections under 35 U.S.C. §103

Claims 1-6, 9-14, 16-19, 21-22, 25 and 26 stand rejected under 35 U.S.C. §103(a) as allegedly being unpatentable U.S. Patent Pub. No. 2002/0180351 (McNulty). Applicants respectfully traverse.

A. Claim 1 currently recites the following limitation. Claim 19 currently recites similar limitations.

> wherein the wavelength conversion component is configured such that in operation a portion of excitation light comprising blue light having a wavelength of greater than or equal to 440 nm generated by the light emitting device is emitted through the wavelength conversion component to contribute to a final visible emission product

Applicants respectfully submit McNulty fails to render the claim unpatentable, because McNulty does not disclose the claimed limitation of a portion of the excitation light contributing to the final visible emission product, and also because the Office Action makes an impermissible determination of obviousness based on Applicants' own disclosure.

1. McNulty does not disclose the claimed element, teaches using a UV LED, and teaches away from using a blue LED

The Office Action states asserts that McNulty at least makes obvious the use of a blue LED, and cites paragraphs [0004]-[0005] of McNulty as teaching that "one must balance the type of light emitted from an LED between UV and blue in order to prevent utilizing a UV light that would be dangerous upon emission and a blue LED that would contribute too heavily in the final emission product." *See Office Action, pg.3.* However, Applicants respectfully submit that McNulty does not make obvious the use of a blue LED, and in fact teaches away from using a blue LED. Paragraphs [0004]-[0005] of McNulty are reproduced below for reference.

[0004] UV light-emitting LEDs are particularly preferred in applications in which visible light is extracted because the color of the light emitted by UV LED-based lamps is controlled largely by the phosphor blend since the UV LED chip does not contribute significantly to the visible light emission. As used herein, the term "UV LEDs" means LEDs that emit UV radiation having wavelengths less than or equal to about 420 nm. However, as the wavelengths of radiation emitted by the LED becomes shorter, and the radiation, thus, becomes more energetic, there is an increasing need to ensure that UV radiation preferably does not escape substantially from the lighting device into the surrounding environment.

[0005] U.S. Pat. Nos. 5,813,752 and 5,813,753 disclose a UV/blue LED-phosphor device that emits visible light. In U.S. Pat. No. 5,813,752 the UV/blue LED is disposed on a sapphire substrate and a phosphor layer is applied directly on the UV/blue LED. A long-wave pass ("LWP") filter preferably composed of a multilayer dielectric stack of alternating materials having high and low refractive indices is disposed directly on the phosphor layer. In U.S. Pat. No. 5,813,753 the UV/blue LED is disposed in a cup. In both patents, the UV/blue LED emits radiation in the UV-to-blue wavelength range. The cup is filled with an epoxy having a UV/blue-excitable phosphor dispersed therein that converts part of the UV/blue radiation to visible light. A LWP filter, preferably composed of alternating layers of dielectric materials having high and low refractive indices, is disposed on top of the phosphor layer. The LWP filter is believed to reflect UV/blue light back to the phosphor and to transmit visible light emitted by the phosphor. However, these patents do not teach the selection of the materials having high and low refractive indices, the design, or the construction of the multilayer LWP filter to achieve these goals. Material selection is among the critical considerations for the success of such a filter in a device of this nature because the effectiveness of the filter in reflecting UV radiation depends, among other things, on the refractive index of the layer disposed adjacent to the epoxy layer relative to the refractive index of the epoxy.

First, Applicants respectfully submit that McNulty does not disclose the claimed element because McNulty teaches using a UV LED and not a blue LED, and in fact teaches away from using a blue LED. McNulty specifically "relates to visible light sources that are based on semiconductor UV light-emitting devices and have reduced UV emission to the surroundings." *See McNulty, para. [0001]*.

In addition, McNulty teaches that UV LEDs "are particularly preferred" for "applications in which visible light is extracted." This is because UV LEDs do not contribute to the visible light emission of the device, allowing for the light emitted by the device to be "controlled largely by the phosphor blend." *See McNulty, para. [0004]*. In other words, paragraph [0004] of McNulty teaches using UV LEDs and teaches away from using blue LEDs. Paragraph [0004] also teaches LED devices wherein the emitted light is controlled by the phosphor blend, and thus teaches away from LED devices wherein the emitted light is a combination of LED light and phosphor light.

Therefore, for at least these reasons, Applicants respectfully submit that McNulty fails to disclose the limitation recited by the claim, because McNulty teaches using a UV LED and teaches away from using a blue LED.

2. **McNulty does not disclose the claimed element, because the cited portions of McNulty teach reflecting LED light so that only phosphor light is emitted**

Paragraph [0005] of McNulty also does not teach the claimed element. Paragraph [0005] of McNulty gives examples of prior patents that disclose a UV/blue LED and using a LWP filter "to reflect UV/blue light back to the phosphor and to transmit visible light emitted by the phosphor." In other words, the prior patents described in paragraph [0005] disclose that only the light emitted by the phosphor is transmitted from the device, while the light from the LED is reflected back and thus does not contribute to the final emission product. This is the direct opposite of the claimed element, which recites that excitation light emitted by the light emitter contributes to the final emission product. Therefore, paragraph [0005] of McNulty also does not teach the claimed element of excitation light from the LED contributing to the final emission product of the LED device, because it teaches reflecting light from the LED so that only light emitted by the phosphor is transmitted.

Therefore, for at least these reasons, Applicants respectfully submit that McNulty fails to disclose the claimed limitation of a portion of the excitation light contributing to the final visible emission product because McNulty teaches reflecting the light from the LED so that only light emitted by the phosphor is transmitted.

Savant Technologies LLC - 1004.202

3. The Office Action determination of obviousness is impermissible due to hindsight

Second, the Office Action makes an impermissible determination of obviousness based on Applicants' own disclosure. The Office Action states that "in light of the Applicant's own disclosure, as well as McNulty's teaching that a UV/blue LED may be used,… it would have been obvious to one of ordinary skill in the art to have a small portion of the light emitted from the LED contribute to a final emission product of the device." *See Office Action, pg. 3.*

MPEP 2142 states that "[t]o reach a proper determination under 35 U.S.C. 103, the examiner must step backward in time and into the shoes worn by the hypothetical 'person of ordinary skill in the art' when the invention was unknown and just before it was made…. The tendency to resort to 'hindsight' based upon applicant's disclosure is often difficult to avoid due to the very nature of the examination process. However, impermissible hindsight must be avoided and the legal conclusion must be reached on the basis of the facts gleaned from the prior art." (emphasis added).

Applicants respectfully submit that the Applicant's own disclosure of particles of light reflective material cannot be used to form a 35 U.S.C. §103(a) rejection of the claims because Applicant's own disclosure is not prior art. Instead, using the teachings of Applicant's own disclosure would constitute impermissible hindsight and thus cannot be used to support a rejection under 35 U.S.C. 103.

Consequently, for at least these reasons, it is respectfully submitted that claim 1 and its dependent claims are allowable over the cited reference. For at least this same reason, claim 23 and its dependent claims are allowable over the cited reference.

II. Claim Rejections under 35 U.S.C. §103

Claims 7 and 23 stand rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over McNulty in view of U.S. Patent No. 4,191,943 (Cairns). Applicants respectfully traverse.

Applicants respectfully submit that these claims are believed to be allowable over McNulty in view of Cairns because Cairns fails to cure McNulty's deficiencies, and further because the Office action does not rely on Cairns in supporting the basis for rejection in claims 1 and 19 from which these rejected claims depend.

Savant Technologies LLC - 1004.203

III. Claim Rejections under 35 U.S.C. §103

Claims 8, 15 and 24 stand rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over McNulty in view of U.S. Publication No. 2009/0272996 (Chakraborty). Applicants respectfully traverse.

Applicants respectfully submit that these claims are believed to be allowable over McNulty in view of Chakraborty because Chakraborty fails to cure McNulty's deficiencies, and further because the Office action does not rely on Chakraborty in supporting the basis for rejection in claims 1 and 19 from which these rejected claims depend.

IV. Claim Rejections under 35 U.S.C. §103

Claims 20 and 27 stand rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over McNulty in view of U.S. Patent No. 6,860,628 (Robertson). Applicants respectfully traverse.

These claims are allowable for at least the same reasons that claim 1 is allowable.

V. Claim Rejections under 35 U.S.C. §103

Claim 28 stands rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over McNulty in view of U.S. Publication No. 2007/0120135 (Soules). Applicants respectfully traverse.

This claim is allowable for at least the same reasons that claim 1 is allowable.

VI. Claim Rejections under 35 U.S.C. §103

Claim 29 stands rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over McNulty in view of U.S. Publication No. 2008/0130285 (Negley). Applicants respectfully traverse.

This claim is allowable for at least the same reasons that claim 1 is allowable.

Savant Technologies LLC - 1004.204

CONCLUSION

Based on the foregoing, all claims are believed allowable, and an allowance of the claims is respectfully requested. If the Examiner has any questions or comments, the Examiner is respectfully requested to contact the undersigned at the number listed below.

Applicant(s) hereby explicitly retracts and rescinds any and all of the arguments and disclaimers presented to distinguish the prior art of record during the prosecution of all parent and related application(s)/patent(s), and respectfully requests that the Examiner re-visit the prior art that such arguments and disclaimers were made to avoid.

The Commissioner is authorized to charge any fees due in connection with the filing of this document to Vista IP Law Group's Deposit Account No. 50-1105, referencing billing number ITMX-00318US1. The Commissioner is authorized to credit any overpayment or to charge any underpayment to Vista IP Law Group's Deposit Account No. 50-1105, referencing billing number ITMX-00318US1.

Respectfully submitted,

Dated: June 5, 2013

By: /Frederick Hsu /
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Savant Technologies LLC - 1004.205

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	)	Group Art Unit: 2879
	)	
Bing Dai et al.	)	Examiner: Bowman, Mary Ellen
	)	
Serial No.: 13/273,212	)	Confirmation No.: 8795
	)	
Filed: October 13, 2011	)	
	)	
For: WAVELENGTH CONVERSION COMPONENT WITH DIFFUSING LAYER	)	
	)	
	)	

INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with 37 CFR §§ 1.97 and 1.98, the items identified in this Information Disclosure Statement (IDS) are being brought to the attention of the Office. The Examiner is requested to make these documents of record.

The items identified in this IDS may or may not be "material" pursuant to 37 CFR § 1.56. The submission thereof by Applicant(s) is not to be construed as an admission that any such patent, publication or other information referred to therein is material or considered to be material (37 CFR § 1.97(h)), or even qualifies as "prior art" under 35 USC § 102 with respect to this invention unless specifically designated by Applicant(s) as such.

1. Fee:

☐ Charge the fee due under 37 CFR § 1.17(p) to the deposit account referenced below.

☐ The fee due under 37 CFR § 1.17(p) is being concurrently submitted with the filing of an electronic IDS submission. Thus, no additional fee is required.

Savant Technologies LLC - 1004.206

☒ Applicant believes that no fee is required for this submission. However, if Applicant is mistaken, then please charge the fee due under 37 CFR § 1.17(p) to the deposit account referenced below.

2. Statement Under 37 CFR § 1.97(e):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1); or

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

3. Copies of the Cited Items:

☒ Copies of all of the items listed under Foreign Patent Documents and/or Non Patent Literature Documents are enclosed.

☐ Copies of the following items listed under Item Nos. ___ under Foreign Patent Documents and Item Nos. ___ under Non Patent Literature Documents are enclosed.

☐ Copies of the following documents listed under Item Nos. ___ under Foreign Patent Documents and Item Nos. ___ under Non Patent Literature Documents are not supplied because they were previously cited by the Office or submitted in Information Disclosure Statements in parent U.S. Application No. _____, of which the current application is a _____ and relied upon in this application for an earlier filing date under 35 USC § 120. See 37 CFR § 1.98(d). The Examiner is requested to make these documents of record.

Savant Technologies LLC - 1004.207

4. Conclusion:

Citation of the above documents shall not be construed as:

1. an admission that the documents are necessarily prior art with respect to the instant invention;
2. a representation that a search has been made, other than as described above; and
3. an admission that the information cited herein is, or is considered to be, material to patentability as defined in § 1.56(b).

It is respectfully requested that the Examiner indicate consideration of the cited references by returning a copy of the attached form with initials or other appropriate marks. If the U.S. Patent Office determines that an extension and/or other relief is required, Applicant(s) petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 501105**, referencing **Docket No. ITMX-00318US1**. However, the Commissioner is not authorized to charge the cost of the issue fee to the Deposit Account.

Respectfully submitted,

Dated: 06-05-2013

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Savant Technologies LLC - 1004.208

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Substitute for form 1449/PTO				***Complete if Known***	
				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	4	of	11	Attorney Docket Number	ITMX-00318US1

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	5371434	12-06-1994	Rawlings, Keith C.	
	2	5947587	09-07-1999	Keuper, et al.	
	3	5998925	12-07-1999	YOSHINORI SHIMIZU	
	4	6147367	11-14-2000	Yang et al.	
	5	6255670	07-03-2001	Srivastava et al.	
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	8	6576930	06-10-2003	Reeh et al.	
	9	6580097	06-17-2003	Soules et al.	
	10	6614170	09-02-2003	Wang et al.	
	11	6680569	01-20-2004	Meueller-Mach et al.	
	12	6717353	04-06-2004	Mueller et al.	
	13	6834979	12-28-2004	Cleaver et al.	
	14	7029935	04-18-2006	Negley et al.	
	15	7220022	05-22-2007	Allen et al.	
	16	7311858	12-25-2007	Ning Wang	
	17	7390437	06-24-2008	Yi Dong	
	18	7575697	08-18-2009	Yi-Qun Li	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Sheet	5	of	11	Attorney Docket Number	ITMX-00318US1

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	19	7601276	10-13-2009	Yi-Qun Li	
	20	7655156	02-02-2010	Shifan Cheng	
	21	7663315	02-16-2010	Hulse, George R.	
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	23	7943951	05-17-2011	Kim et al.	
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	25	8274215	09-25-2012	Shengfeng Liu	
	26	20010000622	05-01-2001	Reeh et al.	
	27	20020047516	04-25-2002	Iwasa et al.	
	28	20030038596	02-27-2003	Ho, Wen-Chih	
	29	20030052595	03-20-2003	Ellens et al.	
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	33	20040183081	09-23-2004	Alexander Shishov	
	34	20040227465	11-18-2004	Menkara et al.	
	35	20040239242	12-02-2004	Yasuhisa Mano	
	36	20050051782	03-10-2005	Negley et al.	
	37	20050052885	03-10-2005	Wu, Han Wen	

Examiner Signature		Date Considered	

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Sheet	6	of	11	Attorney Docket Number	ITMX-00318US1

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	39	20050093430	05-05-2005	Ibbertson et al.	
	40	20050168127	08-04-2005	Shei et al.	
	41	20060001352	01-05-2006	Maruta et al.	
	42	20060027786	02-09-2006	Dong,et al.	
	43	20060028122	02-09-2006	Wang, et al.	
	44	20060028837	02-09-2006	Mrakovich	
	45	20060124947	06-15-2006	Mueller et al.	
	46	20060158090	07-20-2006	Wang, et al.	
	47	20060261309	11-23-2006	Li, et al.	
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	49	20070029526	02-08-2007	Cheng, et al.	
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	53	20080111472	05-15-2008	Shengfeng Liu	
	54	20080218992	09-11-2008	Yi-Qun Li	
	55	20080246044	10-09-2008	Siew It Pang	
	56	20080308825	12-18-2008	Chakraborty et al.	

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	7	of	11	Attorney Docket Number	ITMX-00318US1

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	57	20090026908	01-29-2009	Bechtel et al.	
	58	20090050911	02-26-2009	Chakraborty	
	59	20090283721	11-19-2009	Shengfeng Liu	
	60	20110147778	06-23-2011	Ichikawa, Masatsugu	
	61	20120086034	04-12-2012	Xianglong Yuan	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PTO/SB/08a (07-09) (modified)
Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO				***Complete if Known***	
				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	8	of	11	Attorney Docket Number	ITMX-00318US1

FOREIGN PATENT DOCUMENTS						
Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3] – Number[4] – Kind Code[5] (*if known*)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
	1	CA 2466979	11/18/2005	Prodanov D.		
	2	JP 07094785	04/07/1995	Stanley Electric CO. LTD		
	3	JP 2003101078	04/04/2003	Toyoda Gosei Co Ltd		
	4	JP 2005011953	01/13/2005	Toyoda Gosei Co Ltd		
	5	RU 214492	06/27/1998	Abramov V. S., et al.		
	6	TW 200527664	08/16/2005	Cree, Inc. US		
	7	KR 10-2007-0065486 A	06/25/2007	Samsung Electro-Mechanics Co., Ltd.		
	8	KR 10-2009-0017346 A	02/29/2009	Seoul Semiconductor Co., Ltd.		
	9	WO 2002007228	01/24/2002	Elliiott C. T et al.		
	10	WO 2004077580	09/10/2004	James, IBBETSON et al.		
	11	WO 2005025831	03/24/2005	Gerald NEGLEY et al.		
	12	WO 2006022792	03/02/2006	Wang et al.		
	13	WO 2008043519 A1	04/17/2008	Lexedis Lighting GMBH		
	14	WO 2010074963	01/07/2010	LIU, Shengfeng		
	15					

Examiner Signature		Date Considered	

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PTO/SB/08a (07-09) (modified)
Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO				***Complete if Known***	
				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	9	of	11	Attorney Docket Number	ITMX-00318US1

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	1	BARRY, T., Flurrescence of EU2+ Activated Phases in Bunary Alkaline Earth Orthosilicate Systems, Journal of the Electrochemical Society, November 1968, pp. 1181-1184, Vol. 115, No. 1.	
	2	Docket No. ITMX-00116CN0; First Office Action for Chinese Patent Application No. 200780032995.8 Issued on March 19, 2010	
	3	Docket No. ITMX-00116CN0; Foreign Office Action dated Oct. 29, 2012 for Chinese Appln. No. 200780032995.8	
	4	Docket No. ITMX-00116CN0; Second Office Action for Chinese Patent Application No. 200780032995.8 Issued on August 10, 2011	
	5	Docket No. ITMX-00116CN0; Third Office Action for Chinese Patent Application No. 200780032995.8 Issued on December 12, 2011	
	6	Docket No. ITMX-00116CN1; Foreign Office Action dated Apr. 24, 2012 for Chinese Appln. No. 201010525492.8	
	7	Docket No. ITMX-00116EP0; Foreign Office Action dated July 5, 2012 for European Appln. No. 07811039.2	
	8	Docket No. ITMX-00116JP0; Foreign Office Action for Japanese Application No. 2009-522877 mailed on April 16, 2013	
	9	Docket No. ITMX-00116JP0; Foreign Office Action for Japanese Application No. 2009-522877 mailed on April 24, 2012	
	10	Docket No. ITMX-00116TW0; Taiwanese Office Action and Search Report for ROC (Taiwan) Patent Applicatoin No. 096128666 mailed on September 1, 2011	
	11	Docket No. ITMX-00116US06; Non-Final Office Action dated Sep. 27, 2012 for U.S. Appln. No. 13/436,471	
	12	Docket No. ITMX-00116US1; Final Office Action Mailed on June 23, 2009 for U.S. Application No. 11/640,533	
	13	Docket No. ITMX-00116US1; Final Office Action Mailed on September 23, 2011 for U.S. Application No. 11/640,533	

Examiner Signature		Date Considered	

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				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	10	of	11	Attorney Docket Number	ITMX-00318US1

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	14	Docket No. ITMX-00116US1; Final Office Action Mailed on September 9, 2010 for U.S. Application No. 11/640,533	
	15	Docket No. ITMX-00116US1; Non-Final Office Action Mailed on January 20, 2010 for U.S. Application No. 11/640,533	
	16	Docket No. ITMX-00116US1; Non-Final Office Action Mailed on March 3, 2011 for U.S. Application No. 11/640,533	
	17	Docket No. ITMX-00116US1; Non-Final Office Action Mailed on October 27, 2008 for U.S. Application No. 11/640,533	
	18	Docket No. ITMX-00116US2; Notice of Allowance Mailed on August 12, 2011 for U.S. Application No. 12/624,839	
	19	Docket No. ITMX-00116US2; Notice of Allowance Mailed on September 26, 2011 for U.S. Application No. 12/624,839	
	20	Docket No. ITMX-00116US3; Final Office Action dated Jan. 11, 2013 for U.S. Appln. No. 12/624,900	
	21	Docket No. ITMX-00116US3; Final Office Action Mailed on December 19, 2011 for U.S. Application No. 12/624,900	
	22	Docket No. ITMX-00116US3; Non-Final Office Action Mailed on June 25, 2012 for U.S. Application No. 12/624,900	
	23	Docket No. ITMX-00116US3; Non-Final Office Action Mailed on March 24, 2011 for U.S. Application No. 12/624,900	
	24	Docket No. ITMX-00116US4; Final Office Action dated Jan. 30, 2013 for U.S. Appln. No. 13/087,615	
	25	Docket No. ITMX-00116US4; Non-Final Office Action dated September 21, 2012 for U.S. Appln. No. 13/087,615	
	26	Docket No. ITMX-00116US6; Advisory Action dated May 15, 2013 for U.S. Appln. No. 13/436,471	
	27	Docket No. ITMX-00116US6; Final Office Action dated Mar. 1, 2013 for U.S. Appln. No. 13/436,471	

Examiner Signature		Date Considered	

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PTO/SB/08a (07-09) (modified)
Approved for use through 07/31/2012. OMB 0651-0031

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Substitute for form 1449/PTO				***Complete if Known***	
				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	11	of	11	Attorney Docket Number	ITMX-00318US1

NON PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
	28	Docket No. ITMX-00116US8; Final Office Action dated Apr. 5, 2013 for U.S. Appln. No. 13/441,714	
	29	Docket No. ITMX-00116US8; Non-Final Office Action dated September 19, 2012 for U.S. Appln. No. 13/441,714	
	30	Docket No. ITMX-00116WO0; International Search Report and the Written Opinion dated August 15, 2008 for PCT International Application No. PCT/US2007/017299	
	31	Docket No. ITMX-00307US1; Final Office Action dated Mar. 1, 2013 for U.S. Appln. No. 13/253,031	
	32	Docket No. ITMX-00307US1; Non-Final Office Action dated Oct. 16, 2012 for U.S. Appln. No. 13/253,031	
	33	Docket No. ITMX-00318US2; Final Office Action dated Mar. 1, 2013 for U.S. Appln. No. 13/273,215	
	34	Docket No. ITMX-00307WO0; International Search Report and Written Opinion for PCT Application No. PCT/US11/54827	
	35	Docket No. ITMX-00318US3; Final Office Action dated Mar. 1, 2013 for U.S. Appln. No. 13/273,217	
	36	Docket No. ITMX-00318WO0; International Search Report and Written Opinion dated Mar. 28, 2013 for PCT/US2012/0598292	
	37	PARK J.K., et al., Optical Properties of Eu2+ Activated Sr2Sio4 Phosphor for Light-Emitting Diodes, Electrochemical and Solid-State Letters, February 25, 2004, pp. H15-H17, Vol. 7, No. 5.	
	38	Supplementary European Search Report for EP 07811039.2, April 15, 2011, 15 pages; Docket No. ITMX-00116EP0	
	39	YOO, J.S., et al., Control of Spectral Properties of Strontium-Alkaline Earth-Silicate-Europiem Phosphors for LED Applications, Journal of the Electrochemical Society, April 1, 2005 pp.G382-G385, Vol. 152, No. 5.	

Examiner Signature		Date Considered	

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CAH

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
CLAUDE A.S. HAMRICK
BUCHANAN INGERSOLL, LLP
P.O. BOX 1404
ALEXANDRIA, VA 22313-1404

RECEIVED
SEP 04 2008
FLIESLER MEYER LLP

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 1034172-216 -00160WOΦ	Date of mailing (*day/month/year*) 15 AUG 2008 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US07/17299 ✓	International filing date (*day/month/year*) 02 August 2007 (02.08.2007)
Applicant INTEMATIX CORPORATION	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

   For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☒ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☒ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Nimeshkumar D Patel Telephone No. (571) 272-1550

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

BUCHANAN INGERSOLL & ROONEY PC
AUG 18 2008

Savant Technologies LLC - 1004.217

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 1034172-216	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US07/17299	International filing date (*day/month/year*) 02 August 2007 (02.08.2007)	(Earliest) Priority Date (*day/month/year*) 03 August 2006 (03.08.2006)
Applicant INTEMATIX CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed.
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 Rule 43.6 *bis(a)*
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 2
      ☐ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☒ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

Savant Technologies LLC - 1004.218

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/17299

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **H05B 33/00**(2006.01)

USPC: 313/484,485,486,487,489,501,512;252/301.4R,301.6R,301.6S,301.4H,301.4F
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 313/484,485,486,487,489,501,512; 252/301.4R,301.6R,301.6S,301.4H,301.4F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 7,029,935 B2 (NEGLEY et al.) 18 April 2006 (18.04.2006)	1,2,4-8,13,14,22-27,29-33,38,40,47,48,50-54,59-61,63-67,72,80,83,85 ---------- 18-21,43-46,76-79
X	US 5,371,434 A (RAWLINGS) 06 December 1994 (06.12.1994)	1,3,26,28,47,49,60,62
X	US 20020047516 A1 (IWASA et al.) 25 April 2002 (25.04.2002)	1,11,12,26,36,37,47,57,58,60,70,71
X	CA 2466979 A1 (PRODANOV) 18 November 2005 (18.11.2005)	1,9,26,34,47,55,60,68

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 August 2008 (07.08.2008)	15 AUG 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Nimeshkumar D. Patel Telephone No. (571) 272-1550

Form PCT/ISA/210 (second sheet) (April 2007)

Savant Technologies LLC - 1004.219

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/17299

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,614,170 B2 (WANG et al.) 02 September 2003 (02.09.2003)	1,14,15,26,38,39,60,73,83,84
X	US 2004/0227465 A1 (MENKARA et al.) 18 November 2004 (18.11.2004)	1,16,26,41,60,74
X	US 2004/0016908 A1 (HOHN et al.) 29 January 2004 (29.01.2004)	1,17,26,42,60,75
X	US 2005/0057917 A1 (YATSUDA et al.) 17 March 2005 (17.03.2005)	60,81,82
Y	JP 07-094785 A (TANAKA et al.) 07 April 1995 (07.04.1995)	1,10,26,35,47,56,60,69
Y	US 6,555,958 A (SRIVASTAVA et al.) 29 April 2003 (29.04.2003)	1,10,26,35,47,56,60,69
Y	US 2005/0168127 A1 (SHEI et al.) 04 August 2005 (04.08.2005)	18,43,76
Y	US 6,717,353 B1 (MUELLER et al.) 06 April 2004 (06.04.2004)	19,20,44,45,77,78
Y	US 2003/0052595 A1 (ELLENS et al.) 20 March 2003 (20.03.2003)	21,46,79

Savant Technologies LLC - 1004.220

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
CLAUDE A.S. HAMRICK
BUCHANAN INGERSOLL, LLP
P.O. BOX 1404
ALEXANDRIA, VA 22313-1404

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference 1034172-216	Date of mailing (*day/month/year*) **FOR FURTHER ACTION** 15 AUG 2008 See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/US07/17299	02 August 2007 (02.08.2007)	03 August 2006 (03.08.2006)

International Patent Classification (IPC) or both national classification and IPC

IPC: **H05B 33/00**(2006.01)
USPC: 313/110,111,112,4854,485,486,487,489,501,512

Applicant

INTEMATIX CORPORATION

1. This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☐ Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis(b)* that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/ US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	08 August 2008 (08.08.2008)	Nimeshkumar D Patel Telephone No. (571) 272-1550

Form PCT/ISA/237 (cover sheet) (April 2007)

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/17299

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

a. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table(s) relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Savant Technologies LLC - 1004.222

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/17299

Box No. V Reasoned statement under Rule 43 *bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims 10,18-21,35,43-46,56,69,76-79	YES
	Claims 1-9,11-17,22-34,36-42,47-55,57-68,70-75,80-85	NO
Inventive step (IS)	Claims NONE	YES
	Claims 1-85	NO
Industrial applicability (IA)	Claims 1-85	YES
	Claims NONE	NO

2. Citations and explanations:

Please See Continuation Sheet

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/17299

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

V. 2. Citations and Explanations:

Claims 1, 2, 4-8, 13, 14, 22-27, 29-33, 38, 40, 47, 48, 50-54, 59-61, 63-67, 72, 80, 83 and 85 lack novelty under PCT Article 33(2) as being anticipated by Negley et al. (US 2005/0051782).

Regarding claims 1 and 26, Negley discloses an optical component for a lighting arrangement of a type comprising a radiation source (260) configured to emit radiation having a first wavelength range; a phosphor (110) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component.

Regarding claims 47 and 60, Negley discloses a method of fabricating an optical component for a lighting arrangement of a type comprising a radiation source (260) configured to emit radiation having a first wavelength range; a phosphor (110) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component.

Regarding claim 83, Negley discloses a phosphor material for coating an optical component of an LED lighting arrangement comprising a phosphor powder incorporated within one of an epoxy resin, a silicone material and a polymer material (¶[0020]).

Regarding claim 85, Negley discloses an optical component for a lighting arrangement of a type comprising a radiation source (260) configured to emit radiation having a first wavelength range; a phosphor (120) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, and characterized in that said phosphor is incorporated in said optical component (Fig. 1B).

Regarding claims 2, 27, 48 and 61, Negley discloses the phosphor being provided as a substantially uniform thickness layer on said surface of the optical component.

Regarding claims 4, 29, 50 and 63, Negley discloses the optical component has a convex surface and the phosphor is provided on said convex surface (Fig. 1C).

Regarding claims 6, 31, 52 and 65, Negley discloses the optical component having a substantially hemispherical surface and the phosphor is provided on said hemispherical surface (Fig. 1F).

Regarding claims 5, 30, 51 and 64, Negley discloses the optical component (252) having a concave surface and comprising providing the phosphor on the concave surface (Fig. 2B).

Regarding claims 7, 32, 53 and 66, Negley discloses the optical component (252) comprising a substantially hemispherical shell and the phosphor (202) is provided on the inner hemispherical surface (Fig. 2B).

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Regarding claims 8, 33, 54 and 67, Negley discloses the optical component comprises a substantially hemispherical shell and the phosphor is provided on at least a part of the outer hemispherical surface (Fig. 2B).

Regarding claims 13, 40, 59 and 80, Negley discloses the optical component is made from one of a plastics material, glass (Column 4, lines (19-20).

Regarding claims 14, 38 and 72, Negley discloses the phosphor comprising a powder which is incorporated within one of an epoxy resin, a silicone material and a polymer material to form a mixture (¶[0020]) and in which the phosphor mixture is applied to the optical component to form a layer of phosphor on the optical component surface (Fig. 1E).

Regarding claim 22, Negley discloses the radiation source comprising a light emitting diode (¶[0027]).

Regarding claim 23, Negley discloses the LED chip comprising a gallium nitride LED (¶[0027]).

Regarding claim 24, Negley discloses the radiation source being operable to emit radiation having a wavelength range of 300 to 500 nm (from GaN LED, ¶[0027]).

Regarding claim 25, Negley discloses the phosphor being configured to emit radiation having a wavelength from 450 to 700 nm (YAG:Ce, ¶[0020]).

Claims 1, 3, 26, 28, 47, 49, 60 and 62 lack novelty under PCT Article 33(2) as being anticipated by Rawlings (US 5,371,434).

Regarding claims 1 and 26, Rawlings substantially discloses an optical component (1) for a lighting arrangement of a type comprising a radiation source (20) configured to emit radiation having a first wavelength range; a phosphor (16) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Fig. 2).

Regarding claims 47 and 60, Rawlings discloses a method of fabricating an optical component (1) for a lighting arrangement of a type comprising a radiation source (20) configured to emit radiation having a first wavelength range; a phosphor (16) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 2).

Regarding claims 3, 28, 49 and 62, Rawlings discloses the optical component having a substantially planar surface and comprising providing the phosphor on said substantially planar surface (Fig. 2).

Claims 1, 9, 26, 34, 47, 55, 60 and 68 lack novelty under PCT Article 33(2) as being anticipated by Prodanov (CA 2466979 A1).

Regarding claims 1 and 26, Prodanov substantially discloses an optical component (8) for a lighting arrangement of a type comprising a radiation source (6) configured to emit radiation having a first wavelength range; a phosphor (7) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Fig. 3).

Regarding claims 47 and 60, Prodanov discloses a method of fabricating an optical component (8) for a lighting arrangement of a type comprising a radiation source (6) configured to emit radiation having a first wavelength range; a phosphor (7) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 3).

Regarding claims 9, 34, 55 and 68, Prodanov discloses the optical component comprising a substantially spherical shell and the phosphor provided on at least a part of the inner spherical surface (Fig. 3).

Claims 1, 11, 12, 26, 36, 37, 47, 57, 58, 60, 70 and 71 lack novelty under PCT Article 33(2) as being anticipated by Iwasa et al. (US 2002/0047516 A1).

Regarding claims 1 and 26, Iwasa substantially discloses an optical component (114a, 115b) for a lighting arrangement of a type comprising a radiation source (104) configured to emit radiation having a first wavelength range; a phosphor (114b, 115a) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Figs. 8A-8B).

Regarding claims 47 and 60, Iwasa discloses a method of fabricating an optical component (114a, 115b) for a lighting arrangement of a type comprising a radiation source (104) configured to emit radiation having a first wavelength range; a phosphor (114b, 115a) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 8A-8B).

Regarding claims 11, 36, 57 and 70, Iwasa discloses the optical component comprising a hollow cylinder and comprising providing the phosphor (114b) on at least a part of the inner surface (Fig. 8A).

Regarding claims 12, 37, 58 and 71, Iwasa discloses the optical component comprising a hollow cylinder and comprising providing the phosphor (115a) on at least a part of the outer surface (Fig. 8B).

Claims 1, 14, 15, 26, 38, 39, 60, 73, 83 and 84 lack novelty under PCT Article 33(2) as being anticipated by Wang et al. (US 6,614,170 A).

Regarding claims 1 and 26, Wang substantially discloses an optical component (37) for a lighting arrangement of a type

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comprising a radiation source (31) configured to emit radiation having a first wavelength range; a phosphor (21) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Fig. 3).

Regarding claim 60, Wang discloses a method of fabricating an optical component (37) for a lighting arrangement of a type comprising a radiation source (31) configured to emit radiation having a first wavelength range; a phosphor (21) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 3).

Regarding claims 14, 38, 72 and 83, Wang discloses the phosphor comprising a powder which is incorporated within one of an epoxy resin, a silicone material and a polymer material to form a mixture (39, Column 8, lines 47-65) and in which the phosphor mixture (312) is applied to the optical component to form a layer of phosphor on the optical component surface (Fig. 3).

Regarding claims 15, 39, 73 and 84, Wang discloses incorporating a light diffusing material (311, Column 8, lines 47-65) with the phosphor powder.

Claims 1, 16, 26, 41, 60 and 74 lack novelty under PCT Article 33(2) as being anticipated by Menkara et al. (US 2004/0227465 A1).

Regarding claims 1 and 26, Menkara discloses an optical component for a lighting arrangement of a type comprising a radiation source configured to emit radiation having a first wavelength range; a phosphor configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Figs. 2A-2C, ¶[0044]).

Regarding claims 47 and 60, Menkara discloses a method of fabricating an optical component for a lighting arrangement of a type comprising a radiation source configured to emit radiation having a first wavelength range; a phosphor configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Figs. 2A-2C, ¶[0044]).

Regarding claims 16, 41 and 74, Menkara discloses the phosphor comprising a photoluminescence material having a formula Sr2SiO4:Eu (¶[0057]).

Claims 1, 17, 26, 42, 60 and 75 lack novelty under PCT Article 33(2) as being anticipated by Hohn et al. (US 2004/0016908 A1).

Regarding claims 1 and 26, Hohn discloses an optical component (15) for a lighting arrangement of a type comprising a radiation source (1) configured to emit radiation having a first wavelength range; a phosphor (5) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, and characterized in that said phosphor is provided on a surface of said optical component (Fig. 2).

Regarding claims 47 and 60, Hohn discloses a method of fabricating an optical component (15) for a lighting arrangement of a type comprising a radiation source (1) configured to emit radiation having a first wavelength range; a phosphor (5) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 2).

Regarding claims 17, 42 and 75, Hohn discloses the phosphor comprising a photoluminescence material having a formula Y3Al5O12:Ce (¶[0042]).

Claims 60, 81 and 82 lack novelty under PCT Article 33(2) as being anticipated by Yatsuda et al. (US 2005/0057917 A1).

Regarding claim 60, Yatsuda discloses a method of fabricating an optical component (23) for a lighting arrangement of a type comprising a radiation source (21) configured to emit radiation having a first wavelength range; a phosphor (25) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes through said optical component, the method comprising providing said phosphor on a surface of the optical component (Fig. 15).

Regarding claim 81, Yatsuda discloses a plurality of optical component (52) in the form of an array of optical components having a common planar surface and depositing said phosphor (25) on the planar surface (Fig. 3).

Regarding claim 82, Yatsuda discloses providing the phosphor as a substantially uniform thickness layer on the planar surface of the array of optical components (Fig. 15).

Claims 1,10, 26, 35, 47, 56, 60 and 69 lack an inventive step under PCT Article 33(3) as being obvious over Tanaka et al. (JP 07-094785 A) in view of Srivastava et al. (US 6,555,958).

Regarding claims 1, 10, 26 and 35, Tanaka substantially discloses an optical component (54) for a lighting arrangement of a type comprising a radiation source (50) configured to emit radiation having a first wavelength range; and said optical component being configured such that at least said first wavelength range radiation passes though the optical component, the optical component comprising a substantially spherical shell (540). Tanaka fails to exemplify the limitations of a phosphor configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range and characterized in that said

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phosphor is provided on an outer spherical surface of said optical component. Srivastava discloses an optical component (19) provided with a phosphor (21) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range and characterized in that said phosphor is provided on an outer spherical surface of said optical component so as to modify the light generated by the radiation source to a desired color emission. Thus, it would have been obvious to one skilled in the art to modify Tanaka's teaching to incorporate a phosphor layer as disclosed by Srivastava as to modify the light generated by the radiation source to a desired color emission.

Regarding claims 47, 56, 60 and 69, Tanaka discloses a method of fabricating an optical component (54) for a lighting arrangement of a type comprising a radiation source (50) configured to emit radiation having a first wavelength range; said optical component being configured such that at least said first wavelength range radiation passes through said optical component. Srivastava discloses an optical component (19) provided with a phosphor (21) configured to absorb at least a portion of said first wavelength range radiation and emit radiation having a second wavelength range and characterized in that said phosphor is provided on an outer spherical surface of said optical component so as to modify the light generated by the radiation source to a desired color emission. Thus, it would have been obvious to one skilled in the art to modify Tanaka's teaching to incorporate a phosphor layer as disclosed by Srivastava as to modify the light generated by the radiation source to a desired color emission.

Claims 18, 43 and 76 lack an inventive step under PCT Article 33(3) as being obvious over Negley et al. (US 2005/0051782) in view of Shei et al. (US 2005/0168127 A1).

Regarding claims 18, 43 and 76, Negley fails to exemplify the phosphor comprising an orange-red based phosphor having a formula Sr3SiO5:Eu. Shei discloses a light source provided with a phosphor comprising an orange-red based phosphor having a formula Sr3SiO5:Eu.It is considered within the capabilities of one skilled in the art the selection of a material based on its known suitability for an intended application as an obvious matter of design engineering.

Claims 19, 20, 44, 45, 77 and 78 lack an inventive step under PCT Article 33(3) as being obvious over Negley et al. (US 2005/0051782) in view of Mueller et al. (US 6,717,353).

Regarding claims 19, 44 and 77, Negley fails to exemplify the phosphor comprising a red-silicon nitride based phosphor having a formula SrSi5N8. Mueller discloses a light source provided with a phosphor comprising a red-silicon nitride based phosphor having a formula SrSi5N8. It is considered within the capabilities of one skilled in the art the selection of a material based on its known suitability for an intended application as an obvious matter of design engineering.

Regarding claims 20, 45 and 78, Negley fails to exemplify the phosphor comprising a red sulfate based phosphor having a formula SrCaS. Mueller discloses a light source provided with a phosphor comprising a red sulfate based phosphor having a formula SrCaS. It is considered within the capabilities of one skilled in the art the selection of a material based on its known suitability for an intended application as an obvious matter of design engineering.

Claims 21, 46 and 79 lack an inventive step under PCT Article 33(3) as being obvious over Negley et al. (US 2005/0051782) in view of Ellens et al. (US 2003/0052595 A1).

Regarding claims 21, 46 and 79, Negley fails to exemplify the phosphor comprising a green sulfate based phosphor having a formula SrGa2S4:Eu. Ellens discloses a light source provided with a phosphor comprising a green sulfate based phosphor having a formula SrGa2S4:Eu. It is considered within the capabilities of one skilled in the art the selection of a material based on its known suitability for an intended application as an obvious matter of design engineering.

Claims 1-85 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

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NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article," "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the applicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended ?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Preliminary Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When ? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments ?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How ? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments ?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

Savant Technologies LLC - 1004.228

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

(i) the claim is unchanged;
(ii) the claim is cancelled;
(iii) the claim is new;
(iv) the claim replaces one or more claims as filed;
(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under Article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1*bis*(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43*bis*.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

Savant Technologies LLC - 1004.229

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
PETER C. MEI
VISTA IP LAW GROUP, LLP
1885 LUNDY AVE., STE. 108
SAN JOSE, CA 95131

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 26 JAN 2012
Applicant's or agent's file reference ITMX00307WO0	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 11/54827	International filing date *(day/month/year)* 04 October 2011 (04.10.2011)
Applicant INTEMATIX CORPORATION	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450	Authorized officer Lee W. Young
Facsimile No. 571-273-3201	Telephone No. PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2010)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference ITMX00307WO0	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 11/54827	International filing date *(day/month/year)* 04 October 2011 (04.10.2011)	(Earliest) Priority Date *(day/month/year)* 05 October 2010 (05.10.2010)
Applicant INTEMATIX CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☐ the text is approved as submitted by the applicant.

☒ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/54827

Box No. IV Text of the abstract (Continuation of item 5 of the first sheet)

A solid-state light emitting device comprises a solid-state light emitter (LED) operable to generate excitation light and a wavelength conversion component including a mixture of particles of a photoluminescence material and particles of a light reflective material. The phosphor absorbs at least a portion of the excitation light and emits light of a different color. The emission product of the device comprises the combined light generated by the LED and the phosphor. The wavelength conversion component can be light transmissive and comprise a light transmissive substrate on which the mixture of phosphor and reflective materials is provided as a layer or homogeneously distributed throughout the volume of the substrate. Alternatively the wavelength conversion component can be light reflective with the mixture of phosphor and light reflective materials being provided as a layer on the light reflective surface.

Savant Technologies LLC - 1004.232

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/54827

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G09G 3/34 (2011.01)
USPC - 345/84
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): G09G 3/34 (2011.01)
USPC: 345/84

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8): G09G 3/34 (2011.01)
USPC: 362/84; 345/82, 84, 107

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST; PGPB, USPT, EPAB, JPAB; Google Scholar; Google Patent; Search Terms: LED OLED light emitting diode solid-state phosphor light converting reflect refract scatter particle nano-particle texture diffuse substrate layer coating encapsulate density distribute homogeneous heterogeneous per-cent volume weight sign letter display

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 2009/0272996 A1 (Chakraborty) 05 November 2009 (05.11.2009) para. [0010] through [0105], Fig. 1-7E	1-14 and 16-24 ---------- 15
Y	US 2007/0240346 A1 (Li et al.) 18 October 2007 (18.10.2007) para. [0040] through [0044], Fig. 1	15
A	US 2009/0050911 A1 (Chakraborty) 26 February 2009 (26.02.2009) entire document	1-24
A	US 2009/0026908 A1 (Bechtel et al.) 29 January 2009 (29.01.2009) entire document	1-24
A	US 2008/0308825 A1 (Chakraborty et al.) 18 December 2008 (18.12.2008) entire document	1-24

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 January 2012 (10.01.2012)	26 JAN 2012
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: PETER C. MEI
VISTA IP LAW GROUP, LLP
1885 LUNDY AVE., STE. 108
SAN JOSE, CA 95131

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	26 JAN 2012
Applicant's or agent's file reference: ITMX00307WO0	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 11/54827	04 October 2011 (04.10.2011)	05 October 2010 (05.10.2010)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - G09G 3/34 (2011.01)
USPC - 345/84

Applicant INTEMATIX CORPORATION

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1 *bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Fom PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer:
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	10 January 2012 (10.01.2012)	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (July 2011)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing filed or furnished:

   a. (means)

      ☐ on paper

      ☐ in electronic form

   b. (time)

      ☐ in the international application as filed

      ☐ together with the international application in electronic form

      ☐ subsequently to this Authority for the purposes of search

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Savant Technologies LLC - 1004.235

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	2, 3 and 15	YES
	Claims	1, 4-14 and 16-24	NO
Inventive step (IS)	Claims	none	YES
	Claims	1-24	NO
Industrial applicability (IA)	Claims	1-24	YES
	Claims	none	NO

2. Citations and explanations:

Claims 1, 4-14 and 16-24 lack novelty under PCT Article 33(2) as being anticipated by US 2009/0272996 A1 to Chakraborty.

Regarding claim 1, Chakraborty discloses a light emitting device (LED device 200, para. [0027], Fig. 2) comprising: at least one solid-state light emitter operable to generate excitation light (LED chip 202 is disposed on a mount surface; LED 202 can emit light of different colors and can also emit radiation outside the visible spectrum, such as infrared or ultraviolet, para. [0027]); and a photoluminescence wavelength conversion component (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032], [0055] through [0058], [0082], [0085], [0087], [0092] through [0095]) comprising a mixture of particles of at least one photoluminescence material (phosphor comprises many different compositions and phosphor materials alone or in combination, para. [0028] through [0041]) and particles of a light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]).

Regarding claim 4, Chakraborty discloses the light emitting device of claim 1, wherein the light reflective material has a particle size in a range selected from the group consisting of: 0.01u to 10un; 0.01un to 1un and 0.1um to 1um (nanoparticles and light scattering particles proximate to the light source. Nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]).

Regarding claim 5, Chakraborty discloses the light emitting device of claim 1, wherein a weight percent loading of light reflective material (light scattering particles (LSPs) 210) to the at least one photoluminescence material (phosphor) is in a range selected from the group consisting of: .01% to 10%; 0.01% to 1%; 0.1% to 1% and 0.5% to 1% (e.g.: if the conversion layer material has a RI of 1.5 and the target effective RI is 1.7, then the conversion layer 204 should comprise approximately 20% TiO.sub.2 nanoparticles by volume; other material combinations and compositions may also be used; e.g.: some embodiments may have greater than 5% nanoparticles by volume; other embodiments may have greater than 10% nanoparticles by volume; other embodiments may include 20-40% by volume nanoparticle loading; various percentages of composition of the LSPs 210 can be used as dictated by the application; depending on the materials used, the LSPs 210 will typically be found in concentrations ranging from 0.01% to 5% by volume; other concentrations can be used; however, the loss due to absorption increases with the concentration of the scattering particles; concentrations of the LSPs should be chosen in order to maintain an acceptable loss figure, para. [0057], [0083]).

See Continuation Sheet.

Savant Technologies LLC - 1004.236

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:
Box V, item 2. Citations and explanations.

Regarding claim 6, Chakraborty discloses the light emitting device of claim 1, wherein the light reflective material (light scattering particles (LSPs) 210, para. [0060]) is selected from the group consisting of: titanium dioxide (para. [0060], [0065]), barium sulfate (para. [0060], [0066]) and combinations thereof (para. [0060], [0079]).

Regarding claim 7, Chakraborty discloses the light emitting device of claim 1, wherein the wavelength conversion component (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032], [0055] through [0058], [0082], [0085], [0087], [0092] through [0095]) is selected from the group consisting of:
a light transmissive substrate on which the mixture of photoluminescence material and light reflective material is provided as at least one layer (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082] and [0086]);
a light transmissive substrate configured as a light guide and wherein the mixture of photoluminescence material and light reflective material is provided on at least a part of a face of the light guide (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082] and [0086]); and
a light reflective surface on which the mixture of the photoluminescence material and light reflective material are provided as at least one layer (textured light emission surface 214, the LED chip 202 has a reflective element 216 such as a layer of reflective material; reflective element 216 redirects some of the light generated in the LED chip 202 back towards the textured light emission surface 214; reflective element 214 may comprise a thick silver mirror, para. [0086]).

Regarding claim 8, Chakraborty discloses the light emitting device of claim 1, wherein the at least one solid-state light emitter comprises an LED that is operable to generate blue excitation light having a peak wavelength in a wavelength range 440nm to 480nm (wavelength of light emitted from the LED chip 202 e.g., about.450 nm for a blue emitter, para. [0056]).

Regarding claim 9, Chakraborty discloses the light emitting device of claim 1, wherein the mixture of the photoluminescence material and the light reflective material is distributed over an area of at least 0.8cm^2 (LED devices can be formed from a single wafer; e.g.: when fabricating LED devices having a 1 millimeter (mm) square size, up to 4500 LED devices can be fabricated on a 3 inch wafer, para. [0096], [0098]).

Regarding claim 10, Chakraborty discloses the light emitting device of claim 1, wherein the particles of the light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]) corresponds to a particle size (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]) such that the particles scatter excitation light relatively more than light generated by the at least one phosphor material (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082]).

Regarding claim 11, Chakraborty discloses the light emitting device of claim 1, further comprising a light diffusing layer that is adjacent to the photoluminescence wavelength conversion component (LED chip 202 has a textured light emission surface 214 included to increase light extraction from the LED chip 202 by reducing total internal reflection (TIR), para. [0008], [0009], [0011], [0013], [0086] through [0090], [0099]).

See Continuation Sheet.

Savant Technologies LLC - 1004.237

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:
Box V, item 2. Citations and explanations.

Regarding claim 12, Chakraborty discloses the light emitting device of claim 11, in which the light diffusing layer (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032], [0055] through [0058], [0082], [0085], [0087], [0092] through [0095]) comprises particles of light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]) corresponding to a particle size (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]) such that the particles scatter excitation light relatively more than light generated by the at least one photoluminescence material (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082]).

Regarding claim 13, Chakraborty discloses the light emitting device of claim 12, wherein the light reflective material has a particle size in a range 100nm to 150nm (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]).

Regarding claim 14, Chakraborty discloses the light emitting device of claim 1, in which the at least one photoluminescence material comprises phosphor (phosphor comprises many different compositions and phosphor materials alone or in combination, para. [0028] through [0041], [0060] through [0079]).

Regarding claim 16, Chakraborty discloses a wavelength conversion component (conversion layer 204 phosphor particles are dispersed throughout a binder material 206 such as silicone; refractive index (RI) of the phosphor particles and the RI of the binder 206 can be the same, or they can be different, para. [0041] through [0058]) for a solid-state light emitting device (LED device 200; LED chip 202 is disposed on a mount surface; LED 202 can emit light of different colors and can also emit radiation outside the visible spectrum, such as infrared or ultraviolet, para. [0027], Fig. 2) comprising a mixture of particles of at least one photoluminescence material (phosphor comprises many different compositions and phosphor materials alone or in combination, para. [0028] through [0041]) and particles of a light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]).

Regarding claim 17, Chakraborty discloses the wavelength conversion component of claim 16, wherein the light reflective material has a particle size in a range selected from the group consisting of: 0.01um to 10un; 0.01un to 1um and 0.1 to 1um (nanoparticles and light scattering particles proximate to the light source. Nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]).

Regarding claim 18, Chakraborty discloses the wavelength conversion component of claim 16, wherein a weight percent loading of light reflective material (light scattering particles (LSPs) 210) to the at least one photoluminescence material (phosphor) is in a range selected from the group consisting of: 0.01% to 10%; 0.01% to 1%; 0.1% to 1% and 0.5% to 1% (e.g.: if the conversion layer material has a RI of 1.5 and the target effective RI is 1.7, then the conversion layer 204 should comprise approximately 20% TiO.sub.2 nanoparticles by volume; other material combinations and compositions may also be used; e.g.: some embodiments may have greater than 5% nanoparticles by volume; other embodiments may have greater than 10% nanoparticles by volume; other embodiments may include 20-40% by volume nanoparticle loading; various percentages of composition of the LSPs 210 can be used as dictated by the application; depending on the materials used, the LSPs 210 will typically be found in concentrations ranging from 0.01% to 5% by volume; other concentrations can be used; however, the loss due to absorption increases with the concentration of the scattering particles; concentrations of the LSPs should be chosen in order to maintain an acceptable loss figure, para. [0057], [0083]).

See Continuation Sheet.

Savant Technologies LLC - 1004.238

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:
Box V, item 2. Citations and explanations.

Regarding claim 19, Chakraborty discloses the wavelength conversion component of claim 16, wherein the wavelength conversion component (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032], [0055] through [0058], [0082], [0085], [0087], [0092] through [0095]) is selected from the group consisting of:
a light transmissive substrate on which the mixture of the at least one photoluminescence material and light reflective material are provided as at least one layer (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082] and [0086]);
a light transmissive substrate configured as a light guide and wherein the mixture of photoluminescence material and light reflective material is provided on at least a part of a face of the light guide (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082] and [0086]); and
a light reflective surface on which the mixture of the photoluminescence material and light reflective material are provided as at least one layer (textured light emission surface 214, the LED chip 202 has a reflective element 216 such as a layer of reflective material; reflective element 216 redirects some of the light generated in the LED chip 202 back towards the textured light emission surface 214; reflective element 214 may comprise a thick silver mirror, para. [0086]).

Regarding claim 20, Chakraborty discloses the wavelength conversion component of claim 16, wherein the mixture of the at least one photoluminescence material and the light reflective material are distributed over an area of at least 0.8cm^2 (LED devices can be formed from a single wafer; e.g.: when fabricating LED devices having a 1 millimeter (mm) square size, up to 4500 LED devices can be fabricated on a 3 inch wafer, para. [0096], [0098]).

Regarding claim 21, Chakraborty discloses the wavelength conversion component of claim 16, wherein the particles of the light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]) corresponds to a particle size (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]) such that the particles scatter excitation light relatively more than light generated by the at least one phosphor material (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082]).

Regarding claim 22, Chakraborty discloses the wavelength conversion component of claim 21, wherein the light reflective material has a particle size in a range 100nm to 150nm (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]).

Regarding claim 23, Chakraborty discloses the wavelength conversion component of claim 16, further comprising a light diffusing layer that is adjacent to the photoluminescence wavelength conversion component (LED chip 202 has a textured light emission surface 214 included to increase light extraction from the LED chip 202 by reducing total internal reflection (TIR), para. [0008], [0009], [0011], [0013], [0086] through [0090], [0099]).

See Continuation Sheet.

Savant Technologies LLC - 1004.239

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 11/54827

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:
Box V, item 2. Citations and explanations.

Regarding claim 24, Chakraborty discloses the wavelength conversion component of claim 23, in which the light reflective layer (conversion layer 204) comprises particles of light reflective material (light scattering particles; light extraction efficiency and the color temperature distribution uniformity are improved by the introduction of both nanoparticles and light scattering particles proximate to the light source; light scattering particles (LSPs) 210 are disposed proximate to the LED chip 202; strikes one or more of the scattering particles 210 the index of refraction differential between the medium and the particles 210 causes the light to refract and travel in a different direction, para. [0021], [0058] through [0084]) corresponding to a particle size (nanoparticles and light scattering particles proximate to the light source; nanoparticles having a high index of refraction are dispersed throughout a wavelength conversion layer to adjust the index of refraction of the layer for improved light extraction, para. [0021], [0056], [0057], [0089], [0093], [0095], [0103]) such that the particles scatter excitation light relatively more than light generated by the at least one phosphor material (LSPs 210 can be dispersed throughout various elements so long as they are proximate to the LED chip 202 such that substantially all of the emitted light has a probability of interacting with the LSPs 210; e.g. LSPs 210 are disposed throughout the binder material 206 along with the nanoparticles 208 and the phosphor; conversion layer 204 is disposed on the LED chip 202, substantially all of the emitted light travels through the conversion layer where the LSPs 210 are dispersed before being emitted from the device 200, para. [0082]).

Claims 2 and 3 lack an inventive step under PCT Article 33(3) as being obvious over Chakraborty.

Regarding claim 2, Chakraborty discloses the light emitting device of claim 1, wherein an area over which the mixture of photoluminescence material and light reflective material is distributed (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032]) is larger than the light emitting area of the light emitter (LED chip 202 is disposed on a mount surface; LED 202 can emit light of different colors and can also emit radiation outside the visible spectrum, such as infrared or ultraviolet, para. [0027], illustrated, Fig. 2, 5), yet fails to disclose wherein an area over which the mixture of photoluminescence material and light reflective material is distributed is at least fifty times the light emitting area of the light emitter. However, since the manufacturing methods used by Chakraborty include physical/chemical deposition techniques, electroplating, electrophoretic deposition, spin coating, spray coating, screen printing, and dispensing (para. [0101] through [0103]), it would have been obvious to one of skill in the art to size the area of distribution of the mixture of photoluminescence material and light reflective material to be least fifty times the light emitting area of the light emitter, since such a modification would have been a matter of routine experimentation. (Chakraborty: para. [0101] through [0103]).

Regarding claim 3, Chakraborty discloses the light emitting device of claim 1, wherein the wavelength conversion component (conversion process takes place in the conversion layer 204 which may be loaded with phosphors; wavelength conversion layer 204 converts a portion of the emitted light to a different wavelength; Yttrium aluminum garnet (YAG) is an example of a common phosphor that may be used, para. [0028] through [0032]) is locatable at a distance of at least 5mm from (conversion layer 708 has a thickness such that it may cover/bury the pedestal 706, para. [0103], [0104], [0105]) the at least one light emitter (LED chip 202 is disposed on a mount surface; LED 202 can emit light of different colors and can also emit radiation outside the visible spectrum, such as infrared or ultraviolet, para. [0027]), yet fails to disclose a distance of at least 5mm. However, it would have been obvious to one of skill in the art to size the distance between the wavelength conversion component and the light emitter to at least 5 mm, since such a modification would have been a matter of routine experimentation.

Claim 15 lacks an inventive step under PCT Article 33(3) as being obvious over Chakraborty in view of US 2007/0240346 A1 to Li et al. (hereinafter Li).

Regarding claim 15, Chakraborty discloses the light emitting device of claim 1, yet fails to disclose wherein the device is configured as a light emitting sign. Li discloses wherein a device configured as a light emitting sign (number of light emitting diodes (LEDs) 4 are provided within the light box 2 and are preferably blue LEDs which emit blue light in a wavelength range 410 to 470 nm; layer of phosphor material 6, photo luminescent material, is provided on an under surface, that is the surface facing the LEDs, excitable by the radiation emitted by the LEDs 4; para. [0040] through [0044], Fig. 1). Since both references are directed toward LED lighting, it would have been obvious to one of skill in the art to configure the device of Chakraborty into a light emitting sign as suggested by Li, since such a modification would result in an light emitting sign with greater color saturation. (Li: para. [0044]).

Claims 1-24 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

Savant Technologies LLC - 1004.240

SEARCH HISTORY

Application Number	PCT/US 11/54827
Search Conducted By	MEG
Search Approved By	HHB

US/IPC Classifications Searched	IPC(8): G09G 3/34 (2011.01) USPC: 345/84
Date Conducted	10 January 2012

Documentation Searched	IPC(8): G09G 3/34 (2011.01) USPC: 362/84; 345/82, 84, 107 (keyword limited; terms below)
Search Terms Used	LED OLED light emitting diode solid-state phosphor light converting reflect refract scatter particle nano-particle texture diffuse substrate layer coating encapsulate density distribute homogeneous heterogeneous per-cent volume weight sign letter display
Date Conducted	10 January 2012

Electronic Database Searched	PubWEST
Files Searched	PGPB, USPT, EPAB, JPAB
Date Conducted	10 January 2012
Search Logic:	

DB=PGPB,USPT,USOC,EPAB,JPAB; PLUR=YES; OP=OR
DATE: Tuesday, January 10, 2012

L31	L30 and (sign lettering display)	26
L30	L29 and (LED)	47
L29	L28 and (phosphor)	107
L28	L27 and (scattering adj particle)	107
L27	L25 and ((reflective refractive scattering) adj particle)	113
L26	L25 and ((reflective refractive) adj particle)	8
L25	L24 and (layer encapsulant)	113
L24	L23 and (density percent per-cent volume weight)	113
L23	L22 and (light adj (reflective refractive scattering) adj (particle nano-particle nanoparticle))	127
L22	L21 and (reflective scattered)	284

L21	L20 and ((phosphor conversion) adj (layer region coat$4 material))	322
L20	L19 and (density distribut$4 homogeneous$4 heterogeneous$4)	359
L19	L18 and (substrate layer coating encapsulant)	428
L18	L17 and ((scattering reflective refractive) adj (particle nano-particle nanoparticle))	433
L17	L15 and ((phosphor) adj (particle nano-particle nanoparticle))	2246
L16	L15 and ((phosphor scattering reflective refractive) adj (particle nano-particle nanoparticle))	2787
L15	(LED "light emitting" solid-state OLED) and (phosphor (light adj converting)) and (reflective refractive scattering) and (particle nano-particle nanoparticle)	8717
L14	L13 and (reflecting reflective)	29
L13	L12 and (texture diffuse$4)	29
L12	L11 and (light adj (reflecti$4 refract$4 scatter$4))	41
L11	L10 and ((light reflective refractive scattering) adj (particle nano-particle nanoparticle))	54
L10	L9 and (phosphor (light adj converting))	864
L9	L8 and (LED "light emitting" solid-state OLED)	4886
L8	L7 L6 L5 L4 L3	10520
L7	345/107.ccls.	1621
L6	345/84.ccls.	1256
L5	345/82.ccls.	2291
L4	362/84.ccls.	2054
L3	L2 L1	5582
L2	345/84.ccls.	1256
L1	G09G3/34.ipc.	4724

Electronic Database Searched	Google
Files Searched	Google Patents
Date Conducted	10 January 2012
Search Logic:	
About 505 results (0.28 seconds) LED diode (phosphor OR photoluminescent OR photoluminescence) (reflective OR specular) particle (wavelength OR conversion)	

Electronic Database Searched	Google
Files Searched	Google Scholar
Date Conducted	10 January 2012
Search Logic:	
Results 1 - 10 of about 1,210. (0.28 sec) LED phosphor reflective particle Results 1 - 10 of about 1,400. (0.15 sec) LED diode (phosphor OR photoluminescent OR	

photoluminescence) (reflective OR specular) particle (wavelength OR conversion)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

ROBINSON ROSS T.

WINSTEAD PC P.O. BOX 131851 DALLAS TX 75313 USA

RECEIVED ON

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 51026-P222WO BY WINSTEAD	Date of mailing *(day/month/year)* 28 March 2013 (28.03.2013) **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2012/059892**	International filing date *(day/month/year)* **12 October 2012 (12.10.2012)**
Applicant **INTEMATIX CORPORATION**	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 . 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	Authorized officer COMMISSIONER
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-8754

DOCKETED ON APR 3 2013

By:

Form PCT/ISA/220 (July 2010)

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for three months from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT Services => PCT Services

ID : PCT international application number
PW : **X53X36RK**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com
Email: ipkc@ipkcenter.com
Phone: +1 703 388 1066
Fax: +1 703 388 1084

Notes to Form PCT/ISA/220 (July 2010)

Savant Technologies LLC - 1004.245

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
51026-P222WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2012/059892	**12 OCTOBER 2012 (12.10.2012)**	13 OCTOBER 2011 (13.10.2011)

Applicant

INTEMATIX CORPORATION

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of **4** sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☒ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. **1**
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

DOCKETED ON
APR 09 2013
By:

Form PCT/ISA/210 (first sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/059892

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 7,9,11,14
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 7,9,11,14 are too broad to make a meaningful search because they are dependent claims of multiple dependent claims which also refer to other multiple dependent claims.

3. ☒ Claims Nos.: 4-6,8,10,12,13,15-17,21-23
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
☐ No protest accompanied the payment of additional search fees.

Savant Technologies LLC - 1004.247

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/059892

A. CLASSIFICATION OF SUBJECT MATTER

H01L 33/50(2010.01)i, H01L 33/48(2010.01)i, F21S 2/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 33/50; H01J 1/62; H01J 63/04; H01L 33/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: photoluminescence, scatter, particle size

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0147778 A1 (MASATSUGU ICHIKAWA) 23 June 2011 See abstract, paragraphs [0014]-[0016],[0033]-[0044], and figrues 1,3.	1-3,18-20
A	US 2002-0180351 A1 (THOMAS FRANCIS MCNULTY et al.) 05 December 2002 See paragraphs [0022]-[0024] and figure 1.	1-3,18-20
A	KR 10-2007-0065486 A (SAMSUNG ELECTRO-MECHANICS CO., LTD.) 25 June 2007 See page 5, line 13 - page 6, line 7 and figures 10-12.	1-3,18-20
A	WO 2008-043519 A1 (LEXEDIS LIGHTING GMBH et al.) 17 April 2008 See abstract, page 9, line 9 - page 10, line 28, and figure 2.	1-3,18-20
A	KR 10-2009-0017346 A (SEOUL SEMICONDUCTOR CO., LTD.) 29 February 2009 See paragraphs [0020],[0021] and figure 2.	1-3,18-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 March 2013 (27.03.2013)	**28 March 2013 (28.03.2013)**

Name and mailing address of the ISA/KR
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. 82-42-472-7140

Authorized officer
PARK, Hye Lyun
Telephone No. 82-42-481-3463

Form PCT/ISA/210 (second sheet) (July 2009)

Savant Technologies LLC - 1004.248

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/059892

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011-0147778 A1	23.06.2011	JP 2011-129661 A	30.06.2011
US 2002-0180351 A1	05.12.2002	EP 1390966 A1	25.02.2004
		EP 1390966 A4	19.03.2008
		JP 2004-528714 A	16.09.2004
		JP 2004-528714 T	16.09.2004
		KR 10-2004-0012776 A	11.02.2004
		US 6686676 B2	03.02.2004
		WO 02-089175 A1	07.11.2002
KR 10-2007-0065486 A	25.06.2007	None	
WO 2008-043519 A1	17.04.2008	EP 2074668 A1	01.07.2009
KR 10-2009-0017346 A	18.02.2009	None	

Savant Technologies LLC - 1004.249

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
ROBINSON ROSS T.

WINSTEAD PC P.O. BOX 131851 DALLAS TX 75313 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	**28 March 2013 (28.03.2013)**
Applicant's or agent's file reference 51026-P222WO	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2012/059892	**12 OCTOBER 2012 (12.10.2012)**	13 OCTOBER 2011 (13.10.2011)

International Patent Classification (IPC) or both national classification and IPC

H01L 33/50(2010.01)i, H01L 33/48(2010.01)i, F21S 2/00(2006.01)i

Applicant

INTEMATIX CORPORATION

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☒ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

DOCKETED ON
APR 09 2013
By:

Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140	27 March 2013 (27.03.2013)	PARK, Hye Lyun Telephone No.82-42-481-3463

Form PCT/ISA/237 (cover sheet) (July 2011)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/059892

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

   a. a sequence listing filed or furnished
      ☐ on paper
      ☐ in electronic form

   b. time of filing or furnishing
      ☐ contained in the international application as filed.
      ☐ filed together with the international application in electronic form.
      ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additioanl copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Savant Technologies LLC - 1004.251

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/059892

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application

☒ claims Nos. 4-17,21-23

because:

☐ the said international application, or the said claims Nos. _____ relate to the following subject matter which does not require an international search *(specify)*:

☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. 7,9,11,14 are so unclear that no meaningful opinion could be formed *(specify)*:

Claims 7,9,11,14 are too broad to make a meaningful search because they are dependent claims on multiple dependent claims which also refer to other multiple dependent claims.

☐ the claims, or said claims Nos. _____ are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for said claims Nos. 4-17,21-23

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Istructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.

☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Istructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.

☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13ter.1(a) or (b).

☐ See Supplemental Box for further details.

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/059892

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-3,18-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-3,18-20	NO
Industrial applicability (IA)	Claims	1-3,18-20	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following document:

D1: US 2011-0147778 A1 (MASATSUGU ICHIKAWA) 23 June 2011

1. Novelty and Inventive Step

1.1 Claims 1-3

1.1.1 Independent claim 1

D1, which is considered to be the closest prior art to the subject matter of independent claim 1, discloses a scattering layer and a fluorescent material layer comprising: fluorescent material particles (14) (see paragraph [0033], figure 1 in D1); and particles (20) scattering light (see paragraph [0040], figure 1 in D1). D1 does not explicitly disclose the feature of claim 1 that a light scattering material has an average particle size, such that the light scattering material will scatter excitation light from a radiation source relatively more than the light scattering material generated by the at least one photoluminescence material. However, this feature is virtually suggested by the same document, considering the particles having a mean particle size D that satisfies: $20nm<D\leq 0.4\times\lambda/\pi$ (λ is the wavelength of the primary light propagating in the transparent medium), the particles scattering the primary light of the semiconductor light emitting element significantly more strongly than the secondary light of longer wavelength of the fluorescent material layer (see paragraphs [0014]-[0016],[0039]-[0044], figures 1,3 in D1). Accordingly, claim 1 would have been obvious over D1. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

1.1.2 Dependent claims 2, 3

Claim 2 further specifies that the light scattering material scatters the excitation light at least twice as much as light generated by the at least one photoluminescence material. However, the additional feature of claim 2 is virtually suggested by the feature of D1 considering that the primary light is scattered twice more strongly than the secondary light (see paragraph [0016] in D1). Accordingly, claim 2 would have been obvious over D1. Therefore, claim 2 lacks an inventive step under PCT Article 33(3).

(Continued on Supplemental Box)

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/059892

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 4-6,8,10,12,13,15-17,21-23 do not comply with PCT Rule 6.4(a) because multiple dependent claims should not serve as a basis for any other multiple dependent claim.

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Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Box No. V

The additional feature of claim 3 is identical to the feature of D1 in that the semiconductor light emitting element (2) is constituted by forming a semiconductor layer (6) and has a light emitting layer capable of emitting blue light (see paragraph [0033], figure 1 in D1). Accordingly, claim 3 would have been obvious over D1. Therefore, claim 3 lacks an inventive step under PCT Article 33(3).

1.2 Claims 18-20

1.2.1 Independent claim 18
D1, which is considered to be the closest prior art to the subject matter of independent claim 18, discloses a light emitting device comprising: a semiconductor light emitting element (2) (see paragraph [0033], figure 1 in D1); fluorescent material particles (14) (see paragraph [0033], figure 1 in D1); and particles (20) scattering light (see paragraph [0040], figure 1 in D1). Although D1 does not explicitly disclose that a light scattering material has an average particle size such that the light scattering material will scatter excitation light from a radiation source relatively more than the light scattering material will scatter light generated by the at least one photoluminescence material, this feature is virtually suggested by the same document considering the particles having a mean particle size D that satisfies: $20nm<D\leq 0.4\times\lambda/\pi$ (λ is the wavelength of the primary light propagating in the transparent medium), the particles scattering the primary light of the semiconductor light emitting element significantly more strongly than the secondary light of longer wavelength of the fluorescent material layer (see paragraphs [0014]-[0016],[0039]-[0044], figures 1,3 in D1). Accordingly, claim 18 would have been obvious over D1. Therefore, claim 18 lacks an inventive step under PCT Article 33(3).

1.2.2 Dependent claims 19, 20
Claim 19 further specifies that the average particle size of the light scattering material is selected to improve an OFF state white appearance of the light emitting device. However, the additional feature of claim 19 is virtually suggested by the feature of D1 considering that the particles having a mean particle size D that satisfies: $20nm<D\leq 0.4\times\lambda/\pi$ (λ is the wavelength of the primary light propagating in the transparent medium), the particles scattering the primary light of the semiconductor light emitting element significantly more strongly than the secondary light of longer wavelength of the fluorescent material layer (see paragraphs [0014]-[0016],[0039]-[0044], figures 1,3 in D1).

(Continued on Supplemental Box)

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Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Box No. V

Claim 20 further specifies that the average particle size of the light scattering material is selected to obtain substantially uniform color for emitted light from the light emitting device for emission angles over a ±60° from an emission axis. However, the additional feature of claim 20 is virtually suggested by the feature of D1 considering that the effect of improving the color unevenness becomes more remarkable when the angle of light emission of the light emitting device (1) around the semiconductor light emitting element (2) increases, and the light emission angle θ of the light emitting device is 180 degrees. Accordingly, claim 20 would have been obvious over D1. Therefore, claim 20 lacks an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-3, 18-20 are industrially applicable under PCT Article 33(4).

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DERWENT-ACC-NO: **2006-306696**

DERWENT-WEEK: 200633

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TITLE: Stereometric super light emitting diode for e.g. military industry, has PN semiconductor passages on surface and/or depth of micro-spherical support for executing physical electroluminescent injection process to provide light radiation

INVENTOR: PRODANOV D

PATENT-ASSIGNEE: PRODANOV D[PRODI]

PRIORITY-DATA: 2004CA-2466979 (May 18, 2004)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE
CA 2466979 A1	November 18, 2005	FR

APPLICATION-DATA:

PUB-NO	APPL-DESCRIPTOR	APPL-NO	APPL-DATE
CA 2466979A1	N/A	2004CA-2466979	May 18, 2004

INT-CL-CURRENT:

TYPE	IPC	DATE
CIPS	H01L33/00	20060101

ABSTRACTED-PUB-NO: CA 2466979 A1

BASIC-ABSTRACT:

NOVELTY - The diode has a micro-spherical support (6) for PN semiconductor passages. The passages are disposed on surface and/or depth of the support for executing physical electroluminescent injection process to provide light radiation in surrounding space. Conductors (9) are connected towards the passages for ensuring power supply. Connectors (10) are provided for connecting an anode and a cathode with the conductors.

USE - Used in military, aero spatial, aeronautical and automobile industries for ground signals, speed limitation, street light and discharge lighting, and in tunnel, subway, home, entertainment field such as video lottery and casino, computerized panels for hockey and soccer, in cinema, theatre, disney lands, christmas decorations, and in medicine, tourism, trade, warning and leisure activity applications.

ADVANTAGE - The light emitting diode allows the propagation of luminescence in 99 percentage of the surrounding space, while having long life with functioning time of more than 100000 hours. The diode provides large lighting power in small space, and is economic

DESCRIPTION OF DRAWING(S) - The drawing shows a super light emitting diode.

Micro-spherical support (6)

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Grid (7)

Spherical lens (8)

Conductors (9)

Connectors '(Drawing contains non-English language text)' (10)

CHOSEN-DRAWING: Dwg.3/4

TITLE-TERMS: SUPER LIGHT EMIT DIODE MILITARY INDUSTRIAL PN SEMICONDUCTOR PASSAGE SURFACE DEPTH MICRO SPHERE SUPPORT EXECUTE PHYSICAL ELECTROLUMINESCENT INJECTION PROCESS RADIATE

DERWENT-CLASS: U12

EPI-CODES: U12-A01A; U12-A01A4;

SECONDARY-ACC-NO:
Non-CPI Secondary Accession Numbers: 2006-260302

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(19) Canadian Intellectual Property Office
An Agency of Industry Canada

Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

(11) **CA 2 466 979** (13) **A1**

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(12)

(21) **2 466 979**

(51) Int. Cl. 7: **H01L 33/00**

(22) **18.05.2004**

(71) **PRODANOV, DIMITAR,**
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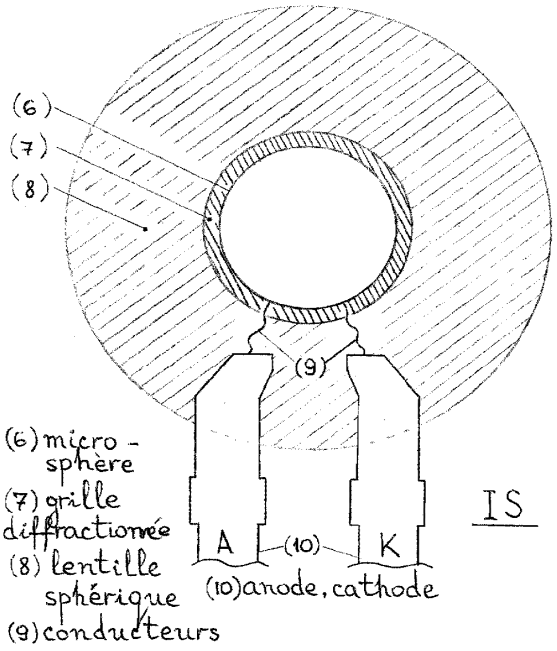
(72) **PRODANOV, DIMITAR (CA).**

(54) SLED STEREOMETRIQUE BULED

(54) STEREOMETRIC SUPERLUMINESCENT LIGHT EMITTING DIODES (SLEDS)

(57)

Dans le domaine d'électronique se develope éxtrement vite la partie appelée optoélectronique. Dans leurs éléments de base l'important partie occupe très bien connue déjà SLED(Super Light Emitted Diodes)(p. I). Il s'agit des éléments semi-conducteurs avec PN passage de InGaN (Indium Gallium Nitrite diodes) mis dans le corps hermétique. Si on applique courant dans la sens"droit" il donne l'émission des ondes quantiques qui l'oeil de l'homme accepte comme lumière par exemple blanche. Dans la présente invention il s'agit d'amélioration du fonctionnement de SLED. Les SLED's connues jusqu'à maintenant ont une grande imperfection. C'est leur diagramme de la diffusion (p. II) de la lumière. Elle occupe une partie petite dans l'espace autour. La lumière se diffuse dans un petit angle stéréométrique surtout de front, devons SLED(max.45.degree.).Si on change l'angle de vue par rapport de la direction frontale, l'intensité de la lumière diminue et presque disparu si on regard de coté. Dans cette nouvelle construction, cette imperfection est complètement éliminée. Cette nouvelle génération SLED propose la diffusion de la lumière avec la force égale dans 99% de l'espace autour. Le diagramme (p. IV) de la diffusion reçois la forme d'une sphère. Cette petite étoile super brillante reçoit un diagramme complet et parfait.



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Canadian Intellectual Property Office
An agency of Industry Canada

CA 2466979 A1 2005/11/18

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CANADIAN PATENT APPLICATION

(13) A1

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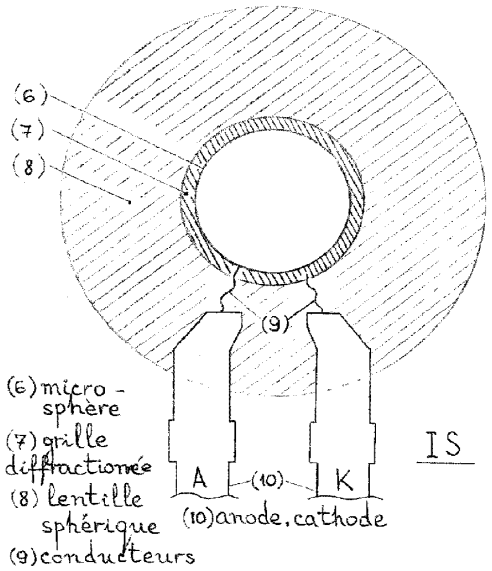
(51) Cl.Int.^{7}/Int.Cl.^{7} H01L 33/00

(71) Demandeur/Applicant:
PRODANOV, DIMITAR, CA

(72) Inventeur/Inventor:
PRODANOV, DIMITAR, CA

(54) Titre : SLED STEREOMETRIQUE BULED

(54) Title: STEREOMETRIC SUPERLUMINESCENT LIGHT EMITTING DIODES (SLEDS)



(57) Abrégé/Abstract:
Dans le domaine d'électronique se develope éxtrement vite la partie appelée optoélectronique. Dans leurs éléments de base l'important partie occupe très bien connue déjà SLED(Super Light Emitted Diodes)(p. I). Il s'agit des éléments semi-conducteurs avec PN passage de InGaN (Indium Gallium Nitrite diodes) mis dans le corps hermétique. Si on applique courant dans la sens"droit" il donne l'émission des ondes quantiques qui l'oeil de l'homme accepte comme lumière par exemple blanche. Dans la présente invention il s'agit d'amélioration du fonctionnement de SLED. Les SLED's connues jusqu'à maintenant ont une grande imperfection. C'est leur diagramme de la diffusion (p. II) de la lumière. Elle occupe une partie petite dans l'espace autour. La lumière se diffuse dans un petit angle stéréométrique surtout de front, devons SLED(max.45°).Si on change l'angle de vue par rapport de la direction frontale, l'intensité de la lumière diminue et presque disparu si on regard de coté. Dans cette nouvelle construction, cette imperfection est complètement éliminée. Cette nouvelle génération SLED propose la diffusion de la lumière avec la force égale dans 99% de l'espace autour. Le diagramme (p. IV) de la diffusion reçois la forme d'une sphère. Cette petite étoile super brillante reçoit un diagramme complet et parfait.

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ABREGE

Dans le domaine d'électronique se develope éxtrement vite la partie appelée optoélectronique. Dans leurs éléments de base l'important partie occupe très bien connue dé jà SLED(Super Light Emitted Diodes)(p. I). Il s'agit des éléments semi-conducteurs avec PN passage de InGaN (Indium Gallium Nitrite diodes) mis dans le corps hermétique. Si on applique courant dans la sens''droit'' il donne l'émission des ondes quantiques qui l'œil de l'homme accepte comme lumière par exemple blanche.

Dans la présente invention il s'agit d'amélioration du fonctionnement de SLED. Les SLED's connues jusqu'à maintenant ont une grande imperfection. C'est leur diagramme de la diffusion (p. II) de la lumière. Elle occupe une partie petite dans l'espace autour. La lumière se diffuse dans un petit angle stéréométrique surtout de front, devons SLED(max.45°).Si on change l'angle de vue par rapport de la direction frontale, l'intensité de la lumière diminue et presque disparu si on regard de coté.

Dans cette nouvelle construction, cette imperfection est complètement éliminée. Cette nouvelle génération SLED propose la diffusion de la lumière avec la force égale dans 99% de l'espace autour. Le diagramme (p. IV) de la diffusion reçois la forme d'une sphère. Cette petite étoile super brillante reçoit un diagramme complet et parfait.

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MÉMOIRE DESCRIPTIF

La présente invention ce rapport a totalité des éléments électroniques bien connues SLED (Super Lights Emitted Diodes)(p. II).
Jusqu'à maintenant l'industrie fabrique SLED's avec des différentes couleurs, différente
intensité de l'émission, etc. . Leur diapason des températures durant utilisation est actuellement entre –40 °C et +85° C. Les SLED's se caractérisent premièrement avec leur diagramme de la diffusion(p. II) – la distribution de la lumière dans l'espace autour.
Elle dépend des quelques facteurs, les plus importantes sont: la construction mécanique du corps, présence ou absence de lentille optique, propriétés optiques du matériel du corps ou de la lentille, etc.
Présentement toutes les SLED's produits ont un DEFAULT ESSENSIELLE : l'angle du vue ne se trouve que dans les 45° degré du volume entourant. Cette particularité limite beaucoup leur fonctionnalité vers l'espace entourant. Alors restant environs 315 degrés l'espace NE SONT PAS couverts par la luminescence(p. II).

Autrement dit c'est la plus grande majorité de l'espace qui n'est pas couverte!

Pour des cas nombreux de la pratique c'est inacceptable, parce qu'on n'est peut pas recevoir la luminescence electro-magnetique dans 99% de l'espace entourant.

Avec cette NOUVELLE GENERATION SLED's ce problème est éliminé. On reçoit la luminescence (p. IV) dans tout l'espace autour. Voilà comment on fait ça:

Comme l'élément de base de la nouvelle construction arrive une support micro sphérique (6,p.III). Elle a pour fonction de supporter le passage(s) P/N. Le passage(s) P/N peut se trouver soit sur la surface et/ou dans la profondeur
de la micro sphère, sans être limité de la façon de la disposition. De cette façon on reçoit la diffusion de la luminescence selon toutes les directions possibles de l'espace autour.
Le vecteur de la luminescence se dirige dans la direction de chaque radius sphérique imaginaire possible(p. IV).Il faut examiner la possibilité d'une micro-sphère faite d'un des matériaux semi-conducteurs. Il a une possibilité de disposer une couche(7) entre la micro sphère (6) et la lentille sphérique (8,p.III), qui peut change certains caractéristiques de la luminescence, par exemple le couleur.

Bien sûr on peut examiner la disposition du passage(s) P/N des façons les plus différentes par rapport du centre et des radius de la sphère, sans être limité.

Cette nouvelle fonction surmonte les difficultés qu'on a avec le diagramme étroit au SLED's conventionnels(p. II).

On attache des conducteurs micro(9,p.III) vers les partis P et N de
façon appropriée pour l'alimentation avec du courant électrique, comme ça se fait habituellement chez SLED conventionnel. Ils se connectent avec les connecteurs (10) pour l'anode et la cathode.
Sur les dessins est montré une construction micro-sphérique du noyau comme exemple, attendu qu'il peut être autre figure stéréométrique sans être limité. Ici c'est un exemple pour la disposition des conducteurs(9) et les connecteurs(10). Bien sur qu'elles peuvent être modifiées au besoin de la technologie et/ou le marché, sans être limité.

La micro sphère(6) peut être faite de saphir artificiel ou de verre/céramique ou

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des autres matériaux différents en accord avec la technologie et selon la fonction du nouveau SLED qu'on va appeler dorénavant BULED™.

Présentement existent des chaînes complètement automatisées pour la production des SLED's. Ils existent plusieurs technologies de disposer des couches semi-conductrices sur des supportes. Par exemple l'épitaxie.

Si l'épitaxie ou LPE (Liquide Phase Épitaxie) le permettent la disposition du passage(s) P/N sur (ou dans) la sphère peut être faite avec. On peut étudier la possibilité de disposé les P/N passage(s) avec la nouvelle technologie ''nanocrystals'' qui peut contrôler l'épaisseur des couches (2nm – 300nm) ou les autres technologies sans être limité pour arriver à la fonction exigée.

On ne se limite pas par rapport aux manières de la disposition des couches semi-conducteurs sur les surfaces et/ou dans la profondeur des différentes supportes stéréométriques, qui peuvent contenir ou non les éléments In, Ga, N, leurs alliages ou les autres éléments et matériaux utilisées. On peut ajouter des différents éléments, alliages et matériaux pour le but de modifier les caractéristiques de la luminescence sortante. Ici, le but de cette invention est de recevoir la surface stéréométrique lumineuse dispersant la luminescence partout dans l'espace entourant. Le vrai but est d'envoie le
bulb d'Edison (avec le wolfram brûlé) dans le musée.

Ce support micro sphérique (6) avec le passage(s) P/N se dispose dans une lentille optique sphérique (8,p.III) pour augmentation de l'effet de la luminescence. La fonction de cette lentille sphérique est pareille aux SLED fabriquées jusqu'à maintenant.

Cette nouvelle BULED™ se caractérise avec toute les avantages bien connus des SLED's:
-propagation de la luminescence partout!
-une vie énormément longue, le temps de fonctionnement sans refuse est plus de 100 000
heures (si on respecte les valeurs limitées admissibles des courants et de la tentions).
-la puissance lumineuse grande dans le volume petit.
-effectivité économique.
-la plus vaste région d'utilisation: l'industrie militaire, aérospatiale, aéronautique, automobile, pour les signaux du trafic, la limitation de la vitesse, la lumière dans les rues, éclairage des sorties, dans les tunnels, dans le métro, a la maison, l'industrie de divertissements(loteries vidéo, casinos, etc.), les panneaux informatisés pour hockey et le soccer, dans le cinéma, théâtre, Disney lands, décorations Noël, dans le domaine de la médecine, tourisme, commerce, avertissements le loisir, etc.

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REVENDICATIONS

Les réalisations de l'invention, au sujet desquelles un droit exclusif de propriété ou de privilège est revendiqué, sont définies comme suit:

1.Un élément électronique SLED stéréométrique, qui dorénavant va être appelé BULED™ basé sur le processus physique électroluminescence injection. .

2.Un BULED™(p. III), comme il est défini dans la revendication 1 ayant comme un noyau de base un taquet(support) stéréométrique (6) pour le(les) passage(s) semi-conducteur(s) P/N.

3.Le noyau (6), défini dans la revendication 2 a une forme stéréométrique (par exemple sphère), peut être fait d'un élément ou plus. Il peut être fait d'un (ou plus) élément(s) qui entrent dans la composition semi-conductrice lumineux P/N ou être fait d'un élément(s) ou des matériaux différents, qui n'entrent pas dans le processus physique de la luminescence.

4. P/N passage(s), qui sont disposées sur la surface et/ou profondeur du noyau(6) défini dans la revendication 3 et exécutent le processus physique électroluminescence injection, donnant le rayonnement lumineux dans la 99% du volume entourant. C'est à dire
selon tout le vectoriel possible ayant la même direction avec des radius sphériques imaginaires
de la micro sphère pris comme exemple, sans être limité (p. IV). Ici, on donne comme un exemple
un BULED™ avec le noyau sphérique(6), comme il est montré sur les dessins (p. III). Il n'y a
aucun restriction sur la façon de la disposition des P/N passage(s) sur la surface stéréométrique
et/ou dans la profondeur de la micro sphère. La seule exigence est de recevoir l'effet lumineux
dans 99% de l'espace entourant le BULED™ .

5. Des conducteurs (9) qui sont connectées vers le(s) P/N passage(s), définis dans la revendication 4 qui ont la tache d'assurer l'alimentation avec l'électricité (courant électrique
avec la tension appropriée) les P/N passage(s) mentionnées plus haut.
Il n'y a aucune restriction sur les questions des matériaux, de l'épaisseur(le moins possible
pour le courant approprier), leur longueur, la forme, la façon de la micro soudure avec la quelle ils sont connectés. Ces questions sont résolues selon la technologie automatisée appliquée(s'il est nécessaire il est possible de corriger certains éléments de la technologie
pour recevoir la fonction exigée du BULED™), sans être limité.

6.Des connecteurs (10) pour l'anode et la cathode micro soudée avec les conducteurs (9),
définis dans la revendication 5, qui ont la fonction exactement la même

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comme dans les SLED's générations précédentes: alimenter avec l'électricité du BULED™.

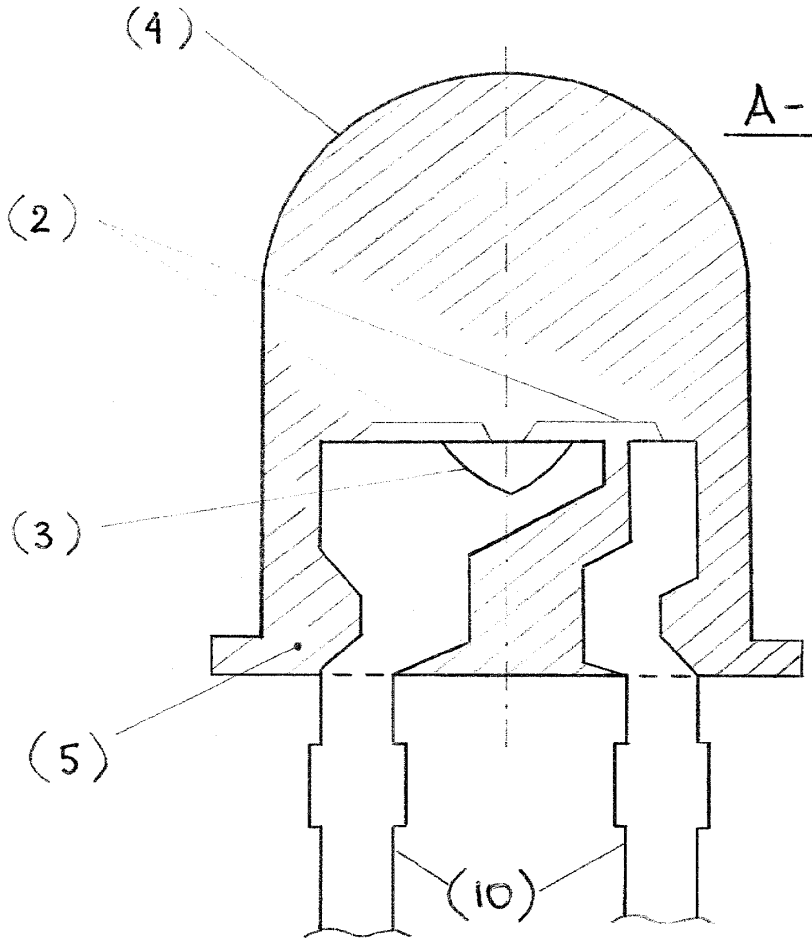
7.Une diode SLED selon les revendications (1-6) qui consiste en addition chimiques et/ou organiques et/ou biochimiques qui exercent une influence sur la luminescence.

8.Une lentille sphérique optique convexe (8) qui a le même but comme dans les SLED précédentes – augmentation de l'effet de la luminescence. Elle peut être aussi une lentille composée avec des façons différentes de la disposition, des sortes, du nombre des éléments composées, sans être limité. Elle entoure tous les éléments décrits dans les revendications précédentes (1-8). Elle peut être faite des différentes sortes d'époxy transparent comme dans les SLED précédentes sans être limité, et avoir au besoin des additions pour modifier les caractéristiques de la luminescence reçue ou d'exécuter la filtration optique d'une partie ou plus du rayonnement.

9.Le nouveau BULED™, défini dans les revendications (1-8) peut être fabriqué avec différentes proportions des éléments établis sans être limité, par exemple dans le cas de la micro- sphère(6), elle peut avoir des diamètres différentes dans chaque cas séparé. On peut le fabriquer avec des différentes caractéristiques de la luminescence sortant,
comme par exemple la couleur, etc., sans être limité. Il peut être fabriqué par connexion de plus d'un BULED™ des façons des plus différents possibles, sans être limité. Cette structure peut consister en BULED™ des sortes différentes. Il est possible de fabriqué BULED™ qui contient plus d'un support stéréométrique(6) dans une lentille sphérique.

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SLED

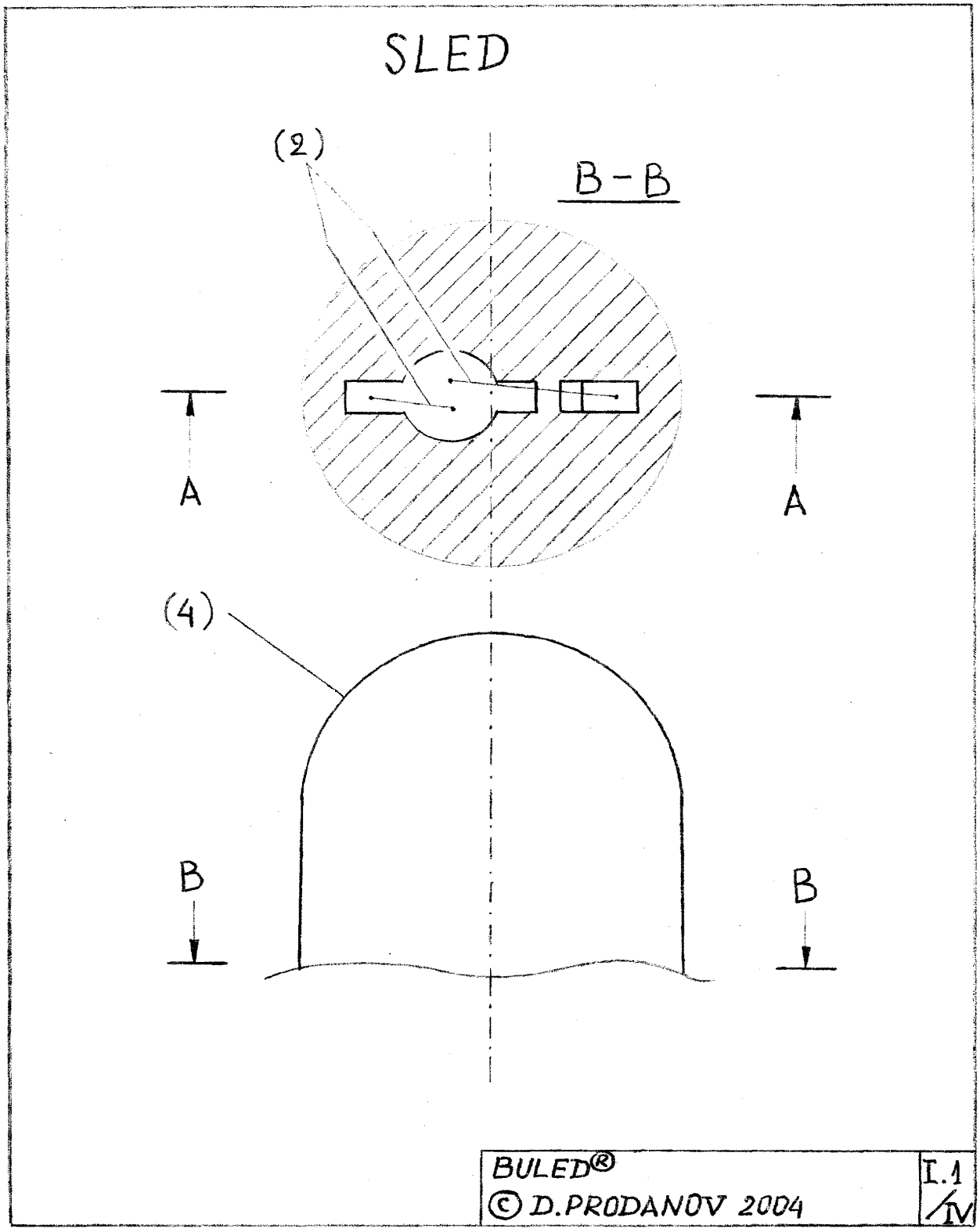


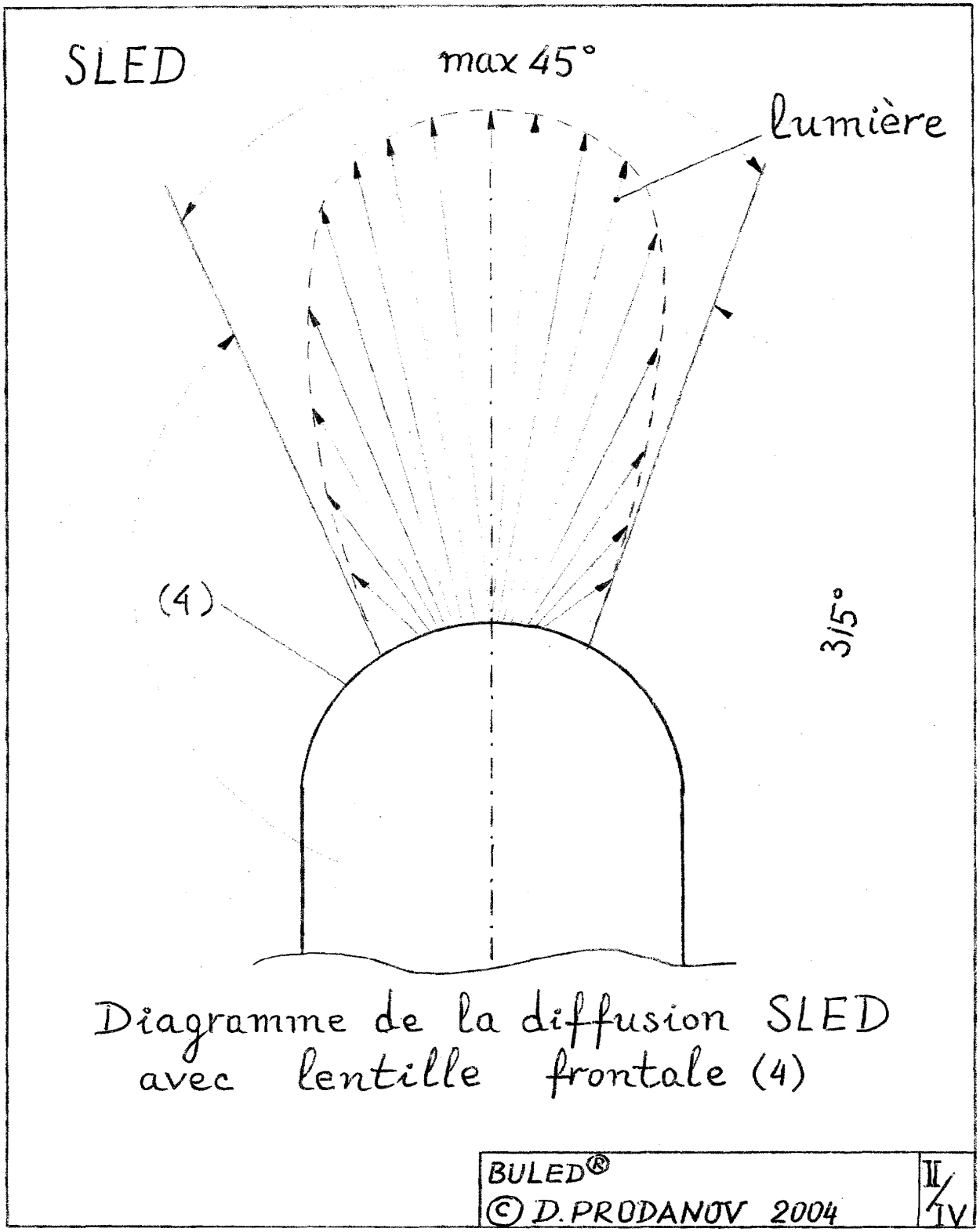
WAS

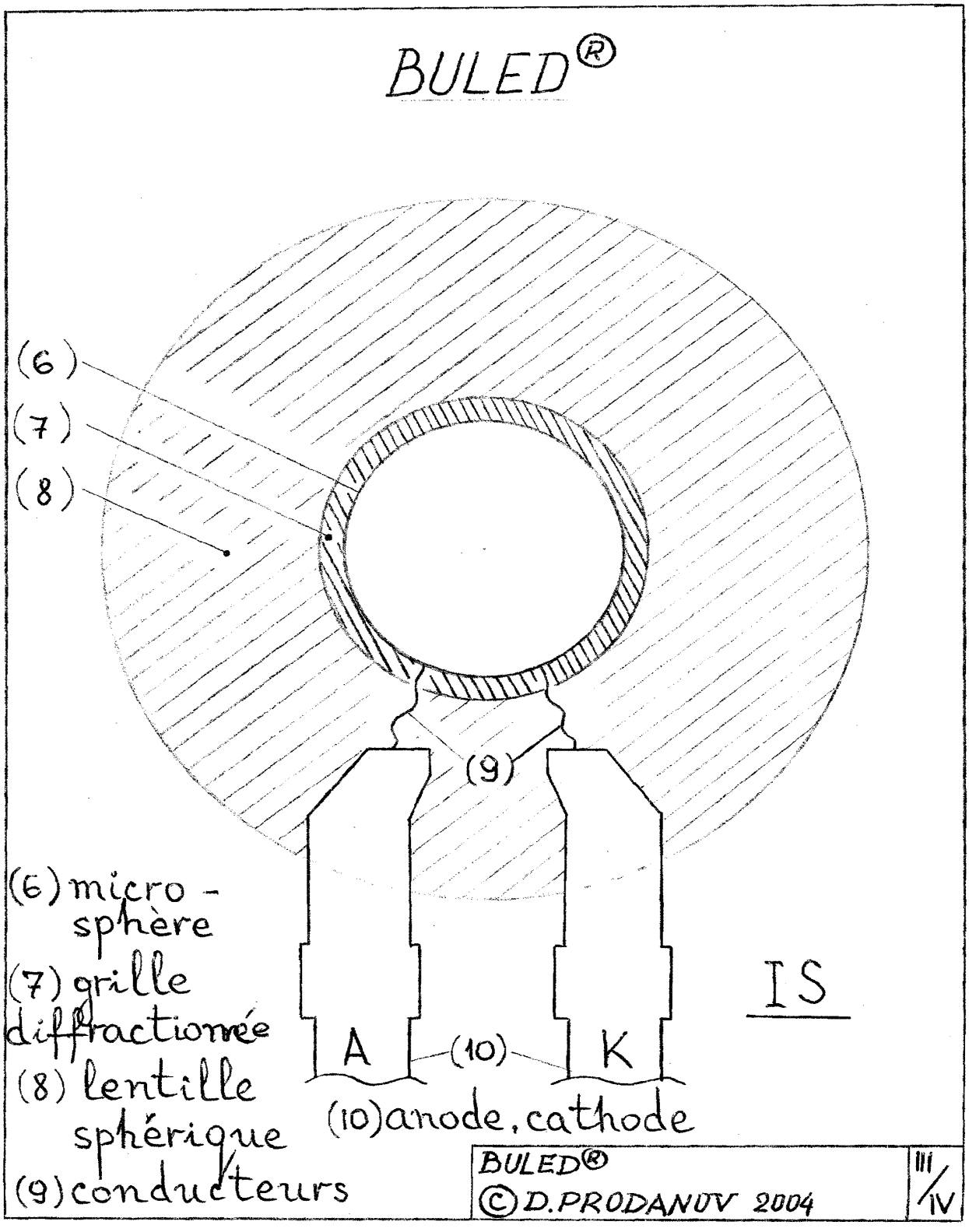
(2) conducteurs
(3) fossé avec P/N passage InGaN
(4) lentille frontale
(5) epoxy
(10) anode, cathode

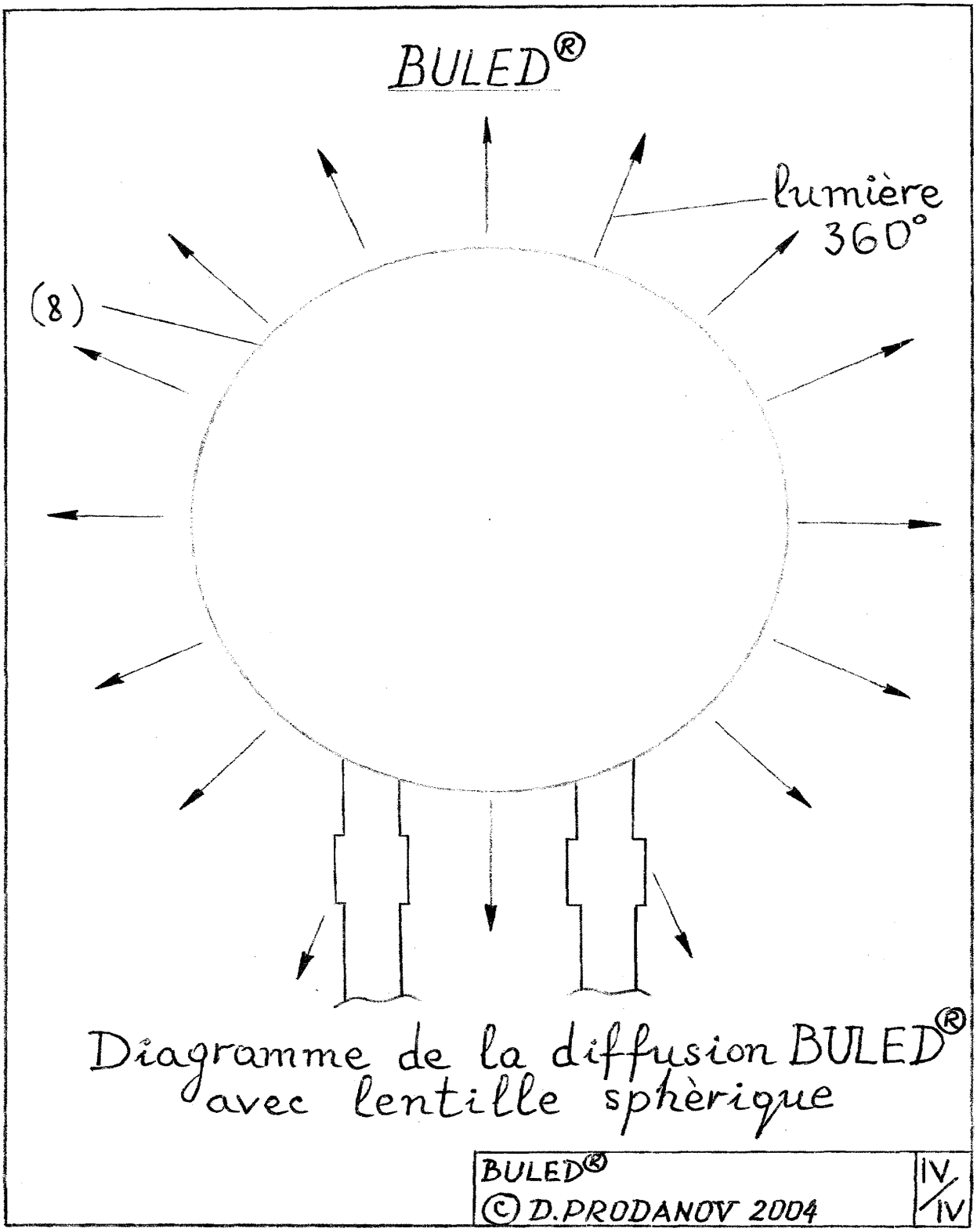
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I/IV


SLED
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I.1
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SLED
max 45°
lumière
(4)
315°
Diagramme de la diffusion SLED
avec lentille frontale (4)
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II/IV


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(6) micro - sphère
(7) grille diffractionnée
(8) lentille sphérique
(9) conducteurs
(10) anode, cathode
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lumière
360°
(8)
Diagramme de la diffusion BULED®
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PATENT ABSTRACTS OF JAPAN

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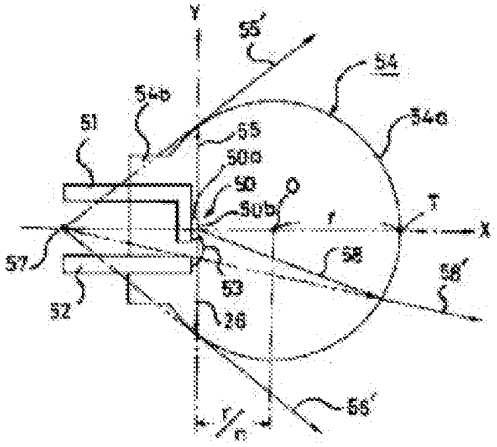
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(71)Applicant : **STANLEY ELECTRIC CO LTD**
(72)Inventor : **TANAKA HIROKAZU**

(54) LIGHT-EMITTING DIODE

(57)Abstract:
PURPOSE: To improve the illuminance of a light-emitting diode in which a lightemitting device is mounted on lead frames, a stem substrate or the like and electrically connected with wire bonding and which is molded overall with transparent resin.
CONSTITUTION: An optical member 54 which has a spherical part 54a with at least a semispherical surface is made of transparent resin material. A light- emitting device 50 is mounted on lead frames 51 and 52 and electrically connected by bonding with a wire 53. The position of the light-emitting device 50 is apart from the center of the spherical part 54a by a distance r/n and a distance between the light-emitting device 50 and the cross point T of the light axis of the device 50 and the spherical part 54a is to be r (1/n+1), wherein (r) and (n) denote the radius and the refractive index of the spherical part 54a respectively. Further, the optical member 54 is formed by molding so as to have the cross point T of the light axis and the spherical part 54a be the summit of the spherical part 54a. Moreover, the optical member 54 is so formed as to cover the incident region of side direction lights emitted from the light- emitting device 50 with the spherical part 54a.



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(21)出願番号　特願平5－257303

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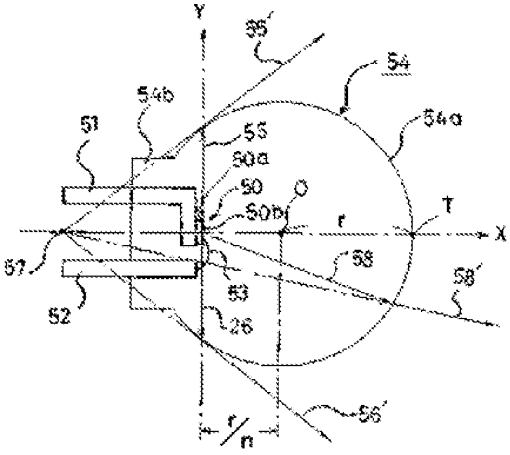
(74)代理人　弁理士　小池　寛治

(54)【発明の名称】　発光ダイオード

(57)【要約】

【目的】　発光素子をリードフレーム、ステム基板上などにマウントすると共に、ワイヤーボンディングし、これらを透明樹脂によってモールドした発光ダイオードの輝度を大幅に向上させることを目的とする。

【構成】　半球以上の球面とした球形部５４ａを有する光学部材５４を透明樹脂材で形成し、リードフレーム５１、５２にマウントすると共にワイヤー５３でボンディングした発光素子５０を、球形部５４ａの半径ｒ及び屈折率ｎに対し球形部５４ａの中心からｒ／ｎ離すと共に光軸と球形部５４ａとの交点までの距離をｒ（１／ｎ＋１）とし、かつ、上記光軸と球形部５４ａとの交点が球形部５４ａの頂点となるようにして上記光学部材５４でモールドし、さらに、発光素子５０から放射される側面方向の光の入射領域まで上記光学部材５４を球形部５４ａによって形成してある。



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1

【特許請求の範囲】

【請求項１】　半球以上の球面とした球形部を有する透明または半透明の光学部材を設け、上記球形部の半径ｒ及び屈折率ｎに対し球形部の中心からｒ／ｎ離なし、球形部の表面と光軸との交点までの距離をｒ（１／ｎ＋１）とした上記光学部材内の位置に光学素子を設けて構成したことを特徴とする発光ダイオード。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、信号灯，表示灯、光通信装置及び各種センサ等の光源として使用される可視光または赤外線を放射する発光ダイオードに関する。

【０００２】

【従来の技術】従来におけるこの種の発光ダイオードの一例を図４に示す。１，２は共にリードフレームで，リードフレーム１の曲折部先端にはＧａＰ系又はＧａＡｓＰ系などの発光素子３が装着されている。また、リードフレーム２はワイヤー４によって発光素子３の上面電極に電気接続されている。５は上記のように接続された両リードフレーム１、２の先端部分と，発光素子３と、ワイヤー４とを包囲する光透過性の樹脂材で形成した光学部材で，前面側にいくほど細くなる形状となっている。図５は円柱形の前方を球面状とした形状の光学部材６を備えた発光ダイオードの従来例を示す。

【０００３】

【発明が解決しようとする課題】上記した従来の発光ダイオードは、発光素子３から放射される光のうち発光素子３の前面部から放射される光と、発光素子３の側面部から放射される光の一部とが各光学部材５、６によって前方に投光され発光ダイオードの有効光線となる。

【０００４】したがって，図４に示す発光ダイオードは，発光素子３の側面部から出る光Ａ，Ｂが有効光線とならず、また，図５に示す発光ダイオードは発光素子３の側面部から出る光Ｃが有効光線とならない。つまり，光Ａ，Ｃは各光学部材５，６の境面で屈折しないでそのままで放射し，また，光Ｂは後方向きに屈折するため、このような光Ａ，Ｂ，Ｃが発光ダイオードの照度アップに寄与しないことになる。

【０００５】上記した実情にかんがみ，本発明は，発光素子の前面部と側面部から放射される光のほぼ全てを有効光線として利用でき、大幅な照度アップを図ることのできるこの種の発光ダイオードを開発することを目的とする。

【０００６】

【課題を解決するための手段】上記した目的を達成するため，本発明では，半球以上の球面とした球形部を有する透明または半透明の光学部材を設け，上記球形部の半径ｒ及び屈折率ｎに対し球形部の中心からｒ／ｎ離なし，球形部の表面と光軸との交点までの距離をｒ（１／ｎ＋１）とした上記光学部材内の位置に光学素子を設けて構成したことを特徴とする発光ダイオードを提案する。

2

【０００７】

【作用】この発明の発光ダイオードは，屈折率ｎを有する光学部材によって半径ｒの球形状に発光素子をモールドし，また、発光素子は球形部の中心からｒ／ｎ離なすと共に、光軸が上記球形部の中心と球形部の頂点を通るようにしてある。また，光学部材の球形部は半球以上の球面をもっており、発光素子の正面と側面から放射される光の入射領域を形成している。

【０００８】したがって，発光素子の前面から放射される光は球形部によって屈折し，発光ダイオードの前方に投光される。また，発光素子の側面から放射される光は，球形部との間で臨界角をなす光を除きこの球形部によって屈折して発光ダイオードの前方に投光される。そして，上記臨界角の光は球形部で全反射して発光ダイオードの前方に投光される。

【０００９】このように，発光素子から放射される光のほぼ全てが発光ダイオードの前方に投光されるので、発光ダイオードの照度が大きく向上する。

【００１０】

【実施例】次に，本発明の実施例について図面に沿って説明する。図１は本発明の発光ダイオードの概略的な断面図であり、ＧａＰ系またはＧａＡｓＰ系などの発光素子５０は従来例同様にＬ字形に折曲した一方のリードフレーム５１の頂部にマウントされ、他方のリードフレーム５２との間においてワイヤー５３がボンディングされ電気的に接続されている。

【００１１】また、発光素子５０、各リードフレーム５１，５２の上端部分及びワイヤー５３は透明樹脂材で形成した光学部材５４でモールドされている。

【００１２】この光学部材５４は，半球以上の球面を有する球形部５４ａを備え，この球形部５４ａの端部には支持部５４ｂが一体形成されている。球形部５４ａは，Ｏ点を球心とした半径ｒの球状体で，Ｔ点を頂点とし，屈折率がｎとなっている。

【００１３】このような光学部材５４に内包された光学素子５０は次のようにして配置されている。光学素子５０の光軸Ｘが球形部５４ａの球心Ｏと頂点Ｔを通るようにし，球形部５４ａの球心Ｏから支持部５４ｂ方向に距離ｒ／ｎだけ離して発光素子５０を配置する。したがって，発光素子５０から球形部５４ａの頂点Ｔまでの距離はｒ（１／ｎ＋１）となる。

【００１４】また，上記球形部５４ａは，このように配置した発光素子５０から放射される側面方向の光が入射する領域まで球面形成されている。つまり，球形部５４ａは，球形の立体角をωとしたとき，発光素子５０よりｒ（１／ｎ＋１）の位置を頂点とするω＞２πである立体角ωをもつようになっている。

【００１５】この発光ダイオードは，発光素子５０が図

Savant Technologies LLC - 1004.273

3

2に示す発光指向特性を示しており、この図よりわかる如く発光素子５０は光軸方向Ｘだけでなく、光軸Ｘと直交する方向、つまりＹ軸方向にも多くの光量を発光している。

【００１６】発光素子５０からＹ軸方向に放射される光、つまり、発光素子５０の側面部５０ａから放射される光５５、５６を一例にとると、これら光５５、５６は球形部５４ａで屈折して光５５′、５６′となって放射していく。なお、この光は球形部５４ａに対し臨界角であり、実際には存在しない。これらの屈折光線５５′、５６′は延長の交りによって生ずる点、つまり、虚光源５７から発した光線のように進んでいく。同様に、発光素子５０の前面部５０ｂから放射される光５８のその屈折光線５８′も虚光源５７から発した光線のように進んでいく。

【００１７】この関係を図３をもって説明すると、光源としての発光素子５０をＬ、虚光源５７をＬ′とし、辺Ｌ′Ｏをｘとすると、光５５の球形部５４ａにおける屈折点Ｐと球心Ｏを結ぶ仮想的直線辺ＯＯ′は点Ｐにおける法線であるから、∠ＬＰＯは光５５の入射角θとなり、∠Ｏ′ＰＬ″は屈折角θ′となる。また、∠Ｏ′ＰＬ″＝∠Ｌ′ＰＯであるから、∠Ｌ′ＰＯ＝θ′となる。

【００１８】ここで、辺ＬＯ＝ｒ／ｎであるから、∠ＰＬＯ＝Ｒ、∠ＰＬ′Ｏ＝Ｒ′とすると、正弦法則により、△ＬＰＯにおいて、ｓｉｎθ／（ｒ／ｎ）＝ｓｉｎＲ／ｒ、これより、

ｎｓｉｎθ＝ｓｉｎＲ　・・・・・・・・・（１）

△Ｌ′ＰＯにおいて、ｓｉｎθ′／ｘ＝ｓｉｎＲ′／ｒ、これより、

ｒｓｉｎθ′＝ｘｓｉｎＲ′・・・・・・（２）

となる。

【００１９】ここで、球形部５４ａの外側は空気であるから絶対屈折率１とみなし、入射角θと反射角θ′の間には、屈折の法則により、

ｎｓｉｎθ＝ｓｉｎθ′　・・・・・・・（３）

の関係が成立する。（１）式及び（３）式よりｓｉｎＲ＝ｓｉｎθ′となり、

Ｒ＝θ′　・・・・・・・・・・・・（４）

となる。

【００２０】また、△ＬＰＯと△Ｌ′ＰＯにおいて、θ＋Ｒ＝θ′＋Ｒ′であるから、（４）式を代入すると、

θ＝Ｒ′　・・・・・・・・・・・（５）

を得る。そして、（２）式に（５）式を代入すると、

ｒｓｉｎθ′＝ｘｓｉｎθ　・・・・・・・・（６）

となり、この（６）式と（３）式より、ｘ＝ｎｒが得られる。すなわち、虚光源Ｌ′が球心Ｏからｎｒの距離にあるとき、球形部５４ａでの屈折光は虚光源Ｌ′から発した光線のように進む。

4

【００２１】一方、入射角θが大きくなれば屈折角θ′も大きくなるが、屈折角θ′はπ／２よりは大きくなり得ず、このため屈折角θ′をπ／２とすると入射角θは臨界角となり、屈折現象は全反射に変わる。これは図３におけるθ′＝π／２の場合、（４）式よりθ′＝Ｒであるから、Ｒ＝π／２となり、光５５は球形部５４ａで全反射する。したがって、空気中への光の放射はＲ＜π／２の条件が成り立つ。なお、Ｒは発光素子５０から出る光の方向角である。図１における光５６も同様である。

【００２２】この結果、発光素子５０の側面部５０ａと前面部５０ｂとから放射される光のほぼ全てを光学部材５４の球形部５４ａによって前方に放射することができる。

【００２３】上記実施例においては、発光素子５０をリードフレームに取付けた場合について述べたが、ステム又は基板上にマウントした場合も同様に構成することができる。また、光学部材５４全体を透明樹脂によって形成したが、半透明樹脂で形成したり、球形部５４ａのみを透明樹脂によって形成するようなことは任意である。

【００２４】

【発明の効果】上記した通り、本発明に係る発光ダイオードは、発光素子から放射される光のほぼ全てを光学部材の球形部で前方へ投光することができるので、発光ダイオードの輝度を大幅にアップさせることができる。

【００２５】また、球形部によって屈折した光は発光素子の虚光源からの光とみなすことができるので、他の光学素子を組合せて用いる場合、光学素子の設置が容易となる利点を有している。

【図面の簡単な説明】

【図１】本発明に係る発光ダイオードの概略的な断面図である。

【図２】この発光ダイオードに備えた発光素子の発光指向特性を示す図である。

【図３】本発明の発光ダイオードの原理説明図である。

【図４】従来例を示し、発光ダイオードの概略的な断面図である。

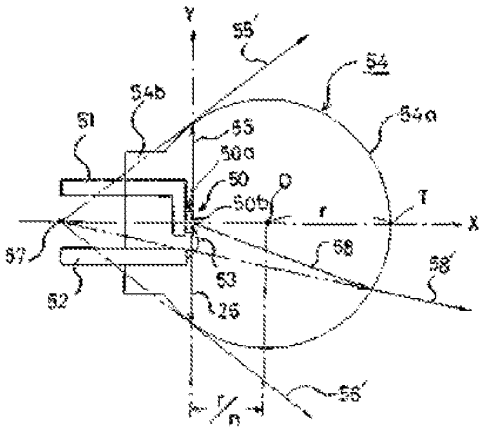
【図５】従来例を示し、他の発光ダイオードの概略的な断面図である。

【符号の説明】

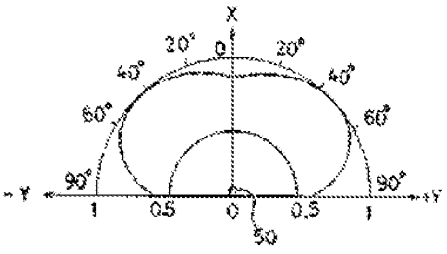
５０　発光素子
５１、５２　リードフレーム
５３　ワイヤー
５４　光学部材
５４ａ　球形部

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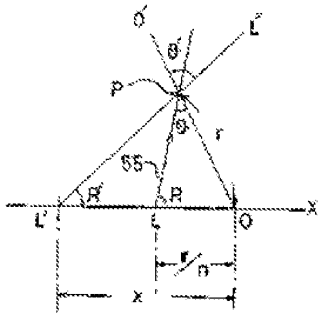
【図1】



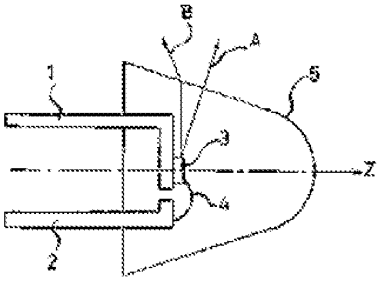
【図2】



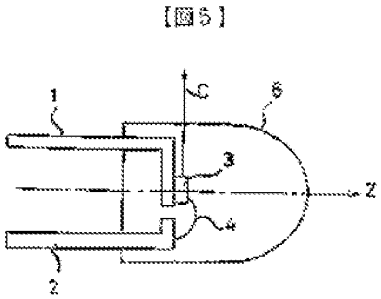
【図3】



【図4】



【図5】



Savant Technologies LLC - 1004.275

PATENT ABSTRACTS OF JAPAN

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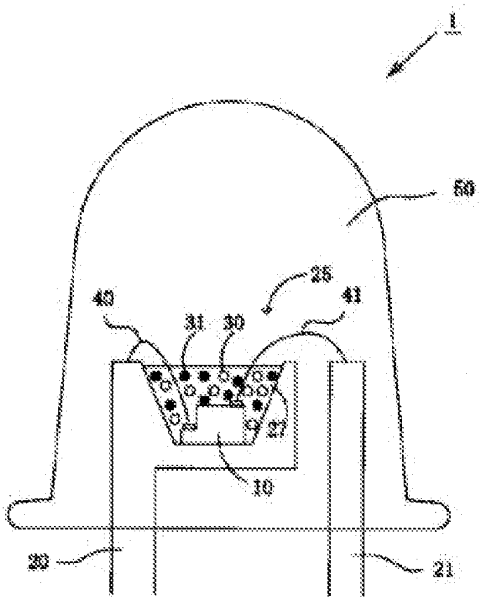
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(54) **LIGHT-EMITTING DEVICE**

(57)Abstract:
PROBLEM TO BE SOLVED: To improve the light guide-out efficiency of a light-emitting device, which converts the wavelength of part of light from a light emitting element by a phosphor and emits light.
SOLUTION: The phosphor 30 and a diffusing material 31, having a refractive index distribution, are incorporated in a transmissive resin layer 27 arranged where it is irradiated with the light from a light-emitting element.



Savant Technologies LLC - 1004.276

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審査請求　未請求　請求項の数６　ＯＬ　（全 ９ 頁）

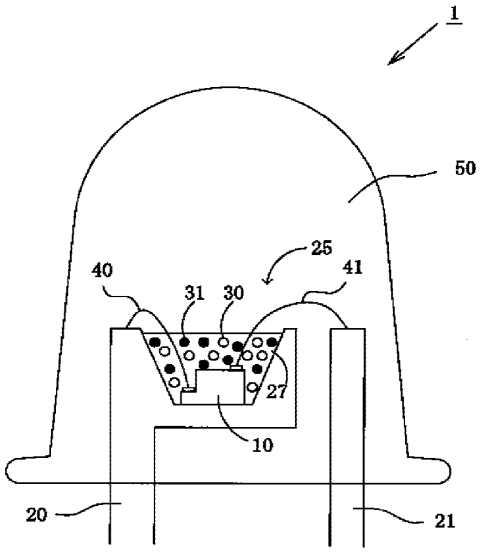
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最終頁に続く

(54)【発明の名称】　発光装置

(57)【要約】　（修正有）
【課題】　発光素子からの光の一部を蛍光体により波長変換して放出する発光装置において、光の取り出し効率を向上する。
【解決手段】　発光素子の光が照射する位置に配置される光透過性樹脂層２７に、蛍光体３０と、屈折率分布を有する拡散材３１とを含有させる。



Savant Technologies LLC - 1004.277

【特許請求の範囲】
【請求項１】　発光素子と、
前記発光素子の光を受けて蛍光する蛍光体、及び屈折率分布を有する拡散材を含む光透過性材料層と、
を備える発光装置。
【請求項２】　前記発光素子が青色系の光を発光する、請求項１に記載の発光装置。
【請求項３】　前記発光素子が青色系の光を発光し、該青色系の光と前記蛍光体からの蛍光とが混色することにより、白色系の光を放射する、請求項１に記載の発光装置。
【請求項４】　前記発光素子が紫外領域の光を発光する、請求項１に記載の発光装置。
【請求項５】　前記発光素子が紫外領域の光を発光し、且つ前記蛍光体がそれぞれ赤色系、緑色系、及び青色系の蛍光を発する蛍光材料を含み、
前記蛍光体から発せられる蛍光が混色することにより、白色系の光を放射する、請求項１に記載の発光装置。
【請求項６】　前記発光素子がIII族窒化物系化合物半導体発光素子である、請求項１～５のいずれかに記載の発光装置。
【発明の詳細な説明】
【０００１】
【産業上の利用分野】本発明は、発光装置に関する。詳しくは、発光素子と蛍光体とを組み合わせた発光装置に関する。
【０００２】
【従来の技術】発光素子の光の一部を蛍光体により波長変換し、当該波長変換された光と波長変換されない発光素子の光とを混合して放出することにより、発光素子本来の発光色と異なる色の光を発光する発光装置が開発されている。例えば、発光素子として青色系の光を発光するIII族窒化物系化合物半導体発光素子を用い、蛍光体としてセリウム（Ｃｅ）を賦活したイットリウム・アルミニウム・ガーネット系蛍光体（ＹＡＧ）を用いた発光装置が市販されている。かかる発光装置では、リードフレームのカップ部に発光素子が載置され、そして蛍光体（ＹＡＧ）を分散した光透過性材料が発光素子を被覆するようにカップ部に充填されている。これにより発光素子の光放出方向には蛍光体層が形成される。かかる構成では、発光素子の光の一部は、蛍光体層を通過する際、蛍光体（ＹＡＧ）に吸収、波長変換された後放射され、その他の光は蛍光体に吸収されることなく蛍光体層を透過して放射される。そして、これら２種類の光が混合されることにより白色系の発光が得られる。
【０００３】
【発明が解決しようとする課題】上記のごとき発光素子及び蛍光体を用いた発光装置では、異なる波長の光を混色して外部放射するため、光の混色を促進し発光色のムラを軽減することが要求される。そこで、蛍光体を分散させる光透過性材料に、拡散材（酸化チタンなど）を含有させた構成が提案されている（例えば、特開平１０－１７３２４０号公報、特開２０００－２０８８１５号公報等）。拡散材を用いることにより、発光素子の光あるいは蛍光体からの光が拡散材によって拡散され、これにより両者の混色が良好に行われる。しかしながら、従来使用されている酸化チタンなどの拡散材はそれに照射する光を乱反射するため、一部の光は発光素子側に反射され、即ち光の取り出し方向と逆行する光となり、その結果、光の取り出し効率（発光効率）が低下してしまう。本発明は以上の課題を解決すべくなされたものであり、蛍光体を用いて一部の光を波長変換して放出する発光装置において、光の取り出し効率、即ち発光効率を向上することを目的とする。
【０００４】
【課題を解決するための手段】本発明者らは、以上の目的を達成すべく鋭意検討した結果、以下の構成に想到した。即ち、本発明は、発光素子と、前記発光素子の光を受けて蛍光する蛍光体、及び屈折率分布を有する拡散材を含む光透過性材料層と、を備える発光装置である。
【０００５】ここで、光透過性材料層に含有される、屈折率分布を有する拡散材は、それに照射する光の多くを進行方向側に反射する。したがって、上記の構成では、拡散材に反射されることによって光の取り出し方向に逆行する光が発生することを大幅に抑制できる。即ち、発光素子からの光あるいは蛍光体により変換された光を、効率よく光の取り出し方向に進行させることができる。その結果、光の取り出し効率（発光効率）が高い発光装置となる。
【０００６】
【発明の実施の形態】発光素子は、その発光波長が３６０ｎｍ～５５０ｎｍの範囲にあるものが好適に用いられる。かかる波長範囲の光は、後述の蛍光体を高効率で励起し、発光させることが可能である。発光素子の選択においては、後述の蛍光体の励起ピーク及び発光色、並びに発光装置全体から発光される光の色が考慮される。白色系の発光を得ようとすれば、例えば、青色系の光を発光する発光素子（例えば、発光ピーク波長が４５０ｎｍ～５００ｎｍの範囲にある発光素子）を採用することができる。この場合には、例えば、後述の蛍光体を青色系の光との混色により白色系の光が得られるように、後述の蛍光体として黄色系ないしは緑色系の蛍光色を有するものを採用することができる。白色系の発光を得る場合の他の例としては、紫外領域の光を発光する発光素子（例えば、発光ピーク波長が３６０ｎｍ～４００ｎｍの範囲にある発光素子）を採用し、それぞれが赤色系、緑色系、及び青色系の蛍光を発する蛍光材料からなる蛍光体を組み合わせて用いる態様を挙げることができる。
【０００７】二以上の波長領域に発光ピークを有する発光素子を採用することもできる。例えば、紫外領域の光

Savant Technologies LLC - 1004.278

の他、可視領域の光をも発光する発光素子を用いれば、紫外領域の光を蛍光体の励起に利用する一方で、可視領域の光を外部放射光の光の一部として利用することができる。このようにすれば、発光装置からは蛍光体の蛍光と発光素子から放出される可視光とが混合された光が外部放射される。例えば、紫外光と青色光とを発光可能な発光素子を採用し、併せて紫外光により緑色系、赤色系などの蛍光を発する蛍光体を組み合わせれば、様々な発光色の発光装置を構成することができる。異なる発光波長（発光色）を有する二以上の発光素子を組み合わせて用いることもできる。このようにすれば、発光装置から放射される光の色を変化、調整、又は補正することができる。

【０００８】発光素子の形成材料は特に限定されるものではない。III族窒化物系化合物半導体層を備える発光素子、即ち、III族窒化物系化合物半導体発光素子を好適に用いることができる。III族窒化物系化合物半導体は、一般式として$Al_XGa_YIn_{1-X-Y}N$（$0 \leqq X \leqq 1$、$0 \leqq Y \leqq 1$、$0 \leqq X+Y \leqq 1$）で表され、AlN、GaN及びInNのいわゆる２元系、$Al_xGa_{1-x}N$、$Al_xIn_{1-x}N$及び$Ga_xIn_{1-x}N$（以上において$0<x<1$）のいわゆる３元系を包含する。III族元素の少なくとも一部をボロン（Ｂ）、タリウム（Ｔｌ）等で置換しても良く、また、窒素（Ｎ）の少なくとも一部もリン（Ｐ）、ヒ素（Ａｓ）、アンチモン（Ｓｂ）、ビスマス（Ｂｉ）等で置換できる。発光素子の素子機能部分は上記２元系若しくは３元系のIII族窒化物系化合物半導体より構成することが好ましい。

【０００９】III族窒化物系化合物半導体は任意のドーパントを含むものであっても良い。n型不純物として、Ｓｉ、Ｇｅ、Ｓｅ、Ｔｅ、Ｃ等を用いることができる。p型不純物として、Ｍｇ、Ｚｎ、Ｂｅ、Ｃａ、Ｓｒ、Ｂａ等を用いることができる。なお、p型不純物をドープした後にIII族窒化物系化合物半導体を電子線照射、プラズマ照射若しくは炉による加熱にさらすことができるが必須ではない。III族窒化物系化合物半導体は、有機金属気相成長法（ＭＯＣＶＤ法）のほか、周知の分子線結晶成長法（ＭＢＥ法）、ハライド系気相成長法（ＨＶＰＥ法）、スパッタ法、イオンプレーティング法、電子シャワー法等によっても形成することができる。

【００１０】III族窒化物系化合物半導体層を成長させる基板の材質はIII族窒化物系化合物半導体層を成長させられるものであれば特に限定されないが、例えば、サファイア、スピネル、シリコン、炭化シリコン、酸化亜鉛、リン化ガリウム、ヒ化ガリウム、酸化マグネシウム、酸化マンガン、III族窒化物系化合物半導体単結晶などを基板の材料として挙げることができる。中でも、サファイア基板を用いることが好ましく、サファイア基板のａ面を利用することが更に好ましい。

【００１１】光透過性材料層の基材（光透過性材料）としては、エポキシ樹脂、シリコーン樹脂、シリコーンゴム、シリコーンエラストマー、尿素樹脂、又はガラス等を用いることができる。これらの材料は、単独で用いられるのは勿論のこと、これらの中から任意に選択される二種以上の材料を用いることもできる。中でも、取り扱い易さや汎用性などの観点からエポキシ樹脂を用いることが好ましい。また、シリコーン樹脂、シリコーンゴム、又はシリコーンエラストマーを採用する場合には、その表面（外部露出面）に耐衝撃性の高い材料によるコーティングなどを施すことが好ましい。例えば、封止部材の表面に成型したエポキシ樹脂などを被せることができる。光透過性材料層は、発光素子からの光が照射する位置に備えられる。これにより、その中に含有される蛍光体への光の照射が行われる。好ましくは、発光素子の光放出側を被覆するように光透過性材料層を形成し、蛍光体に対して光を効率的に照射する。光透過性材料層により発光素子を封止することができる。また、発光素子と光透過性材料層との間に、光透過性材料層と異なる材料からなる層あるいは空間を設けてもよい。例えば、シリコーン樹脂を発光素子の表面に塗布し、その上にエポキシ樹脂等を基材とした光透過性材料層を形成することができる。

【００１２】光透過性樹脂層には蛍光体が添加されている。ここでの蛍光体の種類は、発光素子の光により励起し蛍光するものであれば特に限定されず、無機系、有機系を問わず採用することができる。無機系蛍光体としては、以下のものを採用することができる。例えば、赤色系の発光色を有する$6MgO \cdot As_2O_5:Mn^{4+}$、$Y(PV)O_4:Eu$、$CaLa_{0.1}Eu_{0.9}Ga_3O_7$、$BaY_{0.9}Sm_{0.1}Ga_3O_7$、$Ca(Y_{0.5}Eu_{0.5})(Ga_{0.5}In_{0.5})_3O_7$、$Y_3O_3:Eu$、$YVO_4:Eu$、$Y_2O_2:Eu$、$3.5MgO \cdot 0.5MgF_2GeO_2:Mn^{4+}$、及び$(Y \cdot Cd)BO_2:Eu$等、青色系の発光色を有する$(Ba,Ca,Mg)_5(PO_4)_3Cl:Eu^{2+}$、$(Ba,Mg)_2Al_{16}O_{27}:Eu^{2+}$、$Ba_3MgSi_2O_8:Eu^{2+}$、$BaMg_2Al_{16}O_{27}:Eu^{2+}$、$(Sr,Ca)_{10}(PO_4)_6Cl_2:Eu^{2+}$、$(Sr,Ca)_{10}(PO_4)_6Cl_2 \cdot nB_2O_3:Eu^{2+}$、$Sr_{10}(PO_4)_6Cl_2:Eu^{2+}$、$(Sr,Ba,Ca)_5(PO_4)_3Cl:Eu^{2+}$、$Sr_2P_2O_7:Eu$、$Sr_5(PO_4)_3Cl:Eu$、$(Sr,Ca,Ba)_3(PO_4)_6Cl:Eu$、$SrO \cdot P_2O_5 \cdot B_2O_5:Eu$、$(BaCa)_5(PO_4)_3Cl:Eu$、$SrLa_{0.95}Tm_{0.05}Ga_3O_7$、$ZnS:Ag$、$GaWO_4$、$Y_2SiO_6:Ce$、$ZnS:Ag,Ga,Cl$、$Ca_2B_4OCl:Eu^{2+}$、$BaMgAl_4O_3:Eu^{2+}$、及び一般式$(M1,Eu)_{10}(PO_4)_6Cl_2$（M1は、Mg，Ca，Sr，及びBa

Savant Technologies LLC - 1004.279

からなる群から選択される少なくとも１種の元素）で表される蛍光体等、緑色系の発光色を有する$Y_3Al_5O_{12}:Ce^{3+}$（YAG）、$Y_2SiO_5:Ce^{3+}$，Tb^{3+}、$Sr_2Si_3O_8\cdot 2SrCl_2:Eu$、$BaMg_2Al_{16}O_{27}:Eu^{2+}$，$Mn^{2+}$、$ZnSiO_4:Mn$、$Zn_2SiO_4:Mn$、$LaPO_4:Tb$、$SrAl_2O_4:Eu$、$SrLa_{0.2}Tb_{0.8}Ga_3O_7$、$CaY_{0.9}Pr_{0.1}Ga_3O_7$、$ZnGd_{0.8}Ho_{0.2}Ga_3O_7$、$SrLa_{0.6}Tb_{0.4}Al_3O_7$、ZnS:Cu，Al、（Zn，Cd）S:Cu，Al、ZnS:Cu，Au，Al、$Zn_2SiO_4:Mn$、$ZnSiO_4:Mn$、ZnS:Ag，Cu、（Zn・Cd）S:Cu、ZnS:Cu、GdOS:Tb、LaOS:Tb、$YSiO_4:Ce\cdot Tb$、$ZnGeO_4:Mn$、GeMgAlO:Tb、SrGaS:Eu^{2+}、ZnS:Cu・Co、$MgO\cdot nB_2O_3$:Ge，Tb、LaOBr:Tb，Tm、及びLa_2O_2S:Tb等を用いることができる。また、白色系の発光色を有するYVO_4:Dy、黄色系の発光色を有する$CaLu_{0.5}Dy_{0.5}Ga_3O_7$を用いることもできる。

【００１３】有機系蛍光体としては、以下のものを採用することができる。例えば、1，4－ビス（２－メチルスチリル）ベンゼン（Ｂｉｓ－ＭＳＢ）、トランス－４，４’－ジフェニルスチルベン（ＤＰＳ）等のスチルベン系色素、及び７－ヒドロキシ－４－メチルクマリン（クマリン４）等のクマリン系色素、ＢＯＱＰ、ＰＢＢＯ、ＢＯＴ、ＰＯＰＯＰ等を用いることができる。これらの蛍光体は青色系の発光色を有する。また、ＤＰＯＴ、ブリリアントサルフォフラビンＦＦ（brilliantsulfoflavine FF）、ベーシックイエローＨＧ（basic yellow HG）、SINLOIHI COLOR FZ-5005（シンロイヒ社製）などを用いることもできる。これらの蛍光体は黄色系～緑色系の蛍光色を有する。また、黄色系～赤色系の蛍光体である、エオシン（eosine）、ローダミン６Ｇ（rhodamine 6G）、ローダミンＢ（rhodamineB）、NKP-8303（日本蛍光化学社製）などを用いることもできる。また、ＴＢ（ＥＤＴＡ）ＳＳＡ、ＥｕＴＴＡなどを例えばメチルメタクリレートに溶解、重合固化しポリメチルメタクリレート（ＰＭＭＡ）としたものを用いることもできる。尚、異なる種類の蛍光体を二以上組み合わせて用いることもできる。

【００１４】使用目的、使用条件等に応じて、光透過性材料層内における蛍光体の濃度分布を変化させることができる。即ち、発光素子に近づくに従って蛍光体の量を連続的又は段階的に変化させることができる。例えば、発光素子に近い部分において蛍光体の濃度を大きくする。これにより、効率的に発光素子からの光を蛍光体に照射することができる。その反面、発光素子で発生する熱の影響を受けやすく、蛍光体の劣化が問題となる。他方、発光素子に近づくに従って蛍光体の濃度を小さくすることにより、発光素子の発熱に起因する蛍光体の劣化は抑制される。例えば、蛍光体を分散させた少量の光透過性材料で発光素子の表面（光放出側）をコーティングし、その上に蛍光体を含まない光透過性材料を積層することにより、蛍光体樹脂層内における蛍光体量の濃度分布を変化させることができる。ここで、蛍光体の添加量が異なる封止部材を複数用意し、これらを順に積層することにより、蛍光体添加量を発光素子側から遠ざかるに従って徐変するように構成してもよい。尚、種類の異なる蛍光体を添加された光透過性材料を複数用意し、これらを順に積層することもできる。

【００１５】光透過性材料層には、蛍光体に加えて屈折率分布を有する拡散材が含有される。このような拡散剤を用いることにより、まず光透過性材料層内での光の拡散が促進され、発光素子の光を効率的に蛍光体に照射できる。また、発光素子からの光と蛍光体の蛍光の混色を促進でき、混色ムラ及び発光ムラの低減が図られる。しかも、屈折率分布を有する拡散材を採用することにより、光の取り出し方向と逆方向への光の反射が抑えられ、光の取り出し効率（発光効率）が高くなる。

【００１６】ここで、「屈折率分布を有する」とは、拡散材中において屈折率が一様でないことを意味する。したがって、拡散材中に屈折率の最大となる位置、及び最小となる位置が存在する。このような屈折率分布を有する拡散材としては、例えば特開平６－３４７６１６号公報に開示されるものを採用することができる。当該公報には、屈折率が異なる二以上のラジカル重合性単量体（スチレン、スチレン誘導体、メタクリル酸エステル類、アクリル酸エステル類など）をラジカル共重合させて得られる透明性の拡散材であって、拡散材内の屈折率の最大値と最小値の差が０．００５以上、５０ｎｍ離れた任意の２点の屈折率の差が０．０１以下又は上記の屈折率の最大値と最小値の差の１／２以下、屈折率の異なる領域が偏在しない（拡散材中の任意の位置における径５ｍｍ円内での屈折率の平均が、拡散材全体の屈折率の平均にほぼ等しい）といった特性の拡散材が開示されており、本発明ではかかる特性を備えた拡散材を好適に採用することができる。尚、以上の拡散材についての特性、製法等については当該公報に詳述されるのでこれを参照されたい。拡散材は、光透過性材料層に分散した状態で含有させることもできるが、上記蛍光体と同様に、濃度分布をつけてもよい。

【００１７】光透過性材料層には、上記の蛍光体、及び屈折率分布を有する拡散材の他に、他の拡散材（例えば、酸化チタン、窒化チタン、窒化タンタル、酸化アルミニウム、酸化珪素、チタン酸バリウム等）や着色剤等を添加することもできる。着色剤は、蛍光体自体などが特有の色を示すことを防止するために専ら用いられる。

【００１８】

Savant Technologies LLC - 1004.280

【実施例】以下、実施例を用いて本発明の構成をより詳細に説明する。
（実施例１）図１は本発明の一の実施例である砲弾型ＬＥＤ１を示す図である。ＬＥＤ１は白色系の発光をし、例えば、導光体と組み合わせて面状光源、線状光源に利用することができ、また、各種表示装置等にも利用することができる。図２にはＬＥＤ１に使用される発光素子１０の模式断面図が示される。発光素子１０の発光波長は約４８０ｎｍであり、各層のスペックは次の通りである。

層	：	組成
ｐ型層１５	：	ｐ－ＧａＮ：Ｍｇ
発光する層を含む層１４	：	ＩｎＧａＮ層を含む
ｎ型層１３	：	ｎ－ＧａＮ：Ｓｉ
バッファ層１２	：	ＡｌＮ
基板１１	：	サファイア

【００１９】基板１１の上にはバッファ層１２を介してｎ型不純物としてＳｉをドープしたＧａＮからなるｎ型層１３を形成する。ここで、基板１１にはサファイアを用いたが、これに限定されることはなく、サファイア、スピネル、シリコン、炭化シリコン、酸化亜鉛、リン化ガリウム、ヒ化ガリウム、酸化マグネシウム、酸化マンガン、III族窒化物系化合物半導体単結晶等を用いることができる。さらにバッファ層はＡｌＮを用いてＭＯＣＶＤ法で形成されるがこれに限定されることはなく、材料としてはＧａＮ、ＩｎＮ、ＡｌＧａＮ、ＩｎＧａＮ及びＡｌＩｎＧａＮ等を用いることができ、製法としては分子線結晶成長法（ＭＢＥ法）、ハライド系気相成長法（ＨＶＰＥ法）、スパッタ法、イオンプレーティング法、電子シャワー法等を用いることができる。III族窒化物系化合物半導体を基板として用いた場合は、当該バッファ層を省略することができる。さらに基板とバッファ層は半導体素子形成後に、必要に応じて、除去することもできる。
【００２０】ここでｎ型層１３はＧａＮで形成したが、ＡｌＧａＮ、ＩｎＧａＮ若しくはＡｌＩｎＧａＮを用いることができる。また、ｎ型層１３はｎ型不純物としてＳｉをドープしたが、このほかにｎ型不純物として、Ｇｅ、Ｓｅ、Ｔｅ、Ｃ等を用いることもできる。ｎ型層１３は発光する層を含む層１４側の低電子濃度ｎ-層とバッファ層１２側の高電子濃度ｎ＋層とからなる２層構造とすることができる。発光する層を含む層１４は量子井戸構造（多重量子井戸構造、若しくは単一量子井戸構造）を含んでいてもよく、また発光素子の構造としてはシングルヘテロ型、ダブルヘテロ型及びホモ接合型のものなどでもよい。発光する層を含む層１４はｐ型層１５の側にマグネシウム等のアクセプタをドープしたバンドギャップの広いIII族窒化物系化合物半導体層を含むこともできる。これは発光する層を含む層１４中に注入された電子がｐ型層１５に拡散するのを効果的に防止するためである。発光する層を含む層１４の上にｐ型不純物としてＭｇをドープしたＧａＮからなるｐ型層１５を形成する。このｐ型層はＡｌＧａＮ、ＩｎＧａＮ又はＩｎＡｌＧａＮとすることもできる、また、ｐ型不純物としてはＺｎ、Ｂｅ、Ｃａ、Ｓｒ、Ｂａを用いることもできる。さらに、ｐ型層１５を発光する層を含む層１４側の低ホール濃度ｐ－層と電極側の高ホール濃度ｐ＋層とからなる２層構造とすることができる。上記構成の発光ダイオードにおいて、各III族窒化物系化合物半導体層は一般的な条件でＭＯＣＶＤを実行して形成するか、分子線結晶成長法（ＭＢＥ法）、ハライド系気相成長法（ＨＶＰＥ法）、スパッタ法、イオンプレーティング法、電子シャワー法等の方法で形成することもできる。
【００２１】ｎ電極１９はＡｌとＶの２層で構成され、ｐ型層１５を形成した後、ｐ型層１５、発光する層を含む層１４、及びｎ型層１３の一部をエッチングにより除去し、蒸着によりｎ型層１３上に形成される。透光性電極１７は金を含む薄膜であり、ｐ型層１５の上に積層される。ｐ電極１８も金を含む材料で構成されており、蒸着により透光性電極１７の上に形成される。上記の工程により各半導体層及び各電極を形成した後、各チップの分離工程を行う。
【００２２】発光する層を含む層１４と基板１１との間、又は基板１１の半導体層が形成されない面に反射層を設けることもできる。反射層を設けることにより、発光する層１４で生じ、基板側に向かった光を効率的に光の取り出し方向へ反射することができ、その結果、発光効率の向上が図れる。反射層は、窒化チタン、窒化ジルコニウム、及び窒化タンタルの中から選択される１種類又は２種類以上により形成することができる。また、Ａｌ、Ｉｎ、Ｃｕ、Ａｇ、Ｐｔ、Ｉｒ、Ｐｄ、Ｒｈ、Ｗ、Ｍｏ、Ｔｉ、Ｎｉ等の金属の単体又はこれらの中から任意に選択される２種以上の金属からなる合金を用いて反射層を形成することもできる。
【００２３】発光素子１０はリードフレーム２０に設けられるカップ状部２５に接着剤を用いてマウントされる。接着剤はエポキシ樹脂の中に銀をフィラーとして混合させた銀ペーストである。かかる銀ペーストを用いることにより発光素子１０からの熱の放散がよくなる。尚、銀ペーストに換えて、透明ペースト、白色ペースト等、他の公知の接着剤を用いてもよい。発光素子１０のｐ電極１８及びｎ電極１９は、それぞれワイヤ４１及び４０によりリードフレーム２１及び２０にワイヤボンディングされる。
【００２４】カップ状部２５には蛍光体３０及び拡散材３１を一様に分散させたエポキシ樹脂（以下、「蛍光体／拡散材含有層」という）２７が充填される。後述のワイヤボンディング後に、この蛍光体／拡散材含有層２７をカップ状部２５に充填することもできる。また、発光素子１０をカップ状部２５にマウントする前に発光素子

Savant Technologies LLC - 1004.281

１０の表面に蛍光体／拡散材含有層を形成してもよい。例えば、発光素子１０を蛍光体３０及び拡散材３１を含むエポキシ樹脂にディップすることにより、発光素子１０の表面に蛍光体／拡散材含有層を形成し、その後、発光素子１０をカップ状部２５に銀ペーストを用いてマウントする。蛍光体／拡散材含有層２７の形成方法としては、上記ディップによる他、スパッタリング、塗布、又は塗装等を用いることもできる。

【００２５】蛍光体３０は、ＺｎＳ：Ｃｕ，Ａｕ，Ａｌ（発光ピーク５３５ｎｍ）を用いる。拡散材３１には、メチルメタクリレートとビニルフェニルアクリレートとのランダム共重合体であって、中心部から周辺部に向かって屈折率が連続的に減少する粒子を用いる（製造方法の詳細は特開平６－３４７６１６号公報を参照されたい）。その他、メチルメタクリレートとビニルベンゾエートとのランダム共重合体などを用いることもできる。

【００２６】本実施例では蛍光体３０及び拡散材３１を分散させる基材としてエポキシ樹脂を用いるがこれに限定されるわけではなく、シリコーン樹脂、尿素樹脂、又はガラス等の透明な材料を用いることができる。また、本実施例では蛍光体３０及び拡散材３１を蛍光体／拡散材含有層２７内に一様に分散させる構成としたが、蛍光体／拡散材層内２７で蛍光体３０及び／又は拡散材３１の濃度分布に傾斜を設けることもできる。例えば、蛍光体３０及び拡散材３１の含有濃度の異なるエポキシ樹脂をカップ状部２５内に積層することにより、カップ状部２５内で段階的に蛍光体３０濃度及び拡散材３１濃度を変化させる。連続的に蛍光体３０濃度及び／又は拡散材３１濃度を変化させることもできる。

【００２７】蛍光体／拡散材含有層２７に、酸化チタン、窒化チタン、窒化タンタル、酸化アルミニウム、酸化珪素、チタン酸バリウム等からなる第２の拡散材を更に含ませることもできる。

【００２８】発光素子１０、リードフレーム２０、２１の一部、及びワイヤ４０、４１はエポキシ樹脂からなる封止レジン５０により封止される。封止レジン５０の材料は透明であれば特に限定はされないが、エポキシ樹脂の他、シリコーン樹脂、尿素樹脂、又はガラスが好適に用いられる。また、蛍光体／拡散材含有層２７との接着性、屈折率等の観点から、蛍光体／拡散材含有層２７の基材と同じ材料で形成されることが好ましい。

【００２９】封止レジン５０は、素子構造の保護等の目的で設けられるが、封止レジン５０の形状を目的に応じて変更することにより封止レジン５０にレンズ効果を付与することができる。例えば、図１に示される砲弾型の他、凹レンズ型、又は凸レンズ型等に成形することができる。また、光の取り出し方向（図１において上方）から見て封止レジン５０の形状を円形、楕円形、又は矩形とすることができる。

【００３０】以上のように構成されたＬＥＤ１では、発光素子１０から放出される青色光の一部が蛍光体／拡散材層２７中の蛍光体３０に照射し、蛍光体３０から蛍光が発せられる。この蛍光と、蛍光体の励起に利用されない青色光とが混色することにより、発光装置１からは白色系の光が発光する。ここで、発光素子１０から放出される光の一部は、蛍光体／拡散材層２７を通る際に拡散材３１に照射する。これにより光の拡散が生じ、蛍光体３０に対する効率的な光の照射が行われる。また、発光素子１０からの青色光と、蛍光体３０からの蛍光との混色が促進される。一方、蛍光体３０から発せられる蛍光の一部も蛍光体／拡散材層２７を通る際に拡散材３１により拡散されることから、当該蛍光と青色光との混色が一層促進される。このように、蛍光体３０の励起に利用されない青色光と、蛍光体３０からの蛍光との混色が効率的に行われることから、混色ムラ及び発光ムラが少なくなる。一方、蛍光体／拡散材層２７に含有される拡散材３１は、それに照射する光の多くを進行方向側に反射する。したがって、上記の構成では、拡散材３１での反射に起因する、光の取り出し方向に逆行する光の発生を大幅に抑制できる。即ち、発光素子１０からの光あるいは蛍光体３０により変換された光を効率よく光の取り出し方向に進行させることができ、高輝度の発光が得られる。

【００３１】上記発光素子１０に加えて、他の発光素子を併せて用いることもできる。他の発光素子としては発光素子１０と発光波長の異なる発光素子が用いられる。好ましくは、蛍光体３０を実質的に励起、発光させない発光波長を有する発光素子が用いられる。かかる他の発光素子を用いることにより、ＬＥＤ１の発光色を変化させ、又は調整することができる。また、発光素子１０を複数個用いて輝度アップを図ることもできる。

【００３２】図３に示すように、封止レジン５０に蛍光体３０及び拡散材３１を添加することにより、蛍光体／拡散材含有層２７を省略することもできる（ＬＥＤ２）。尚、図３において図１と同一の部材には同一の符号を付してある。この場合においても、上記蛍光体樹脂層２７における場合と同様に、封止レジン５０内において蛍光体３０及び／又は拡散材３１の濃度分布に傾斜を設けることができる。

【００３３】（実施例２）図４は、本発明の他の実施例であるＳＭＤタイプのＬＥＤ３の概略断面図である。実施例１のＬＥＤ１と同一の部材には同一の符号を付してその説明を省略する。ＬＥＤ３も実施例１と同様に白色系の発光をし、例えば、導光体と組み合わせて面状光源、線状光源に利用することができ、また、各種表示装置等にも利用することができる。発光素子１０は基板８０に銀ペースト等を用いて固定される。ワイヤ４０及び４１は発光素子１０の各電極を基板８０に設けられた電極８１及び８２にそれぞれ接続する。符号９０は、発光素子の周囲に形成されるリフレクタであって、その表面

Savant Technologies LLC - 1004.282

は鏡面化されている。

【００３４】基板８０及びリフレクタ９０で形成されるカップ状部には、蛍光体／拡散材含有層１００及び封止レジン８５が充填される。蛍光体／拡散材含有層１００は、蛍光体３０及び拡散材３１を分散したエポキシ樹脂からなる。蛍光体／拡散材含有層１００は、発光素子１０をマウントした後、ポッティングなどの方法により形成される。封止レジン８５はエポキシ樹脂からなり、蛍光体／拡散材含有層１００を形成した後、蛍光体／拡散材含有層１００と同様の方法により形成される。

【００３５】以上のように構成されたＬＥＤ３では、発光素子１０から放出される青色光の一部が蛍光体／拡散材層１００中の蛍光体３０に照射し、蛍光体３０から蛍光が発せられる。この蛍光と、蛍光体３０の励起に利用されない青色光とが混色することにより、ＬＥＤ３からは白色系の光が発光する。ここで、上記のＬＥＤ１の場合と同様に、蛍光体／拡散材含有層１００内の拡散材３１の作用により、発光素子１０からの青色光と蛍光体からの蛍光との混色が促進されるとともに、光の取り出し方向に逆行する光の発生が抑制される。その結果、混色ムラ及び発光ムラが少なく、高輝度に発光するＬＥＤとなる。

【００３６】図４のＬＥＤ３では蛍光体／拡散材含有層１００と封止レジン８５とを別個に設けたが、図５に示されるように封止レジン１０１に蛍光体３０及び拡散材３１を分散させてもよい。尚、図５において図４と同一の部材には同一の符号を付してある。

【００３７】また、リフレクタ９０を用いないＳＭＤタイプのＬＥＤ５を構成した例を図６に示す。ＬＥＤ５では、発光素子１０を被覆して断面略矩形の封止レジン１０２が形成される。封止レジン１０２は、蛍光体３０及び拡散材３１を分散させたエポキシ樹脂からなる。このような封止レジン１０２は所望の型を用いた型成型により形成することができる。また、予め所望の形状に成型した封止レジン１０２を用意しておき、これを発光素子１０を覆うように基板８０に接着させることによっても形成できる。

【００３８】この発明は、上記発明の実施の形態及び実施例の説明に何ら限定されるものではない。特許請求の範囲の記載を逸脱せず、当業者が容易に想到できる範囲で種々の変形態様もこの発明に含まれる。

【００３９】以下、次の事項を開示する。１０　前記発光素子は、リードフレームに設けられたカップ状部に載置され、前記光透過性材料層が前記カップ状部内に形成されている、ことを特徴とする請求項１～６のいずれかに記載の発光装置。１１　前記発光素子は、リードフレームに設けられたカップ状部に載置され、前記光透過性材料層により、前記発光素子、及び前記リードフレームの一部が被覆されている、ことを特徴とする請求項１～６のいずれかに記載の発光装置。１２　前記発光素子は基板に載置され、前記光透過性材料層が前記発光素子の表面を被覆するように形成されている、ことを特徴とする請求項１～６のいずれかに記載の発光装置。１３　前記発光素子は基板に載置され、前記光透過性材料層により前記発光素子が封止されている、ことを特徴とする請求項１～６のいずれかに記載の発光装置。１４　前記発光素子は基板に設けられたカップ状部に載置され、前記光透過性材料層が前記カップ状部内に形成されている、ことを特徴とする請求項１～６のいずれかに記載の発光装置。

【図面の簡単な説明】

【図１】図1は、本発明の一の実施例の砲弾型ＬＥＤ１を示す図である。

【図２】図２は、ＬＥＤ１に使用される発光素子１０の概略断面図である。

【図３】図３は、封止レジン５０に蛍光体３０及び拡散材３１を分散させた例（ＬＥＤ２）を示す図である。

【図４】図４は、本発明の他の実施例であるＳＭＤタイプのＬＥＤ３を示す図である。

【図５】図５は、同じく本発明の他の実施例であるＳＭＤタイプのＬＥＤ４を示す図である。

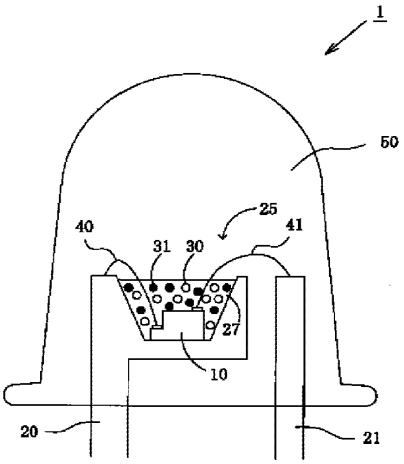
【図６】図６は、同じく本発明の他の実施例であるＳＭＤタイプのＬＥＤ５を示す図である。

【符号の説明】

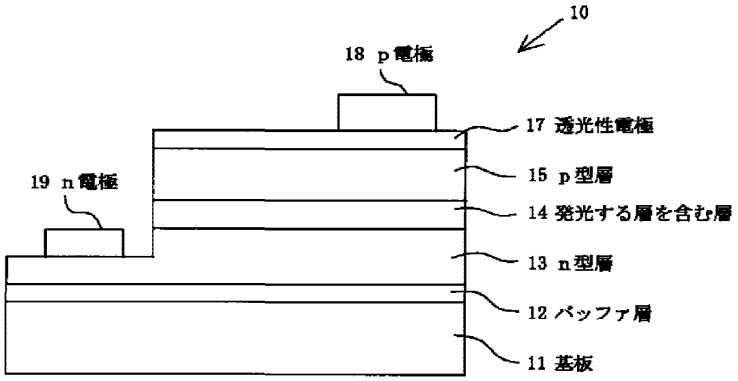
１、２　砲弾型ＬＥＤ
３、４、５　ＳＭＤタイプＬＥＤ
１０　発光素子
２７、１００　蛍光体／拡散材含有層
３０　蛍光体
３１　拡散材
５０、１０１、１０２　封止レジン

Savant Technologies LLC - 1004.283

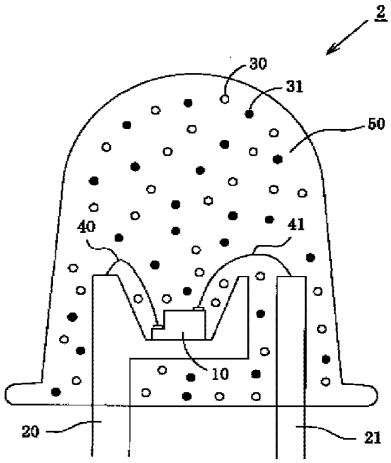
【図1】



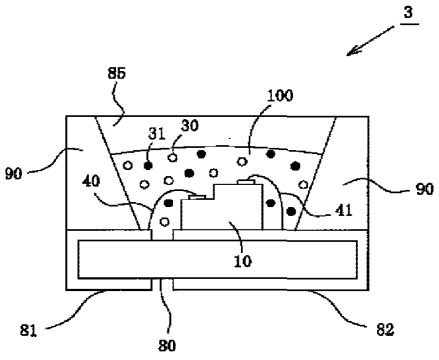
【図2】



【図3】

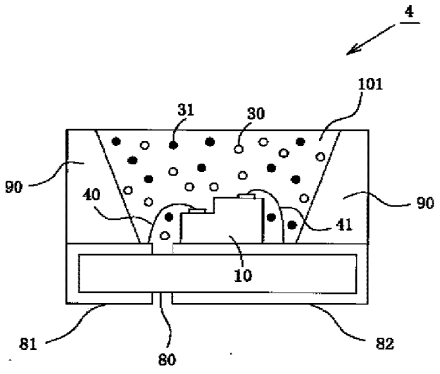


【図4】

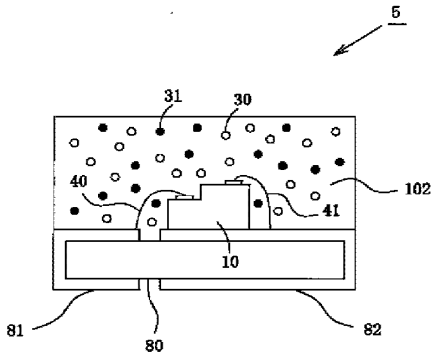


Savant Technologies LLC - 1004.284

【図5】



【図6】



フロントページの続き

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Savant Technologies LLC - 1004.285

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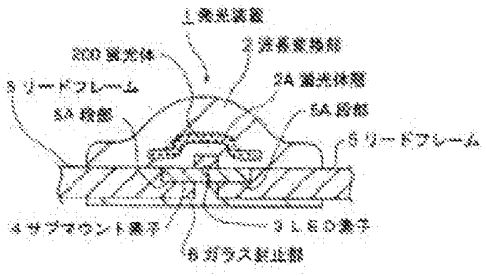
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(71)Applicant : **TOYODA GOSEI CO LTD**
(72)Inventor : **SUEHIRO YOSHINOBU**
TOUMON RYOICHI
KATO HIDEAKI

(54) LIGHT EMITTING DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a light emitting device which is excellent in moisture proof characteristic, light resistance characteristic and can obtain easily uniform wavelength conversion characteristic without lowering external radiation efficiency based on the light emission of an LED (light emitting diode) element.
SOLUTION: A fluorescent material layer 2A formed like a thin film on a glass sheet 201 is sandwiched with a glass sheet 202, and is thermally fused to form a wavelength converting unit 2. Consequently, the shape and the thickness of the fluorescent material layer 2A can be controlled easily with higher accuracy, and amount of use of the fluorescent material can be controlled accurately. Moreover, since the fluorescent material can be used effectively when the expensive fluorescent material is used, cost reduction of the light emitting device 1 can be realized.



Savant Technologies LLC - 1004.286

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(51)Int.Cl.[7]	F I		テーマコード（参考）
H01L 33/00	H01L 33/00	N	5F041

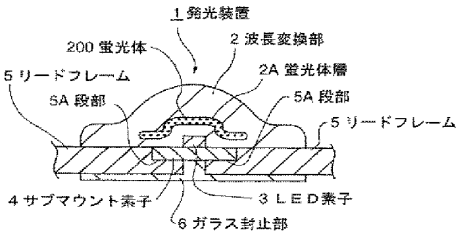
審査請求 未請求　請求項の数 5　OL　（全 12 頁）

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最終頁に続く

(54)【発明の名称】発光装置

(57)【要約】
【課題】耐湿性、耐光性に優れ、ＬＥＤ素子の発光に基づく外部放射効率を低下させることなく均一な波長変換性を容易に得ることができる発光装置を提供する。
【解決手段】ガラスシート２０１に薄膜状に形成された蛍光体層２Ａをガラスシート２０２で挟んで熱融着することによって波長変換部２を形成する。このことにより蛍光体層２Ａの形状、膜厚を容易に、かつ精度良く制御することが可能になり、蛍光体の使用量を正確に制御することができる。また、高価な蛍光体を使用する場合に蛍光体を無駄に使用することを防げるので、発光装置１のコストダウンを図れる。
【選択図】　図１



Savant Technologies LLC - 1004.287

【特許請求の範囲】
【請求項1】
所定の波長の光を放射する発光素子部と、
前記所定の波長の光によって励起される蛍光体を透明な不透湿性の材料で層状に包囲して形成される波長変換部とを有することを特徴とする発光装置。
【請求項2】
所定の波長の光を放射する発光素子部と、
前記所定の波長の光によって励起される蛍光体をガラスを含む不透湿性の材料で層状に包囲して形成される波長変換部とを有することを特徴とする発光装置。
【請求項3】
前記波長変換部は、前記発光素子部を包囲して密封するとともに前記蛍光体を前記発光素子部の周囲に薄膜状に配置することを特徴とする請求項第２項記載の発光装置。
【請求項4】
前記波長変換部は、前記発光素子部から所望の配光特性に応じて前記光を放射させる光学形状を有することを特徴とする請求項第２項記載の発光装置。
【請求項5】
前記波長変換部は、第１のガラスの表面に薄膜状に形成された前記蛍光体を第２のガラスで挟み込んで熱融着させることにより一体化されていることを特徴とする請求項第２項記載の発光装置。

【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、発光ダイオード（Ｌｉｇｈｔ－Ｅｍｉｔｔｉｎｇ　Ｄｉｏｄｅ：以下「ＬＥＤ」という。）から放射される光を蛍光体で吸収し、異なる波長の光に波長変換して放射させる発光装置に関し、特に、蛍光体の発光効率低下、および発光素子を封止する封止材の劣化を防いで信頼性に優れる発光装置に関する。
【０００２】
【従来の技術】
従来、ＬＥＤ素子から放射される光を蛍光体で波長変換して放射する発光装置がある。このような発光装置として、蛍光体を含有したエポキシ樹脂等の封止樹脂でＬＥＤ素子の周囲を覆って一体化したものがある。
【０００３】
ＬＥＤ素子を封止樹脂で封止することにより発光装置の設計自由度や生産性に優れる反面、ＬＥＤ素子から放射される光によって、封止樹脂の光学的特性および化学的特性が劣化し、その結果、発光装置の発光効率低下が生じることが問題視されている。
【０００４】
蛍光体を用いた波長変換型の発光装置では、蛍光体の発光効率低下が問題となる。例えば、エポキシ樹脂は透湿性を有し、多湿条件下で使用することによって樹脂に水分が浸透する。樹脂にこのような吸湿が生じると、蛍光体が浸透した水分によって変質又は分解を生じ、発光効率の低下が生じるという不都合がある。
【０００５】
また、上記したエポキシ樹脂は、ＬＥＤ素子から放射される強い光を受けることによって次第に黄変し、着色されてしまうことが知られている。このような着色が生じると、ＬＥＤ素子から放射される光が吸収されて発光装置の光出力を低下させるという問題がある。
【０００６】
かかる問題を解決するものとして、耐湿性を有するガラス層でＬＥＤ素子を封止するとともに、このガラス層に蛍光体を含有させた発光装置がある（例えば、特許文献１参照。）。
【０００７】
図１３は、特許文献１に示される発光装置を示す縦断面図である。

Savant Technologies LLC - 1004.288

この発光装置３０は、配線導体３１および３２と、配線導体３２に形成されるカップ３３と、カップ３３内の底部３３Ａに接着されるＬＥＤ素子３４と、ＬＥＤ素子３４の電極部と配線導体３１および３２とを電気的に接続するワイヤ３５と、カップ３３内に設けられるＬＥＤ素子３４を封止するガラス層３６と、ガラス層３６に含有される蛍光物質３６Ａと、光透過性を有して全体を封止する砲弾形状の封止樹脂３７とを有する。

【０００８】

このような構成によると、ＬＥＤ素子３４がカップ３３に注入されたガラス層３６によって包囲されるので、水分の透過が防止されて蛍光体の劣化を防げるとともに、黄変や着色による光の減衰が生じることを防止することができる。

【０００９】

【特許文献１】

特開平１１－２０４８３８号公報（第１図）

【００１０】

【発明が解決しようとする課題】

しかし、従来の発光装置によると、以下のような問題がある。

（１）配線導体に設けられたカップにガラスを注入してカップの底部に設けられたＬＥＤ素子を封止しているため、蛍光体がＬＥＤ素子の周囲に密集して沈降し、その部分で光が吸収されることによる光こもりが生じてＬＥＤ素子の外部放射効率を著しく低下させるという問題がある。

（２）蛍光体の配置はカップへのガラス注入操作に依存するため、ガラスに含有された蛍光体の状態によって均一な波長変換性を得ることが難しいという問題がある。これを防ぐにはガラス中に含有される蛍光体の混合状態を厳しく管理する必要がある。

【００１１】

従って、本発明の目的は、耐湿性、耐光性に優れ、ＬＥＤ素子の発光に基づく外部放射効率を低下させることなく均一な波長変換性を容易に得ることのできる発光装置を提供することにある。

【００１２】

【課題を解決するための手段】

本発明は、上記目的を達成するため、所定の波長の光を放射する発光素子部と、
前記所定の波長の光によって励起される蛍光体を透明な不透湿性の材料で層状に包囲して形成される波長変換部とを有することを特徴とする発光装置を提供する。

【００１３】

蛍光体を層状に包囲する不透湿性の材料としてはガラスを用いることが好ましい。このガラスとしては、低温での成形性が容易な低融点ガラスを用いることができる。

【００１４】

波長変換部は、発光素子部を包囲して密封するとともに蛍光体を発光素子部の周囲に薄膜状に配置することが好ましい。また、波長変換部は、発光素子部から所望の配光特性に応じて光を放射させる光学形状を有するように形成することもできる。また、波長変換部は、第１のガラスの表面に薄膜状に形成された蛍光体を第２のガラスで挟み込んで熱融着させることにより一体化することが可能である。

【００１５】

このような構成によれば、発光素子部から放射される光による封止材の劣化や、吸湿による蛍光体の分解又は変質が防止されることにより、波長変換性の劣化が生じなくなる。

【００１６】

【発明の実施の形態】

以下に、本発明の実施の形態を図面を参照しながら説明する。

図１は、本発明の第１の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、透明なガラス材によって形成されて蛍光体２００からなる蛍光体層２Ａを有する波長変換部２と、所定の波長の光を放射するＬＥＤ素子３と、ＬＥＤ素子３を搭載するサブマウント素子４と、ＬＥＤ素子３に電力を供給する配線導体であるリードフ

Savant Technologies LLC - 1004.289

レーム５と、リードフレーム５の下面を保護するガラス封止部６とを有する。

【００１７】

波長変換部２は、屈折率ｎ＝１．５の透明な低融点ガラスを使用し、２枚の低融点ガラスの間に薄膜状の蛍光体層２Ａを配置し、２枚のガラス材を熱融着して蛍光体層２Ａとともに一体化させることによって形成されている。また、波長変換部２は加熱プレスによって所望の配光特性に応じたドーム状の光学形状に成形されるとともにリードフレーム５上に融着固定されてＬＥＤ素子３を密封している。蛍光体層２Ａは、波長変換部２の成形に基づいてＬＥＤ素子３の発光観測面側を凸状に覆うように形成されている。

【００１８】

ＬＥＤ素子３は、Al_2O_3 基板を有するフリップチップ型の発光素子であり、発光波長は３８０ｎｍである。このＬＥＤ素子３は、電極部を図示しないＡｕバンプを介してサブマウント素子４に形成された配線パターンと電気的に接続されている。

【００１９】

サブマウント素子４は、ＡｌＮによって形成されており、その表面には銅箔によって図示しない配線パターンが形成されている。配線パターンはＬＥＤ素子３の電極部と電気的に接合されるとともにリードフレーム５とはんだ接合されている。

【００２０】

リードフレーム５は、銅あるいは銅合金によって形成されており、表面にＡｕめっき処理が施されている。サブマウント素子４と接合される先端部分は、サブマウント素子４の厚さに応じた段部５Ａが設けられており、この段部５Ａにはんだ接合されたサブマウント素子４の上面とリードフレーム５の上面とが平坦な面を形成するようになっている。

【００２１】

ガラス封止部６は、波長変換部２を構成する低融点ガラスと同一のガラス材によって形成されており、上記した加熱プレスに基づいて波長変換部２と一体化することによりリードフレーム５の下面を保護するようになっている。

【００２２】

図２（ａ）から（ｅ）は、波長変換部の製造工程を示す工程図である。

【００２３】

（１）準備工程

図２（ａ）は、準備工程におけるガラスシートの側面図である。

まず、シート状の低融点ガラスからなるガラスシート２０１を用意する。このガラスシート２０１は、長尺方向に複数のＬＥＤ素子３を配置することが可能な長さを有して形成されている。

【００２４】

（２）印刷工程

図２（ｂ）は、印刷工程におけるガラスシートの側面図である。

増粘材として約１％のニトロセルロースを含むｎ－酢酸ブチルに蛍光体２００を溶解した蛍光体溶液を作成し、この溶液をガラスシート２０１の表面にＬＥＤ素子３の配置間隔に応じたピッチでスクリーン印刷して薄膜状に付着させる。次に、蛍光体溶液を印刷されたガラスシート２０１を加熱処理して溶剤分を除去することにより蛍光体層２Ａを形成する。なお、加熱処理を減圧雰囲気中で行うようにしても良い。

【００２５】

（３）接合準備工程

図２（ｃ）は、接合準備工程におけるガラスシートの側面図である。

ガラスシート２０１と同じ低融点ガラスで形成されたガラスシート２０２を用意し、印刷工程で形成されたガラスシート２０２の蛍光体層２Ａを挟み込むようにして配置する。なお、ガラスシート２０１および２０２は同一の形状であることが好ましいが、異なる形状を有していても良い。

【００２６】

（４）接合工程

Savant Technologies LLC - 1004.290

図２（ｄ）は、接合工程におけるガラスシートの側面図である。
蛍光体層２Ａを挟み込んだガラスシート２０１および２０２を減圧雰囲気中で加熱プレスすることによって熱融着させる。蛍光体層２Ａは、熱融着されたガラスシート２０１および２０２の境界部分に位置するように層状に設けられる。
【００２７】
図２（ｅ）は、波長変換部の平面図である。
波長変換部２は、スクリーン印刷で形成された形状の蛍光体層２Ａをガラスシート２０１および２０２に挟み込んで形成されている。なお、同図においては蛍光体層２Ａを正方形としているが、この形状はスクリーン印刷が可能な種々の形状に変更が可能であり、例えば、円形状に形成することもできる。
【００２８】
図３および図４は、波長変換部を用いた発光装置の組み立てを示す工程図である。
【００２９】
（１）ＬＥＤ素子搭載工程
図３（ａ）は、素子搭載工程におけるリードフレームの平面図である。
銅合金の条材をプレス加工に基づいて打ち抜き加工することによりリードフレーム５を形成する。次に、リードフレーム５にＡｌＮからなるサブマウント素子４をはんだ接合する。次に、ＬＥＤ素子３の電極部をサブマウント素子４に形成される図示しない配線パターンに位置するように位置決めしてＡｕバンプを介して電気的に接合する。
【００３０】
（２）封止準備工程
図３（ｂ）は、封止準備工程におけるリードフレーム５を長手方向側面から見た側面図である。
リードフレーム５のＬＥＤ素子３搭載側に波長変換部２を配置する。次に、リードフレーム５の下側（ＬＥＤ素子３を搭載しない側）に低融点ガラスからなるガラスシート２０３を配置する。
【００３１】
（３）位置決め工程
図３（ｃ）は、位置決め工程におけるリードフレームの平面図である。
ＬＥＤ素子３に対して波長変換部２の蛍光体層２Ａが適正な位置に配置されるように、波長変換部２、リードフレーム５、およびガラスシート２０３の位置決めを行う。
【００３２】
図４（ａ）から（ｃ）は、波長変換部の成形工程および成形後の発光装置を示す図である。
図４（ａ）は、波長変換部２の成形工程における金型の縦断面図である。
リードフレーム５を波長変換部２およびガラスシート２０３で挟んだ状態で、上金型７０および下金型８０を用いて加熱プレスに基づくガラス材の成型を行う。上金型７０は、波長変換部２にドーム状の光学形状を形成するためのドーム形状部７０Ａを有して形成されている。下金型８０は、ガラスシート２０３を成型して発光装置１の底部を形成するための底部形状部８０Ａを有して形成されている。なお、ドーム形状部７０Ａおよび底部形状部８０Ａは、発光装置１に要求される光学特性や形状特性に応じて適切な形状を選択することができる。
【００３３】
図４（ｂ）は、成形後のリードフレームの平面図である。
波長変換部２は、上金型７０および下金型８０の加熱プレスに基づいてリードフレーム５のリード未形成部分に薄肉部２０４が形成される。
【００３４】
図４（ｃ）は、図４（ｂ）のＡ－Ａ部分における破断図である。
波長変換部２は、加熱プレスに基づいて上記したガラスシート２０３と熱融着することによって形成されるガラス封止部６とともにリードフレーム５を包囲しており、ＬＥＤ素子

Savant Technologies LLC - 1004.291

３の発光観測面側には加熱プレスに基づいて凸状に変形した蛍光体層２Ａが所定の間隔を有して配置される。また、薄肉部２０４は、後工程でのダイシング等によって発光装置１を分離する際にガラス材を損傷することのない厚さを有している。

【００３５】

以下に、第１の実施の形態における発光装置１の動作について説明する。

リードフレーム５に電源線を接続して、図示しない電源装置から電力を供給することによってＬＥＤ素子３が発光する。

【００３６】

ＬＥＤ素子３から放射される光は、ほぼ水平方向へ放射される光を除いて蛍光体層２Ａに照射される。蛍光体層２Ａでは、蛍光体２００が光によって励起されることに基づいて励起光を放射し、この励起光とＬＥＤ素子３から放射される光とが混合されることによって波長変換された光を生じる。この波長変換された光は、波長変換部２のドーム状に形成された光学形状部から所定の方向へ放射される。

【００３７】

上記した第１の実施の形態の発光装置１によると、以下の効果が得られる。

（１）ガラスシート２０１に薄膜状に形成された蛍光体層２Ａをガラスシート２０２で挟んで熱融着することによって波長変換部２を形成するようにしたので、蛍光体層２Ａの形状、膜厚を容易に、かつ精度良く制御することが可能になり、蛍光体の使用量を正確に制御することができる。例えば、ＹＡＧ（イットリウム・アルミニウム・ガーネット）等の高価な蛍光体を使用する場合には、蛍光体を無駄に使用することを防げるので、発光装置１のコストダウンを図れる。

（２）ガラスシート２０１および２０２の厚さを制御することでＬＥＤ素子３と蛍光体層２Ａとの配置（距離）を容易かつ正確に規定できるので、ガラス材の使用に基づく優れた防湿性、耐光性を有するとともに、蛍光体の光吸収による外部放射効率の低下や製品毎の発光効率にばらつきが生じることを防いで発光装置１の信頼性を高めることができる。

（３）蛍光体層２Ａが波長変換部２の加熱プレスによりＬＥＤ素子３の形状に応じた凸状に変形してＬＥＤ素子３を覆うので、蛍光体２００がＬＥＤ素子３から照射される光によって均一に励起されるようになる。このことによって蛍光体層２Ａ全体で均一に波長変換が行われるようになり、色むらの発生が抑制される。

（４）ＬＥＤ素子３を搭載したリードフレーム５に対して長尺状に形成された波長変換部２を位置決めして加熱プレスによって一体化するので、一度に多数の発光装置１を同時に、かつ精度良く形成できることから、生産性に優れる。

（５）通電量の増大によってＬＥＤ素子３の発熱量が大になる場合でも、波長変換部２を構成するガラス材によってＬＥＤ素子３の放熱性が確保されるので、高出力化、高輝度化に有効である。また、発光装置１としての耐湿性が向上するので、水中や多湿条件下での使用が可能になる。

【００３８】

図５は、第２の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、ｎ＝１．９の屈折率を有するガラス材によって形成される波長変換部２と、ＧａＮ基板を有し、このＧａＮ基板の角部が傾斜面を有するようにカットされたＬＥＤ素子３とを有する構成において第１の実施の形態の発光装置１と相違している。

【００３９】

上記した第２の実施の形態の発光装置１によると、高屈折率のガラス材を用いて波長変換部２を形成することで、第１の実施の形態の好ましい効果に加えてＬＥＤ素子３から放射される光の取出し効率が向上する。また、角部が傾斜面を有するようにカットされたＬＥＤ素子３を用いることで、波長変換部２とＬＥＤ素子３との境界面で反射された戻り光をＬＥＤ素子３の外部に再放射させ易くなる。

【００４０】

また、ＬＥＤ素子３の角部に傾斜を設けることで、ガラスモールド時に付与される外力を傾斜面に沿って逃がすことが可能になり、その結果として内部残留応力を小にできる。ま

Savant Technologies LLC - 1004.292

た、ガラス封止時にＬＥＤ素子３の表面に残留気泡が生じることを防げるので、クラック等の不良が生じにくくなる。

【００４１】

図６は、第３の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、白色ガラスからなるガラスシート２０３を用いてガラス封止部６を形成した構成において第１の実施の形態の発光装置１と相違している。

【００４２】

上記した第３の実施の形態の発光装置１によると、リードフレーム５の下面を保護するように白色ガラスからなるガラス封止部６を形成することで、第１の実施の形態の好ましい効果に加えてＬＥＤ素子３から発光装置１の下側に放射された光が白色ガラスで反射されて波長変換部２側に放射されるようになり、そのことによって光の放射効率を向上させることができる。

【００４３】

図７は、第４の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、ＬＥＤ素子３を搭載したサブマウント素子４の上面がリードフレーム５の上面から突出しており、蛍光体層２Ａは、ＬＥＤ素子３およびサブマウント素子４の突出形状に応じた形状でＬＥＤ素子３およびサブマウント素子４に対して所定の間隔を有して配置される構成において第１の実施の形態の発光装置１と相違している。

【００４４】

上記した第４の実施の形態の発光装置１によると、サブマウント素子４の上面をリードフレーム５の上面から突出させることで、第１の実施の形態の好ましい効果に加えて波長変換部２の熱融着時に蛍光体層２ＡがＬＥＤ素子３の発光観測面側から側面にかけて包囲することから、ＬＥＤ素子３から放射された光の多くが蛍光体層２Ａを通過することによって波長変換性が向上する。

【００４５】

図８は、第５の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、ＬＥＤ素子３およびサブマウント素子４の表面に沿うように蛍光体層２Ａを有する波長変換部２を設けたものであり、蛍光体層２Ａは、第１の実施の形態で説明したガラスシート２０１に蛍光体溶液をスクリーン印刷し、加熱処理して溶剤分を除去することにより薄膜状に形成したものである。このガラスシート２０１を蛍光体層２Ａが設けられた面がＬＥＤ素子３およびサブマウント素子４に対向するように配置し、リードフレーム５の下側にガラスシート２０３を配置して上金型７０および下金型８０を用いて加熱プレスによって一体化することにより形成する。

【００４６】

上記した第５の実施の形態の発光装置１によると、ガラス材による優れた防湿性が得られるとともに、１層のガラスシート２０１によって波長変換部２を形成できるので、第１の実施の形態で説明した接合準備工程および接合工程を省略でき、生産性および省コスト性に優れる。また、ＬＥＤ素子３の表面が蛍光体層２Ａの薄膜で覆われることから、光取り出し効率を低下させることなく波長変換性を向上させることができる。

【００４７】

なお、蛍光体層２Ａは、ガラス側に形成することに限定されず、スクリーン印刷等によって発光素子側に形成するようにしても同等の効果を得ることができる。

【００４８】

また、上記した各実施の形態では、サブマウント素子４を介してＬＥＤ素子３をリードフレーム５に搭載する構成について説明したが、ＬＥＤ素子３を他の基板材等に搭載する構成の発光装置１に適用することも可能である。

【００４９】

図９は、第６の実施の形態に係る発光装置の中心部分における縦断面図である。

この発光装置１は、透明なガラス材によって形成されて蛍光体２００からなる蛍光体層２Ａを有する波長変換部２と、スルーホール９Ａを有するセラミック基板９と、セラミック

Savant Technologies LLC - 1004.293

基板９の表面に銅箔によって形成される配線パターン９１および９２と、配線パターン９１に設けられる間隔部９１Ａと、配線パターン９１にＡｕバンプ３Ａを介して電気的に接合されるＬＥＤ素子３とを有する構成において第１の実施の形態の発光装置１と相違している。

【００５０】

セラミック基板９の配線パターン９１は、スルーホール９Ａを介して配線パターン９２と電気的に接続されており、配線パターン９２は、図示しない外部回路とはんだ接合等によって電気的に接続される。また、配線パターン９１は、波長変換部２との熱融着においてガラス材の密着性を高めることにより、防湿性を高めるようになっている。

【００５１】

図１０（ａ）から（ｃ）は、第６の実施の形態に係る発光装置の製造工程を示す図である。

以下の説明において、波長変換部２の製造工程については第１の実施の形態で説明したものと同じであることから、セラミック基板９を用いることによる製造工程について接説する。

【００５２】

図１０（ａ）は、ＬＥＤ素子を搭載したセラミック基板の平面図である。

セラミック基板９は、正方形状に形成されており、その表面および裏面に配線パターン９１および９２が形成されている。ＬＥＤ素子３は、配線パターン９１に対して位置決めされた後、Ａｕバンプ接合される。同図においては３行×３列＝９個のＬＥＤ素子３が配線パターン９１上に搭載されている。

【００５３】

また、セラミック基板９より小なるサイズで正方形状の波長変換部２を別工程で形成し、ＬＥＤ素子３が搭載されたセラミック基板９に対し、波長変換部２を位置決めして分割可能な一対の金型で加熱プレスすることにより、波長変換部２をセラミック基板９に密着させる。ここで、波長変換部２をセラミック基板９より小なるサイズで形成するのは、加熱プレス時に溶融したガラス材がセラミック基板９の周囲に回り込んで金型の分離を阻害することを防ぐためである。

【００５４】

図１０（ｂ）は、波長変換部を加熱プレスしたセラミック基板の平面図である。

波長変換部２は、加熱プレスに基づいてセラミック基板９の表面に密着するとともに薄肉部２０４が形成されている。

【００５５】

図１０（ｃ）は、セラミック基板の側面図である。

波長変換部２に形成された薄肉部２０４をダイシング等でセラミック基板９とともに切断することにより、発光装置１として分離することができる。

【００５６】

上記した第６の実施の形態の発光装置１によると、第１の実施の形態の好ましい効果に加えてセラミック基板９を用いることでサブマウント素子４を設けることなく配線パターン９１にＬＥＤ素子３を搭載できることから、ＬＥＤ素子３の搭載を容易に行えるようになり。生産性が向上する。また、配線パターン９１の銅箔は波長変換部２のガラス材との密着性に優れることから、セラミック基板９と波長変換部２との境界部分における防湿性を高めることができる。

【００５７】

また、上記した発光装置１では、ＬＥＤ素子３から放射させる光を波長変換部２に透過させる構成を説明したが、例えば、単独の波長変換体として用いることも可能である。

【００５８】

図１１は、第７の実施の形態に係る波長変換体の動作原理図である。

この波長変換部２は、白色ガラスからなるガラスシート２０１と、透明ガラスからなるガラスシート２０２と、ガラスシート２０１および２０２との間に挟み込まれて封止された

Savant Technologies LLC - 1004.294

蛍光体層２Ａによって構成されており、レーザダイオード等の光源３００から入射する光を拡散反射する波長変換体を構成している。なお、白色ガラスを用いる代わりにアルミ板等の高反射金属を用いても良い。

【００５９】

上記した第７の実施の形態の波長変換体によると、ガラス材によって蛍光体層２Ａを封止しているので、防湿性に優れ、蛍光体２００の吸湿による変質や劣化が生じないとともに耐光性に優れることから、長期にわたって安定した波長変換性が得られる。また、波長変換体を光源３００と独立して設けることができ、寿命や損傷が生じた場合でも波長変換体のみを単独で交換すれば良く、所望の波長変換性を速やかに復元できる。

【００６０】

なお、上記した波長変換体は光反射型の構成であるが、光透過型の波長変換体とすることも可能である。

【００６１】

図１２は、第８の実施の形態に係る光透過型の波長変換部を用いた発光装置の縦断面図である。

この発光装置１は、エポキシ等の樹脂で形成された本体１０と、本体１０の内側に傾斜を有して形成された光反射部１０Ａと、本体１０の内側底部に露出した銅箔からなる配線部１１と、配線部１１にＡｕバンプ３Ａを介して電気的に接続されるＬＥＤ素子３と、配線部１１を表面に形成されて本体１０と一体化されるセラミック基板９と、本体１０の上部開口部に配置される光透過型の波長変換部２とを有し、本体１０の内部はシリコン樹脂１２によって充填されている。

【００６２】

上記した第８の実施の形態の発光装置１によると、ＬＥＤ素子３から放射された光が本体１０の上部開口部に配置された波長変換部２に照射されることによって蛍光体層２Ａの蛍光体が励起される。このことにより蛍光体層２ＡでＬＥＤ素子３からの光と励起光とが混合されて波長変換が行われる。このような光透過型としても防湿性、耐光性に優れ、光放射効率が良好な発光装置１を形成できる。

【００６３】

【発明の効果】

以上説明した通り、本発明の発光装置によると、発光素子部から放射される光によって励起される蛍光体を透明な不透湿性の材料で層状に包囲して波長変換部を形成したため、耐湿性、耐光性に優れ、ＬＥＤ素子の発光に基づく外部放射効率を低下させることなく均一な波長変換性を容易に得ることができる。

【図面の簡単な説明】

【図１】本発明の第１の実施の形態に係る発光装置の中心部分における縦断面図である。

【図２】（ａ）から（ｅ）は、波長変換部の製造工程を示す工程図であり、（ａ）は、準備工程におけるガラスシートの側面図。（ｂ）は、印刷工程におけるガラスシートの側面図。（ｃ）は、接合準備工程におけるガラスシートの側面図。（ｄ）は、接合工程におけるガラスシートの側面図。（ｅ）は、波長変換部の平面図である。

【図３】波長変換部を用いた発光装置の組み立てを示す工程図であり、（ａ）は、素子搭載工程におけるリードフレームの平面図。（ｂ）は、封止準備工程におけるリードフレームを長手方向側面から見た側面図。（ｃ）は、位置決め工程におけるリードフレームの平面図である。

【図４】波長変換部を用いた発光装置の組み立てを示す工程図であり、（ａ）は、波長変換部の成形工程における金型の縦断面図。（ｂ）は、成形後のリードフレームの平面図。（ｃ）は、図４（ｂ）のＡ－Ａ部分における破断図である。

【図５】第２の実施の形態に係る発光装置の中心部分における縦断面図である。

【図６】第３の実施の形態に係る発光装置の中心部分における縦断面図である。

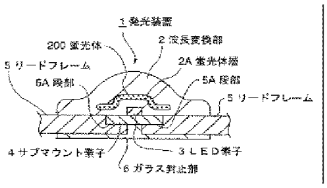
【図７】第４の実施の形態に係る発光装置の中心部分における縦断面図である。

【図８】第５の実施の形態に係る発光装置の中心部分における縦断面図である。

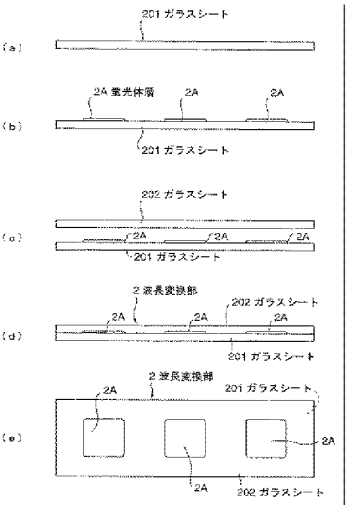
Savant Technologies LLC - 1004.295

【図９】第６の実施の形態に係る発光装置の中心部分における縦断面図である。
【図１０】第６の実施の形態に係る発光装置の製造工程を示す図であり、（ａ）は、ＬＥＤ素子を搭載したセラミック基板の平面図。（ｂ）は、波長変換部を加熱プレスしたセラミック基板の平面図。（ｃ）は、セラミック基板の側面図である。
【図１１】第７の実施の形態に係る波長変換体の動作原理図である。
【図１２】第８の実施の形態に係る光透過型の波長変換部を用いた発光装置の縦断面図である。
【図１３】特許文献１に示される発光装置を示す縦断面図である。
【符号の説明】
１、発光装置　２、波長変換部　２Ａ、蛍光体層　３、ＬＥＤ素子
３Ａ、Ａｕバンプ　４、サブマウント素子　５、リードフレーム
５Ａ、段部　６、ガラス封止部　９、セラミック基板　９Ａ、スルーホール
１０、本体　１０Ａ、光反射部　１１、配線部　１２、シリコン樹脂
３０、発光装置　３１、配線導体　３２、配線導体　３３、カップ
３３Ａ、底部　３４、素子　３５、ワイヤ　３６、ガラス層
３６Ａ、蛍光物質　３７、封止樹脂　７０、上金型　７０Ａ、ドーム形状部
８０、下金型　８０Ａ、底部形状部　９１Ａ、間隔部　９１、配線パターン
９２、配線パターン　２００、蛍光体　２０１、ガラスシート
２０２、ガラスシート　２０３、ガラスシート　２０４、薄肉部
３００、光源

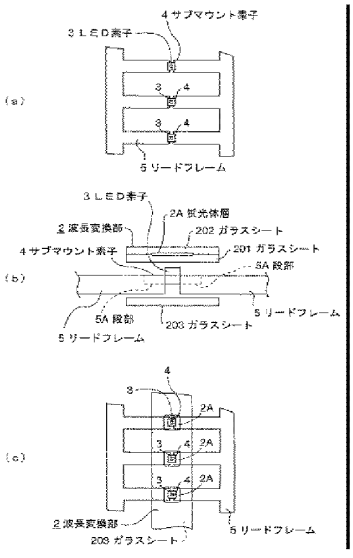
【図1】



【図2】

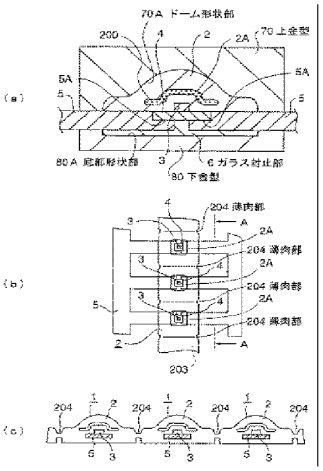


【図3】

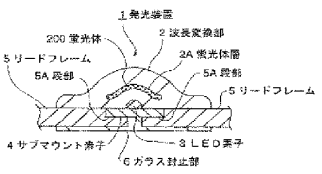


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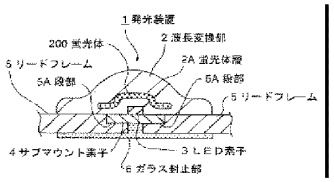
【図4】



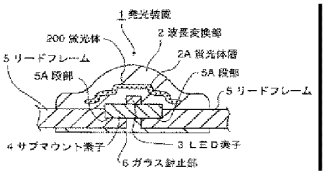
【図5】



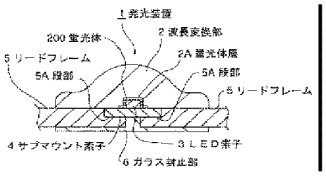
【図6】



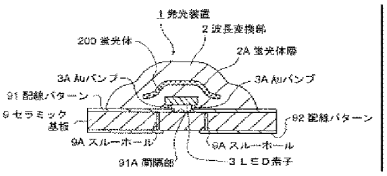
【図7】



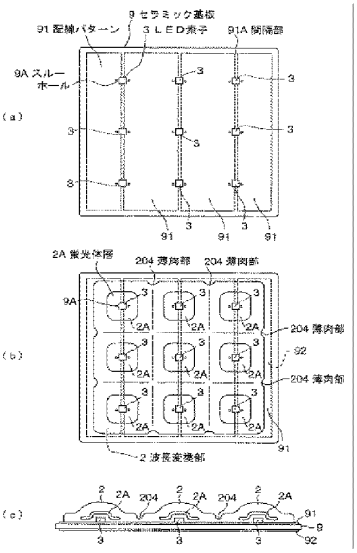
【図8】



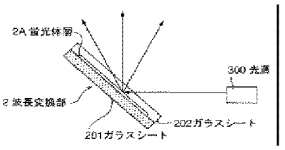
【図9】



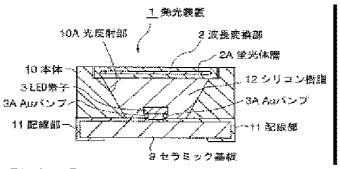
【図10】



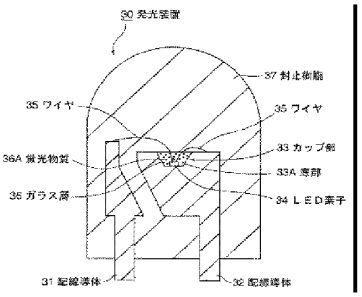
【図11】



【図12】



【図13】



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(54) 백색 발광 장치

(57) 요약

휘도와 연색지수가 개선된 백색 발광 장치를 제공한다. 본 발명에 따른 백색 발광 장치는, 자외선 LED와; 상기 자외선 LED를 봉지하는 몰딩 수지와; 상기 자외선 LED에서 방출된 자외선에 의해 여기되어 각각 청색, 녹색 및 적색광을 발하는 청색, 녹색 및 적색 형광체와; 상기 자외선 LED에서 방출된 자외선을 상기 형광체로 반사시키는 반사 매체를 포함한다.

대표도

도 2

특허청구의 범위

청구항 1.

자외선 LED;

상기 자외선 LED를 봉지하는 몰딩 수지;

상기 자외선 LED에서 방출된 자외선에 의해 여기되어 각각 청색, 녹색 및 적색광을 발하는 청색, 녹색 및 적색 형광체; 및

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상기 자외선 LED에서 방출된 자외선을 상기 형광체로 반사시키는 반사 매체를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 2.

제1항에 있어서,

상기 반사 매체는, 상기 몰딩 수지 상에 형성되어 자외선을 반사시키고 가시광선을 투과시키는 자외선 반사막을 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 3.

제2항에 있어서,

상기 자외선 반사막은 다층 유전체막으로 이루어진 것을 특징으로 하는 백색 발광 장치.

청구항 4.

제3항에 있어서,

상기 다층 유전체막은 서로 다른 굴절율을 갖는 2이상의 유전체막을 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 5.

제3항에 있어서,

상기 다층 유전체막은 TiO_2, ZrO_2, MgF_2 및 LiF_2로 이루어진 그룹으로부터 선택된 적어도 하나를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 6.

제3항에 있어서,

상기 다층 유전체막은 제1 굴절율의 제1 유전체막과 제1 굴절율보다 작은 제2 굴절율의 제2유전체막이 서로 교대로 적층되어 형성된 다층막인 것을 특징으로 하는 백색 발광 장치.

청구항 7.

제6항에 있어서,

상기 제1 굴절율은 1.82 내지 2.5이고, 상기 제2 굴절율은 1.35 내지 1.45인 것을 특징으로 하는 백색 발광 장치.

청구항 8.

제2항에 있어서,

상기 백색 발광 장치는 상기 몰딩 수지와 상기 자외선 반사막 사이에 배치된 유리 기판을 더 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 9.

제1항에 있어서,

상기 반사 매체는, 상기 몰딩 수지 내에 분산되어 상기 자외선 LED에서 방출된 자외선을 반사시키는 반사용 분말 매체를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 10.

제9항에 있어서,

상기 반사용 분말 매체는 MgO, $BaSO_4$, Al_2O_3, ZrO_2 및 TiO_2로 구성된 그룹으로부터 적어도 하나 선택된 재료로 이루어진 것을 특징으로 하는 백색 발광 장치.

청구항 11.

제9항에 있어서,

상기 반사용 분말 매체의 입자 크기는 상기 자외선의 파크 방출 파장보다 더 큰 것을 특징으로 하는 백색 발광 장치.

청구항 12.

제9항에 있어서,

상기 형광체와 상기 반사용 분말 매체는 상기 몰딩 수지 내에 균일하게 혼합되어 있는 것을 특징으로 하는 백색 발광 장치.

청구항 13.

제9항에 있어서,

상기 형광체와 상기 반사용 분말 매체는 상기 자외선 LED 상에서 서로 분리되어 불연속적인 층 구조를 형성하는 것을 특징으로 하는 백색 발광 장치.

청구항 14.

제13항에 있어서,

상기 형광체는 상기 자외선 LED 위에 배치되고 상기 반사용 분말 매체는 상기 형광체 위에 배치되는 것을 특징으로 하는 백색 발광 장치.

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청구항 15.

제1항에 있어서,

상기 반사 매체는,

상기 몰딩 수지 상에 형성되어 자외선을 반사시키고 가시광선을 투과시키는 자외선 반사막; 및

상기 몰딩 수지 내에 분산되어 상기 자외선 LED에서 방출된 자외선을 반사시키는 반사용 분말 매체를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 16.

제1항에 있어서,

상기 백색 발광 장치는 반사컵을 갖는 케이싱을 더 포함하고,

상기 자외선 LED는 상기 반사컵 내에 실장되어 있고, 상기 반사컵은 그 내측면에 형성된 반사면을 갖는 것을 특징으로 하는 백색 발광 장치.

청구항 17.

제16항에 있어서,

상기 반사컵은 프레스된 $BaSO_4$로 형성된 반사면을 갖는 것을 특징으로 하는 백색 발광 장치.

청구항 18.

제1항에 있어서,

상기 자외선 LED 상에 형성된 광산란층을 더 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 19.

제18항에 있어서,

상기 광산란층의 상면부의 평균 입자 크기는 상기 자외선의 파장과 같거나 그보다 더 큰 것을 특징으로 하는 백색 발광 장치.

청구항 20.

제18항에 있어서,

상기 광산란층의 굴절율은, 상기 자외선 LED의 구성물질의 굴절율과 같거나 그보다 더 큰 것을 특징으로 하는 백색 발광 장치.

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청구항 21.

제18항에 있어서,

상기 광산란층은 Al_2O_3, SiO_2 및 SiN_x 로 구성된 그룹으로부터 선택된 물질로 이루어진 것을 특징으로 하는 백색 발광 장치.

청구항 22.

제18항에 있어서,

상기 광산란층은 바닥부에 형성된 서브코팅부를 포함하고,

상기 서브코팅부의 평균 입자 크기는 상기 광산란층의 상면부의 평균 입자 크기보다 작고,

상기 서브코팅부의 평균 입자 크기는 상기 청색광의 파장과 같거나 그보다 작은 것을 특징으로 하는 백색 발광 장치.

청구항 23.

제22항에 있어서,

상기 서브 코팅부의 굴절율은, 상기 청색 LED의 구성물질의 굴절율과 같거나 그보다 더 큰 것을 특징으로 하는 백색 발광 장치.

청구항 24.

제22항에 있어서,

상기 서브코팅부는 형광체 물질로 이루어진 것을 특징으로 하는 백색 발광 장치.

청구항 25.

제1항에 있어서,

상기 자외선 LED는 350 내지 410nm의 피크 방출 파장을 갖는 것을 특징으로 하는 백색 발광 장치.

청구항 26.

제1항에 있어서,

상기 청색 형광체는 420 내지 480nm의 피크 방출 파장을 갖고, 상기 녹색 형광체는 490 내지 550nm의 피크 방출 파장을 갖고, 상기 적색 형광체는 580 내지 620nm의 피크 방출 파장을 갖으며,

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상기 청색 형광체는 상기 자외선에 의해 여기되어 청색광을 방출하고, 상기 녹색 형광체는 상기 자외선과 상기 청색광에 의해 여기되어 녹색광을 방출하고, 상기 적색 형광체는 상기 자외선과 상기 청색광과 상기 녹색광에 의해 여기되어 적색광을 방출하는 것을 특징으로 하는 백색 발광 장치.

청구항 27.

제1항에 있어서,

상기 청색 형광체는 $(Sr,Ca)_5(PO_4)_3Cl:Eu^{2+}$, $La_{2.99}Ce_{0.01}(SiS_4)_2$l 및 $Ce_3(SiS_4)_2X$ (X는 Cl, Br 또는 I)로 이루어진 그룹으로부터 적어도 하나 선택된 형광체를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 28.

제1항에 있어서,

상기 녹색 형광체는 $SrGa_2S_4:Eu^{2+}$ 및 $(Ba,Sr)_2SiO_4:Eu^{2+}$로 이루어진 그룹으로부터 적어도 하나 선택된 형광체를 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 29.

제1항에 있어서,

상기 적색 형광체는 $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$을 포함하는 것을 특징으로 하는 백색 발광 장치.

청구항 30.

제1항에 있어서,

상기 청색, 녹색 및 적색 형광체는, 각각 분리되어 있으며, 상기 자외선 LED 상에 불연속적인 층 구조를 형성하는 것을 특징으로 하는 백색 발광 장치.

청구항 31.

제30항에 있어서,

상기 적색 형광체는 상기 자외선 LED 상에 있고, 상기 녹색 형광체는 상기 적색 형광체 상에 있고, 상기 청색 형광체는 상기 녹색 형광체 상에 있는 것을 특징으로 하는 백색 발광 장치.

명세서

발명의 상세한 설명

발명의 목적

발명이 속하는 기술 및 그 분야의 종래기술

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본 발명은 백색 발광 장치에 관한 것으로, 보다 상세하게는 자외선 발광 다이오드(자외선 LED 또는 UV LED 라고도 함)와 형광 물질들을 구비하는 백색 발광 장치에 관한 것이다.

백색 LED 장치는, 종래의 소형 램프 또는 형광 램프 대신에 액정 표시 장치의 백라이트(backlight)로 사용되고 있다. S. Nakamura 외의 "The Blue Laser", pp. 216-221 (Springer 1997)의 Chapter 10.4에서 논의된 바와 같이, 백색 LED 장치는 청색 LED의 출사면 상에 세라믹 형광체층을 형성함으로써 제조될 수 있다.

종래의 대표적인 백색 LED 장치는, InGaN 양자 우물을 갖는 청색 LED와 $Y_3Al_5O_{12}:Ce^{3+}$(YAG:Ce) 황색 형광체를 구비한다. 청색 LED로부터 방출된 청색광은 상기 형광체를 여기시킴으로써 황색광을 방출시킨다. 청색 LED로부터의 청색광과 황색 형광체로부터의 황색광은 혼합됨으로써, 관찰자에게 백색광으로 인식된다.

또한, 백색광을 발생시키기 위해, 청색 LED는 적색 형광체 및 녹색 형광체와 결합될 수 있다. 적절한 형광체는 약 420 내지 480nm의 범위에서 높은 여기 효율과 넓은 색도 영역(chromatic zone)을 가져야 한다.

또한, 백색광은 적색 LED, 녹색 LED 및 청색 LED를 결합함으로써 얻을 수 있다. 그러나, 다른 LED는 다른 전기적 광학적 특성(예컨대, 광속(lumen) 대 수명 프로파일, 출력광의 파워 대 입력 전류 곡선, 및 저항 대 온도 곡선 등)을 갖기 때문에, 이러한 LED들의 조합은 백색 발광 장치의 제조 비용을 증가시키고 장치의 소형화에 불리하며 일관적인 색도 및 균일성을 갖는 빛을 내지 못한다.

백색 LED 장치를 구현하기 위한 다른 방안으로서, 청, 적 및 녹색 형광체가 자외선 LED(UV LED)와 결합될 수 있다. 이 형광체들은 UV LED로부터 방출되는 자외선을 백색광으로 변환하기위해 사용된다. 이에 사용되는 각각의 형광체는 전자기 스펙트럼의 소정 영역에서 에너지를 흡수하여 다른 영역의 방사 에너지를 방출한다. 통상, 방출되는 광자의 에너지는 흡수되는 광자의 에너지보다 낮다. 백색광을 얻기 위해서, UV LED와 결합되는 형광체들은 가시 영역 밖에 있는 방사 에너지(자의선)의 흡수에 응답하여 스펙트럼의 가시 영역에 있는 방사 에너지(가시광)를 방출한다.

그러나, 실제로 백색광을 얻기 위해, 자외선에 의해 여기되어 각각 적, 녹, 청색 영역의 빛을 발하는 적절한 3개의 형광체를 찾기가 매우 어렵다. 일반적으로, 적색 형광체의 양자 수율(quantum yield)은 녹색 및 청색 형광체에 비하여 매우 낮다. 따라서, 우수한 연색 지수를 갖는 고품질의 백색광을 얻지 못하고 있는 실정이다.

도 1은 UV LED를 사용한 종래의 백색 발광 장치를 개략적으로 나타낸 단면도이다. 도 1을 참조하면, 백색 발광 장치(50)는, 반사컵(reflect cup: 55)이 형성된 케이싱(51)과 케이싱(51) 내에 실장된 UV LED(52)를 포함한다. 반사컵(55)의 측면은 반사면(56)을 형성한다. 반사컵(55) 내에는 UV LED(52)를 봉지하는 몰딩 수지(57)가 형성되어 있고, 이 몰딩 수지(57)에는 형광체(53)가 분산되어 있다. 형광체(53)는 청색 형광체, 녹색 형광체 및 적색 형광체로 이루어질 수 있으며, 이들은 UV LED(52)에서 나온 자외선에 의해 여기되어 각각 청색광, 녹색광 및 적색광을 발한다. 형광체(53)에서 방출되는 청, 녹 및 적색광은 서로 혼색되어 백색광을 출력하게 된다.

그러나, 이러한 종래의 백색 발광 장치(50)에 따르면, 형광체(53)(특히, 적색 형광체)의 양자 수율이 충분하지 않고 발광 장치(50) 내에서의 광손실이 상당하다. 따라서, 발광 장치(50)의 전체 휘도가 낮고 충분한 발광효율과 우수한 연색지수를 얻기가 어렵다.

발명이 이루고자 하는 기술적 과제

본 발명은 상기한 문제점을 해결하기 위한 것으로서, 본 발명의 목적은 UV LED를 구비한 백색 발광 장치로서 발광효율과 연색지수가 개선된 고품질 고휘도의 백색 발광 장치를 제공하는 것이다.

발명의 구성

상술한 기술적 과제를 달성하기 위하여, 본 발명에 따른 백색 발광 장치는, UV LED와; 상기 UV LED를 봉지하는 몰딩 수지와; 상기 UV LED에서 방출된 자외선에 의해 여기되어 각각 청색, 녹색 및 적색광을 발하는 청색, 녹색 및 적색 형광체와; 상기 UV LED에서 방출된 자외선을 상기 형광체로 반사시키는 반사 매체를 포함한다.

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본 발명의 바람직한 실시형태에 따르면, 상기 반사 매체는, 상기 몰딩 수지 상에 형성되어 자외선은 반사시키되 가시광선은 투과시키는 자외선 반사막(UV 반사막)을 포함한다. 바람직하게는, 상기 UV 반사막은 다층 유전체막(multilayer dielectric film)으로 이루어진다. 상기 다층 유전체막은 서로 다른 굴절율을 갖는 2이상의 유전체막을 포함한다. 상기 다층 유전체막은 TiO_2, ZrO_2, MgF_2 및 LiF_2로 이루어진 그룹으로부터 적어도 하나를 포함할 수 있다. 바람직하게는, 상기 다층 유전체막은 제1 굴절율의 제1 유전체막과 제1 굴절율보다 작은 제2 굴절율의 제2유전체막이 서로 교대로 적층되어 형성된 다층막이다. 바람직하게는, 상기 제1 굴절율은 1.82 내지 2.5이고, 상기 제2 굴절율은 1.35 내지 1.45이다. 상기 백색 발광 장치는 상기 몰딩 수지와 상기 자외선 반사막 사이에 배치된 유리 기판을 더 포함할 수 있다.

본 발명의 실시형태에 따르면, 상기 반사 매체는, 상기 몰딩 수지 내에 분산되어 상기 UV LED에서 방출된 자외선을 반사시키는 반사용 분말 매체를 포함할 수 있다. 상기 반사용 분말 매체는 MgO, $BaSO_4$, Al_2O_3, ZrO_2 및 TiO_2로 구성된 그룹으로부터 적어도 하나 선택된 재료로 이루어질 수 있다. 바람직하게는, 상기 반사용 분말 매체의 입자 크기는 상기 자외선의 피크 방출 파장(peak emission wavelength)보다 더 크다.

본 발명의 일 실시형태에서는, 상기 형광체와 상기 반사용 분말 매체는 상기 몰딩 수지 내에 균일하게 혼합될 수 있다. 다른 실시형태에 따르면, 상기 형광체와 상기 반사용 분말 매체는 상기 UV LED 상에서 서로 분리되어 불연속적인 층 구조를 형성할 수 있다. 이 경우, 바람직하게는 상기 형광체는 상기 UV LED 위에 배치되고 상기 반사용 분말 매체는 상기 형광체 위에 배치된다.

본 발명의 실시형태에 따르면, 상기 반사 매체는, 상기 UV 반사막과 상기 반사용 분말 매체를 함께 포함할 수도 있다. 이 경우, 반사 매체에 의한 자외선 반사 효과는 더욱 증대된다.

바람직한 실시형태에 따르면, 상기 백색 발광 장치는 반사컵을 갖는 케이싱을 더 포함하고, 상기 UV LED는 상기 반사컵 내에 실장되어 있다. 상기 반사컵은 그 내측면에, 에컨대 프레스된 $BaSO_4$로 형성된 반사면을 가질 수 있다.

본 발명의 실시형태에 따르면, 상기 백색 발광 장치는 상기 UV LED 상에 형성된 광산란층을 더 포함할 수 있다. 바람직하게는, 상기 광산란층의 상면부의 평균 입자 크기는 상기 자외선의 파장과 같거나 그보다 더 크다. 바람직하게는, 상기 광산란층의 굴절율은, 상기 UV LED의 구성물질의 굴절율과 같거나 그보다 더 크다. 상기 광산란층은 Al_2O_3, SiO_2 및 SiN_x 로 구성된 그룹으로부터 선택된 물질로 이루어질 수 있다.

상기 광산란층은 그 바닥부에 서브코팅부(subcoating)-상기 서브코팅부의 평균 입자 크기는 상기 광산란층 상면부의 평균 입자 크기보다 더 작고 상기 자외선 파장이하임-를 포함할 수 있다. 바람직하게는, 상기 서브 코팅부의 굴절율은, 상기 UV LED의 구성물질의 굴절율과 같거나 그보다 더 크다. 상기 서브코팅부는 형광체 물질로 이루어질 수 있다.

본 발명의 바람직한 실시형태에 따르면, 상기 청색 형광체는 420 내지 480nm의 피크 방출 파장(peak emission wavelength)을 갖고, 상기 녹색 형광체는 490 내지 550nm의 피크 방출 파장을 갖고, 상기 적색 형광체는 580 내지 620nm의 피크 방출 파장을 갖는다. 또한, 상기 청색 형광체는 상기 자외선에 의해 여기되어 청색광을 방출하고, 상기 녹색 형광체는 상기 자외선과 상기 청색광에 의해 여기되어 녹색광을 방출하고, 상기 적색 형광체는 상기 자외선과 상기 청색광과 상기 녹색광에 의해 여기되어 적색광을 방출한다. 바람직하게는, 상기 UV LED는 350 내지 410nm의 피크 방출 파장을 갖는다.

바람직하게는, 상기 청색 형광체는 $(Sr,Ca)_5(PO_4)_3Cl:Eu^{2+}$, $La_{2.99}Ce_{0.01}(SiS_4)_2I$ 및 $Ce_3(SiS_4)_2X$ (X는 Cl, Br 또는 I)로 이루어진 그룹으로부터 적어도 하나 선택된 형광체를 포함한다. 바람직하게는, 상기 녹색 형광체는 $SrGa_2S_4:Eu^{2+}$ 및 $(Ba,Sr)_2SiO_4:Eu^{2+}$로 이루어진 그룹으로부터 적어도 하나 선택된 형광체를 포함한다. 바람직하게는, 상기 적색 형광체는 $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$을 포함한다.

본 발명의 바람직한 실시형태에 따르면, 상기 청색, 녹색 및 적색 형광체는, 각각 분리되어 있으며, 상기 UV LED 상에 불연속적인 층 구조를 형성한다. 바람직하게는, 상기 적색 형광체는 상기 UV LED 상에 있고, 상기 녹색 형광체는 상기 적색 형광체 상에 있고, 상기 청색 형광체는 상기 녹색 형광체 상에 있다. 바람직하게는, 상기 청색, 녹색 및 적색 형광체는 상기 몰딩 수지 내에 분산되어 있다.

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이하, 첨부된 도면을 참조하여 본 발명의 실시형태를 설명한다. 그러나, 본 발명의 실시형태는 여러가지 다른 형태로 변형될 수 있으며, 본 발명의 범위가 이하 설명하는 실시형태로 한정되는 것은 아니다. 본 발명의 실시형태는 당업계에서 평균적인 지식을 가진 자에게 본 발명을 보다 완전하게 설명하기 위해서 제공되는 것이다.

도 2는 본 발명의 백색 발광 장치를 개략적으로 나타낸 단면도이다. 도 2를 참조하면, 백색 발광 장치(100)는 케이싱(101)과 UV LED(102)를 포함한다. 케이싱(101)에는 오목한 반사컵(105)이 형성되어 있고, UV LED(102)는 이 반사컵(105)의 바닥에 실장되어 있다. 반사컵(105)은 그 내측면에, 반사면(106)을 가진다. 반사면(106)은, 예컨대 프레스된 $BaSO_4$ (pressed $BaSO_4$)로 형성될 수 있다. 반사면(106)은, 반사면(106)에 입사된 빛을 상방향으로 반사시킴으로써, 출력광의 휘도를 높이는 역할을 한다. 또한, 반사컵(105) 내에는 UV LED(102)를 봉지하는 투광성 몰딩 수지(107)가 채워져 있다.

몰딩 수지(107)에는 파장 변환용 형광체(103)가 분산되어 있다. 형광체(103)는 청색 형광체, 녹색 형광체 및 적색 형광체로 이루어지며, 이들은 UV LED(102)로부터 나온 자외선에 의해 여기되어 각각 청색광, 녹색광 및 적색광을 발한다. 청색광, 녹색광 및 적색광은 서로 혼색되어 백색광을 출력하게 된다.

도 2를 참조하면, 백색 발광 장치(100)는 몰딩 수지(107) 상에 형성된 UV 반사막(108)을 구비한다. 이 UV 반사막(108)은 일종의 반사 매체로서, 자외선을 반사시키는 반면 가시광선을 투과시키는 일종의 대역 통과 필터(band pass filter) 특성을 갖는다. 이러한 UV 반사막(108)을 사용하면, 백색 발광 장치(100)의 휘도와 발광 효율이 향상되는데, 이는 UV 반사막(108)에 의해 반사된 자외선이 형광체(103)를 또다시 여기시키기 때문이다. 즉, 형광체(103)는, UV LED(102)로부터 직접 입사된 자외선에 의해 여기될 뿐만 아니라, UV 반사막(108)에 의해 반사된 자외선에 의해서도 여기된다. 몰딩 수지(107)와 UV 반사막(108) 사이에는 유리 기판(미도시)이 배치될 수도 있다.

UV 반사막(108)은 다층 유전체막(multilayer dielectric film)으로 이루어질 수 있다. 이 경우, UV 반사막(108)은 서로 다른 굴절율(n)을 갖는 2이상의 유전체막으로 이루어질 수 있다. 특히 UV 반사막(108)은 고굴절율 유전체막(바람직하게는, n=1.82~2.5)과 저굴절율 유전체막(바람직하게는, n=1.35~1.45)이 서로 교대로 적층되어 형성된 다층막일 수 있다. UV 반사막(108)을 이루는 다층 유전체막은, TiO_2 (n=2.38), ZrO_2 (n=1.99), MgF_2 (n=1.38) 및 LiF_2 (n=1.39)로 이루어진 그룹으로부터 선택된 적어도 하나를 포함할 수 있다. 예컨대, UV 반사막(108)은 TiO_2막(n=2.38)과 MgF_2막(n=1.38)을 서로 교대로 적층함으로써 만들어질 수 있다.

도 3은 본 발명의 다른 실시형태에 따른 백색 발광 장치를 개략적으로 나타낸 단면도이다. 도 3을 참조하면, 백색 발광 장치(200)는 반사 매체로서, 전술한 UV 반사막(108)과 함께, 반사용 분말 매체(104)를 더 포함한다. 이 반사용 분말 매체(104)는 UV LED(102)로부터 나온 자외선의 일부를 반사시킨다. 반사용 분말 매체(104)에 의해 반사된 자외선은 (청색 형광체, 녹색 형광체 및 적색 형광체의 조합인) 형광체(103)를 추가적으로 여기시킨다. 추가적인 여기에 의해 청색광, 녹색광 및 적색광이 추가적으로 발생하고, 형광체(103)의 전체적인 양자 효율을 증대시키게 된다. 이에 따라, 백색 발광 장치(100)의 전체적인 휘도는 더 증가하게 되고, 출력되는 백색광의 연색 지수는 더욱 개선된다.

바람직하게는, 반사용 분말 매체(104)는 MgO, $BaSO_4$, Al_2O_3, ZrO_2 및 TiO_2로 구성된 그룹으로부터 적어도 하나 선택된 재료로 이루어진다. 예를 들어, 상기 반사용 분말 매체는 사파이어(Al_2O_3) 재료를 사용하여 만들어질 수 있다. 그 밖에도 반사율이 높은 금속 또는 무기재료로 반사용 분말 매체(104)를 만들 수 있다. 자외선을 충분히 반사시킬 수 있도록, 반사용 분말 매체(104)의 입자 크기는 상기 자외선의 피크 방출 파장보다 더 큰 것이 바람직하다. 반사면(106)은 반사용 분말 매체(104)와 동일한 분말 물질로 만들어질 수 있다.

형광체(103)와 반사용 분말 매체(104)는 몰딩 수지(107) 내에 균일하게 혼합될 수 있다. 이와 달리, 형광체(103)와 반사용 분말 매체(104)는 UV LED(102) 상에서 서로 분리되어 불연속적인 층 구조를 형성할 수도 있다. 이 경우, 형광체(103)는 상기 UV LED(102) 위에 배치되고 반사용 분말 매체(104)는 형광체(103) 위에 배치되는 것이 바람직하다. 이러한 순서로 형광체 층과 반사용 분말 매체 층을 배치함으로써, 반사용 분말 매체에 의해 반사된 자외선은 후방에 위치하는 형광체를 보다 더 용이하게 여기시킬 수 있게 된다.

도 4는 또 다른 실시형태에 따른 백색 발광 장치의 단면도이다. 도 4를 참조하면, 백색 발광 장치(300)는, 반사 매체인 UV 반사막(108) 및 반사용 분말 매체(104)와 함께, 광산란층(110)을 포함한다. 이 광산란층(110)은 UV LED(102)로부터의 광선 경로의 대칭(symmetry of ray paths)과, 전반사(total internal reflection) 매카니즘을 수정하는 역할을 한다. 이러한 광산란층(110)에 의해, UV LED(102)로부터의 광추출 효율이 향상된다.

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도 10은 본 발명의 일 실시형태에 따른 광산란층을 개략적으로 나타낸 단면도이다. 도 10을 참조하면, 광산란층(110)은 UV LED(102)의 광출사면 상에 형성되어, UV LED(102)와의 계면에서 자외선을 터널링시킨다. 이에 따라, UV LED(102)에서 나온 자외선의 대칭이 변화되고 UV LED(102)와의 계면에서의 전반사 매카니즘이 달라지게 된다. 또한 광산란층(110)의 상면부는, 광산란층(110)을 통과하는 자외선을 산란시킨다. 이러한 자외선의 터널링 현상과 산란 특성은, 자외선을 몰딩 수지쪽으로 쉽게 추출될 수 있도록 돕는다.

UV LED(102)의 활성 영역(26)에서 발생된 자외선(27)의 일부(30)는 광산란층(110)과 LED(102) 간의 계면에서 터널링되고, 상기 자외선(27)의 다른 일부(29)는 그 계면에서 반사된다. 이러한 터널링 현상은, 자외선(27)이 임계각보다 더 큰 입사각으로 입사될 경우에도 발생한다. 즉, UV LED(102)의 표면과 광산란층(110)의 입자(111) 표면 간의 거리가 자외선(27)의 파장에 상당하거나 그보다 더 작을 경우에는, UV LED(102)로부터 광산란층(110)으로의 자외선의 터널링 현상이 발생하게 된다. 상기 터널링된 자외선은 광산란층(110)을 통과하여 광산란층(110)의 상면부에서 산란됨으로써, 외부로(몰딩 수지 쪽으로) 용이하게 빠져나오게 된다.

광산란층(110)이 갖는 산란 특성은, 광산란층(110)을 구성하는 입자의 크기, 특히 광산란층(110)의 상면부에서의 입자 크기에 영향을 받는다. 상기 광산란층(110)의 표면에서 자외선을 효과적으로 산란시키기 위해서는, 상기 광산란층(110)의 상면부의 평균 입자 크기는 자외선의 파장과 같거나 그보다 더 크다.

바람직하게는, 광산란층(110)의 굴절율은, UV LED(102)의 구성물질의 굴절율과 같거나 그보다 더 크다. 이와 같이, UV LED(102)의 굴절율 이상의 굴절율을 갖는 광산란층(110)을 사용함으로써, 광산란층(110)과 UV LED(102) 간의 계면에서의 전반사 현상을 더욱 감소시킬 수 있게 된다.

바람직하게는, 광산란층(110) 내의 입자 단층(particle monolayers)의 수는 1 내지 5이다. 광산란층(110)의 입자 단층의 수가 너무 많으면 광산란층(110)에서의 빛의 흡수량이 커지기 때문에, 상기 입자 단층의 수는 5를 넘지않는 것이 바람직하다.

광산란층(110)은 예를 들어, Al_2O_3, SiO_2 및 SiN_x 로 구성된 그룹으로부터 선택된 물질로 이루어질 수 있다. 이와 달리, 상기 광산란층은 절연성 폴리머로 이루어질 수도 있다. 도 10에 도시된 바와 같이, 광산란층(110)은 균일한 입자 크기를 갖는 단일 물질로 이루어질 수 있다. 예를 들어, 광산란층(110)은 약 1㎛의 평균 입자 크기를 갖는 사파이어(Al_2O_3) 입자로 이루어질 수 있다. 그러나, 광산란층은 다른 입자 크기를 갖는 단일 물질로 이루어지거나, 다른 입자 크기를 갖는 다른 물질들로 이루어질 수도 있다.

도 11은 본 발명의 다른 실시형태에 따른 광산란층을 개략적으로 나타낸 단면도이다. 도 11을 참조하면, 광산란층(110)은 그 바닥부에 형성된 서브코팅부(121)를 포함한다. 이 서브코팅부(121)의 평균 입자 크기는 광산란층(110)의 상면부(111')의 평균 입자 크기보다 작으며, 또한 UV LED(102)로부터 나온 자외선의 파장이하이다. 서브코팅부(121)는 광산란층(110)의 일부를 구성하며, 광산란층(110)과 동일한 물질로 이루어질 수 있다.

이러한 서브코팅부(121)는, UV LED(102)와 광산란층(110) 계면에서의 빛의 터널링 현상을 크게 촉진시킨다. 구체적으로 설명하면, 서브코팅부(121)의 입자 크기가 자외선의 파장이하이기 때문에, UV LED(102)의 표면과 서브코팅부(121)의 입자 표면 간의 거리가 청색광 파장에 상당하거나 그보다 더 작게 된다. 따라서, UV LED(102)의 표면상에 입사된 빛은 대부분 터널링하게 된다. 즉, 청색광(27)의 대부분(30)은, 서브코팅부(121)와 LED(102) 간의 계면에서 터널링되고, 극히 일부(29)만이 반사된다.

바람직하게는, 서브코팅부(121)의 굴절율은 UV LED(102)의 구성물질의 굴절율과 같거나 그보다 더 크다. 예컨대, 자외선이 LED(102)의 사파이어 기판쪽으로 출사되는 경우, 서브코팅부(121)의 굴절율은 사파이어 기판의 굴절율에 상당하거나 그보다 더 클 수 있다.

도 12는 본 발명의 또 다른 실시형태에 따른 광산란층을 개략적으로 나타낸 단면도이다. 도 12를 참조하면, 광산란층(110)의 바닥부에 배치된 서브코팅부(131)는 광산란층(110)의 상면부와는 다른 물질로 이루어져 있다. 예컨대, 광산란층(110)의 상면부는 사파이어 입자들로 이루어지고, 서브코팅부(131)는 형광체 물질로 이루어질 수 있다. 서브코팅부(131)를 형성하는 형광체 물질은 몰딩 수지(107) 내에 분산된 형광체(103)와 동일한 물질일 수도 있다.

Savant Technologies LLC - 1004.309

전술한 실시형태들에서는, 반사 매체로서 UV 반사막만을 구비하거나 UV 반사막과 반사용 분말 매체를 함께 구비하고 있다. 그러나, 본 발명이 이에 한정되는 것은 아니며, 예를 들어 반사 매체로서 반사용 분말 매체만을 구비할 수도 있다.

바람직하게는, UV LED(102)에서 나오는 자외선은 350 내지 410nm의 범위에서 피크 방출 파장(peak enission wavelength)을 가진다. 바람직하게는, 청색 형광체는 420 내지 480nm의 피크 방출 파장을 가지며, 녹색 형광체는 490 내지 550nm의 피크 방출 파장을 가지며, 적색 형광체는 580 내지 620m의 피크 방출 파장을 가진다. 바람직하게는, 상기 형광체들은 UV LED(102)의 방출 파장에서 높은 광자 효율을 갖는다. 또한, 각 형광체들은 다른 형광체에 의해 방출된 가시광선에 대해 상당한 투광성을 가진다.

바람직하게는, 녹색 형광체는 UV LED(102)와 청색 형광체에 의해 2중 여기되고, 적색 형광체는 UV LED(102)와 청색 형광체와 녹색 형광체에 의해 3중 여기된다. 이에 따라, 적색 형광체 및 녹색 형광체의 양자 수율은 더욱 커지게 된다. 결국, 백색 발광 장치의 전체 휘도(또는 발광 효율) 및 연색지수가 향상된다.

구체적으로 설명하면, 녹색 형광체는 UV LED(102)로부터 방출된 자외선에 의해 여기될 뿐만 아니라, 청색 형광체의 방출광(청색광)에 의해서도 여기된다. 이에 따라, 녹색 형광체의 양자 수율은 높아지게 된다. 특히 종래에 쓸데없이 버려지는 청색 방출광(예컨대, 출사면의 후방으로 빠져나가는 청색 방출광)을 녹색 형광체를 여기시키는 데에 사용한다면, 전체적인 발광 효율은 더욱 더 커지게 된다. 바람직하게는, 자외선 및 청색광에 의해 충분히 효율적으로 여기될 수 있도록, 상기 녹색 형광체는 350 내지 480nm의 범위에서 피크 여기 파장(peak excitation wavelength)을 갖는다.

또한, 적색 형광체는 UV LED(102)에서 방출된 자외선에 의해 여기될 뿐만 아니라, 청색 형광체의 방출광(청색광) 및 녹색 형광체의 방출광(녹색광)에 의해서도 여기된다. 이에 따라, 적색 형광체의 양자 수율은 높아지게 된다. 특히 종래 문제가 되었던 적색 형광체의 낮은 양자 수율(이로 인한 백색광의 연색지수 악화)이 극복 또는 경감될 수 있다. 더욱이 종래에 쓸데없이 버려지는 청색광 및 녹색광(예컨대, 출사면의 후방으로 빠져 나가는 청색 방출광 및 녹색 방출광)을 적색 형광체를 여기시키는 데에 사용한다면, 전체적인 발광 효율은 더욱 더 커지게 된다. 바람직하게는, 상기 청색광 및 녹색광에 의해 충분히 효율적으로 여기될 수 있도록, 상기 적색 형광체는 420 내지 480nm의 범위 및 490 내지 550nm의 범위에서 각각 피크 여기 파장를 갖는다. 더 바람직하게는, 350 내지 410nm의 범위, 420 내지 480nm의 범위 및 490 내지 550nm의 범위에서 각각 피크 여기 파장을 갖는다.

전술한 바와 같이 녹색 형광체와 적색 형광체의 다중 여기(multiexcitation)를 이용함으로써, 이들 형광체의 양자 수율이 증대될 수 있다. 이에 따라, 전체적인 발광 효율, 휘도 및 연색지수가 종래에 비하여 개선된 고품질의 백색광을 출력하게 된다.

도 5는 본 발명의 바람직한 실시형태에 따른 백색 발광 장치의 동작 원리를 설명하기 위한 모식도이다. 도 5을 참조하면, UV LED(102)는 자외선(2)을 방출하여 이를 청색 형광체, 녹색 형광체 및 적색 형광체에 입사시킨다. 청색 형광체는 자외선(2)을 흡수하여(상기 자외선(2)에 의해 여기되어), 420 내지 480nm의 피크 방출 파장을 갖는 청색광(4, 5, 6)을 방출한다.

녹색 형광체는 자외선(2)과 청색 형광체의 방출광(청색광(5))을 흡수한 후, 490 내지 550nm의 피크 방출 파장을 갖는 녹색광(7, 8, 9)을 방출한다. 녹색광(7)은 청색 형광체의 방출광(청색광(5))의 흡수로 인해 녹색 형광체에 의해 방출된 녹색광이다. 녹색광(9)은 UV LED(102)의 방출광(자외선(2))의 흡수로 인해 녹색 형광체에 의해 방출된 녹색광이다.

적색 형광체는 자외선(2), 청색 형광체의 방출광(청색광(6)) 및 녹색 형광체의 방출광(녹색광(8))을 흡수한 후, 580 내지 620nm의 피크 방출 파장을 갖는 적색광(10, 11, 12)을 방출한다. 특히 적색 형광체가 420 내지 480nm의 범위 및 490 내지 550nm의 범위에서 각각 피크 여기 파장을 가질 경우, 상기 청색광(6) 및 녹색광(8)을 효과적으로 흡수할 수 있다. 적색광(10)은 청색 형광체의 방출광(6)의 흡수로 인해 적색 형광체에 의해 방출된 적색광이다. 적색광(11)은 녹색 형광체의 방출광(8)의 흡수로 인해 적색 형광체에 의해 방출된 적색광이다. 적색광(12)는 UV LED(102)의 방출광(자외선(2))의 흡수로 인해 적색 형광체에 의해 방출된 적색광이다. 이와 같이, 형광체들의 다중 여기로 인해 빛을 보다 효율적으로 이용할 수 있으며, 연색 지수를 더욱 개선할 수 있게 된다.

도 5를 참조하면, 반사 매체(R)에 의해 반사된 자외선에 의해 형광체들이 추가적으로 여기된다. 전술한 UV 반사막(108) 및/또는 반사용 분말 매체(104)이 반사 매체(R)에 해당된다. 반사 매체(R)는 자외선(2)을 반사시키고, 그 반사된 자외선에

의해 청색, 녹색 및 적색 형광체가 추가적으로 여기될 수 있다. 이에 따라, 청색, 녹색 및 적색 형광체는 추가적으로 청색광(14), 녹색광(17) 및 적색광(20)을 각각 발생시킨다. 반사 매체(R)에 의한 추가적 여기로 인해 형광체들의 광자 효율은 더욱 높아지게 된다.

상술한 UV LED(102), 형광체 및 반사 매체 간의 상호 작용에 의해, 관찰자는 청색광(4, 14), 녹색광(7, 9, 17) 및 적색광(10, 11, 12, 20)의 조합을 백색광(40)으로 감지하게 된다. 이 백색광(40)은 보다 우수한 휘도와 연색지수를 나타냄은 이미 설명한 바와 같이 명백하다.

바람직하게는, 청색 형광체는, $(Sr, Ca)_5(PO_4)_3Cl:Eu^{2+}$, $La_{2.99}Ce_{0.01}(SiS_4)_2I$ 및 $Ce_3(SiS_4)_2X$ (X는 Cl, Br 또는 I)로 이루어진 그룹으로부터 적어도 하나 선택될 수 있다. 이들 형광체는 약 450 내지 480nm의 범위에서 피크 방출 파장을 갖는 것으로 알려져 있다.

바람직하게는, 녹색 형광체는 $SrGa_2S_4:Eu^{2+}$ 및 $(Ba,Sr)_2SiO_4:Eu^{2+}$로 이루어진 그룹으로부터 적어도 하나 선택될 수 있다. 이들 형광체는 약 490 내지 530nm의 범위에서 피크 방출 파장을 갖는 것으로 알려져 있다. 특히, $SrGa_2S_4:Eu^{2+}$ 형광체가 바람직하다. $SrGa_2S_4:Eu^{2+}$ 형광체는 350 내지 500nm의 파장을 갖는 입사광에 대해 적어도 90%의 양자 효율을 갖고 있기 때문에, 녹색 형광체의 2중 여기(double excitation)가 매우 용이하다.

바람직하게는, 적색 형광체로는 $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$을 사용할 수 있다. 이 형광체는 자외선 영역(350 내지 410nm), 청색 영역(420 내지 480nm) 및 녹색 영역(490 내지 550nm)에서 각각 피크 여기 파장을 갖는다. 따라서, 3중 여기 형광체(triple excited phosphor)에 대한 유력한 후보 물질이 된다.

도 6은 본 발명의 일 실시형태의 백색 발광 장치에 사용되는 형광체들간의 에너지 전이를 개략적으로 나타낸 모식도이다. 도 6를 참조하면, 청색 형광체는 400nm 정도의 자외선을 흡수하여(즉, 자외선에 의해 여기되어) 465nm 정도의 청색광을 방출한다. 녹색 형광체는 400nm 정도의 자외선뿐만 아니라 청색 형광체의 방출광 일부를 흡수하여 530nm 정도의 녹색광을 방출한다. 적색 형광체는 자외선, 청색 형광체의 방출광 및 녹색 형광체의 방출광을 흡수하여 613nm 정도의 적색광을 방출한다. 이와 같이 본 실시형태의 백색 발광 장치는 다중 흡수 또는 다중 여기를 기초로 동작하여 백색광을 출력할 수 있다.

도 7은 본 발명의 일 실시형태에서 사용되는 적색 형광체의 여기 스펙트럼과 발광 스펙트럼을 나타내는 그래프이다. 특히, 도 7은 $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$의 여기 스펙트럼(excitation spectrum)과 발광 스펙트럼(emission spectrum)을 나타낸다. 도 7에서 여기 스펙트럼은 613nm의 발광 파장에서 측정한 여기 스펙트럼이며, 발광 스펙트럼은 395nm의 여기광 파장을 사용하여 얻은 발광 스펙트럼이다. 도 7에 도시된 바와 같이, $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$은 약 395nm에서 뿐만 아니라, 약 460nm 및 약530nm에서도 피크 여기 파장을 갖는다. 피크 방출 파장은 약 613nm 정도이다. 따라서, $Ca(Eu_{0.5}La_{0.5})Si_3O_{13}$은 전술한 바와 같은 '3중 여기가 가능한 적색 형광체'에 해당한다.

도 8a 및 도 8b는 각각 본 발명의 일 실시형태에서 사용되는 청색 형광체의 여기 스펙트럼 및 발광 스펙트럼을 나타내는 그래프이다. 특히, 도 8a는 $La_{2.99}Ce_{0.01}(SiS_4)_2I$ 및 $Ce_3(SiS_4)_2X$ (X는 Cl, Br 또는 I)의 여기 스펙트럼을 나타내며, 도 8b는 그 발광 스펙트럼을 나타낸다. 도 8a 및 도 8b에서 알 수 있는 바와 같이, $La_{2.99}Ce_{0.01}(SiS_4)_2I$ 및 $Ce_3(SiS_4)_2X$ (X는 Cl, Br 또는 I)는 350 내지 410nm의 자외선에 의해 효율적으로 여기되어 420 내지 480nm의 청색광을 방출할 수 있다.

도 9a 및 도 9b는 각각 본 발명의 일 실시형태에서 사용되는 녹색 형광체의 여기 스펙트럼 및 발광 스펙트럼을 나타내는 그래프이다. 특히, 도 9a 및 9b는 각각 $SrGa_2S_4:Eu^{2+}$의 여기 스펙트럼 및 방출 스펙트럼을 나타낸다. 도 9a에 도시된 바와 같이 $SrGa_2S_4:Eu^{2+}$은 350 내지 410nm의 범위에서 뿐만 아니라 420 내지 480nm의 범위에서도 충분한 여기가 발생하여 상당한 강도의 녹색광을 방출시킬 수 있다. 따라서, $SrGa_2S_4:Eu^{2+}$은 전술한 바와 같은 '2중 여기가 가능한 녹색 형광체'에 해당한다.

상술한 형광체의 다중 여기를 이용하는 경우, 청색, 녹색 및 적색 형광체는 서로 분리된 층 구조를 형성하는 것이 바람직하다. 이는, 형광체들의 혼합물을 이용하는 것보다 각각 분리된 층구조의 형광체를 이용하는 것이, 출사면 후방으로 방출되

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는 버려지는 방출광을 효율적으로 이용하기에 더 적합하기 때문이다. 이 경우, 바람직하게는, 청색 형광체보다 녹색 형광체를 더 후방으로(즉, UV LED(102)에 더 가깝게) 배치하고, 녹색 형광체보다 적색 형광체를 더 후방으로 배치한다. 이렇게 배치함으로써, 청색 형광체로부터 후방으로 방출된 빛(5, 6)은 녹색 형광체 및 적색 형광체에 의해 용이하게 흡수되고, 녹색 형광체로부터 후방으로 방출된 빛(8)은 적색 형광체에 의해 용이하게 흡수될 수 있다 (도 5 참조).

본 발명은 상술한 실시형태 및 첨부된 도면에 의해 한정되는 것이 아니고, 첨부된 청구범위에 의해 한정하고자 하며, 청구범위에 기재된 본 발명의 기술적 사상을 벗어나지 않는 범위 내에서 다양한 형태의 치환, 변형 및 변경이 가능하다는 것은 당 기술분야의 통상의 지식을 가진 자에게 자명할 것이다.

발명의 효과

이상 설명한 바와 같이 본 발명에 따르면, UV LED, 적색 형광체, 녹색 형광체, 청색 형광체 및 반사 매체를 사용함으로써, 향상된 휘도와 발광 효율 및 연색 지수를 갖는 고품질 백색 발광을 얻게 된다. 또한, 부가적으로 광산란층을 구비함으로써 광 추출 효율을 높일 수 있고, 다중 여기의 녹색 및 청색 형광체를 사용함으로써 발광 효율을 더욱 높일 수 있게 된다.

도면의 간단한 설명

도 1은 종래의 백색 발광 장치를 개략적으로 나타낸 단면도이다.

도 2는 본 발명의 일 실시형태에 따른 백색 발광 장치를 개략적으로 나타낸 단면도이다.

도 3은 본 발명의 다른 실시형태에 따른 백색 발광 장치를 개략적으로 나타낸 단면도이다.

도 4는 본 발명의 또 다른 실시형태에 따른 백색 발광 장치를 개략적으로 나타낸 단면도이다.

도 5는 본 발명의 실시형태에 따른 백색 발광 장치의 동작 원리를 나타낸 모식도이다.

도 6은 본 발명의 일 실시형태의 백색 발광 장치에 사용되는 형광체들간의 에너지 전이를 개략적으로 나타낸 모식도이다.

도 7은 본 발명의 일 실시형태에서 사용되는 적색 형광체의 여기 스펙트럼과 발광 스펙트럼을 나타내는 그래프이다.

도 8a는 본 발명의 일 실시형태에서 사용되는 청색 형광체의 여기 스펙트럼을 나타내는 그래프이다.

도 8b는 본 발명의 일 실시형태에서 사용되는 청색 형광체의 발광 스펙트럼을 나타내는 그래프이다.

도 9a는 본 발명의 일 실시형태에서 사용되는 녹색 형광체의 여기 스펙트럼을 나타내는 그래프이다.

도 9b는 본 발명의 일 실시형태에서 사용되는 녹색 형광체의 발광 스펙트럼을 나타내는 그래프이다.

도 10 내지 도 12는 본 발명의 여러 실시형태에 따른 광산란층을 개략적으로 나타낸 단면도들이다.

<도면의 주요부분에 대한 부호의 설명>

100: 백색 발광 장치 101: 케이싱

102: 자외선 LED (UV LED) 103: 형광체

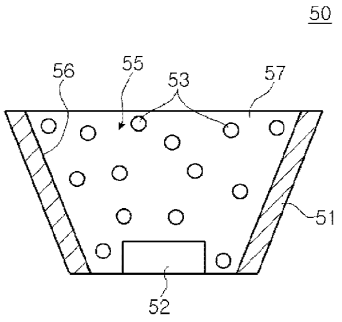
104: 반사용 분말 매체 105: 반사컵

106: 반사면 107: 몰딩 수지

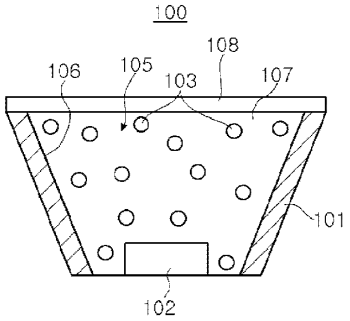
108: 자외선 반사막 (UV 반사막) 110: 광산란층

도면

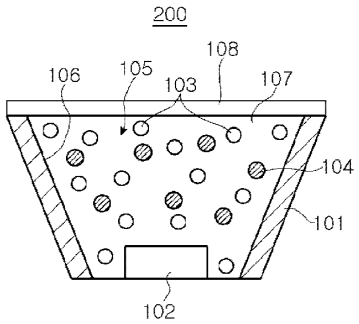
도면1



도면2

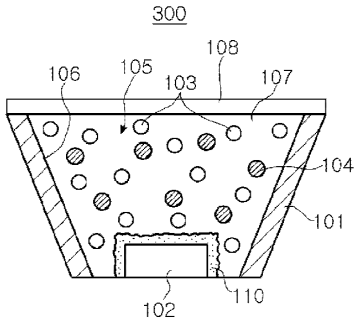


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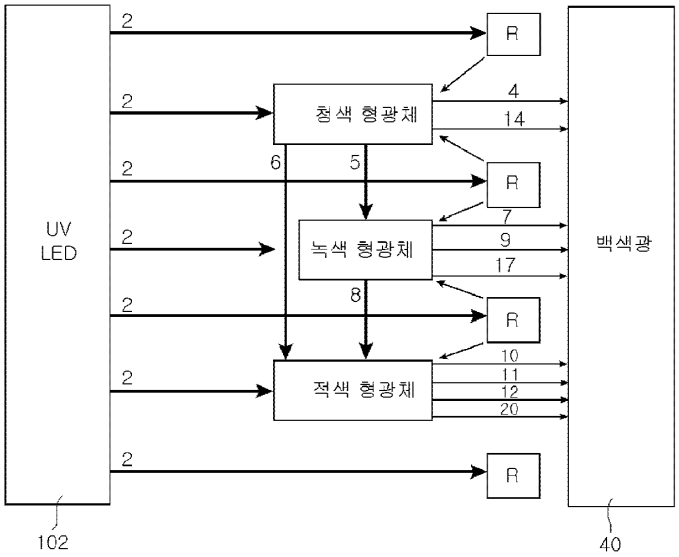


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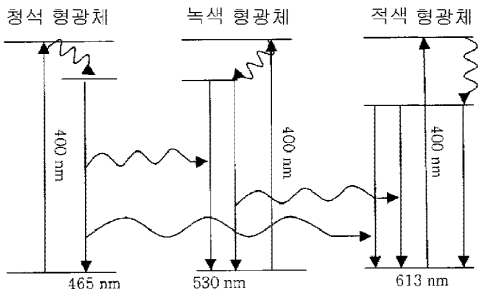
도면4



도면5

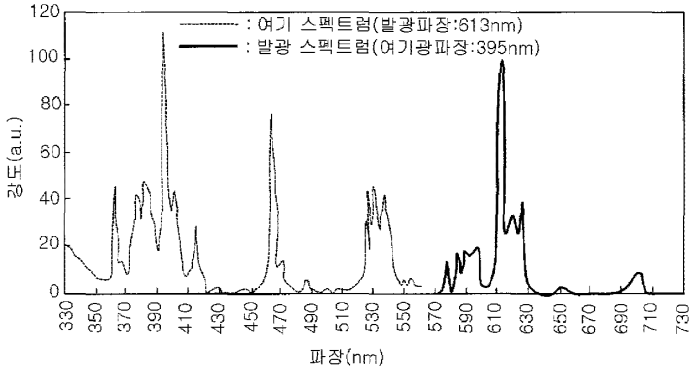


도면6

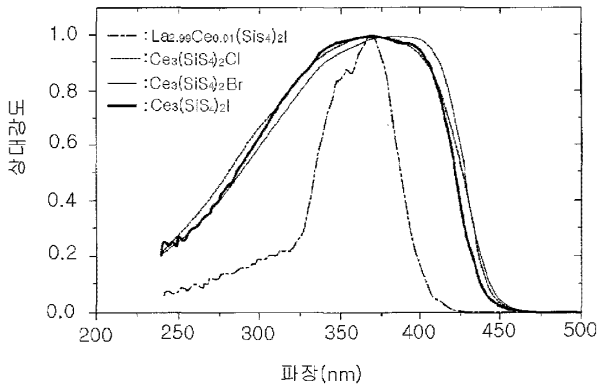


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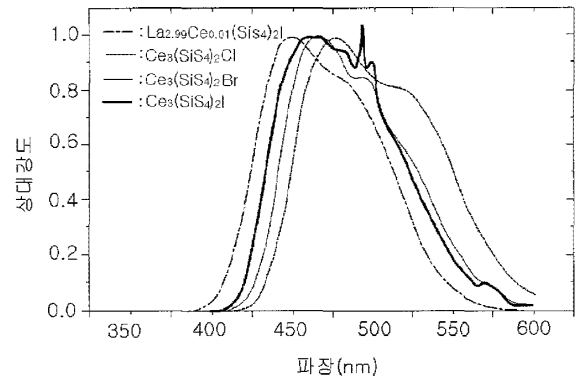
도면7



도면8a

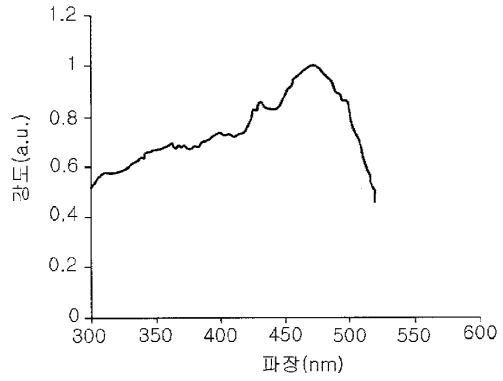


도면8b

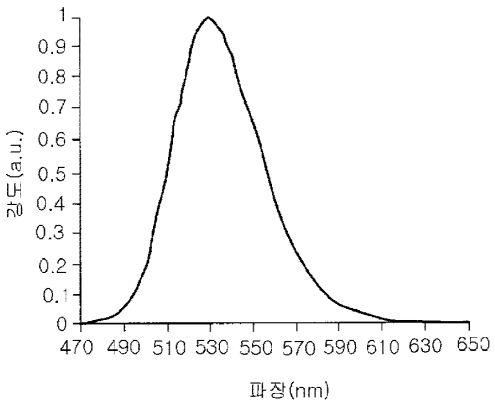


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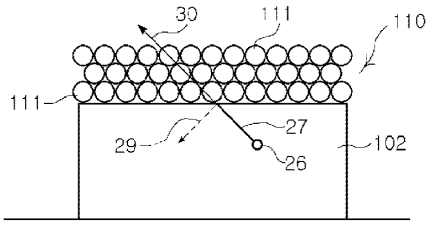
도면9a



도면9b

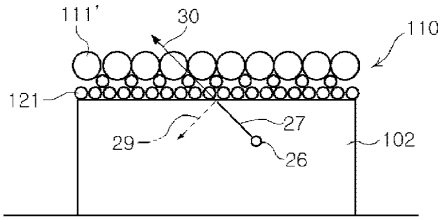


도면10

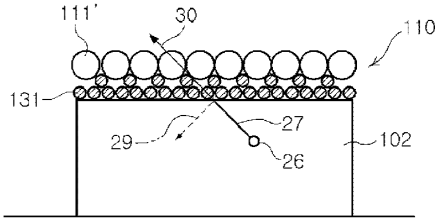


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도면11



도면12



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이수완, 이 성 규, 조진태, 윤종섭

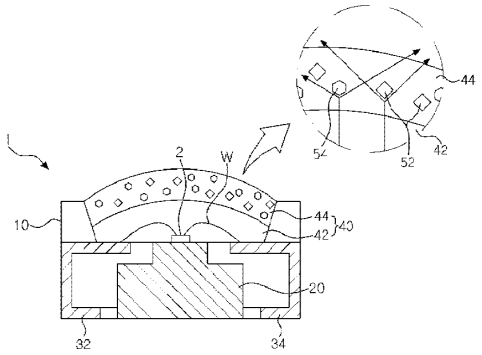
전체 청구항 수 : 총 8 항

(54) 산란수단을 갖는 LED 패키지

(57) 요 약

봉지재에 광을 산란시키는 수단을 산포시킴으로써, 광의 큰 손실 없이도, 광을 넓게 산란시켜 외부로 내보낼 수 있도록 구성된 LED 패키지가 개시된다. 개시된 LED 패키지는, 전류인가에 의해 발광 동작되는 LED칩과, 상기 LED칩을 덮도록 형성된 투광성의 봉지재와, 상기 봉지재의 내부 또는 표면에 산포되어, 상기 LED칩으로부터 나온 광을 산란시키는 반사성 파티클 또는 기포와 같은 산란수단을 포함한다.

대 표 도 - 도1



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특허청구의 범위

청구항 1

전류인가에 의해 발광 동작되는 LED칩과;

상기 LED칩을 덮도록 형성된 투광성의 봉지재와;

상기 봉지재의 내부 또는 표면에 산포되어, 상기 LED칩으로부터 나온 광을 산란시키는 산란수단을;

포함하는 LED 패키지.

청구항 2

청구항 1에 있어서, 상기 산란수단은 다수의 반사성 파티클들인 것을 특징으로 하는 LED 패키지.

청구항 3

청구항 2에 있어서, 상기 다수의 반사성 파티클들은 고유색이 같은 1종의 파티클들로 이루어지거나 고유색이 다른 2종 이상의 파티클들로 이루어진 것을 특징으로 하는 LED 패키지.

청구항 4

청구항 3에 있어서, 상기 봉지재 내에는 상기 LED칩과 상기 다수의 반사성 파티클들 사이에 형광체가 포함된 것을 특징으로 하는 LED 패키지.

청구항 5

청구항 4에 있어서, 상기 LED칩과 상기 형광체는 백색광을 만들도록 조합되는 것임을 특징으로 하는 LED 패키지.

청구항 6

청구항 1에 있어서, 상기 산란수단은 상기 봉지재의 내부에 산포된 다수의 기포들인 것을 특징으로 하는 LED 패키지.

청구항 7

청구항 2 또는 청구항 6에 있어서, 상기 봉지재는, 상기 LED칩 바로 위에 형성되는 제 1 봉지부와, 상기 제 1 봉지부 위에 형성되는 제 2 봉지부를 포함하며, 상기 산란수단은, 상기 제 2 봉지부에 포함되어, 상기 LED칩과 분리되어 있는 것을 특징으로 하는 LED 패키지.

청구항 8

청구항 1에 있어서, 상기 봉지재에는 형광체가 포함되는 것을 특징으로 하는 LED 패키지.

명 세 서

발명의 상세한 설명

기 술 분 야

<1> 본 발명은, LED(Light Emitting Diode) 패키지에 관한 것으로서, 더욱 상세하게는, LED칩으로부터 나온 빛을 산란시키는 수단을 봉지재에 포함하는 LED 패키지에 관한 것이다.

배 경 기 술

<2> 일반적으로, LED는 전류 인가에 의한 P-N 반도체 접합(P-N junction)에서 전자와 정공이 만나 빛을 발하는 소자이다. 이러한 LED는 통상, LED칩이 탑재된 패키지의 구조로 제작되어 이용되고 있다.

<3> LED 패키지는, LED칩과, LED칩에 전류를 인가하기 위한 예를 들면, 리드프레임 등의 수단과, LED칩으로부터의 광 방출을 허용하면서 그 LED칩을 외부로부터 보호하기 위한 봉지재 등을 포함한다. 위와 같은 LED 패키지에 있

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어서, LED칩은 직진성이 큰 발광 특성을 갖는다. 이러한 LED칩의 발광 특성으로 인해, 그것이 포함된 LED 패키지는, 일정 범위의 특정 조사면에 빛을 조사하는, 예를 들면, 백라이트 광원에는 유용하게 이용될 수 있지만, 주변을 넓게 비추는 조명기구, 특히, 장식용 조명기구로의 이용에는 제한이 있었다.

<4> 이에 대하여, 종래에는 직진성이 크고 눈부심이 큰 LED 패키지로부터의 광을 반사갓, 반사체 등의 추가적인 기구를 이용하여 넓게 확산시키는 기술이 제안된 바 있다. 그러나, 그와 같은 추가적인 기구를 이용하는 것은, 조명장치의 전체적인 크기를 증가시키며, 더 나아가, 많은 광 손실을 야기하여, 광 효율을 크게 떨어뜨린다. 특히, 종래의 LED 패키지는, 여러 형태 및/또는 다양한 색의 조명 연출이 어렵다는 점에서, 장식용 조명기구로의 활용에는 큰 한계가 있다. 또한, LED 패키지 외부의 광 경로에 별도의 광투과성 확산 기구를 마련하여 광을 넓게 확산시키는 것도 고려될 수 있는데, 그러한 경우에도 확산 기구 설치를 위한 추가적인 공간이 요구되는 문제점이 있다.

발명의 내용

해결 하고자하는 과제

<5> 따라서, 본 발명의 기술적 과제는, 외부와 근접한 봉지재에 광을 산란시키는 수단을 산포시킴으로써, 광의 큰 손실 없이도, 광을 넓게 산란시켜 외부로 내보낼 수 있도록 구성된 LED 패키지를 제공하는 것이다.

<6> 또한, 본 발명의 다른 기술적 과제는, 고유색을 갖는 반사성 파티클(particles)들을 봉지재에 산포시킨 구조에 의해, 다양한 색 연출이 가능한 LED 패키지를 제공하는 것이다.

과제 해결수단

<7> 본 발명에 따라, 전류인가에 의해 발광 동작되는 LED칩과, 상기 LED칩을 덮도록 형성된 투광성의 봉지재와, 상기 봉지재의 내부 또는 표면에 산포되어, 상기 LED칩으로부터 나온 광을 산란시키는 산란수단을 포함하는 LED 패키지가 제공된다.

<8> 본 발명의 바람직한 실시예에 따라, 상기 산란수단은 다수의 반사성 파티클들이며, 상기 다수의 반사성 파티클들은 고유색이 같은 1종의 파티클들로 이루어지거나 고유색이 다른 2종 이상의 파티클들로 이루어진다. 상기 봉지재 내에는 상기 LED칩과 상기 다수의 반사성 파티클들 사이에 형광체가 포함되며, 상기 LED칩과 상기 형광체는 백색광을 만들도록 조합된다.

<9> 대안적인 실시예에서, 상기 산란수단은 상기 봉지재의 내부에 산포된 다수의 기포들일 수 있다.

<10> 위 실시예들에 있어서, 상기 봉지재는, 상기 LED칩 바로 위에 형성되는 제 1 봉지부와, 상기 제 1 봉지부 위에 형성되는 제 2 봉지부를 포함하며, 상기 산란수단은, 상기 제 2 봉지부에 포함되어, 상기 LED칩과 분리되어 있게 된다.

효 과

<11> 본 발명에 따르면, 광의 큰 손실 없이, 주변을 폭 넓게 밝히는, 콤팩트한 구조의 LED 패키지가 구현될 수 있다. 또한, 고유색을 갖는 반사성 파티클들을 광의 산란에 이용하는 경우, 다양한 색 연출이 가능한 장식용 조명기구로 적용될 수 있다.

발명의 실시를 위한 구체적인 내용

<12> 이하, 첨부한 도면들을 참조하여 본 발명의 실시예들을 상세히 설명하기로 한다. 다음에 소개되는 실시예들은 당업자에게 본 발명의 사상이 충분히 전달될 수 있도록 하기 위해 예로서 제공되는 것이다. 따라서, 본 발명은 이하 설명되는 실시예들에 한정되지 않고 다른 형태로 구체화될 수도 있다. 그리고, 도면들에 있어서, 구성요소의 폭, 길이, 두께 등은 편의를 위하여 과장되어 표현될 수 있다. 명세서 전체에 걸쳐서 동일한 참조번호들은 동일한 구성요소들을 나타낸다.

<13> 도 1은 본 발명의 일 실시예에 따른 LED 패키지를 도시한 단면도이다.

<14> 도 1에 도시된 바와 같이, 본 실시예에 따른 LED 패키지(1)는 하우징(10)을 포함하는 패키지 구조로 이루어진다. 상기 하우징(10)은 상부가 개방된 구조를 이루며, LED칩(2) 및 그 LED칩(2)이 실장되는 부분을 수용하는 공간을 내부에 갖는다.

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<15> 본 실시예에서, 상기 하우징(10)의 내부에는 상기 LED칩(2)의 방열을 촉진하여 그 LED칩(2)의 성능 및 수명 저하를 억제하는 대략 원통형의 방열 슬러그(20)가 삽입 설치되며, 상기 LED칩(2)은 상기 방열 슬러그(20) 상단의 돌출부에 부착된다. 본 실시예에서, 상기 LED칩(2)이 방열 슬러그(20) 상에 부착되지만, 이와 달리, 방열 슬러그가 생략된 채 제 1 및 제 2 리드프레임(32, 34) 중 어느 하나에 LED칩(2)이 부착될 수 있다.

<16> 상기 LED 패키지(1)는 LED칩(2)에 전류를 인가하기 위한 제 1 및 제 2 리드프레임(32, 34)을 포함한다. 상기 제 1 및 제 2 리드프레임(32, 34)은 상기 하우징(10)에 지지된 채 본딩와이어(W)들에 의해 상기 LED칩(2)과 전기적으로 연결된다. 상기 하우징(10)의 상부 개방부에는 상기 LED칩(2)을 보호하도록 상기 LED칩(2)을 덮는 투광성 봉지재(40)가 형성된다. 본 실시예에서, 상기 봉지재(40)는, 예를 들면, 에폭시, 실리콘과 같은 투광성 수지로 형성되는 것으로, 상기 LED칩(2) 바로 위에 형성되는 제 1 봉지부(42)와, 상기 제 1 봉지부(42) 위에 형성되는 제 2 봉지부(44)를 포함한다. 이때, 상기 제 1 봉지부(42)와 상기 제 2 봉지부(44)의 재질은 서로 다를 수 있다.

<17> 상기 봉지재(40)에는 LED칩(2)으로부터 발생한 광이 외부로 방출되기 직전에 그 광을 산란하여 방출시키는 산란수단이 구비된다. 본 실시예에서, 상기 산란수단은 반사성 파티클(52, 54)들로 이루어지며, 도 1의 확대도로 알 수 있는 것과 같이, 상기 봉지재(40)의 제 2 봉지부(44)의 내부에 포함된다. 이때, 상기 반사성 파티클(52, 54)들을 상기 제 2 봉지부(44)의 외표면에 형성하는 것도 고려될 수 있다.

<18> 도 1의 확대도에 도시된 것과 같이, 상기 제 2 봉지부(44)에는 광을 산란시켜 외부로 방출시키는 다수의 반사성 파티클(52, 54)들이 산포된 상태로 마련된다. 본 실시예에서, 상기 다수의 반사성 파티클(52, 54)들은 서로 다른 고유색을 갖는 2종 이상의 반사성 파티클들을 포함한다. 도 2에서는 2종의 반사성 파티클들, 즉, 금박 재질의 파티클(52)과 은박 재질의 파티클(54)이 제 2 봉지부(44)에 제공되는 것으로 도시되어 있지만, 다른 재질의 반사성 파티클이 추가로 제공될 수도 있다. 또한, 고유색이 같은 1종의 반사성 파티클만을 이용하는 것도 고려될 수 있다.

<19> 본 실시예에서, 상기 반사성 파티클(52, 54)은 제 1 봉지부(42)에는 전혀 포함되지 않은 채 제 2 봉지부(44) 내에만 포함되는데, 이는 LED칩(2)과 반사성 파티클(52, 54)을 멀리 분리시킴으로써, LED칩(2)으로부터 나온 광이 반사성 파티클(52, 54)에 바로 부딪힘으로써 야기되는 광 손실을 막고, 더 나아가, 반사성 파티클(52, 54)과 LED칩(2) 사이의 접촉에 의해 야기될 수 있는 전기적 성능의 저하를 미연에 막는다.

<20> 도 2는 본 발명의 다른 실시예를 설명하기 위한 도면으로서, 도 2를 참조하면, 봉지재(40)의 제 2 봉지부(44)에는 앞선 실시예와 마찬가지로 반사성 파티클(52, 54)이 산포된 형태로 제공되는 한편, 상기 제 1 봉지부(42) 내에는 LED칩(2)과 함께 백색광을 만들도록 조합되는 형광체(62)가 제공된다. 예를 들면, 청색 발광하는 LED칩(2) 상부에 그 광의 일부를 여기광원으로 하여 황록색 또는 황색 을 발광하는 형광체(62)를 위치시킴으로써 백색광을 만들 수 있다. 그 외에 다양한 LED칩(2)과 형광체(62)의 조합에 의해 백생광을 만들 수 있다.

<21> 이때, 상기 형광체(62)가 제 1 봉지부(42) 아래의 LED칩(2)과 제 2 봉지부(44) 내의 반사성 파티클(52, 54) 사이에 위치하므로, 1 봉지부(42) 아래쪽에서 만들어진 백색광은 제 2 봉지부(44)의 반사성 파티클(52, 54)에 부딪혀 산란된다. 상기 반사성 파티클(52, 54)은, 예를 들면, 금색, 은색 또는 기타 다른 색의 고유색을 가지므로, 백색광에 부딪혀서, 그 백색광이 자체 고유색으로 보이도록 방출된다. 따라서, 본 실시예의 LED 패키지(1)는, 기존의 LED 패키지가 단조로운 색의 광을 방출하던 것과 달리, 반사성 파티클(52, 54)에 의해 변화된 다양한 색의 광을 외부로 방출시킬 수 있고, 이에 의해, 다양한 조명 연출이 가능하다.

<22> 도 3은 본 발명의 또 다른 실시예를 설명하기 위한 도면이다. 도 3을 참조하면, 본 실시예의 LED 패키지(1)는, 앞선 실시예와 마찬가지로, 제 1 봉지부(42)와 제 2 봉지부(44)로 구성된 봉지재(40)를 포함한다. 다만, 상기 제 2 봉지부(44)에는, 앞선 실시예와는 달리, 광을 굴절 또는 산란시키는 수단으로 기포(56)들이 산포된 구조로 이루어진다. 상기 기포(56)들은 제 2 봉지부(44)를 이루는 수지들, 특히, 에폭시 또는 실리콘 수지와 다른 광굴절율을 갖는다. 따라서, 광은 기포(56)에 부딪히면, 그 기포(56)를 통과하지 못하고 산란된다.

<23> 상기 기포(56)를 봉지재(40)에 산포시키는 방법은 여러가지 고려될 수 있는데, 그 중 하나는, 제 1 봉지부(42)를 먼저 형성한 후, 기포가 다수 존재하는 수지를 이용하여 제 2 봉지부(44)를 형성하는 것이며, 그 중 다른 하나는 LED칩(2)을 덮도록 주입 또는 도포된 수지 내로 그 수지가 굳기 전에 기포를 불어넣는 것이다. 이를 위해 주사 바늘을 이용하는 인젝션 기술이 이용될 수 있다.

<24> 본 발명을 예시하기 위해 첨부된 도면들에는 봉지재의 봉지부가 2개인 것로 도시되어 있지만, 그 봉지부의 개수에 본 발명이 한정되지 않으며, 바람직하게는, 봉지재가 2개 이상의 봉지부로 이루어질 수 있고, 그 봉지부 중

어느 하나에 산란수단이 제공된다. 또한, 복수의 봉지부로 구획되지 않은, 즉, 단일 봉지부로 이루어진 봉지재가 본 발명의 LED 패키지에 이용되는 것도 고려될 수 있다.

도면의 간단한 설명

<25> 도 1은 본 발명의 일 실시예에 따른 LED 패키지를 설명하기 위한 단면도.

<26> 도 2는 본 발명의 다른 실시예에 따른 LED 패키지를 설명하기 위한 단면도.

<27> 도 3은 본 발명의 또 다른 실시예에 따른 LED 패키지를 설명하기 위한 단면도.

<28> <도면의 주요부분에 대한 부호설명>

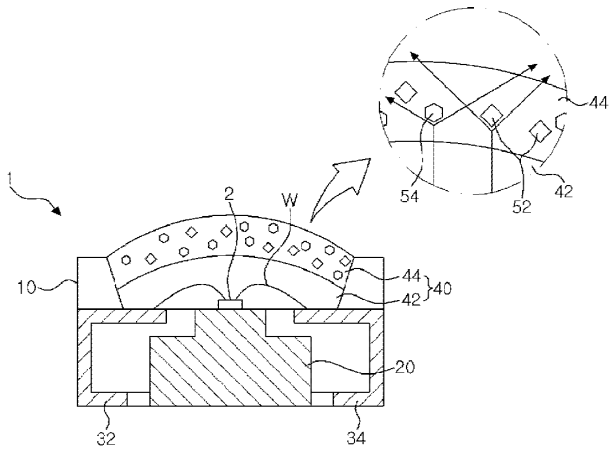
<29> 2: LED칩 40: 봉지재

<30> 42: 제 1 봉지부 44: 제 2 봉지부

<31> 52, 54: 반사성 파티클 56: 기포

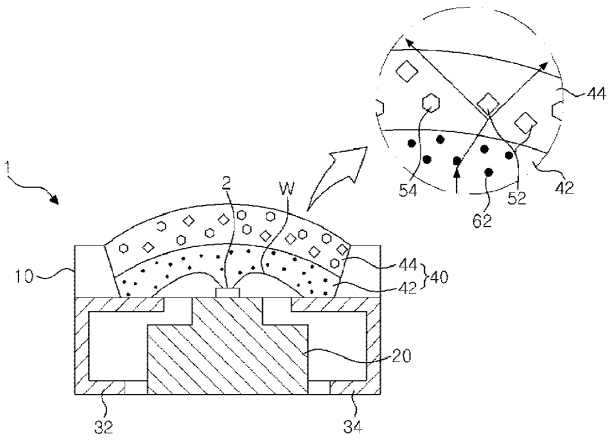
도면

도면1

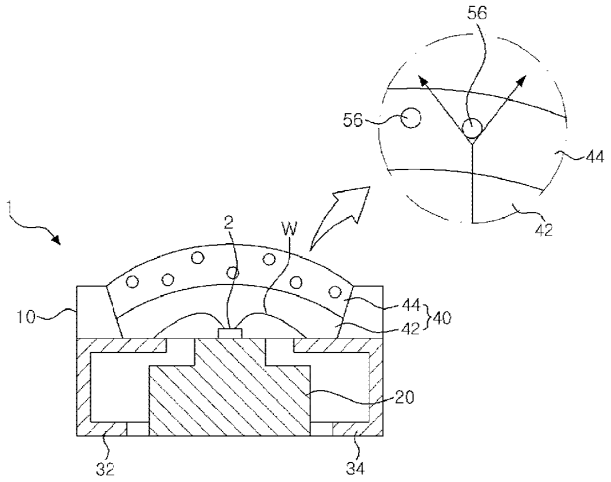


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도면2



도면3



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DERWENT-ACC-NO: 1999-632342
DERWENT-WEEK: 199954
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TITLE: Light-emitting diode

INVENTOR: ABRAMOV V S; BELENKOV N M ; DENISOV S D

PATENT-ASSIGNEE: ABRAMOV V S[ABRAI]

PRIORITY-DATA: 1996RU-105089 (March 19, 1996)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE
RU 2114492 C1	June 27, 1998	RU

APPLICATION-DATA:

PUB-NO	APPL-DESCRIPTOR	APPL-NO	APPL-DATE
RU 2114492C1	N/A	1996RU-105089	March 19, 1996

INT-CL-CURRENT:

TYPE	IPC DATE
CIPS	H01L33/00 20060101

ABSTRACTED-PUB-NO: RU 2114492 C1

Savant Technologies LLC - 1004.323

BASIC-ABSTRACT:

NOVELTY - Device has metal-glass holder which has metal substrate which are connected to terminals, one of which is insulated from substrate by glass insulator. In addition device has light-emitting crystal which is mounted on holder and is connected by means of conductor to insulated connecting terminal. In addition device has cap with light-converging lens and base. Cap is designed as half-spherical lens with cylindrical base. Depth of lens base is less than lens radius. Lower edge of cap base carries directing rods which are located according positional holes in substrate which depth is equal to or is greater than four crystal depth. Substrate has recess which shape is cone frustum which surface reflects light. Flat surface of cone frustum has mounting surface for light-emitting crystal in depth of at least two crystal depths. Diameter of mounting surface is greater than size of diagonal of lower crystal edge but is less than one and a half of this size. Volume between lower cap base and upper surface of substrate is filled with sealing compound. Connection of conductor to insulated connecting terminal is covered with layer of current-conducting glue.

USE - Electronic equipment, in particular, semiconductors.

ADVANTAGE - Increased output light, possibility to alter angle of aspect. 2 dwg.

CHOSEN-DRAWING: Dwg.1/1
TITLE-TERMS: LIGHT EMIT DIODE

DERWENT-CLASS: U11 U12

EPI-CODES: U11-D01B1; U12-A01A4;

SECONDARY-ACC-NO:
Non-CPI Secondary Accession Numbers: 1999-466763

Savant Technologies LLC - 1004.324

(19) **RU** (11) **2 114 492** (13) **C1**

(51) МПК[6] **H 01 L 33/00**

РОССИЙСКОЕ АГЕНТСТВО
ПО ПАТЕНТАМ И ТОВАРНЫМ ЗНАКАМ

(12) ОПИСАНИЕ ИЗОБРЕТЕНИЯ К ПАТЕНТУ РОССИЙСКОЙ ФЕДЕРАЦИИ

(21), (22) Заявка: 96105089/25, 19.03.1996

(46) Дата публикации: 27.06.1998

(56) Ссылки: 1. Optoelectronics Designer's Catalog фирмы Hewlett Packard. - 1993, p. 3 - 44. 2. Selection Guide Optoelectronic Devices, каталог фирмы AEG-Telefu nken. - 1982, p. 11. 3. Зи. С. Физика полупроводниковых приборов. В 2-х кн игах, Кн. 2, Пер. с англ. - 2-е перераб. и доп. изд. - М.: Мир, 1984, с. 2 89, рис. 16а.

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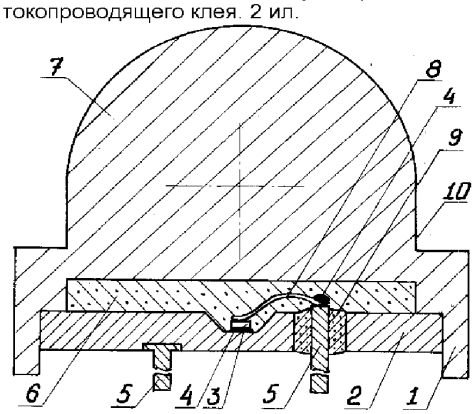
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(54) СВЕТОИЗЛУЧАЮЩИЙ ДИОД

(57) Реферат:

Использование: электронная техника, а именно светоизлучающие диоды, полупроводниковая техника. Технический результат: повышение мощности излучения светоизлучающего диода с возможностью варьирования угла обзора. Сущность: светоизлучающий диод содержит металлостеклянный держатель, состоящий из металлической подложки и присоединительных выводов, один из которых изолирован от нее стеклоизолятором, кристалл излучателя света, установленный на держателе и соединенный проводником с изолированным присоединительным выводом, крышку с собирающей излучение линзой и основанием, при этом крышка выполнена в виде полусферической линзы с цилиндрическим основанием, толщина основания линзы не превышает величину радиуса линзы, а на нижней грани основания крышки имеются направляющие штыри, размещенные соответственно позиционным отверстиям в подложке, имеющей толщину, равную или большую четырех толщин кристалла, причем в подложке выполнено углубление в форме усеченного конуса, поверхность которого отражает излучение, на плоской части поверхности усеченного конуса расположено посадочное место для кристалла излучателя света на глубине не меньше двух толщин кристалла, а величина диаметра посадочного места кристалла превышает размер диагонали нижней грани кристалла, но не превосходит полутора значений этого размера, при этом объем между нижней гранью основания крышки и верхней поверхностью подложки заполнен герметизирующим компаундом, а место присоединения проводника к изолированному присоединительному выводу покрыто слоем токопроводящего клея. 2 ил.



Фиг. 1

RU 2114492 C1

RU 2114492 C1

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(19) **RU** (11) **2 114 492** (13) **C1**

(51) Int. Cl.[6] **H 01 L 33/00**

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(12) ABSTRACT OF INVENTION

(21), (22) Application: **96105089/25, 19.03.1996**

(46) Date of publication: **27.06.1998**

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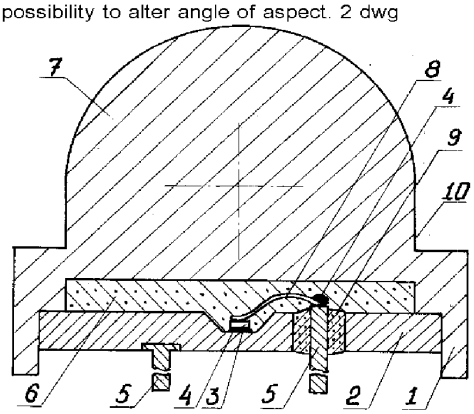
(72) Inventor: **Abramov Vladimir Semenovich, Belen'kov Nikolaj Mikhajlovich, Denisov Sergej Dmitrievich, Shcherbakov Nikolaj Valentinovich**

(73) Proprietor:
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Belen'kov Nikolaj Mikhajlovich,
Denisov Sergej Dmitrievich,
Shcherbakov Nikolaj Valentinovich

(54) LIGHT-EMITTING DIODE

(57) Abstract:

FIELD: electronic equipment, in particular, semiconductors. SUBSTANCE: device has metal-glass holder which has metal substrate which are connected to terminals, one of which is insulated from substrate by glass insulator. In addition device has light-emitting crystal which is mounted on holder and is connected by means of conductor to insulated connecting terminal. In addition device has cap with light-converging lens and base. Cap is designed as half-spherical lens with cylindrical base. Depth of lens base is less than lens radius. Lower edge of cap base carries directing rods which are located according positional holes in substrate which depth is equal to or is greater than four crystal depth. Substrate has recess which shape is cone frustum which surface reflects light. Flat surface of cone frustum has mounting surface for light-emitting crystal in depth of at least two crystal depths. Diameter of mounting surface is greater than size of diagonal of lower crystal edge but is less than one and a half of this size. Volume between lower cap base and upper surface of substrate is filled with sealing compound. Connection of conductor to insulated connecting terminal is covered with layer of current-conducting glue. EFFECT: increased output light, possibility to alter angle of aspect. 2 dwg



Фиг. 1

RU 2114492 C1

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Изобретение относится к области электронной техники, а именно к светоизлучающим диодам (СИД), и может найти применение в полупроводниковой технике при разработке и производстве СИД.

В технике СИД широко применяются для сигнализации режима работы различной аппаратуры подсветки, источники информации типа информационных табло, бегущих строк, светофоров, дополнительных сигналов торможения в автомобилях и т. д. Использование СИД вместо ламп накаливания существенно повышает надежность и снижает энергопотребление аппаратуры.

При этом требуются СИД с различными цветами светового потока, величиной и равномерностью светящегося пятна и мощностями (силой света) излучения.

Наиболее важным параметром СИД является мощность излучения (сила света), зависящая в первую очередь от величины протекающего прямого тока и значения теплового сопротивления держателя, на котором установлен кристалл излучателя света.

Известен СИД красного цвета свечения типа HLMP-C100 с кристаллом излучателя света, укрепленным на держателе, соединенным с одним из выводов и размещенным в пластмассовом монолитном корпусе, который состоит из цилиндрического основания и полусферической собирающей излучение линзы диаметром 5 мм [1] . При прямом токе $I_{пр}$=20 мА минимальное значение силы света составляет 0,29 кд при угле обзора ±30° на половине мощности излучения. Величина теплового сопротивления корпуса 210 °С/Вт.

Недостатком такого решения является невысокая сила света СИД, обусловленная невозможностью увеличения величины прямого тока через прибор из-за значительного теплового сопротивления корпуса и перегрева кристалла излучателя света, т.к. выделяемое тепло отводится только через вывод. В этом случае наблюдается нарушение линейности люмен-амперной характеристики, приводящее к отсутствию роста силы при увеличении прямого тока.

Другое техническое решение описывает СИД инфракрасного излучения типа CQX 19, у которого кристалл излучателя света установлен на держателе корпуса TO-39, на котором сформирована полусферическая пластмассовая линза диаметром 8 мм [2]. При прямом токе $I_{пр}$=250 мА выделяемая мощность излучения составляет 20 мВт при угле обзора ±20° на половине мощности излучения. Величина теплового сопротивления корпуса 250 °С300° С/Вт, что составляет значительную величину и не позволяет повысить мощность излучения за счет увеличения прямого тока.

Наиболее близким по технической сущности решением к предлагаемому изобретению является эффективный СИД красного цвета свечения типа IN 6092, содержащий металлостеклянный держатель с выводами, кристалл излучателя света с омическими контактами, установленный на держателе посредством токопроводящего клея, соединенный проводником с соответствующим выводом, и металлическую крышку с собирающей излучение линзой [3]. Допустимый прямой ток через прибор составляет: $I_{пр}$=35 мА, тепловое сопротивление - 425°С/Вт, угол обзора ±18° на половине мощности излучения, а типовое значение мощности излучения - 5 мкд при прямом токе $I_{пр}$=20 мА.

Недостатком этого решения является невысокая мощность излучения СИД вследствие отсутствия внутри корпуса полимерного компаунда и высокого значения теплового сопротивления, обусловленного отводом выделяемого кристаллом тепла через вывод, на котором он установлен. Ограниченное значение рассеиваемой мощности не допускает протекания достаточно высоких значений прямого тока вследствие нарушения линейности люмен-амперной характеристики.

Техническим результатом предлагаемого изобретения является повышение мощности (силы света) излучения СИД с возможностью варьирования угла обзора.

Технический результат достигается тем, что крышка светоизлучающего диода выполнена в виде полусферической линзы с цилиндрическим основанием, толщина основания линзы не превышает величину радиуса линзы, а на нижней грани основания крышки имеются направляющие штыри, размещенные соответственно позиционным отверстиям в подложке, имеющей толщину, равную или большую четырех толщин кристалла излучателя света, при этом в подложке выполнено углубление в форме усеченного конуса, поверхность которого отражает излучение, на плоской части поверхности усеченного конуса расположено посадочное место для кристалла излучателя света на глубине не меньше двух толщин кристалла, а величина диаметра посадочного места кристалла превышает размер диагонали нижней грани кристалла, но не превосходит полутора значений этого размера, причем объем между нижней гранью основания крышки и верхней поверхностью подложки заполнен полимерным герметизирующим компаундом, а место присоединения проводника к изолированному присоединительному выводу покрыто слоем токопроводящего клея.

На фиг. 1 представлен в разрезе СИД, содержащий крышку 1, металлическую подложку 2 с углублением в форме усеченного конуса, поверхность которого отражает излучение, кристалл излучателя света 3, токопроводящий клей 4, выводы 5, полимерный герметизирующий компаунд 6, полусферическую линзу 7, проводник 8, стеклоизолятор 9, цилиндрическое основание 10 линзы 7.

На фиг. 2 представлена крышки СИД, содержащая полусферическую линзу 7, цилиндрическое основание 10, направляющие штыри 11.

Предлагаемый СИД работает следующим образом.

При подаче на выводы 5 электрического напряжения, обеспечивающего протекание прямого тока через кристалл излучателя света 3, он начинает испускать свет. Излучение с верхней поверхности кристалла излучателя света 3 и с его боковых граней,

RU 2114492 C1

RU 2114492 C1

Savant Technologies LLC - 1004.327

отраженное усеченной конической поверхностью, попадает в слой герметизирующего компаунда 6, цилиндрическое основание 10 и фокусируется полусферической линзой 7.

Наличие полимерного герметизирующего компаунда 6, цилиндрического основания 10 толщиной, не превышающей величины радиуса полусферической линзы 7, обеспечивает снижение потерь мощности излучения и требуемую диаграмму направленности излучения. Кроме того, полимерный герметизирующий компаунд 6 обеспечивает влагозащищенность кристалла излучателя света 3 и мест присоединения к нему проводника 8, а также к выводу 5, изолированному от подложки 2 стеклоизолятором 9.

Место присоединения проводника 8 к изолированному выводу 5, защищенное слоем токопроводящего клея 4, повышает надежность основания, а также СИД в целом.

Конструкция СИД с полимерным герметизирующим компаундом 6 на основе металлостеклянного держателя, состоящего из металлической подложки 2 и присоединительных выводов 5, позволяет увеличить мощность излучения в два - три раза.

В подложке выполнено углубление в форме усеченного конуса, поверхность которого отражает излучение, на плоской части поверхности усеченного конуса расположено посадочное место для кристалла излучателя света 3 на глубине не меньше двух толщин кристалла.

Величина диаметра посадочного места для кристалла излучателя света 3 превышает размер диагонали его нижней грани, но не превосходит полутора значений этого размера, что позволяет практически полностью собирать излучение вдоль оптической оси СИД.

Углубление в форме усеченного конуса, на плоской поверхности которого расположено посадочное место для кристалла излучателя света 3, позволяет использовать боковое свечение кристалла излучателя света 3.

Направляющие штыри 11 крышки 1 облегчают центровку кристалла излучателя света 3 вдоль оптической оси СИД.

Изменение расстояния от подложки 2 до нижней грани цилиндрического основания 10 линзы 7, путем перемещения держателя вдоль направляющих штырей 11 крышки 1 позволяет регулировать величину мощности излучения за счет изменения угла обзора на половине мощности излучения от ± 4 до $\pm 50^{o}$.

Толщина металлической подложки 2, равная или большая четырех толщин кристалла излучателя света 3, обеспечивает эффективное рассеяние потребляемой мощности с нижней грани подложки 2.

При монохроматическом исполнении предлагаемого СИД могут быть использованы кристаллы излучателя света 3 с инфракрасным или красным, оранжевым, желтым, зеленым, голубым или синим цветом свечения. Насыщенность цвета и восприятие информации может быть достигнута дополнительной окраской крышки 1 соответствующим цветом за счет введения красителя при ее исполнении, или введением диспергатора, которым, например, может быть измельченный оптический кварц.

Применение диспергатора позволяет улучшить восприятие свечения из-за увеличения размера светящегося пятна без ухудшения физико-химических свойств материала крышки..

Подложка 2 в общем случае может быть выполнена не только чисто металлической, а металлизированной, например диэлектрической, с покрытием с одной или двух сторон медно-никелевым слоем. При этом на верхней грани подложки на основе медно-никелевого слоя может быть сформирована схема разводки, соединяющаяся с соответствующими выводами 5, что обеспечивает установку кристалла излучателя света 3 на посадочное место с разводкой проводников на вывод 5.

Схема разводки может быть выполнена таким образом, что медно-никелевое покрытие занимает максимальную площадь подложки 2, за исключением промежутков, обеспечивающих схему разводки, что повышает отражение излучения кристалла излучателя света 3 и увеличивает мощность излучения.

Наличие медно-никелевого покрытия на тыльной стороне основания, кроме места выхода присоединительного вывода 5, обеспечивает снижение теплового сопротивления.

Ниже приведен пример конкретного исполнения предлагаемого светодиода.

Конструкция СИД, изготовленная согласно данному изобретению, содержит металлостеклянный держатель из стали толщины 1,0 мм с нанесенным слоем никеля и присоединенными никелевыми выводами диаметром 0,55 мм. Посадочное место кристалла излучателя света 3 имеет глубину 0,5 мм, диаметр плоской части поверхности усеченного конуса составляет 1,6 мм, а диаметр посадочного места кристалла излучателя света 3 равен 0,6 мм. Крышка была отлита из пластической массы - поликарбоната типа "Lexan". Радиус полусферической линзы равен 5 мм, высота основания - 3 мм, расстояние между подложкой и основанием варьировалось в пределах 1-3 мм. В качестве герметизирующего материала служит полимерный компаунд марки 159-322. В качестве кристалла излучателя света использован кристалл красного цвета излучения с длиной волны 662 нм. Токопроводящий клей, служащий для установки кристалла и покрытия места присоединения проводника к изолированному присоединительному выводу на основе серебра, имеет марку ТОК-2.

Такая конструкция СИД обеспечивает величину теплового сопротивления 170 °С/Вт и увеличение прямого тока через СИД до 80 мА без потери линейности люкс-амперной характеристики, что позволяет получать силу света более 1,5 кд или мощность излучения более 25 мВт при токах 20 и 100 мА соответственно.

Известных технических решений, направленных на повышение мощности излучения СИД указанными средствами при поиске в патентном фонде и других научно-технических источниках, не обнаружено. Следовательно, предлагаемый светоизлучающий диод соответствует критерию "новизна".

RU 2114492 C1

RU 2114492 C1

Savant Technologies LLC - 1004.328

Сравнение предлагаемого изобретения не только с прототипом, но и с другими техническими решениями в данной области техники, не выявило технических решений, сходных по отличительным в заявленном решении признакам, проявляющим аналогичные свойства. Поскольку оно явным образом не следует из уровня техники, то это позволяет сделать вывод о соответствии предлагаемого светоизлучающего диода критерию "изобретательский уровень".

Предлагаемое изобретение является промышленно применимым, так как оно может быть широко использовано в различных отраслях промышленности для производства светоизлучающих диодов с повышенной мощностью излучения.

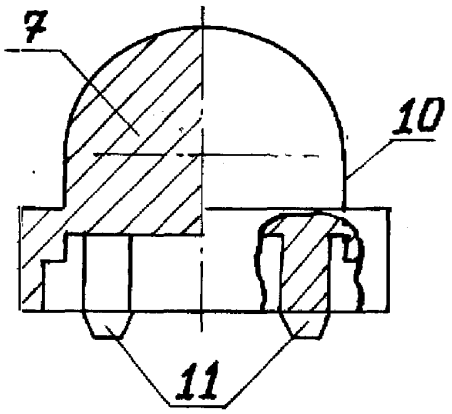
Формула изобретения:

Светоизлучающий диод, содержащий металлостеклянный держатель, состоящий из металлической подложки и присоединительных выводов, один из которых изолирован от нее стеклоизолятором, кристалл излучателя света, установленный на держателе и соединенный проводником с изолированным присоединительным выводом, крышку с собирающей излучение линзой и основанием, отличающийся тем, что крышка выполнена в виде полусферической линзы с цилиндрическим основанием, толщина основания линзы не превышает величину радиуса линзы, а на нижней грани основания крышки имеются направляющие штыри, размещенные соответственно позиционным отверстиям в подложке, имеющей толщину, равную или большую четырех толщин кристалла, при этом в подложке выполнено углубление в форме усеченного конуса, поверхность которого отражает излучение, на плоской части поверхности усеченного конуса расположено посадочное место для кристалла излучателя света на глубине не меньше двух толщин кристалла, а величина диаметра посадочного места кристалла превышает размер диагонали нижней грани кристалла, но не превосходит 1,5 значений этого размера, причем объем между нижней гранью основания крышки и верхней поверхностью подложки заполнен полимерным герметизирующим компаундом, а место присоединения проводника к изолированному присоединительному выводу покрыто слоем токопроводящего клея.

RU 2114492 C1

RU 2114492 C1

Savant Technologies LLC - 1004.329



Фиг. 2

RU 2114492 C1

RU 2114492 C1

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Search terms: (1) (200527664)@PN 【 申出 】

Patent/Publication Number	200527664
Title	Transmissive optical elements including transparent plastic shell having a phosphor dispersed therein, and methods of fabricating same
Issued/Publication Date	2005/08/16
Application Date	2004/09/08
Application Number	093127193
IPC	H01L-027/15
Inventor	NEGLEY, GERALD H. US; LOH, BAN US
Applicant	CREE, INC.US
Priority Number	20030909US20030659240
Abstract	A transmissive optical element is fabricated by filling a mold with molten liquid that includes a transparent plastic and a phosphor additive, and allowing the molten liquid to solidify to produce the transmissive optical element having phosphor dispersed therein. Accordingly, a separate phosphor coating or phosphor-containing encapsulant need not be used. Transmissive optical elements include a shell made of transparent plastic with a phosphor dispersed therein. The phosphor may be uniformly and/or nonuniformly dispersed in the shell.
Individual	F

Information on this system is for reference only, it cannot be used as grounds for approval or rejection.
In all instances of discrepancy, official publication from TIPO shall prevail and should be consulted.

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發明專利說明書 200527664

(本說明書格式、順序及粗體字，請勿任意更動，※記號部分請勿填寫)

※ 申請案號：92127193

※ 申請日期：92.9.8 ※IPC 分類：H01L 27/15

一、發明名稱：(中文/英文)

包含一具有一磷分散於一透明塑膠殼中之光學穿透元件及其製造方法

TRANSMISSIVE OPTICAL ELEMENTS INCLUDING TRANSPARENT PLASTIC SHELL HAVING A PHOSPHOR DISPERSED THEREIN, AND METHODS OF FABRICATING SAME

二、申 請 人：(共 1 人)

姓名或名稱：(中文/英文)

美商克立公司

CREE, INC.

代表人：(中文/英文)

查爾斯 M 史華波達

SWOBODA, CHARLES M.

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美國 U.S.A.

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三、發明人：(共 2 人)

姓　名：(中文/英文)

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NEGLEY, GERALD H.

2.班　羅

LOH, BAN

國　籍：(中文/英文)

1.-2.均美國　U.S.A.

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四、聲明事項：

☐ 主張專利法第二十二條第二項☐第一款或☐第二款規定之事實，其事實發生日期為：　年　月　日。

☑申請前已向下列國家(地區)申請專利：

【格式請依：受理國家(地區)、申請日、申請案號　順序註記】

☑ 有主張專利法第二十七條第一項國際優先權：

1. 美國；2003年09月09日；10/659,240

2.

☐ 無主張專利法第二十七條第一項國際優先權：

1.

2.

☐ 主張專利法第二十九條第一項國內優先權：

【格式請依：申請日、申請案號　順序註記】

☐ 主張專利法第三十條生物材料：

☐ 須寄存生物材料者：

國內生物材料　【格式請依：寄存機構、日期、號碼　順序註記】

國外生物材料　【格式請依：寄存國家、機構、日期、號碼　順序註記】

☐ 不須寄存生物材料者：

所屬技術領域中具有通常知識者易於獲得時，不須寄存。

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五、中文發明摘要：

本發明係關於一光學穿透元件，其可藉由以一包含透明塑膠及磷添加劑之熔融液體填充一模並容許該熔融液體凝固以產生具有磷分散於其中之光學穿透元件而被予製造。因此，無需使用一單獨的磷塗層或含磷密封劑。光學穿透元件包含一殼，其係由具有磷分散於其中之透明塑膠所製成的。磷可均一及/或不均一地分散於殼中。

六、英文發明摘要：

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七、指定代表圖：

(一)本案指定代表圖為：第(1F)圖。

(二)本代表圖之元件符號簡單說明：

100 殼

110 磷

150 透明內核

160 發光裝置/發光元件

162 光線

八、本案若有化學式時，請揭示最能顯示發明特徵的化學式：

(無)

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九、發明說明：

【發明所屬之技術領域】

本發明係關於發光裝置及其製造方法，且更特定言之，係關於發光裝置之封裝及封裝方法。

【先前技術】

許多應用中廣泛使用諸如發光二極體(LED)或雷射二極體之半導體發光裝置。正如熟習此項技術者所熟知的，半導體發光二極體通常係藉由以拱頂狀透明塑膠殼至少部分地環繞半導體發光二極體來加以封裝。

通常需要將磷併入發光裝置中，以增強特定頻帶中所發射之輻射及/或以將至少一些輻射轉換成另一頻帶。可使用習知技術將磷包含於發光裝置中。在一技術中，將磷塗佈於塑膠殼內部及/或外部。在其它技術中，例如使用電泳沈積將磷塗佈於半導體發光裝置本身上。在其它實施例中，可將一滴其中含有磷之材料(諸如環氧物)置放於塑膠殼內部，位於半導體發光裝置上及/或於裝置與殼之間。使用磷塗層之LED描述於例如美國專利第6,252,254、6,069,440、5,858,278、5,813,753、5,277,840及5,959,316號中。

對於已完成之發光裝置而言，封裝可構成耗費及/或製造時間之主要部分。

【發明內容】

本發明之一些實施例係藉由以下操作來形成光學穿透元件：以包括透明塑膠及磷添加劑之熔融液體填充一模，並容許該熔融液體凝固以產生一具有磷分散於其中的光學穿

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透元件。因此，雖然此等實施例可提供單獨的磷塗層或含磷之密封劑，但其無需提供該等單獨的磷塗層或含磷之密封劑。

在本發明之一些實施例中，光學穿透元件為一拱頂，發光裝置通過其發射光線。在此等實施例中，亦可在拱頂內部形成一透明核。或者，可首先形成透明核且隨後藉由以包括透明塑膠及磷添加劑之熔融液體填充一包含該透明核之拱頂狀模來執行模製。

在其它實施例中，光學穿透元件為鍵盤鍵，發光裝置通過其發射光線。在其它實施例中，光學元件為鍵盤鍵面，發光裝置通過其發射光線。在此等實施例中，可提供一單獨的步驟來形成一附著至鍵盤鍵面之鍵盤鍵壁。

根據本發明之一些實施例的光學穿透元件包含一殼，該殼包括一包含一磷分散於其中之透明塑膠。在一些實施例中，磷均一地分散於殼中，而在其它實施例中，磷不均一地分散於殼中。

在一些實施例中，殼為拱頂狀殼且光學穿透元件進一步包括一位於拱頂狀殼內部之透明內核。在一些實施例中，透明內核填充拱頂狀殼以提供一半球狀光學元件。在其它實施例中，可將拱頂狀殼與一半導體發光裝置相組合，該半導體發光裝置經配置成發射光線至透明內核內並通過該透明內核且通過拱頂狀殼以自拱頂狀殼顯露出。其它實施例添加一鄰近半導體發光裝置且遠離透明內核之安裝基板。其它實施例在發光裝置與透明內核之間添加密封劑。

Savant Technologies LLC - 1004.338

在本發明之其它實施例中，殼為一包含一鍵盤鍵面及一自該鍵盤鍵面延伸之鍵盤鍵壁的鍵盤鍵殼。在一些此等實施例中，磷均一地分散於鍵盤鍵殼中。在其它實施例中，磷均一地分散在鍵盤鍵面中，且不包含於鍵盤鍵壁中。在其它實施例中，磷不均一地分散於鍵盤鍵面中且可或可不包括於鍵盤鍵壁中。

根據本發明之其它實施例的發光裝置包括一安裝基板及一位於該安裝基板上的半導體發光裝置。一包括一包含一磷分散於其中之透明塑膠的拱頂狀殼提供於該安裝基板上且至少部分地環繞該半導體發光裝置。一透明內核提供於該拱頂狀殼內部。在其它實施例中，半導體發光裝置與透明內核之間提供有一密封劑。在其它實施例中，安裝基板中包含一空穴，半導體發光裝置至少部分地位於該空穴中，拱頂狀殼位於安裝基板上環繞該空穴且密封劑位於該空穴中。

【實施方式】

現在將參看展示本發明之實施例的隨附圖式於下文中更全面地描述本發明。然而，可以許多不同形式實施本發明且不應將其限於本文所述之實施例。相反，此等實施例係提供以使得本揭示徹底及完整，並全面地向熟習此項技術者傳達本發明之範疇。在圖式中，為清晰之目的，可誇示層及區域之尺寸及相對尺寸。全文中相似數字表示相似元件。

應瞭解：當稱一元件(諸如層、區域或基板)"位於"另一元

Savant Technologies LLC - 1004.339

件"上"時，其可直接位於其它元件上或亦可存在介入元件。應瞭解：若稱一元件之部分(諸如導線之表面)為"外部"，則其比該元件之其它部分更接近裝置之外部。此外，本文可使用諸如"在…下方"之相關術語來描述一層或區域至另一層或區域相對於基板或基層之關係。應瞭解：該等術語係用以包含裝置之除圖中所描繪之方向以外的不同方向。最後，術語"直接地"意味著不存在介入元件。

圖1A至1H為根據本發明之各種實施例之光學穿透元件的截面圖。此等光學元件可用於封裝發光裝置，諸如半導體發光裝置。

如圖1A中所示，根據本發明之一些實施例的光學穿透元件包含一包括透明塑膠之殼100。該殼100包含一分散於其中之磷110。正如熟習此項技術者所熟知的，該殼可包括用於製造光學穿透元件之聚碳酸酯材料及/或其它習知塑膠材料。此外，該磷可包括任意包含摻雜有鈰之習知磷及/或其它習知磷。在一些特定實施例中，磷包括摻雜有銪之釔鋁石榴石(YAG：Ce)。在其它實施例中，可使用奈磷。磷為熟習此項技術者所熟知且本文無需進行進一步描述。

在圖1A中，磷110均一地分散於殼100內。相反，在圖1B中，磷120不均一地分散於殼中。可形成各種圖案之磷120例如以當照明時於殼100上提供更高強度及/或不同顏色之區域及/或提供各種標誌。圖1A至1B中，殼100為拱頂狀殼。如本文中所用，術語"拱頂"及"拱頂狀"係指具有一大致弓狀表面輪廓之結構，包含規則半球狀結構以及其它未形成規

Savant Technologies LLC - 1004.340

則球狀之大致弓狀結構，其在形狀上為偏心的且/或具有其它特徵、結構及/或表面。此外，如下所述，可提供各種其它形狀。

現在參看圖1C，可於殼100之外部提供一或多個塗層130。該塗層可為熟習此項技術者所熟知的用於光學元件之保護性塗層、偏光塗層、具標誌之塗層及/或任意其它習知塗層。圖1D中，於殼100之內表面上提供一或多個內塗層140。此外，可使用任意習知塗層或塗層之組合。

此外，本發明之其它實施例提供用於殼100之內及外塗層，其包含均一分佈於其中之磷110及/或不均一分佈於其中之磷120。通過提供內塗層及外塗層，可提供與磷匹配之經改良指數。因此，根據本發明之一些實施例可對三層進行射出成型。本發明之其它實施例可使用殼內之指數匹配媒介(諸如液體及/或固體凝膠)來輔助指數匹配。內塗層及外塗層之使用可減少歸因於指數匹配問題而截留於含磷層中之光子的數目。

圖1E描述本發明之其它實施例，其中於拱頂狀殼100內部提供一透明內核150。在一些實施例中，亦如圖1E中所示，透明內核150填充拱頂狀殼100，以提供一半球狀光學元件。透明內核150可為均一透明的及/或其中可包含半透明及/或不透明區域。透明內核150可包括玻璃、塑膠及/或其它光學耦接媒介。

圖1F說明本發明之其它實施例，其中將一含磷殼100與一半導體發光裝置160相組合，該半導體發光裝置160經配置

Savant Technologies LLC - 1004.341

成發射光線162至透明內核150中並通過該透明內核150且通過拱頂狀殼100，以自拱頂狀殼100顯露出。半導體發光裝置可包括發光二極體、雷射二極體及/或其它裝置，該等其它裝置可包含一或多個半導體層(其可包括矽、碳化矽、氮化鎵及/或其它半導體材料)、一基板(其可包括藍寶石、矽、碳化矽)或其它微電子基板，及一或多個接觸層(其可包括金屬及/或其它導電層)。熟習此項技術者熟知半導體發光裝置之設計及製造。

例如，發光元件160可為基於氮化鎵之LED或於碳化矽基板上製造之雷射，諸如由Cree, Inc. of Durham, North Carolina製造及銷售之那些裝置。舉例而言，本發明可適於與LED及/或雷射一起使用，正如美國專利第6,201,262、6,187,606、6,120,600、5,912,477、5,739,554、5,631,190、5,604,135、5,523,589、5,416,342、5,393,993、5,338,944、5,210,051、5,027,168、5,027,168、4,966,862及/或4,918,497號中所描述，其揭示內容以引用的方式併入本文中，其引用程度就如本文之全面陳述一般。其它合適LED及/或雷射描述於發明名稱為『Group III Nitride Based Light Emitting Diode Structures With a Quantum Well and Superlattice、Group III Nitride Based Quantum Well Structures及Group III Nitride Based Superlattice Structures』之已公開的美國專利公開案第US 2003/0006418A1號(公開於2003年1月9日)，以及發明名稱為『Light Emitting Diodes Including Modifications for Light Extraction and Manufacturing

Savant Technologies LLC - 1004.342

Methods Therefor』之已公開的美國專利公開案第US 2002/0123164 A1號中。此外，經磷塗佈之LED，諸如在於2002年9月19日申請之發明名稱為『Phosphor-Coated Light Emitting Diodes Including Tapered Sidewalls, and Fabrication Methods Therefor』的美國臨時申請案第60/411,980號(其揭示內容以引用的方式併入本文中)中所描述的那些，亦可適用於本發明之實施例中。

LED及/或雷射經配置可運作以使得光發射發生通過基板。在此等實施例中，舉例而言，如在以上所引用之美國專利公開案第US 2002/0123164 A1號中所描述的，可圖案化基板以增強裝置之光輸出。

圖1G為本發明之其它實施例的截面圖。如圖1G中所示，提供一安裝基板170，使得發光裝置160位於該安裝基板170與透明內核150之間。亦如圖1G中所示，在一些實施例中，安裝基板170包含一空穴172於其中且發光裝置160至少部分地位於空穴172中。

最後，圖1H說明本發明之其它實施例。在此等實施例中，可用諸如環氧物及/或其它光學耦接媒介(例如，矽)之密封劑180填充空穴170。密封劑180可增強自發光裝置160至透明內核150之光學耦接。可用於本發明之一些實施例中之安裝基板170的設計及製造係描述於Negley的同時申請且發明名稱為『Solid Metal Block Mounting Substrates for Semiconductor Light Emitting Devices, and Oxidizing Methods for Fabricating Same』(Attorney Docket 5308-311)

Savant Technologies LLC - 1004.343

之美國專利申請案(其讓渡給本發明之受讓人)中，其全文以引用的方式併入本文中，該引用程度如本文之完全描述一般。

熟習此項技術者將瞭解：儘管將圖1A至1H之實施例作為單獨的實施例來加以說明，但可以元件之各種組合及次組合來共同使用圖1A至1H之各種元件。因此，例如，可共同使用內塗層及外塗層140及130之組合、均一分佈之磷110及不均一分佈之磷120、發光裝置160、安裝基板170、空穴172、內核150及密封劑180。因此，不應將本發明限於圖1A至1H中所示之單獨的實施例。

圖2A為根據本發明之其它實施例的發光裝置之截面圖。如圖2A中所示，此等實施例包含一可由載有磷及/或其它化學物質之光學清晰材料所製成之外殼200。內核250可由諸如塑膠或玻璃之光學清晰材料製成且可被置放於安裝基板270中之含密封劑之空穴272上。外殼200及內核250形成用於發光二極體260之複合透鏡。

圖2B為根據本發明之其它實施例的發光裝置之截面圖。如圖2B中所示，此等實施例包括一內殼202，其可由諸如載有磷及/或其它化學物質之聚合物的光學清晰材料製成。外殼252可由諸如塑膠或玻璃之光學清晰材料製成。如圖2A中之狀況，提供一密封空穴272及一安裝基板270以形成一用於發光二極體260之複合透鏡。

圖3A至3F為根據本發明之其它實施例的光學穿透元件之截面圖，其可用於形成(例如)可用於行動電話、汽車儀錶

Savant Technologies LLC - 1004.344

板、攜帶型電腦及其它包括經說明之鍵盤之習知裝置中的鍵盤鍵。現在參看圖3A，一光學穿透元件包含一鍵盤鍵殼，其包含一具有磷310分散於其中之鍵盤鍵面300。在圖3A中，磷310均一地分散其中，而在圖3B中，磷320不均一地分散於其中。如上所述，不均一分散可提供不同光強度、不同顏色及/或標誌。

圖3C中，鍵盤鍵亦包含自鍵盤鍵面300延伸之鍵盤鍵壁330。在圖3C中，磷310均一地分佈在鍵盤鍵面300及鍵盤鍵壁330中。在圖3D中，磷320'均一地分佈在鍵盤鍵面300上，但不包含於鍵盤鍵壁330中。在圖3E中，磷320不均一地分佈在鍵盤鍵面300中且不包含於鍵盤鍵壁330中。

圖3F說明了一鍵盤鍵，其包含一鍵盤鍵面300及一安裝於罩殼370中之鍵盤鍵壁330，且包括一位於罩殼及鍵之間的發光裝置(諸如半導體發光裝置)以發射光線362通過鍵盤鍵面300及/或鍵壁330之發光裝置。應瞭解：可將光導引件用於定位半導體發光裝置360使其遠離鍵。亦應瞭解：可以組合及/或次組合使用圖3A至3F中所示之各種元件，使得(例如)可將均一及/或不均一分佈之磷310、320、320'用於鍵面及/或鍵壁330中。因此，不應將本發明限於圖3A至3F中個別展示之各種元件組合。

圖4為用於形成根據本發明之各種實施例之光學穿透元件之設備的示意性方塊圖。詳言之，圖4說明了可用於形成根據本發明之各種實施例之光學穿透元件的射出成型設備。如圖4中所示，射出成型設備包含一其中提供透明塑膠

Savant Technologies LLC - 1004.345

及/或磷添加劑450之給料斗410或其它儲存裝置。可以顆粒、粉末及/或固體形式提供透明塑膠及/或磷添加劑。正如熟習此項技術者所熟知的，可包含諸如溶劑、黏合劑等等之其它添加劑。注射器420可包含一加熱器及一螺絲機構，其係用於熔化透明塑膠及磷添加劑及/或將此等材料維持於於熔合狀態，以提供包括透明塑膠及磷添加劑之熔融液體。注射器420將該熔融液體經由噴嘴430注入模440中。模440中包含一可用於界定諸如拱頂或鍵盤鍵之光學元件之形狀的適當通道450。光學元件之射出成型係為熟習此項技術者所熟知且被描述(例如)於美國專利4,826,424、5,110,278、5,882,553、5,968,422、6,156,242及6,383,417中，且本文無需對其進行進一步詳細描述。亦應瞭解：亦可使用澆鑄技術，其中包括透明塑膠及磷添加劑之熔融液體係提供於一陰模(female mold)中，隨後將該陰模耦接至一陽模(male mold)(或反之亦然)以澆鑄光學元件。光學元件之澆鑄係描述(例如)於美國專利4,107,238、4,042,552、4,141,941、4,562,018、5,143,660、5,374,668、5,753,730及6,391,231中，且本文無需對其進行進一步詳細描述。

圖5為可用於製造根據本發明之各種實施例之光學穿透元件的步驟流程圖。如圖5中所示，在步驟510中，以包括透明塑膠及磷添加劑之熔融液體填充一模(諸如圖4之模440)。在步驟520中，容許該熔融液體凝固以產生具有磷分散於其中之光學元件。

圖6為可執行以製造根據本發明之實施例之半導體發光

裝置的步驟流程圖。如圖6中所示，在步驟610中，使用射出成型、澆鑄及/或其它習知技術來模製一包括一包含磷分散於其中之透明塑膠的殼，諸如圖1A之拱頂狀殼100。在步驟620中，形成一核，諸如圖1E之核150。應瞭解，在一些實施例中，核150置放或形成於拱頂狀殼100內部，而在其它實施例中，步驟620藉由如下操作而先於步驟610：形成一透明核150且以包括透明塑膠及磷添加劑之熔融液體填充一包含透明核150之模，以環繞該透明核形成拱頂狀殼100。

仍參看圖6，將一半導體發光裝置(諸如圖1G之裝置160)置放於一安裝基板(諸如安裝基板170)上。在步驟640中，將密封劑(諸如圖1H之密封劑180)施加至安裝基板170、發光裝置160及/或核150。最後，在步驟650中，使用環氧物、搭扣配合及/或其它習知安裝技術將殼配合至安裝基板。

需要內核150填充整個透鏡，以減少或最小化可使用之密封劑180的數量。正如熟習此項技術者所熟知的，密封劑180可具有與安裝基板170及/或內核110不同之熱膨脹係數。藉由減少或最小化在步驟640中所使用之密封劑180的數量可減少或最小化此等熱失配之影響。

亦應注意：在一些替代實施中，圖5及/或6之步驟中所說明的功能/行為可以與流程圖中所說明之順序不相稱之順序而發生。舉例而言，視所涉及之功能/行為而定，實際上可大體同時執行相繼展示之兩步驟或有時可以相反順序執行該等步驟。

Savant Technologies LLC - 1004.347

因此，本發明之一些實施例可使用模製或澆鑄技術形成諸如透鏡之複合光學元件。舉例而言，用於電話之鍵盤可使用兩步驟射出成型處理來形成雙色鍵，或當僅使用一層較薄且更昂貴的材料時使用較低成本之塑膠以給出機械穩定性來增強外觀並降低成本。在一些實施例中，可將射出成型用於將分散於模製材料中之磷層置放於內或外表面上並隨後在剩餘體積中完成模製或澆鑄處理，以形成所需光學元件。在一些實施例中，此等光學元件可將鍵或拱頂後之藍光發射二極體轉換成白光。

本發明之其它實施例可使用磷來均勻地分散光線及/或將光線分散成所需圖案。舉例而言，習知發光裝置可以"蝙蝠翼"輻射圖案發射光線，其中與軸上(0°)或側面(例如，大於約40°之角度)相比，在軸外角(諸如約40°軸外角)處提供較大光強度。其它發光二極體可提供"Lambertian"輻射圖案，其中最大強度集中於一中央區域至約40°軸外處且隨後在較大角度處迅速降落。其它習知裝置可提供側面發射輻射圖案，其中最大光強度係提供於大角度(諸如自軸90°)處且在接近軸之較小角度處迅速下降。相反，本發明之一些實施例可減少或消除自發光裝置輸出之光線的依賴角度之輻射圖案，諸如與顏色相關之溫度(CCT)的角度依賴性。因此，在一些實施例中，來自透鏡所有表面之光強度及x,y色度值/座標可相對保持恆定。當用於照明應用(例如其中無需聚光效果之房間)時其為有利的。

根據本發明之一些實施例，上述射出成型處理可容許形

Savant Technologies LLC - 1004.348

成一具有諸如透鏡化及白色轉換之多種特徵的單個光學元件。此外，根據一些實施例，使用二模製或澆鑄技術，可將磷層定型成所需之形態，以減少或最小化對具視角之色溫的角度依賴性。

在圖式及說明書中已揭示了本發明之實施例，且儘管使用了特定術語，但其僅用於一般及描述意義且並非用於限制之目的，本發明之範疇陳述於如下申請專利範圍中。

【圖式簡單說明】

圖1A至1H為根據裝置之本發明之第一實施例的光學穿透元件之截面圖。

圖2A及2B為根據本發明之其它實施例的半導體發光裝置之截面圖。

圖3A至3F為根據可提供鍵盤鍵之本發明之其它實施例的光學元件之截面圖。

圖4為根據本發明之實施例可用於製造光學元件之模製設備的示意圖。

圖5及圖6為根據本發明之實施例可執行以製造發光裝置之操作的流程圖。

【主要元件符號說明】

100	殼
120, 110, 310, 320, 320'	磷
130	外塗層
140	內塗層
150	透明內核

Savant Technologies LLC - 1004.349

160	發光裝置/發光元件
162, 362	光線
170, 270	安裝基板
172	空穴
180	密封劑
250	內核
252	外殼
200	外殼
260	發光二極體
272	密封空穴
202	內殼
300	鍵面
330	鍵壁
360	發光裝置
370	罩殼
410	給料斗
450	磷添加劑
420	注射器
430	噴嘴
440	模
460	通道

Savant Technologies LLC - 1004.350

十、申請專利範圍：

1. 一種用於形成一光學穿透元件之方法，其包括：

以一包括一透明塑膠及一磷添加劑之熔融液體填充一模；及

容許該熔融液體凝固以產生具有磷分散於其中之該光學穿透元件。

2. 如請求項1之方法，其中該光學穿透元件為一拱頂，一發光裝置發射光線通過該拱頂，且其中該填充步驟包括以一包括一透明塑膠及一磷添加劑之熔融液體填充一拱頂狀模。

3. 如請求項2之方法，其進一步包括：

形成一透明核於該拱頂內部。

4. 如請求項2之方法，其進一步包括：

形成一透明外殼於該拱頂外部。

5. 如請求項3之方法，其進一步包括：

形成一透明外殼於該拱頂外部。

6. 如請求項2之方法，其中形成一透明核之步驟係先於該填充步驟，且其中該填充步驟包括以一包括一透明塑膠及一磷添加劑之熔融液體填充一包含該透明核之拱頂狀模。

7. 如請求項1之方法，其中該光學穿透元件為一鍵盤鍵，一發光裝置發射光線通過該鍵盤鍵，且其中該填充步驟包括以一包括一透明塑膠及一磷添加劑之熔融液體填充一鍵盤鍵狀模。

Savant Technologies LLC - 1004.351

8. 如請求項1之方法，其中該光學穿透元件為一鍵盤鍵面，一發光裝置發射光線通過該鍵盤鍵面，該方法進一步包括：

形成一附著至該鍵盤鍵面之鍵盤鍵壁。

9. 一種光學穿透元件，其包括：

一殼，其包括一含有一磷分散於其中之透明塑膠。

10. 如請求項9之光學穿透元件，其中該磷均一地分散於該殼中。

11. 如請求項9之光學穿透元件，其中該磷不均一地分散於該殼中。

12. 如請求項9之光學穿透元件，其中該殼為一拱頂狀殼，該光學穿透元件進一步包括一位於該拱頂狀殼內部之透明內核。

13. 如請求項9之光學穿透元件，其中該殼為一拱頂狀殼，該光學穿透元件進一步包括一位於該拱頂狀殼外部之透明外核。

14. 如請求項12之光學穿透元件，其中該殼為一拱頂狀殼，該光學穿透元件進一步包括一位於該拱頂狀殼外部之透明外核。

15. 如請求項12之光學穿透元件，其中該透明內核填充該拱頂狀殼。

16. 如請求項12之光學穿透元件，其與一半導體發光裝置相組合，該半導體發光裝置經配置成發射光線至該透明內核中並通過該透明內核且通過該拱頂狀殼，以自該拱頂

Savant Technologies LLC - 1004.352

狀殼顯露出。

17. 如請求項16之光學穿透元件，其進一步與一鄰接於該半導體發光裝置之安裝基板相組合，使得該半導體發光裝置位於該安裝基板與該透明內核之間。

18. 如請求項17之光學穿透元件，其進一步與一位於該半導體發光裝置與該透明內核之間的密封劑相組合。

19. 如請求項9之光學穿透元件，其中該殼為一鍵盤鍵殼，其包括一鍵盤鍵面及一自該鍵盤鍵面延伸之鍵盤鍵壁。

20. 如請求項19之光學穿透元件，其中該磷均一地分散於該鍵盤鍵殼中。

21. 如請求項19之光學穿透元件，其中該磷均一地分散於該鍵盤鍵面中且不包含於該鍵盤鍵壁中。

22. 如請求項19之光學穿透元件，其中該磷不均一地分散於該鍵盤鍵面中。

23. 一種發光裝置，其包括：

一安裝基板；

一位於該安裝基板上之半導體發光裝置；

一位於該安裝基板上並包括一含有一磷分散於其中之透明塑膠的拱頂狀殼，其至少部分環繞該半導體發光裝置；及

一位於該拱頂狀殼內部之透明內核。

24. 如請求項23之發光裝置，其進一步包括：

一位於該半導體發光裝置與該透明內核之間的密封劑。

Savant Technologies LLC - 1004.353

25. 如請求項24之發光裝置，其中該安裝基板中包含一空穴，其中該半導體發光裝置至少部分地位於該空穴中，其中該拱頂狀殼位於該安裝基板上環繞該空穴，且其中該密封劑位於該空穴中。

26. 如請求項23之發光裝置，其進一步包括：

一位於該拱頂狀殼外部之透明外殼。

十一、圖式：

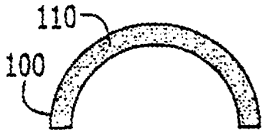


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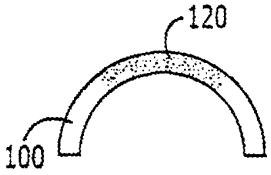


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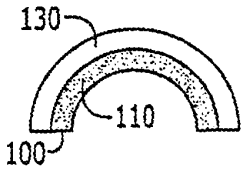


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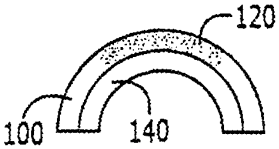


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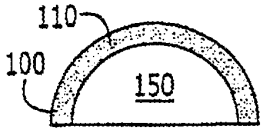


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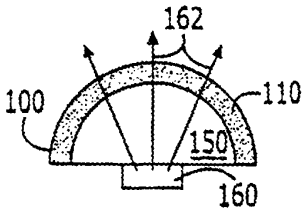


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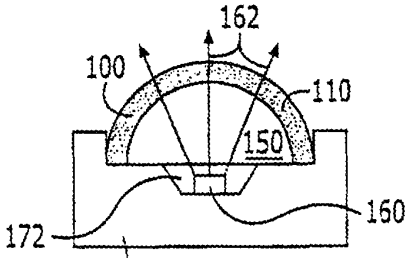


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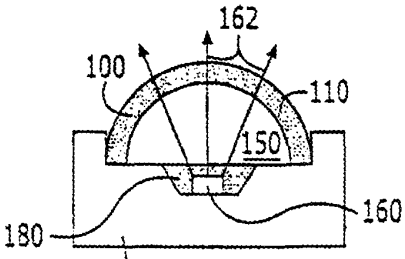


圖 1H

Savant Technologies LLC - 1004.355

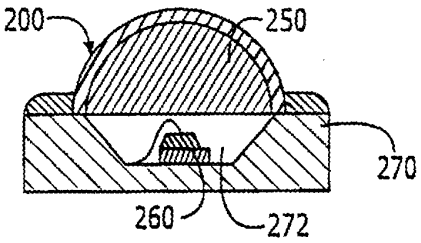


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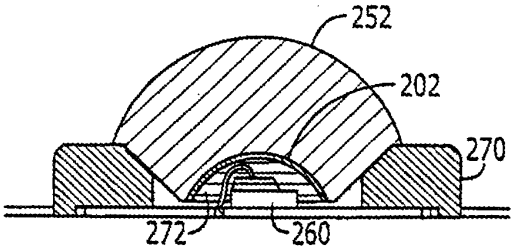


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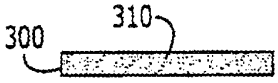


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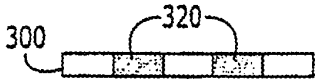


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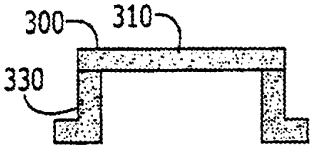


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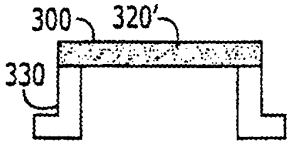


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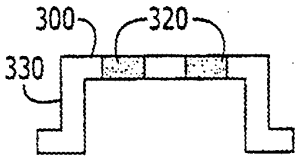


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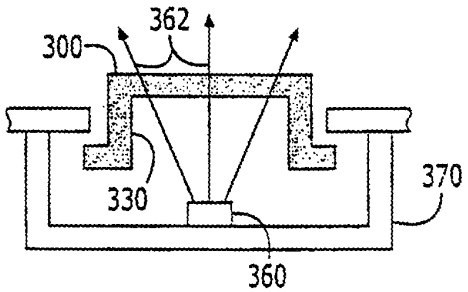


圖 3F

Savant Technologies LLC - 1004.356

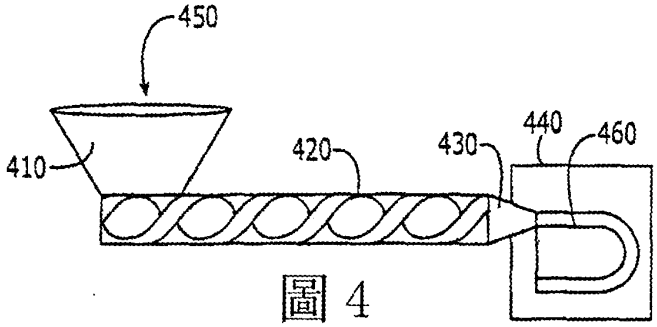


圖 4

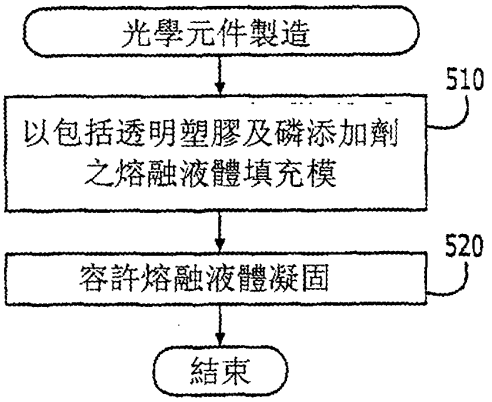


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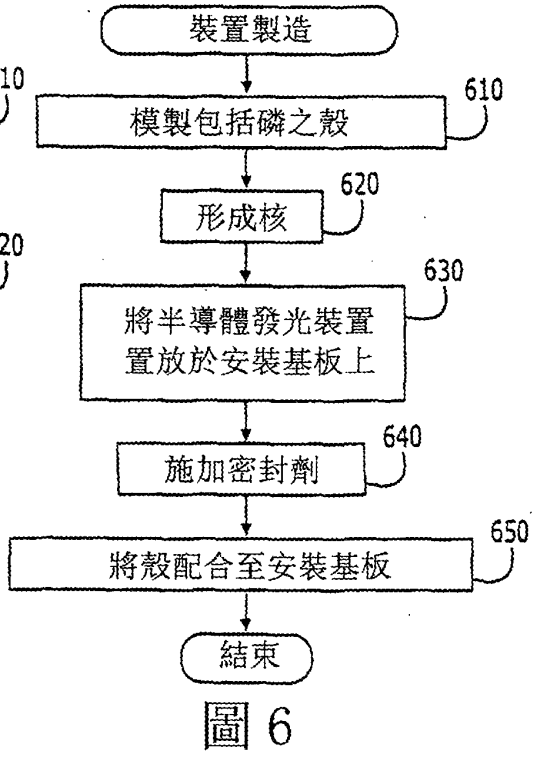


圖 6

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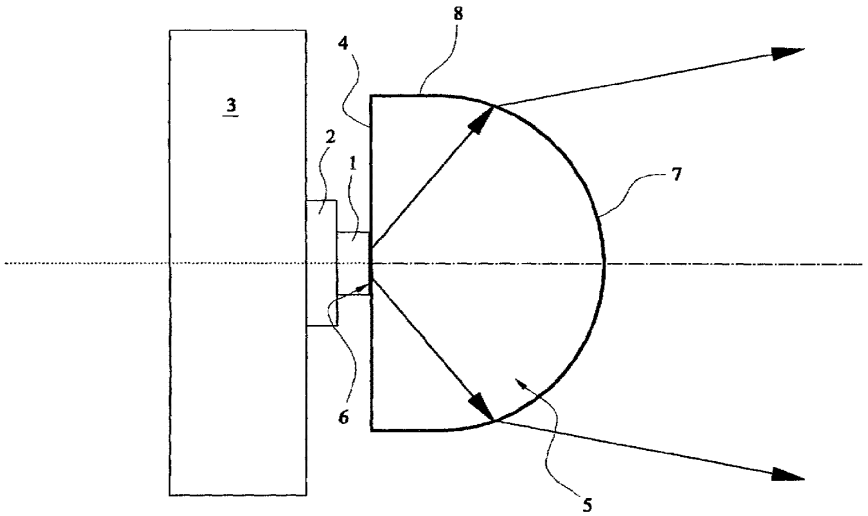
(74) Agents: **GODDARD, David, John**; Harrison Goddard Foote, Orlando House, 11c Compstall Road, Marple Bridge, Stockport SK6 5HH et al. (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

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[Continued on next page]

(54) Title: LIGHT EMITTING DIODE WITH LENS



(57) Abstract: To increase the amount and/or directionality of light from a light emitting diode (LED) 1, it is provided on its light emitting surface with a lens (5) comprising a substantially hemispherical portion (7) of radius (r) on a base portion (8) of height (h), where (h) is no greater than 0.95 r/n, or no greater than (r/n)(1 - d/2r), d is the LED diameter and n is the real refractive index of the lens. Preferably lens (5) is substantially index matched to the LED, for example Ge on an indium antimonide or indium antimonide alloy LED for use in the infra-red, and has an antireflection coating. It may be provided by depositiong and shaping a semiconducting layer during and/or after the formation of the LED, or a separate layer may be secured thereto by an optically thin layer of adhesive.

WO 02/07228 A1

Savant Technologies LLC - 1004.358

patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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Light Emitting Diode With Lens

The present invention relates to light emitting diodes (LEDs). It is particularly but not exclusively directed to LEDs which emit electromagnetic radiation through a side surface of the semiconductor structure which lies parallel to the diode junction.

Light emitting diodes have many applications, including telecommunications, spectroscopy and gas sensing. A recent development is that of room temperature infra-red light emitting diodes which cover the 3 to 12 micron spectral region where gases such as carbon dioxide, carbon monoxide, nitrogen oxides, sulphur oxides and carbohydrates have strong selective absorption bands enabling quantitative gas detection.

It is clearly advantageous to be able to maximise the optical output power of a light emitting diode. For example in infra-red gas sensing at low concentrations, such as in the parts-per-billion (ppb) to parts-per-million (ppm) range, the output powers of existing devices are not sufficient to provide conditions allowing a good signal-to-noise ratio.

A major reason for the low output power is the inefficiency in transmitting the light generated at the diode junction to the exterior, and a principal cause thereof is total internal reflection within the device. As is well known, light can only pass from an optically dense medium (high real refractive index of value n) to air (where n is nominally unity) if its angle of incidence is no greater than $\sin^{-1}(1/n)$, and it otherwise undergoes total internal reflection. Thus, for a side emitting LED based on indium antimonide (InSb), where $n = 4$, and assuming a uniform angular distribution of optical emission from the diode junction over a solid hemispherical angle 2π towards a planar side surface of the device, only 3% of the light emitted within the junction is directly transmitted through the planar surface.

Additionally, the latter small amount of light is emitted over a large solid angle. It is commonly difficult or impractical to collect light within a large solid angle by the use of external optics, thereby adding to the disadvantages when a directed beam of light is required.

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The present invention is directed to reducing the amount of light lost due to reflection within LEDs, and/or to increasing the directionality of light emitted from LEDs. The first step should reduce the optical output power necessary from the diode junction for a given device overall output, or should increase the device overall output for a given output from the diode junction. The second step should reduce the optical output power necessary from the diode junction for a given device output in a predetermined direction, or should increase the device output in a predetermined direction for a given output from the diode junction.

It is known to provide the light emitting surface of a light emitting diode with a focussing structure for increasing the amount of emitted light by reason of its shape and improved index matching with the LED. Typical examples are a hemisphere, a Weierstrasse sphere and a glass dome, each of which is described in pages 58 to 63 of "Injection Luminescent Devices" by C H Gouch, Wiley 1979.

Conventionally the Weierstrasse sphere, viz. a hemisphere of radius r on a spherical segment base of equal radius r, is formed with a base height h = r/n, where n is the refractive index of the material of the sphere, and it can provide an increase in light output of up to $2n^2$ times (about 32 for Ge) relative to that of the diode 1 without a focussing element. The glass dome is similar, except that the a spherical segment base is replaced by a coaxial right cylinder base of radius r and height r/n, which is easier to manufacture but does lead to a some lowering of efficiency.

However, it has now been appreciated that this base thickness is not always optimal since ray tracing diagrams indicate that the output thereof provides both diverging and converging rays, as illustrated in Figure 2. The existence of the converging rays increases the apparent size of the source and hence decreases the radiance of the source (the LED).

To eliminate this effect it has been found that the height h needs to be no greater than (r/n)(1 - d/2r) where d is the LED diameter. Where d = 0.3 and r = 1.5, this leads to the conclusion that h has to be less than 0.9r/n.

Savant Technologies LLC - 1004.361

The present invention provides a light emitting diode device provided on its light emitting surface with a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than 0.95r/n, where n is the real refractive index of the lens.

The present invention also provides light emitting diode device provided on its light emitting surface with a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than (r/n)(1 - d/2r) where d is the LED diameter and n is the real refractive index of the lens.

The invention extends to a lens as defined in either of the two preceding paragraphs. It also extends to methods of making a device (or an adapted LED) as defined in either of the two preceding paragraphs.

It should be understood that although specific reference has been made to a glass dome and a Weierstrasse sphere, in which the base has a specific shape, any other optically appropriate base shape could be employed with the invention so long as its height is within the specified range.

Preferably h is no greater than 0.85r/n. A preferred lower limit for h is 0.3r/n, more preferably 0.5r/n.

The focussing element may be formed in an additional layer made integrally with LED, for example by deposition of a semiconducting layer during or after formation of the LED. Shaping of the additional layer may be by any means known per se, for example by etching or ion beam milling, e.g. after deposition thereof.

Alternatively, the focussing element may be made from a separate layer, for example of glass or a semiconducting material such as germanium, which is secured to the light emitting surface of the LED in optical contact therewith. By "optical contact" is meant that the gap between the device and the element is no greater than one quarter of the LED wavelength within the material (i.e. vacuum wavelength divided by n), thus providing a condition in which total internal reflection is effectively prevented and permitting light generated within the device to penetrate through the element surface over a wide range of incident angles.

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Preferably the securing is effected by use of a sufficiently thin layer of optically transparent adhesive. This will generally require specialised or adapted tooling and a controlled pressure.

While shaping of a layer thus secured may be effected after the securing step, it is preferably effected prior thereto.

The refractive index of the material of the focussing element preferably has a refractive index differing from the adjacent LED layer by no more than 1, more preferably no more than 0.5, even more preferably no more than 0.3, and most preferably, it equals that of the adjacent LED layer, e.g. by being made of the same material.

Further details and advantages of the invention will become apparent upon a reading of the appended claims, to which the reader is referred, and upon a consideration of the following description of embodiments of the invention made with reference to the accompanying drawings, in which:

Figure 1 shows an embodiment of the invention in diagrammatic cross-section; and

Figure 2 is a ray tracing for a typical dome structure with base height of r/n.

Figure 1 shows a first arrangement according to the invention in which an indium antimonide or indium antimonide alloy LED mesa 1 is formed upon (and normally integrally with) a semiconductor substrate 2, the latter in turn being supported upon a further substrate 3. The flat surface 4 of a germanium lens 5 is secured to a flat light emitting surface of the diode mesa 1 by a layer 6 of optically transparent glue, using tooling and a controlled pressure to ensure that the glue thickness is less than one quarter of the LED wavelength inside the material. As shown, the lens 5 comprises a convex (hemispherical) portion 7 with a radius of curvature of 2.5 mm, and a right cylindrical base portion 8 which is 0.5 mm high (thick), allowing the light from the LED to be retransmitted without total internal reflection restrictions. The LED is coaxial with the lens 5 and has a diameter of up to 1 mm.

Savant Technologies LLC - 1004.363

Spherical aberration of lens 5 can be avoided only for point sources on the axis, and for all sources of finite dimension the spherical aberration is significant. In the latter case, as in Figure 1, both the apparent source position and its apparent area are determined by the circle of least confusion, which depends strongly on the actual emitting area and also on the thickness h. It should therefore be clear that the geometry normally needs to be optimised with respect to the brightness of the LED 1 and the angular distribution of light therefrom.

Optimisation of the height h for a particular LED light emitting area is effected by ray tracing the position and diameter of the circle of least confusion, using ray tracing software.

The surface of the lens 5 will normally be provided with an antireflection coating.

Savant Technologies LLC - 1004.364

CLAIMS

1. A light emitting diode device provided on its light emitting surface with a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than 0.95r/n, where n is the real refractive index of the lens.

2. A device according to claim 1 wherein h is no greater than 0.85r/n.

3. A device according to claim 1 or claim 2 wherein h is no less than 0.3r/n.

4. A light emitting diode device provided on its light emitting surface with a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than (r/n)(1 - d/2r) where d is the LED diameter and n is the real refractive index of the lens.

5. A device according to any preceding claim wherein the refractive index of the material of the lens has a refractive index differing from the adjacent LED layer by no more than 1.

6. A device according to claim 4 wherein the refractive index n of the material of the focussing element differs from that the adjacent LED layer by no more than 0.5.

7. A device according to claim 4 wherein the refractive index n of the material of the lens is substantially equal to that of the adjacent LED layer.

8. A device according to claim 7 wherein the material of the lens is substantially the same as that that of the adjacent LED layer

9. A device according to any preceding claim wherein the LED emits infra-red light.

10. A device according to claim 9 wherein the LED emits at a wavelength within the 3 to 12 micron range.

11. A device according to any preceding claim wherein the LED is formed of indium antimonide or an indium antimonide alloy.

Savant Technologies LLC - 1004.365

12. A device according to any one of claims 1 to 7, 9 to 11 wherein the focussing element is formed of germanium.

13. A method of making a light emitting diode device, comprising forming a light emitting diode on or in a substrate, and depositing a further layer on the outer surface of the diode, said further layer providing a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than 0.95r/n, where n is the real refractive index of the lens.

14. A method of making a light emitting diode device, comprising forming a light emitting diode on or in a substrate, and depositing a further layer on the outer surface of the diode, said further layer providing a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than (r/n)(1 - d/2r) where d is the LED diameter and n is the real refractive index of the hypersphere.

15. A method according to claim 13 or claim 14 wherein said further layer is shaped to provide said lens subsequent to the formation of the light emitting diode.

16. A method of adapting a light emitting diode formed in or on a substrate comprising securing a further layer on the outer surface of the diode, said further layer providing a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than 0.95r/n, where n is the real refractive index of the lens.

17. A method of adapting a light emitting diode formed in or on a substrate comprising securing a further layer on the outer surface of the diode, said further layer providing a lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than (r/n)(1 - d/2r) where d is the LED diameter and n is the real refractive index of the hypersphere.

18. A method according to claim 16 or claim 17 wherein the further layer is shaped to provide said lens prior to said securing step.

Savant Technologies LLC - 1004.366

19. A lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than 0.95r/n, where n is the real refractive index of the lens.

20. A lens comprising a substantially hemispherical portion of radius r on a base portion of height h, where h is no greater than (r/n)(1 - d/2r) where d is the LED diameter and n is the real refractive index of the hypersphere.

21. An optical element according to claim 19 or claim 20 wherein the hypersphere is made of germanium.

22. A light emitting diode substantially as hereinbefore described with reference to the accompanying drawing.

Savant Technologies LLC - 1004.367

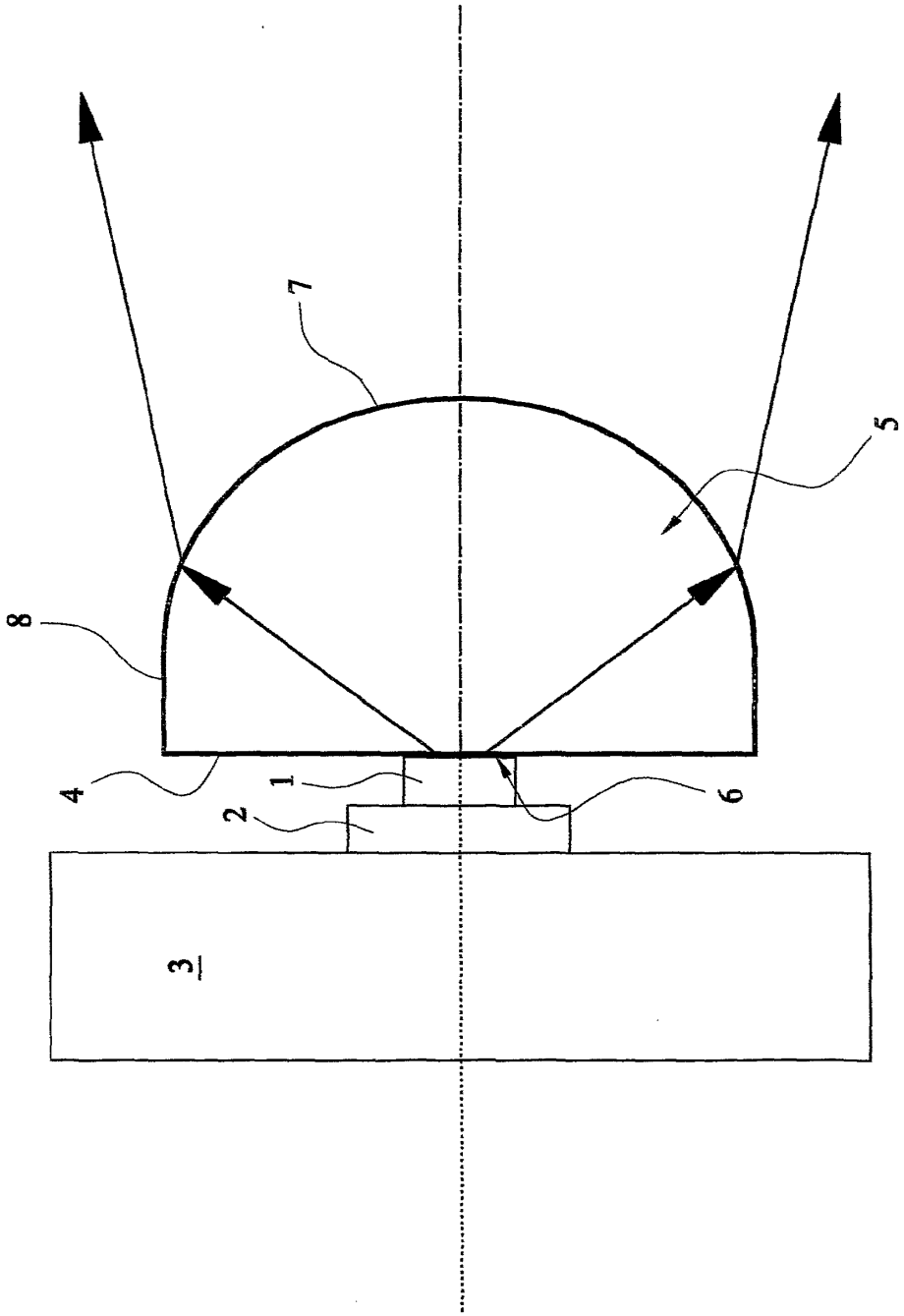


FIG. 1

Savant Technologies LLC - 1004.368

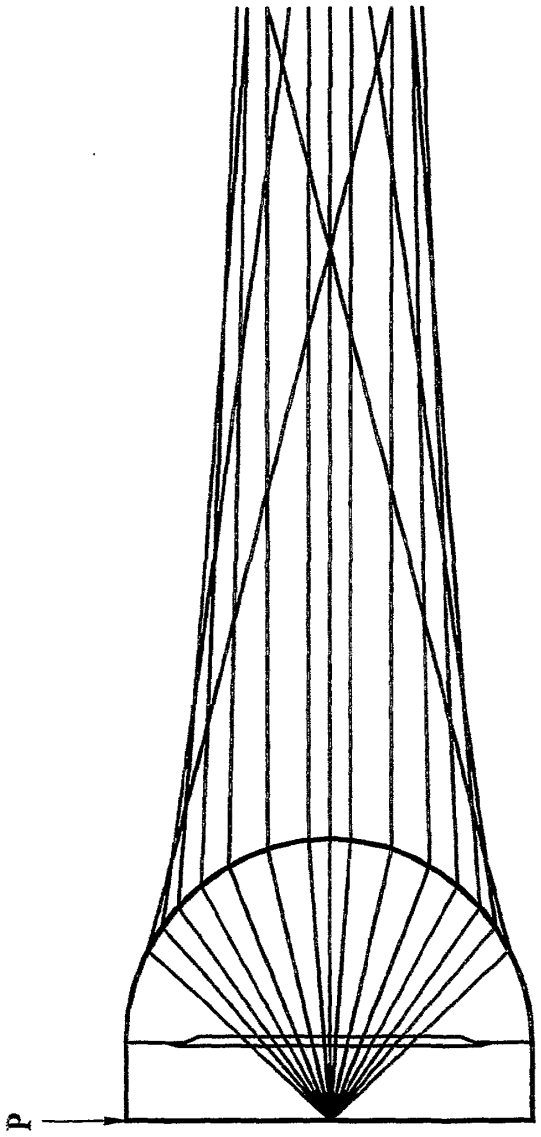


FIG. 2

Savant Technologies LLC - 1004.369

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 01/03155

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Savant Technologies LLC - 1004.370

INTERNATIONAL SEARCH REPORT

International Application No
I../GB 01/03155

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Savant Technologies LLC - 1004.371

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 01/03155

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Savant Technologies LLC - 1004.372

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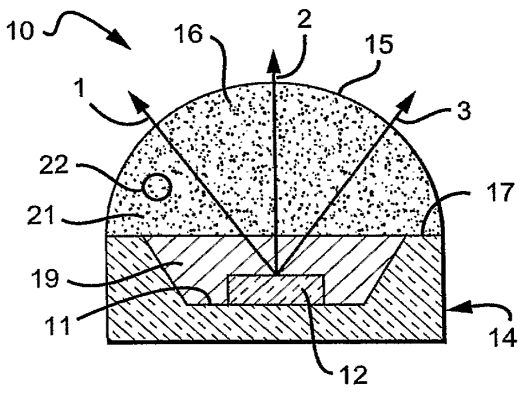
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Published:
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(54) Title: COMPOSITE WHITE LIGHT SOURCE AND METHOD FOR FABRICATING



(57) Abstract: An emitter includes a light source and a separately formed conversion material region with conversion particles. The light source is capable of emitting light along a plurality of light paths extending through the conversion material region where at least some of the light can be absorbed by the conversion particles. The light from the light source and the light re-emitted from the conversion particles combine to provide a desired color of light. Each light path extends through a substantially similar amount of conversion particles so that the desired color of light has a substantially uniform color and intensity along each light path.

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Savant Technologies LLC - 1004.373

COMPOSITE WHITE LIGHT SOURCE AND METHOD FOR FABRICATING

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 60/451,067 filed February 26, 2003.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention relates to light emitters and, more particularly, to light emitters where the wavelength of at least some of the emitted light is converted to another wavelength by a conversion material region.

Description of the Related Art

[0003] Light emitting diodes (LEDs) are an important class of solid-state devices that convert electric energy to light energy and generally comprise an active layer of semiconductor material sandwiched between two oppositely doped layers. When a bias is applied across the doped layers, holes and electrons are injected into the active layer where they recombine to generate light. Light is typically emitted omnidirectionally from the active layer and from the surfaces of the LED.

[0004] One disadvantage of conventional LEDs used for lighting applications is that they cannot generate white light from their active layers. One way to cause a single blue emitting LED to emit white light is to surround it with a yellow phosphor, polymer or dye. [See

Savant Technologies LLC - 1004.374

Nichia Corp. white LED, Part No. NSPW300BS, NSPW312BS, etc.; See also U.S. Patent No. 5959316 to Hayden, "Multiple Encapsulation of Phosphor-LED Devices"]. The surrounding material "downconverts" the wavelength of at least some of the light, changing its color. For example, if a blue emitting LED is surrounded by a yellow phosphor, then some of the blue light passes through the phosphor without being changed while the remaining light is downconverted to yellow. Hence, the LED emits both blue and yellow light, which combines to form a white light.

[0005] One conventional method for manufacturing an LED surrounded by a conversion material region is to mount the LED in a cup shaped submount with the necessary electrical connections to apply a bias to the LED. A syringe mechanism is filled with an optically clear and curable material (e.g. epoxy, silicon, sol gel, etc.) with the conversion material mixed in the material, where the conversion material typically includes phosphor particles. The syringe mixture is then injected into the submount, covering the LED and partially filling the submount. When the clear material is first injected into the cup, the conversion particles are generally uniformly mixed/suspended throughout the material. The clear material is then cured to form the conversion material region and the entire assembly is encased in a clear epoxy.

[0006] One disadvantage of this manufacturing method is that under certain circumstances the conversion particles can be non-uniformly distributed in the cured state. After the clear material mixture is injected into a cup,

there can be a time delay before it is cured. During this delay, the conversion particles can settle toward the base of the cup and over the LED such that there are different concentrations of particles throughout the conversion material region. This settling problem can be compounded in clear materials that dehydrate during the curing process, which allows the conversion particles to settle more quickly. The settled conversion material region can result in light from the emitter appearing as different colors and/or intensities when viewed from different angles because the emitted light encounters different amounts of conversion material.

[0007] Another disadvantage of this method is that the injection of the optically clear material from a syringe can introduce variations in the concentration of conversion particles from emitter to emitter, which can reduce the consistent reproducibility of the emitters. The conversion particles can settle in the syringe such that emitters injected with the clear material mixture when the syringe is full can have a greater concentration of conversion particles than emitters formed later. The amount of clear material injected from the syringe into the cup can also be difficult to control and different amounts of clear material mixture can be deposited in different emitters. This can also result in different amounts of conversion particles in different emitters. The end surface shape of the cured material can also vary such that light from different LEDs pass through different amounts of clear material and particles. These problems reduce the ability to manufacture emitters with consistent light emission characteristics.

[0008] Another disadvantage of the conventional emitter manufacturing method is the waste of material when the emitter does not meet the necessary emission standards. There is no practical method for separating the two so the entire emitter must be discarded if the emitter or the conversion material region is defective. Hence, if the LED is good but the conversion material region is defective, then both will be unusable. Discarding the entire emitter results in the excessive wasting of otherwise good LEDs, which can add to the overall cost of manufacturing.

SUMMARY OF THE INVENTION

[0009] The present invention provides an improved LED based emitter and method for fabricating an emitter that addresses the disadvantages of conventional emitters and methods. One embodiment of an emitter according to the present invention comprises a light source which emits a first spectrum of light. A conversion material region is included that is formed separately from said light source and includes conversion particles. The conversion material region is positioned in proximity to the light source such that at least some of the light source light passes through the conversion material region. The conversion particles absorb at least some of the light source light passing through the conversion material region and emitting a second spectrum of light.

[0010] Another embodiment of an emitter according to the present invention comprises a light source which emits a first spectrum of light and a conversion material region

Savant Technologies LLC - 1004.377

formed separately from said light source. The conversion material region is positioned proximate to the light source and arranged to absorb at least some of the light emitted by the light source and re-emit light at a second spectrum of light. The emitter emits a combination of the first and second spectrums of light in a uniform third spectrum of light.

[0011] One embodiment of a method of fabricating an emitter according to the present invention comprises providing a light source and providing a separately formed conversion material region which includes conversion particles. The conversion material region is then bonded proximate to the light source. The conversion material region is positioned so that at least some of the light emitted from the light source at different angles flows through said conversion material region and through the substantially the same amount of conversion particles.

[0012] These and other further features and advantages of the invention would be apparent to those skilled in the art from the following detailed description, taking together with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a sectional view of one embodiment of a light emitter according to the present invention having a hemispheric shaped phosphor-containing lens that is manufactured separately from the LED and submount;

[0014] FIG. 2 is a sectional view of the emitter of FIG. 2, with the separate pieces bonded together;

Savant Technologies LLC - 1004.378

[0015] FIG. 3 is a sectional view of another embodiment of an emitter according to the present invention having a dome shaped phosphor-containing lens;

[0016] FIG. 4 is a sectional view of the emitter of FIG. 3, with the separate pieces bonded together;

[0017] FIG. 5 is a sectional view of another embodiment of an emitter according to the present invention having a dome shaped phosphor-containing lens;

[0018] FIG. 6 is a sectional view of the emitter of FIG. 5 with the separate pieces bonded together;

[0019] FIG. 7 is a sectional view of another embodiment of an emitter according to the present invention having a dome shaped phosphor-containing lens;

[0020] FIG. 8 is a sectional view of the emitter of FIG. 7 with the separate pieces bonded together;

[0021] FIG. 9 is a sectional view of another embodiment of an emitter according to the present invention having a hemispheric lens with a phosphor-containing layer and scattering particles;

[0022] FIG. 10 is a sectional view of the emitter of FIG. 9 with the separate pieces bonded together;

[0023] FIG. 11 is a sectional view of another embodiment of an emitter according to the present invention having a generally hemispheric lens with a phosphor-containing layer;

[0024] FIG. 12 is a sectional view of the emitter of FIG. 11 with the separate pieces bonded together;

[0025] FIG. 13 is a sectional view of another embodiment of an emitter according to the present invention having a phosphor-loaded cap;

Savant Technologies LLC - 1004.379

[0026] FIG. 14 is a sectional view of the emitter of FIG. 13 with the separate pieces bonded together;

[0027] FIG. 15 is a sectional view of another embodiment of an emitter according to the present invention having a perforated phosphor loaded cap;

[0028] FIG. 16 is a sectional view of the emitter of FIG. 15 with the separate pieces bonded together; and

[0029] FIGS. 17 and 18 are flow diagrams illustrating methods of fabricating an emitter according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0030] FIGS. 1 and 2 illustrate one embodiment of a light emitter 10 in accordance with the present invention. Emitter 10 can be used in many different applications such as being included in a display system where it is desired to emit light at a uniform color and/or intensity through a range of angles. The system can include a single emitter or an array of emitters, but one emitter is illustrated here for simplicity and ease of discussion.

[0031] Emitter 10 includes a light source 12 positioned on a surface 11 of a cup shaped submount 14. Light source 12 can be mounted on surface 11 using known bonding methods. A filler material 19 is positioned on surface 11 and surrounds light source 12 so that filler material 19 fills the volume within the cup. A hemispheric lens 16, which includes phosphor, is positioned adjacent to submount 14. Lens 16 includes conversion particles 22 distributed throughout so that

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lens 16 and particles 22 form a conversion material region 21. Surface 11 can be reflective at the wavelengths of interest so that light emitted by light source 12 reflects from surface 11 and contributes to the light emission of emitter 10. It should be noted that conversion particles 22 are represented as dots in lens 16 as shown in FIGS. 1 and 2, and the rest of the figures shown in this disclosure.

[0032] A surface 13 of lens 16 bonds to filler material 19 and is held in place relative to submount 14. Hence, lens 16 is positioned so that a portion of the light emitted by light source 12 flows through lens 16 from surface 13 to a surface 15. However, filler material 19 is optional and lens 16 can be bonded directly to a surface 17 of submount 14. Filler material 19 can include an epoxy or another filler material capable of bonding lens 16 to submount 14. Lens 16 and filler material 19 can include a material transparent to the wavelengths of interest. Conversion particles 22 can include one or more fluorescent or phosphorescent materials such as a phosphor, a fluorescent dye, or a photoluminescent semiconductor material.

[0033] As shown, light source 12 includes a single light emitting diode (LED). However, light source 12 can include other light emitters, such as a solid-state laser, a laser diode, an organic light emitting diode, among others. The desired wavelengths of interest typically range from the infrared to the ultraviolet regions, although other wavelengths could be used. Further, light source 12 can include multiple light

Savant Technologies LLC - 1004.381

sources which emit light at the same or different wavelengths.

[0034] The operation and fabrication details of conventional LEDs and other light emitters are known and are only briefly discussed. Conventional LEDs can be fabricated from a number of material systems by many known methods, with a suitable method being fabrication by Chemical Vapor Deposition (CVD). Other suitable methods include Molecular Beam Epitaxy (MBE) and Metal Organic Chemical Vapor Deposition (MOCVD).

[0035] LEDs typically include an active region sandwiched between two oppositely doped layers that are either doped p-type or n-type. The top layer of the LED is usually p-type and the bottom layer is usually n-type, although LEDs also work if the conductivities of the layers are reversed. The p- and n-type layers have respective contacts and an electrical signal can be applied across the contacts so that a current is injected into the active region to produce light emission.

[0036] Submount 14 can include electrical circuitry (not shown) coupled to light source 12, such as electrical circuitry to provide power for light emission. Submount 14 can also include components and circuitry to protect light source 12 from large electrical signals such as electrostatic shock.

[0037] In operation, light source 12 emits light at a desired wavelength where the emitted light flows through lens 16 either directly from the light source or indirectly by reflection from surface 11. A portion of the light emitted by light source 12 flows through lens 16 and is absorbed by conversion particles 22

[0038] A portion of the absorbed radiation is re-emitted at one or more wavelength spectrums which are generally different from the absorbed wavelength, with the re-emitted light typically having a longer wavelength than the absorbed light. The combination of the transmitted light and the retransmitted light allows the emitter 10 to emit different wavelengths of light than the original emitted light. For example, light source 12 can emit blue light and conversion particles 22 can absorb a portion of the blue light and convert it to yellow light. The emitter 10 then emits a white light combination of The blue and yellow light. A full range of broad yellow spectral emission is possible using conversion particles which include phosphors based on the $(Gd,Y)_3(Al,Ga)_5O_{12}$:Ce system. In another example, conversion particles 22 can re-emit green light, with a suitable green emitting material being a Sr:thiogallate phosphor. Other conversion particles can be used that absorb blue light and re-emit at different wavelengths of light. Different conversion particles can also be used that absorb different wavelengths of light and re-emit light at different wavelengths, such as particles the absorb ultra-violet light and emit light at a different wavelength.

[0039] In accordance with the invention, it is desired to distribute conversion particles 22 uniformly throughout lens 16 so that the color and the intensity of the emitted light is uniform throughout a wide range of viewing angles. Consequently, lens 16 is fabricated separately from submount 14 and light source 12. Hence, instead of injecting the clear material mixture which

forms lens 16 into submount 14, material can be used to mass produce lenses using known methods such as injection molding or the conventional syringe manufacturing process. By fabricating lens 16 separately from submount 14 and light source 12, a number of advantages are realized that overcome problems associated with emitters manufactured using conventional methods.

[0040] One advantage is that the manufacturing process can provide lenses which are less expensive than conventional techniques. One reason the process is less expensive is because the formation of emitter 10 reduces the waste generated since light source 12 can be tested before lens 16 is bonded onto submount 14. If emitter 10 has substandard emission or is otherwise defective, then a determination can be made as to whether light source 12 or lens 16 is defective. The defective component can then be discarded and substituted with a new component. The replacement process avoids the waste associated with the conventional manufacturing processes where the entire emitter is discarded if the emission is substandard.

[0041] Another advantage is that the emitters can be formed with a more flexible manufacturing process. For example, different lenses can be used to match the geometry of submount 14 and light source 12. Also, the color emitted by a particular emitter 10 can be changed by using a lens which includes a different type of conversion particles to produce different light combinations. The changing of lenses can be done at the assembly line by simply substituting a different supply of lenses.

Savant Technologies LLC - 1004.384

[0042] Flexibility in the manufacturing process is also obtained because a wider selection of materials can be used to form lens 16. For example, because the clear material is injected directly on the LED in the conventional syringe method, only material with a relatively low melting/curing temperature can be used. If higher temperature materials are used, then light source 12 or submount 14 can be damaged when contacted by the clear material mixture.

[0043] Lens 16 is manufactured separate from light source 12 and submount 14 and then bonded to submount 14 as discussed above. As a result, materials that might otherwise cause damage in the conventional syringe process can now be used, one such material being glass. By encasing conversion particles 22 in a rugged material such as glass, conversion particles 22 are better protected from contaminants in the ambient atmosphere that can undesirably react with particles 22 and reduce the usable lifetime of emitter 10. It should be understood that the lens 16 can be made of many different materials beyond glass, such as an epoxy or plastic, and the invention is not limited to the particular lens materials mentioned herein.

[0044] The manufacturing process also has the advantage that the light is emitted with a more uniform color, intensity, and temperature than provided by conventional manufacturing techniques. One reason better uniformity is achieved is because the light emitted from source 12 at different angles passes through similar thicknesses of lens 16 and, accordingly, through substantially similar amounts of conversion particles 22 since they are have

substantially uniform distribution throughout region 21. For example, as shown in FIG. 2, light paths 1, 2, and 3 travels through substantially the same thickness of lens 16 and through substantially the same amount of conversion particles.

[0045] The uniformity of conversion particles 22 is better controlled since lens 16 is formed separately. The settling of conversion particles 22 can be avoided by quickly curing the material mixture after the mixture is injected into the mold or by shaking the injection mold during curing.

[0046] Another advantage is that conversion material region 21 does not generally contact light source 12, so variations in the surface or shape of light source 12 will not significantly impact the performance of emitter 10. Further, heat can damage conversion particles 22 if conversion material region 21 is positioned too close to light source 12.

[0047] FIGS. 3 and 4 illustrate an embodiment of an emitter 30 in accordance with the present invention. It should be noted that emitter 30 includes components similar to the components illustrated in FIGS. 1 and 2. Similar numbering is used on similar components with the understanding that the discussion above in conjunction with emitter 10 applies equally to emitter 30 and the other embodiments discussed in the rest of the disclosure.

[0048] Emitter 30 includes light source 12 mounted to submount 14. Filler material 19 can be positioned on surface 11 to surround light source 12, but is left out here and in the rest of the figures for simplicity and

ease of discussion. Emitter 30 includes a lens 36 mounted to surface 17. Lens 36 includes an inside layer 38 with conversion particles 22 and an outside layer 40, where layers 38 and 40 preferably have uniform thicknesses throughout. Lens 36 is dome shaped and is positioned on surface 17 so that a portion of the light emitted from light source 12 flows through lens 36 from a surface 33 to a surface 35.

[0049] Conversion particles 22 are distributed throughout conversion material region 21. However, conversion material region 21 includes only a portion of lens 36. In particular, conversion particles 22 are distributed throughout inside layer 38 and preferably not within outside layer 40. Hence, inside layer 38 can include clear material mixed with conversion particles 22 and outside layer 40 can include clear material. In this arrangement, light emitted at different angles from light source 12 passes through nearly the same thickness of lens 36 and the same amount of conversion particles 22. (i.e. light paths 1, 2, and 3 are equal)

[0050] By forming lens 36 in the shape of a dome, an inside distance 42 (See FIG. 4) can be maintained between light source 12 and inside layer 38 and conversion particles 22, with distance 42 being optimized for the particular light source 12 and submount 14. The optimum value for distances 42 and thickness 44 depends on the type and dimensions of light source 12 and submount 14. Distance 42 is chosen to allow for light source 12 to provide a higher intensity of light without generating excessive heat which can damage conversion particles 22. Heat can damage conversion particles 22 if conversion

Savant Technologies LLC - 1004.387

material region 21 is positioned too close to light source 12.

[0051] Distance 42 can also affect the light efficiency of emitter 30. When directional light from light source 12 passes into inner layer 38 and is redirected back towards light source 12, a portion of the directional light can be absorbed by conversion particles 22 and re-emitted omnidirectionally. If distance 42 is too small or if conversion particles 22 are positioned directly on light source 12, then some of the re-emitted light can be directed back into and absorbed by light source 12. The absorption of this light can reduce the overall light emitting efficiency of emitter 30 because it can increase the temperature of light source 12. If distance 42 is too large, then thickness 44 can be reduced to a point that light from conversion particles 22 can be trapped in lens 36 by total internal reflection, which also reduces the overall efficiency of emitter 30.

[0052] FIGS. 5 and 6 illustrate an emitter 50 in accordance with the present invention, where emitter 50 includes a flat submount 54. In this embodiment, a dome shaped lens 56 is positioned over light source 12 and mounted to a surface 51 of submount 54, with light source 12 arranged in the space provided between an inside surface 53 of lens 56 and submount 54 (See FIG. 6). Light source 12 and inside surface 53 can be spaced apart such that the absorption by light source 12 of re-emitted light from conversion material regions 22 is minimized. Lens 56 includes conversion particles 22 distributed throughout lens 56 such that when light emitted from light source 12 passes through lens 56, a portion of it

Savant Technologies LLC - 1004.388

is absorbed by conversion particles 22 and re-emitted at a different wavelength.

[0053] FIGS. 7 and 8 illustrate an embodiment of an emitter 70 in accordance with the present invention. In this embodiment, emitter 70 includes a dome shaped lens 76 mounted to surface 51 of submount 54. Lens 76 includes an inside layer 78 which has clear material mixed with conversion particles 22 and an outside layer 80 which has clear material, preferably without any conversion particles. Light flow is from light source 12 through lens 76 from a surface 73 to a surface 75.

[0054] As discussed above in conjunction with FIGS. 3 and 4, an inside distance 82 is chosen between light source 12 and inside layer 78 to minimize the absorption of re-emitted light from conversion particles 22 into light source 12. Distance 82 and thickness 84 can be chosen to optimize the light efficiency of emitter 50 where the light efficiency is optimized by minimizing the absorption of the re-emitted light and by reducing the total internal reflection as discussed above.

[0055] FIGS. 9 and 10 illustrate an embodiment of an emitter 90 in accordance with the present invention where emitter 90 includes light source 12 mounted to surface 11 of submount 14. In this embodiment, a hemispheric shaped lens 96 is mounted to surface 17 where lens 96 includes a bottom layer 98 with conversion particles 22. However, in addition to conversion particles 22 being distributed throughout layer 98, layer 98 also includes scattering particles 100 for redirecting some of the light.

[0056] A portion of the light absorbed and re-emitted by conversion particles 22 in layer 98 is directed along

layer 98, as shown by arrow 99 (See FIG. 10). This re-emitted light can be directed away from surface 95. Hence, one reason scattering particles 100 are included in layer 98 is to redirect the light towards surface 95 so that the light emitting efficiency of emitter 90 is increased.

[0057] The conversion and scattering efficiency of conversion particles 22 can depend on the wavelength of the light and the size of the conversion particles. Conversion material region 21 typically does not scatter light effectively because the conversion efficiency of particles 22 decreases as their size decreases. As a result, it is difficult to obtain high conversion efficiency particles that are smaller than approximately one micron in diameter. To effectively scatter light, the diameter of scattering particles 100 should be approximately one half of the wavelength of the light being scattered. In air, this would result in particles 100 being approximately 0.2 to 0.25 microns in diameter. This range of diameters would be smaller for particles in a different medium, such as epoxy or another material with an index of refraction greater than free space. As a result, phosphor particles are generally too large to effectively scatter light.

[0058] FIGS. 11 and 12 illustrate an embodiment of an emitter 110 in accordance with the present invention, where emitter 110 includes light source 12 mounted to a surface 111 of a submount 114. In this embodiment, a lens 116 is positioned on a surface 117 of submount 114 where lens 116 has a bottom layer 118 which includes

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conversion particles 22. Light flow is from light source 12 through lens 116 from a surface 103 to a surface 105.

[0059] Submount 114 includes a surface 101 and a surface 115 which are oriented to redirect light emitted from conversion particles 22 towards surface 105. Hence, bottom layer 118 does not have to include scattering particles similar to scattering particles 100 discussed above to scatter the re-emitted light from conversion particles 22. However, it should be noted that scattering particles 100 can still be included in layer 118, but are left out for simplicity and ease of discussion.

[0060] Surfaces 101 and 115 are shaped so light directed along layer 118 reflects off surfaces 101 and/or 117 and is combined with the light emitted from light source 12 that flows through layer 118 to surface 105. The light reflected from surfaces 101 and 115 can contribute to the light emitted by emitter 110. Hence, the light emission efficiency of emitter 110 is increased by including surfaces 101 and 115 in submount 114.

[0061] FIGS. 13 and 14 illustrate an embodiment of an emitter 130 in accordance with the present invention, where emitter 130 includes an LED 152 which can be shaped. In this embodiment, emitter 130 does not include a submount as in the embodiments discussed previously. Instead, emitter 130 includes contacts 134 and 135 arranged on the bottom of LED 152. Hence, LED 152 can be mounted in a metal cup with contacts 134 and 135 electrically connected to a bias source at the cup to provide power for the illumination of LED 152.

[0062] Instead of having a lens, emitter 130 includes a phosphor loaded cap 136 having the same basic shape as LED 152 and, preferably, having a generally consistent thickness. Cap 136 can be made of a similar material as the lenses described above and can include conversion particles distributed thoughout. Cap 136 can be manufactured separately from LED 152 by the same methods as the lenses described above, one method being injection molding. Cap 136 can be mounted in place over LED 152 with an epoxy or another similar material.

[0063] In operation, light emitting from LED 152 at different angles will pass through similar thicknesses of cap 136 and, accordingly, the light will encounter similar amounts of conversion particles 22 which allows emitter 130 to provide essentially the same color and intensity of light when viewed at different angles.

[0064] FIGS. 15 and 16 illustrate an embodiment of an emitter 150 in accordance to the present invention where emitter 150 includes LED 152 and a phosphor-loaded cap 154. In this embodiment, however, instead of including two bottom contacts, LED 152 has a bottom contact 156 and a top contact 158. Cap 154 has a top perforation 160 slightly larger that top contact 158 so that when cap 154 is bonded to LED 152, top contact 158 is arranged within, and accessible though, top perforation 160. Perforation 160 can be positioned anywhere along the phosphor cap, but is shown centered on the top for simplicity and ease of discussion.

[0065] The arrangement of top contact 158 allows an electrical signal to be provided to LED 152 through bottom and top contacts 156 and 158, respectively. For

LED 150 as shown in FIG. 16, the electrical signal is provided to top contact 158 through conductor 162 which is wire bonded to contact 158. The electrical signal can also be provided to bottom contact 156 through a conductor (not shown) or through a metal cup.

Methods of Fabrication

[0066] FIG. 17 is a flow diagram of one embodiment of an emitter fabrication method 170 according to the present invention, where the components of the emitter are fabricated separately and then bonded together. In a step 172, an LED is fabricated using any know method such as fabrication in a MOCVD reactor. In a step 174 the submount is fabricated and in step 176 the LED is bonded to the base of the submount using known bonding methods. In a step 178 the lens with conversion material region is fabricated using known fabrication methods such as injection molding. In a final step 180, the lens is bonded to the submount over the LED, with a preferred method being filling the space between the lens and submount/LED with an epoxy or another filler material, and contacting the inside surface of the lens to hold it in place.

[0067] In alternative intermediate steps (not shown), the emitter can be tested with the lens in place on the submount, but before it is bonded to the submount. If the emission of the emitter is substandard a determination can be made as to whether the LED or the lens is defective. The defective part can then be discarded and replaced with a new part. Bonding step 180

Savant Technologies LLC - 1004.393

can occur after the testing process is repeated until the emitter operates efficiently.

[0068] FIG. 18 is a flow diagram of another embodiment of an emitter fabrication method 190 in accordance with the present invention. In a step 192, an LED is fabricated using any known method such as fabrication in a MOCVD reactor, where the LED can be arbitrarily shaped. In a step 194 contacts are formed on the LED using known methods such as sputtering. In a step 196 a phosphor-loaded cap is fabricated using known methods, such as injection molding. In a step 198, the cap is mounted to the LED so that a portion of the LED light passes through the cap. The cap can be mounted to the LED using epoxy or another bonding material. In one method, the contacts are deposited on the bottom surface of the LED and the cap cover's the LED's top and side surfaces. In another method, a contact is deposited on the LED's bottom surface and another contact is deposited on the LED's top surface. The cap is perforated on its top surface and when it is bonded to the LED the top contact is housed in, and accessible through, the perforation.

[0069] The method can also include intermediate steps of testing the emitter before it the cap is bonded to the LED. If either the cap or the LED are found to be defective, then the defective part can be discarded and replaced with a different part. The testing can be repeated until the emitter emits light at a sufficient color and intensity over a range of viewing angles before the cap is bonded to the LED.

[0070] Although the present invention has been described in considerable detail with reference to certain

preferred configurations thereof, other versions are possible. The sequence of the steps in the methods described above can be different. Other methods according to the invention can use more or less steps and can use different steps. The lenses and caps described above can take many different shapes and layers and can include many different types of conversion particles. The lens and caps can be shaped to adapt to the particular application and can be shaped to focus the emitted light. Each of the lenses and caps described can also include scattering particles throughout or in different locations.

[0071] Therefore, the embodiments of the invention described herein are exemplary and numerous modifications, variations and rearrangements can be readily envisioned to achieve substantially equivalent results, all of which are intended to be embraced within the spirit and scope of the invention as defined in the appended claims.

WE CLAIM:

1. An emitter, comprising:

a light source which emits a first spectrum of light; and

a conversion material region formed separately from said light source and including conversion particles, said conversion material region positioned in proximity to said light source such that at least some of said light source light passes through said conversion material region, said conversion particles absorbing at least some of said light source light passing through said conversion material region and emitting a second spectrum of light.

2. The emitter of claim 1, wherein said light source emits said first spectrum of light along a plurality of light paths extending through said conversion material region, each light path extending through a substantially equal amount of conversion particles.

3. The emitter of claim 1, wherein said conversion particles are distributed in said conversion material region such that said conversion particles emit said second spectrum of light at a uniform color and intensity.

Savant Technologies LLC - 1004.396

4. The emitter of claim 1, wherein said conversion particles emit said second spectrum of light at a uniform color and intensity.

5. The emitter of claim 1, wherein said conversion material region includes scattering particles which redirect at least some of said first and second spectrum of light.

6. The emitter of claim 1, wherein said conversion material region comprises a glass lens.

7. The emitter of claim 6, wherein said glass lens is formed separately from said light source and bonded proximate to said light source.

8. The emitter of claim 1, wherein said conversion material region comprises a phosphor loaded cap.

9. The emitter of claim 8, wherein said phosphor loaded cap is shaped to fit closely over one or more of the surfaces of said emitter such that said light source light passing through said phosphor cap passes through substantially the same amount of said conversion particles.

10. The emitter of claim 8, wherein said phosphor loaded cap includes a perforation for receiving an electrical contact to said light source.

Savant Technologies LLC - 1004.397

11. The emitter of claim 10, wherein said perforation is at least partially filled with at least one of conversion particles and scattering particles.

12. The emitter of claim 8, wherein said phosphor loaded cap is formed separately from said light source and bonded proximate to at least on of the surfaces of said light source.

13. The emitter of claim 1, further comprising a submount, said light source mounted to said submount and said conversion material region mounted to said submount.

14. The emitter of claim 1, wherein said conversion material region is hemispheric shaped and said light source is arranged to emit light toward the base of and through said conversion material region.

15. The emitter of claim 1, wherein said light source comprises a light emitting diode.

16. The emitter of claim 1, emitting a spectrum of light that is a combination of said first and second spectrums of light.

17. The emitter of claim 1, wherein said conversion material region is positioned in relation to said light sources such that there is a space between the two.

18. An emitter, comprising:

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a light source which emits a first spectrum of light; and

a conversion material region formed separately from said light source and positioned proximate to said light source, said conversion material region arranged to absorb at least some of the light emitted by said light source and re-emit light at a second spectrum of light, said emitter emitting a combination of said first and second spectrums of light in a uniform third spectrum of light.

19. The emitter of claim 18, wherein said conversion material region is separable from said position proximate to said light source.

20. The emitter of claim 18, further comprising a submount, wherein said light source is positioned on a first surface of said submount and said conversion material region positioned on a second surface of said submount.

21. The emitter of claim 18, wherein said submount is configured to reflect some of said first and second spectrums of light.

22. The emitter of claim 20, wherein said conversion material region comprises a lens, said lens being bonded to said second surface of said submount, said second surface being above said first surface.

Savant Technologies LLC - 1004.399

23. The emitter of claim 20, wherein said at least one of said submount surface reflects some of the first and second spectrums of light to said lens.

24. The emitter of claim 20, wherein said submount includes one of a cup-shaped submount and a flat submount.

25. The emitter of claim 22, wherein said lens includes said conversion material region and a clear material region.

26. The emitter of claim 22, wherein said lens is shaped to fit within said submount.

27. The emitter of claim 18, wherein said conversion material region comprises a phosphor loaded cap.

28. The emitter of claim 27, wherein said phosphor loaded cap is shaped to fit the shape of said light source.

29. The emitter of claim 27, wherein said phosphor loaded cap is formed separately from said light source and bonded proximate to said light source.

30. The emitter of claim 18, wherein said conversion material region is positioned in relation to said light source such that there is a space between the two, said space chosen to obtain substantially uniform emission of said third spectrum of light.

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31. The emitter of claim 18, wherein said conversion material region is positioned in relation to said light source such that there is a space between the two, said space chosen to provide said third spectrum of light with at least one of a desired color and intensity.

32. A method of fabricating an emitter, comprising:

providing a light source;

providing a separately formed conversion material region which includes conversion particles; and

bonding said conversion material region proximate to said light source, said conversion material region being positioned so that at least some of the light emitted from said light source at different angles flows through said conversion material region and through the substantially the same amount of conversion particles.

33. The method of claim 32, further including a step of providing a submount, said light source being bonded to a first surface of said submount.

34. The method of claim 32, wherein said conversion particles are distributed throughout said conversion material region so that said emitter emits at least one of the same color and intensity of light.

35. The method of claim 32, wherein the step of providing said conversion material region includes a step

of providing a lens which includes said conversion material region.

36. The method of claim 33, wherein the step of bonding said conversion material region proximate to said light source includes a step of bonding said lens to one of said first surface and a second surface of said submount.

37. The method of claim 35, wherein the step of providing said lens includes a step of providing a lens with an opening configured to at least partially surround said light source.

38. The method of claim 33, wherein the step of providing said submount includes a step of providing one of a flat submount and a cup-shaped submount.

39. The method of claim 33, wherein said submount includes a cup-shaped submount with a third side configured to reflect at least a portion of the light re-emitted from said conversion material region.

40. The method of claim 32, wherein the step of providing said conversion material region includes a step of providing a phosphor loaded cap which includes said conversion material region.

41. The method of claim 40, wherein the step of providing said phosphor loaded cap includes a step of

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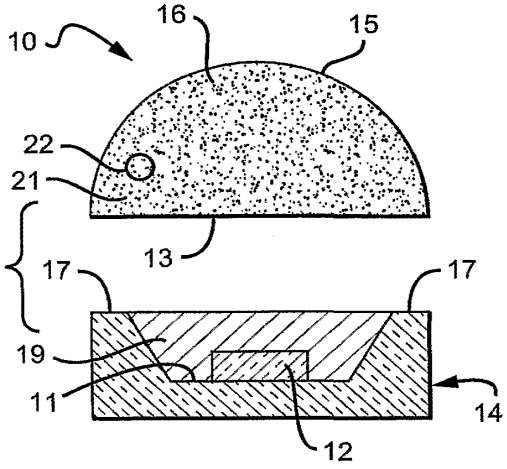
providing a phosphor loaded cap which is shaped to at least partially surround said light source.

42. The method of claim 40, wherein the step of providing said phosphor loaded cap includes step of providing a phosphor loaded cap with a perforation for engaging a contact.

43. The method of claim 42, further including a step of filling said perforation with at least one of conversion particles and scattering particles.

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FIG. 1



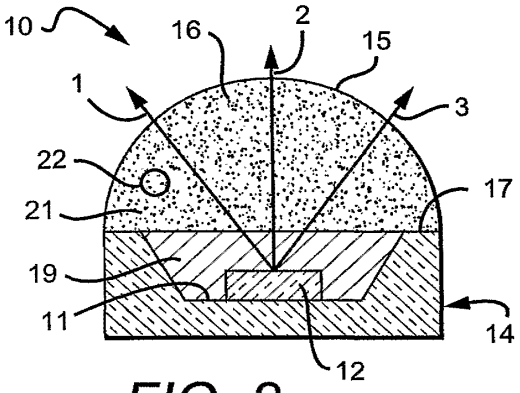
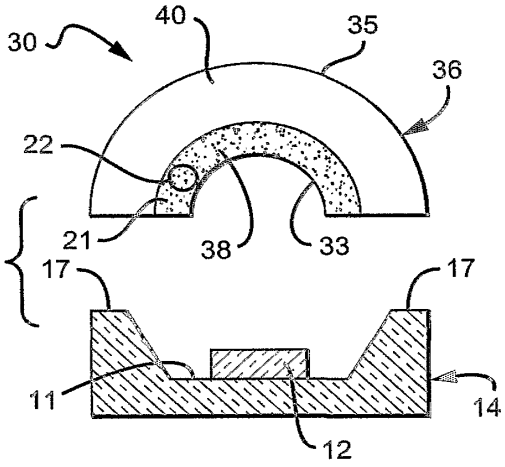


FIG. 2

FIG. 3



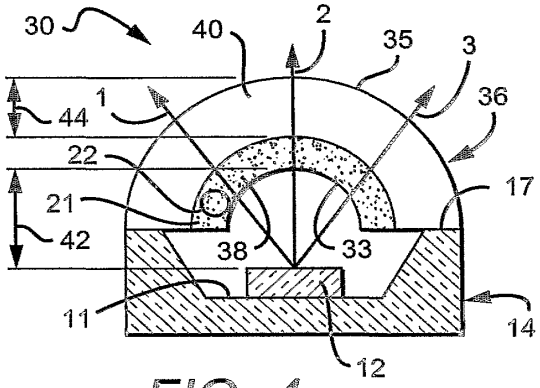
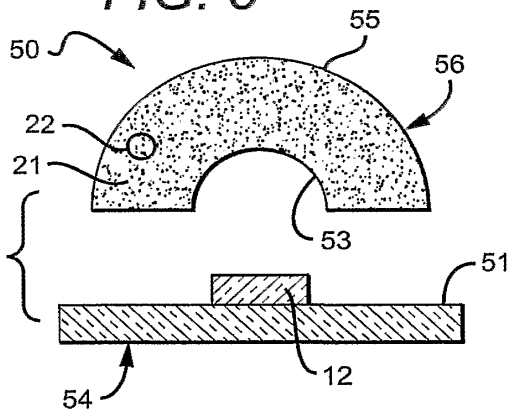


FIG. 4

FIG. 5



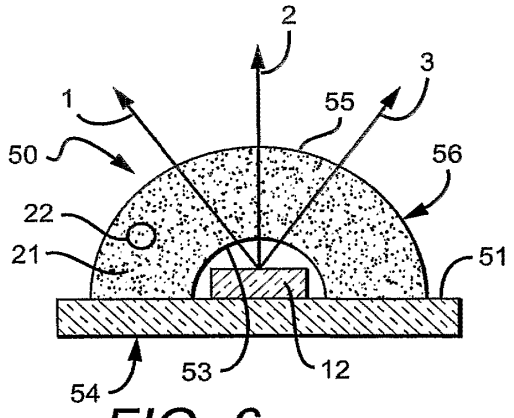
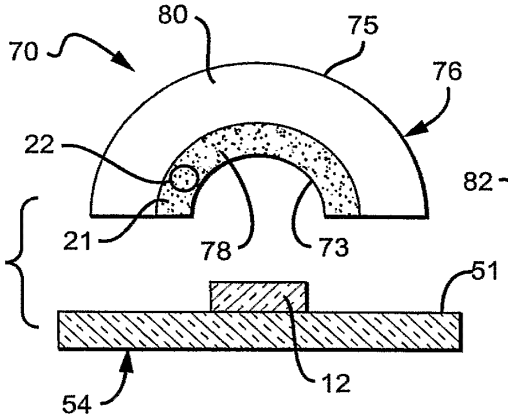


FIG. 6

FIG. 7



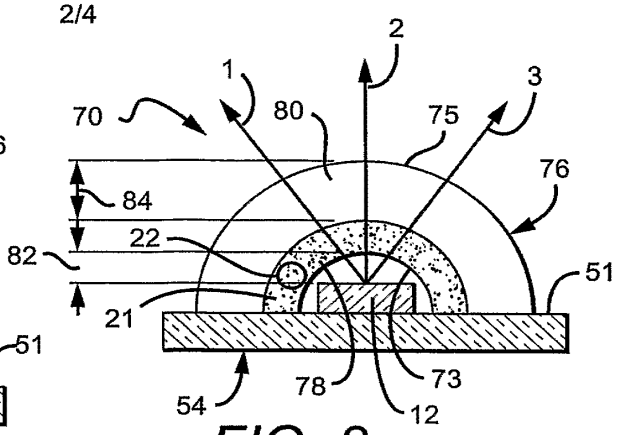
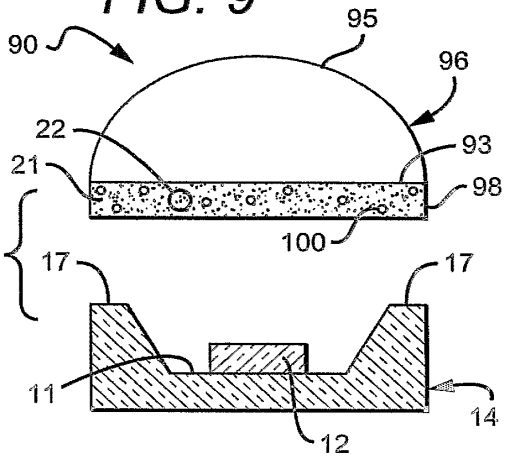


FIG. 8

FIG. 9



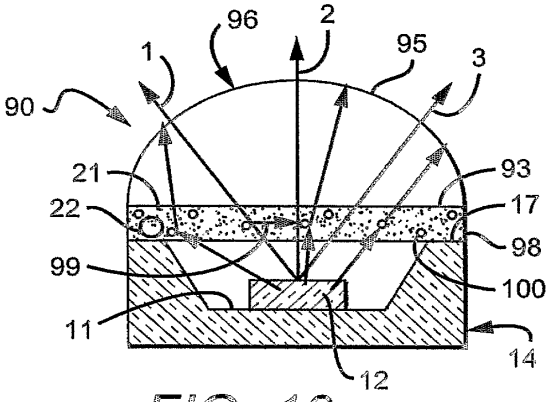
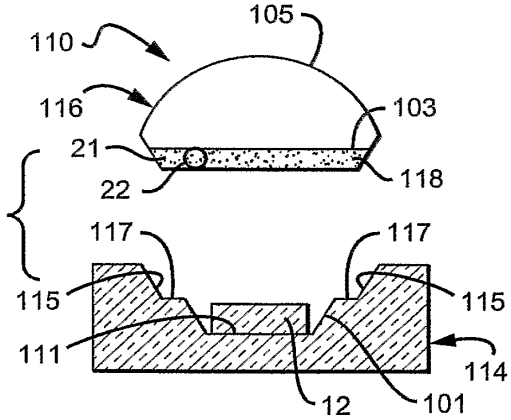


FIG. 10

FIG. 11



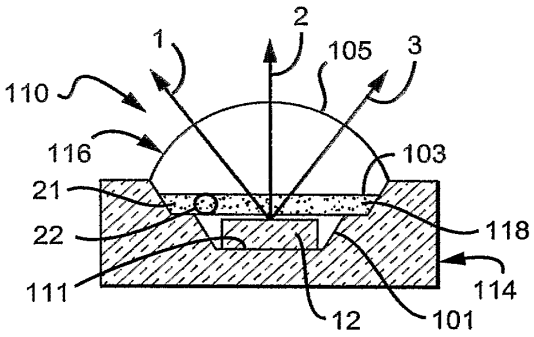


FIG. 12

FIG. 13

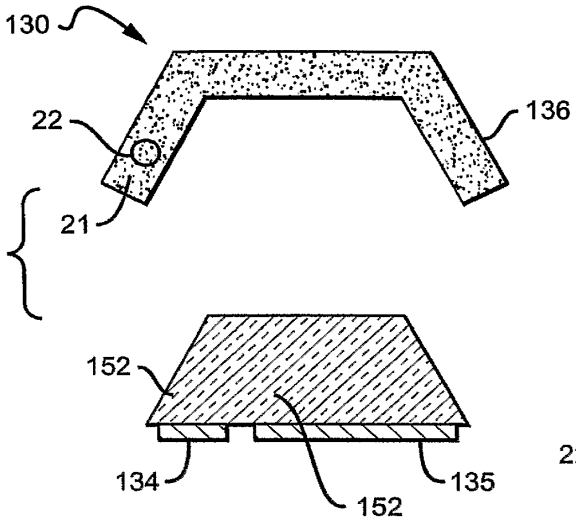


FIG. 14

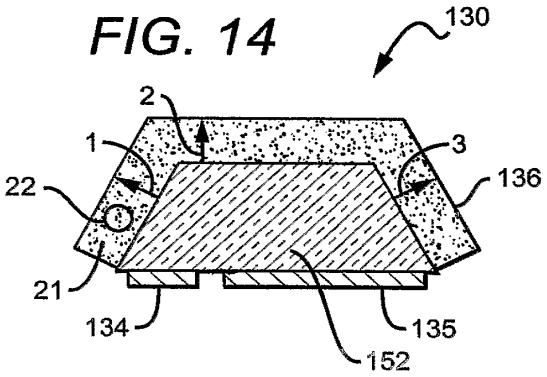


FIG. 15

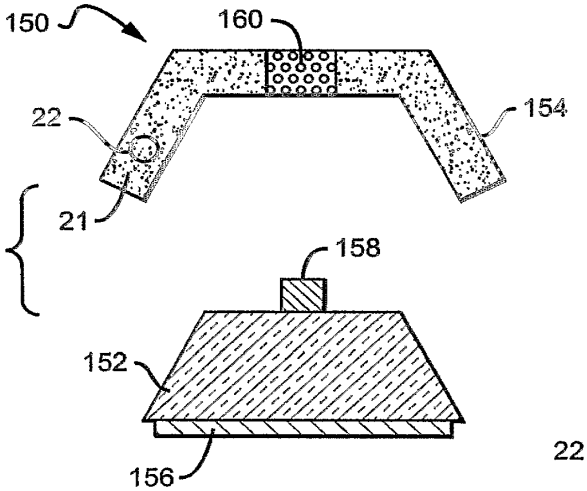


FIG. 16

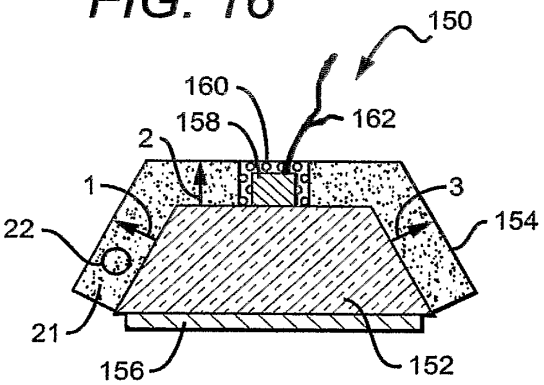


FIG. 17

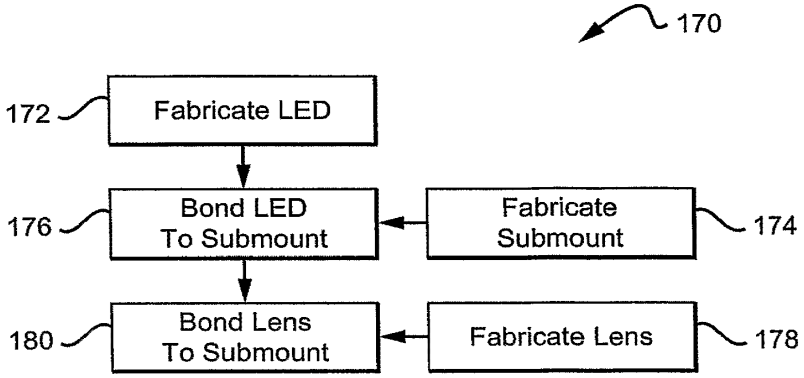
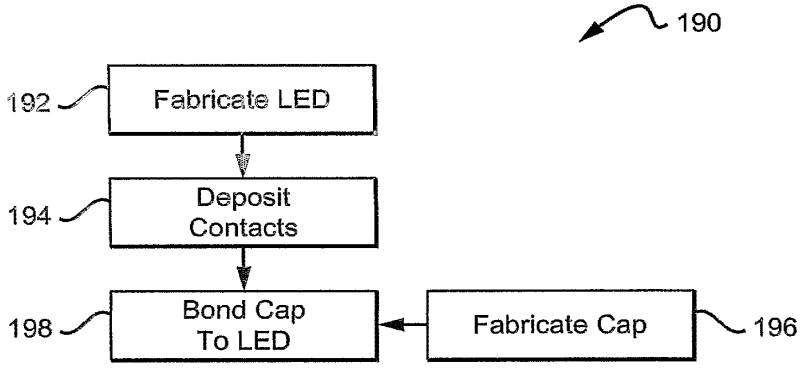

170
172
Fabricate LED
176
Bond LED To Submount
Fabricate Submount
174
180
Bond Lens To Submount
Fabricate Lens
178

FIG. 18


190
192
Fabricate LED
194
Deposit Contacts
198
Bond Cap To LED
Fabricate Cap
196

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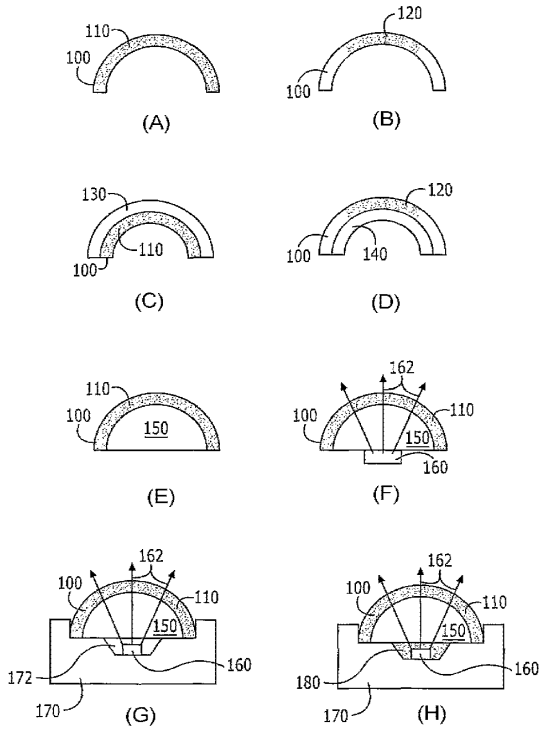
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(54) Title: TRANSMISSIVE OPTICAL ELEMENTS INCLUDING TRANSPARENT PLASTIC SHELL HAVING A PHOSPHOR DISPERSED THEREIN, AND METHODS OF FABRICATING SAME



(57) Abstract: A transmissive optical element is fabricated by filling a mold with molten liquid that includes a transparent plastic and a phosphor additive, and allowing the molten liquid to solidify to produce the transmissive optical element having phosphor dispersed therein. Accordingly, a separate phosphor coating or phosphor-containing encapsulant need not be used. Transmissive optical elements include a shell made of transparent plastic with a phosphor dispersed therein. The phosphor may be uniformly and/or nonuniformly dispersed in the shell.

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TRANSMISSIVE OPTICAL ELEMENTS INCLUDING TRANSPARENT PLASTIC SHELL HAVING A PHOSPHOR DISPERSED THEREIN, AND METHODS OF FABRICATING SAME

Field of the Invention

This invention relates to light emitting devices and fabricating methods therefor, and more particularly to packaging and packaging methods for light emitting devices.

Background of the Invention

Semiconductor light emitting devices such as Light Emitting Diodes (LED) or laser diodes are widely used for many applications. As is well known to those having skill in the art, a semiconductor light emitting diode is generally packaged by at least partially surrounding the semiconductor light emitting diode with a dome-shaped transparent plastic shell.

It is often desirable to incorporate a phosphor into the light emitting device, to enhance the emitted radiation in a particular frequency band and/or to convert at least some of the radiation to another frequency band. Phosphors may be included in a light emitting device using many conventional techniques. In one technique, phosphor is coated inside and/or outside the plastic shell. In other techniques, phosphor is coated on the semiconductor light emitting device itself, for example using electrophoretic deposition. In still other embodiments, a drop of a material such as epoxy that contains phosphor therein may be placed inside the plastic shell, on the semiconductor light emitting device and/or between the device and the shell. LEDs that employ phosphor coatings are described, for example, in U.S. Patents, 6,252,254; 6,069,440; 5,858,278; 5,813,753; 5,277,840; and 5,959,316.

Packaging may constitute a major portion of the expense and/or fabrication time for a finished light emitting device.

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Summary of the Invention

Some embodiments of the present invention form a transmissive optical element by filling a mold with molten liquid that comprises a transparent plastic and a phosphor additive, and allowing the molten liquid to solidify to produce the transmissive optical element having phosphor dispersed therein. Accordingly, these embodiments need not provide a separate phosphor coating or phosphor-containing encapsulant, although they may.

In some embodiments of the present invention, the transmissive optical element is a dome through which a light emitting device emits light. In these embodiments, a transparent core may also be formed inside the dome. Alternatively, the transparent core may first be formed and then the molding may be performed by filling a domed-shaped mold that includes the transparent core with a molten liquid that comprises a transparent plastic and a phosphor additive.

In still other embodiments, the transmissive optical element is a keypad key through which a light emitting device emits light. In yet other embodiments, the optical element is a keypad key face through which a light emitting device emits light. In these embodiments, a separate step may be provided for forming a keypad key wall that is attached to the keypad key face.

Transmissive optical elements according to some embodiments of the present invention include a shell that comprises a transparent plastic including a phosphor dispersed therein. In some embodiments, the phosphor is uniformly dispersed in the shell, whereas in other embodiments, the phosphor is nonuniformly dispersed in the shell.

In some embodiments, the shell is a dome-shaped shell and the transmissive optical element further comprises a transparent inner core inside the dome-shaped shell. In some embodiments, the transparent inner core fills the dome-shaped shell to provide a hemispherical optical element. In yet other embodiments, the dome-shaped shell may be combined with a semiconductor light emitting device that is configured to emit light into and through the transparent inner core and through the dome-shaped shell, to emerge from the dome-shaped shell. Still other embodiments add a mounting substrate that is adjacent the semiconductor light emitting device and remote from the transparent inner core. Still other embodiments add an encapsulant between the light emitting device and the transparent core.

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In other embodiments of the invention, the shell is a keypad key shell including a keypad key face and a keypad key wall that extends from the keypad key face. In some of these embodiments, phosphor is uniformly dispersed in the keypad key shell. In other embodiments, phosphor is uniformly dispersed in the keypad key face, and is not included in the keypad key wall. In still other embodiments, phosphor is nonuniformly dispersed in the keypad key face and may or may not be included in the keypad key wall.

Light emitting devices according to other embodiments of the present invention include a mounting substrate and a semiconductor light emitting device on the mounting substrate. A dome-shaped shell that comprises a transparent plastic including a phosphor dispersed therein is provided on the mounting substrate and at least partially surrounds the semiconductor light emitting device. A transparent inner core is provided inside the dome-shaped shell. In other embodiments, an encapsulant is provided between the semiconductor light emitting device and the transparent inner core. In still other embodiments, the mounting substrate includes therein a cavity, the semiconductor light emitting device is at least partially in the cavity, the dome-shaped shell is on the mounting substrate surrounding the cavity and the encapsulant is in the cavity.

Brief Description of the Drawings

Figures 1A-1H are cross-sectional views of transmissive optical elements according to first embodiments of the present invention that may provide semiconductor light emitting devices.

Figures 2A and 2B are cross-sectional views of semiconductor light emitting devices according to other embodiments of the present invention.

Figures 3A-3F are cross-sectional views of optical elements according to still other embodiments of the invention that may provide keypad keys.

Figure 4 is a schematic diagram of a molding apparatus that may be used to fabricate optical elements according to embodiments of the present invention.

Figures 5 and 6 are flowcharts of operations that may be performed to fabricate light emitting devices according to embodiments of the present invention.

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Detailed Description

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity. Like numbers refer to like elements throughout.

It will be understood that when an element such as a layer, region or substrate is referred to as being "on" another element, it can be directly on the other element or intervening elements may also be present. It will be understood that if part of an element, such as a surface of a conductive line, is referred to as "outer," it is closer to the outside of the device than other parts of the element. Furthermore, relative terms such as "beneath" may be used herein to describe a relationship of one layer or region to another layer or region relative to a substrate or base layer as illustrated in the figures. It will be understood that these terms are intended to encompass different orientations of the device in addition to the orientation depicted in the figures. Finally, the term "directly" means that there are no intervening elements.

Figures 1A-1H are cross-sectional views of transmissive optical elements according to various embodiments of the present invention. These optical elements may be used to package light emitting devices, such as semiconductor light emitting devices.

As shown in Figure 1A, transmissive optical elements according to some embodiments of the present invention include a shell **100** that comprises transparent plastic. The shell **100** includes a phosphor **110** dispersed therein. As is well known to those having skill in the art, the shell may comprise polycarbonate material and/or other conventional plastic materials that are used to fabricate transmissive optical elements. Moreover, the phosphor can comprise any conventional phosphor including cerium-doped YAG and/or other conventional phosphors. In some specific embodiments, the phosphor comprises Cesium doped Yttrium Aluminum Garnet (YAG:Ce). In other embodiments, nano-phosphors may be used. Phosphors are well known to those having skill in the art and need not be described further herein.

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In Figure 1A, the phosphor **110** is uniformly dispersed within the shell **100**. In contrast, in Figure 1B, the phosphor **120** is nonuniformly dispersed in the shell. Various patterns of phosphor **120** may be formed, for example, to provide areas of higher intensity and/or different color and/or to provide various indicia on the shell **100** when illuminated. In Figures 1A-1B, the shell **100** is a dome-shaped shell. As used herein, the terms "dome" and "dome-shaped" refer to structures having a generally arcuate surface profile, including regular hemispherical structures as well as other generally arcuate structures that do not form a regular hemisphere, which are eccentric in shape and/or have other features, structures and/or surfaces. Moreover, as will be described below, various other shapes may be provided.

Referring now to Figure 1C, one or more coatings **130** may be provided on the outside of the shell **100**. The coating may be a protective coating, a polarizing coating, a coating with indicia and/or any other conventional coating for an optical element that is well known to those having skill in the art. In Figure 1D, one ore more inner coatings **140** is provided on the inner surface of the shell **100**. Again, any conventional coating or combination of coatings may be used.

Moreover, other embodiments of the invention provide both an inner and an outer coating for the shell **100** that includes uniformly distributed phosphor **110** and/or non-uniformly distributed phosphor **120** therein. By providing an inner and outer coating, improved index matching to the phosphor may be provided. Thus, three layers may be injection molded according to some embodiments of the present invention. Other embodiments of the present invention can use an index matching media, such as a liquid and/or solid gel, within the shell, to assist in index matching. The use of inner and outer layers can reduce the number of photons that can be trapped in the phosphor-containing layer due to index matching issues.

Figure 1E describes other embodiments of the present invention wherein a transparent inner core **150** is provided inside the dome-shaped shell **100**. In some embodiments, as also shown in Figure 1E, the transparent inner core **150** fills the dome-shaped shell **100**, to provide a hemispherical optical element. The transparent inner core **150** may be uniformly transparent and/or may include translucent and/or opaque regions therein. The transparent inner core **150** may comprise glass, plastic and/or other optical coupling media.

Figure 1F illustrates other embodiments of the present invention wherein a phosphor-containing shell **100** is combined with a semiconductor light emitting

Savant Technologies LLC - 1004.414

device **160** that is configured to emit light **162** into and through the transparent inner core **150** and through the dome-shaped shell **100**, to emerge from the dome-shaped shell **100**. The semiconductor light emitting device can comprise a light emitting diode, laser diode and/or other device which may include one or more semiconductor layers, which may comprise silicon, silicon carbide, gallium nitride and/or other semiconductor materials, a substrate which may comprise sapphire, silicon, silicon carbide or other microelectronic substrates, and one or more contact layers which may comprise metal and/or other conductive layers. The design and fabrication of semiconductor light emitting devices are well known to those having skill in the art.

For example, the light emitting elements **160** may be gallium nitride based LEDs or lasers fabricated on a silicon carbide substrate such as those devices manufactured and sold by Cree, Inc. of Durham, North Carolina. For example, the present invention may be suitable for use with LEDs and/or lasers as described in United States Patent Nos. 6,201,262, 6,187,606, 6,120,600, 5,912,477, 5,739,554, 5,631,190, 5,604,135, 5,523,589, 5,416,342, 5,393,993, 5,338,944, 5,210,051, 5,027,168, 5,027,168, 4,966,862 and/or 4,918,497, the disclosures of which are incorporated herein by reference as if set forth fully herein. Other suitable LEDs and/or lasers are described in published U.S. Patent Publication No. US 2003/0006418 A1 entitled *Group III Nitride Based Light Emitting Diode Structures With a Quantum Well and Superlattice, Group III Nitride Based Quantum Well Structures and Group III Nitride Based Superlattice Structures*, published January 9, 2003, as well as published U.S. Patent Publication No. US 2002/0123164 A1 entitled *Light Emitting Diodes Including Modifications for Light Extraction and Manufacturing Methods Therefor.* Furthermore, phosphor coated LEDs, such as those described in United States Provisional Application Serial No. 60/411,980, entitled *Phosphor-Coated Light Emitting Diodes Including Tapered Sidewalls, and Fabrication Methods Therefor*, filed September 19, 2002, the disclosure of which is incorporated by reference herein as if set forth fully, may also be suitable for use in embodiments of the present invention.

The LEDs and/or lasers may be configured to operate such that light emission occurs through the substrate. In such embodiments, the substrate may be patterned so as to enhance light output of the devices as is described, for example, in the above-cited U.S. Patent Publication No. US 2002/0123164 A1.

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Figure 1G is a cross-sectional view of other embodiments of the present invention. As shown in Figure 1G, a mounting substrate **170** is provided, such that the light emitting device **160** is between the mounting substrate **170** and the transparent inner core **150**. As also shown in Figure 1G, in some embodiments, the mounting substrate **170** includes a cavity **172** therein and the light emitting device **160** is at least partially in the cavity **172**.

Finally, Figure 1H illustrates yet other embodiments of the present invention. In these embodiments, the cavity **170** may be filled with an encapsulant **180**, such as epoxy and/or other optical coupling media (e.g., silicon). The encapsulant **180** can enhance optical coupling from the light emitting device **160** to the transparent inner core **150**. The design and fabrication of mounting substrates **170** that may be used in some embodiments of the present invention, are described in concurrently filed U.S. Patent Application Serial No. _____ to Negley, entitled *Solid Metal Block Mounting Substrates for Semiconductor Light Emitting Devices, and Oxidizing Methods for Fabricating Same* (Attorney Docket 5308-311), assigned to the assignee of the present application, the disclosure of which is hereby incorporated herein by reference in its entirety as if set forth fully herein.

It will be understood by those having skill in the art that, although the embodiments of Figures 1A-1H have been illustrated as separate embodiments, various elements of Figures 1A-1H may be used together in various combinations and subcombinations of elements. Thus, for example, combinations of inner and outer coatings **140** and **130**, uniformly distributed phosphor **110** and nonuniformly distributed phosphor **120**, light emitting devices **160**, mounting substrates **170**, cavities **172**, inner cores **150** and encapsulant **180** may be used together. Accordingly, the present invention should not be limited to the separate embodiments that are shown in Figures 1A-1H.

Figure 2A is a cross-sectional view of light emitting devices according to other embodiments of the present invention. As shown in Figure 2A, these embodiments include an outer shell **200** which may be made of optically clear material that is loaded with phosphor and/or other chemicals. An inner core **250** may be made of optically clear material such as plastic or glass and may be placed on an encapsulating-containing cavity **272** in a mounting substrate **270**. The outer shell **200** and the inner core **250** form a composite lens for a light emitting diode **260**.

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Figure 2B is a cross-sectional view of light emitting devices according to still other embodiments of the present invention. As shown in Figure 2B, these embodiments include an inner shell **202**, which may be made of optically clear material such as a polymer loaded with phosphor and/or other chemicals. An outer shell **252** may be made of optically clear material such as plastic or glass. An encapsulating cavity **272** and a mounting substrate **270** are provided, as was the case in Figure 2A, to form a composite lens for light emitting diode **260**.

Figures 3A-3F are cross-sectional views of transmissive optical elements according to still other embodiments of the present invention that may be used to form keypad keys which may be used, for example, in cell phones, automobile dashboards, portable computers and other conventional devices that include an illuminated keypad. Referring now to Figure 3A, a transmissive optical element includes a keypad key shell including a keypad key face **300** with phosphor **310** dispersed therein. In Figure 3A, the phosphor **310** is uniformly dispersed therein, whereas in Figure 3B, the phosphor **320** is nonuniformly dispersed therein. Nonuniform dispersion may provide different light intensity, different colors and/or indicia as was described above.

In Figure 3C, the keypad key also includes a keypad key wall **330** that extends from the keypad key face **300**. In Figure 3C, the phosphor **310** is uniformly distributed in the keypad key face **300** and in the keypad key wall **330**. In Figure 3D, the phosphor **320'** is uniformly distributed on the keypad key face **300**, but is not included in the keypad key wall **330**. In Figure 3E, the phosphor **320** is nonuniformly distributed in the keypad key face **300** and is not included in the keypad key wall **330**.

Figure 3F illustrates a keypad key including a keypad key face **300** and a keypad key wall **330** mounted in a housing **370** and including a light emitting device **360**, such as a semiconductor light emitting device, between the housing and the key, to emit light **362** through the keypad key face **300** and/or wall **330**. It will be understood that light guides may be used to position the semiconductor light emitting device **360** remote from the key. It also will be understood that various elements shown in Figures 3A-3F may be used in combination and/or subcombination, so that, for example, uniformly and/or nonuniformly distributed phosphor **310**, **320**, **320'** may be used in a key face and/or key wall **330**. Accordingly, the invention should not be limited to the various combinations of elements that are individually shown in Figures 3A-3F.

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Figure 4 is a schematic block diagram of an apparatus for forming transmissive optical elements according to various embodiments of the present invention. In particular, Figure 4 illustrates an injection molding apparatus that may be used to form transmissive optical elements according to various embodiments of the present invention. As shown in Figure 4, an injection molding apparatus includes a hopper **410** or other storage device in which a transparent plastic and/or phosphor additive **450** are provided. The transparent plastic and/or phosphor additive may be provided in pellet, powder and/or solid form. Other additives, such as solvents, binders, etc. may be included, as is well known to those having skill in the art. An injector **420** may include a heater and a screw mechanism that is used to melt the transparent plastic and phosphor additive and/or maintain these materials in a melted state, to provide a molten liquid that comprises transparent plastic and the phosphor additive. The injector **420** injects the molten liquid into a mold **440** via nozzle **430**. The mold **440** includes an appropriate channel **450** therein, which can be used to define the shape of the optical element, such as a dome or keypad key. Injection molding of optical elements is well known to those having skill in the art and is described, for example, in U.S. Patents 4,826,424; 5,110,278; 5,882,553; 5,968,422; 6,156,242 and 6,383,417, and need not be described in further detail herein. It also will be understood that casting techniques also may be used, wherein molten liquid that comprises a transparent plastic and a phosphor additive is provided in a female mold which is then coupled to a male mold (or vice versa) to cast the optical element. Casting of optical elements is described, for example, in U.S. Patents 4,107,238; 4,042,552; 4,141,941; 4,562,018; 5,143,660; 5,374,668; 5,753,730 and 6,391,231, and need not be described in further detail herein.

Figure 5 is a flowchart of steps that may be used to manufacture transmissive optical elements according to various embodiments of the present invention. As shown in Figure 5, at Block **510**, a mold, such as mold **440** of Figure 4, is filled with molten liquid that comprises a transparent plastic and a phosphor additive. At Block **520**, the molten liquid is allowed to solidify to produce the optical element having phosphor dispersed therein.

Figure 6 is a flowchart of steps that may be performed to manufacture semiconductor light emitting devices according to embodiments of the present invention. As shown in Figure 6 at Block **610**, a shell such as a dome-shaped shell **100** of Figure 1A, that comprises a transparent plastic including a phosphor dispersed

Savant Technologies LLC - 1004.418

therein, is molded using injection molding, casting and/or other conventional techniques. At Block **620**, a core such as a core **150** of Figure 1E is formed. It will be understood that, in some embodiments, the core **150** is placed or formed inside the dome-shaped shell **100**, whereas, in other embodiments, Block **620** precedes Block **610** by forming a transparent core **150** and filling a mold that includes a transparent core **150** with a molten liquid that comprises a transparent plastic and a phosphor additive, to form the dome-shaped shell **100** around the transparent core.

Still referring to Figure 6, a semiconductor light emitting device, such as device **160** of Figure 1G, is placed on a mounting substrate such as mounting substrate **170**. At Block **640**, an encapsulant, such as encapsulant **180** of Figure 1H, is applied to the mounting substrate **170**, the light emitting device **160** and/or the core **150**. Finally, at Block **650**, the shell is mated to the mounting substrate using an epoxy, a snap-fit and/or other conventional mounting techniques.

It may be desirable for the inner core **150** to fill the entire lens, so as to reduce or minimize the amount of encapsulant **180** that may be used. As is well known to those having skill in the art, the encapsulant **180** may have a different thermal expansion coefficient than the mounting substrate **170** and/or the inner core **110**. By reducing or minimizing the amount of encapsulant **180** that is used at Block **640**, the effect of these thermal mismatches can be reduced or minimized.

It should also be noted that in some alternate implementations, the functions/acts noted in the blocks of Figures 5 and/or 6 may occur out of the order noted in the flowcharts. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

Accordingly, some embodiments of the present invention can form a composite optical element such as a lens using molding or casting techniques. For example, keypads for a telephone may use a two-step injection molding process to form a two-color key, or to use a lower cost plastic to give mechanical stability while using only a thinner layer of more expensive material to enhance the appearance and reduce the cost. In some embodiments, injection molding can be used to place a phosphor layer dispersed in the molding material on the inner or outer surface and then completing the molding or casting process in the remaining volume, to form a desired optical element. These optical elements can, in some embodiments, convert a blue light emitting diode behind the key or dome, to white light.

Savant Technologies LLC - 1004.419

Other embodiments of the present invention may use the phosphor to evenly disperse the light and/or to disperse the light in a desired pattern. For example, conventional light emitting devices may emit light in a "Batwing" radiation pattern, in which greater optical intensity is provided at off-axis angles, such as angles of about 40° off-axis, compared to on-axis (0°) or at the sides (for example, angles greater than about 40°). Other light emitting diodes may provide a "Lambertian" radiation pattern, in which the greatest intensity is concentrated in a central area to about 40° off-axis and then rapidly drops off at larger angles. Still other conventional devices may provide a side emitting radiation pattern, wherein the greatest light intensity is provided at large angles, such as 90° from the axis, and falls rapidly at smaller angles approaching the axis. In contrast, some embodiments of the present invention can reduce or eliminate angular-dependent radiation patterns of light output from a light emitting device, such as angular dependence of Color Correlated Temperature (CCT). Thus, light intensity and the x,y chromaticity values/coordinates from all surfaces of the lens can remain relatively constant in some embodiments. This may be advantageous when used for illumination applications, such as a room where a spotlight effect is not desirable.

Injection molding processes as described above, according to some embodiments of the invention, can allow formation of a single optical element with multiple features, such as lensing and white conversion. Additionally, by using a two-molding or casting technique, according to some embodiments, one can shape the phosphor layer to its desired configuration, to reduce or minimize the angular dependence of color temperature with viewing angle.

In the drawings and specification, there have been disclosed embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

Savant Technologies LLC - 1004.420

What is Claimed is:

1. A method for forming a transmissive optical element comprising:

filling a mold with a molten liquid that comprises a transparent plastic and a phosphor additive; and

allowing the molten liquid to solidify to produce the transmissive optical element having phosphor dispersed therein.

2. A method according to Claim 1 wherein the transmissive optical element is a dome through which a light emitting device emits light and wherein the filling comprises filling a dome-shaped mold with a molten liquid that comprises a transparent plastic and a phosphor additive.

3. A method according to Claim 2 further comprising:

forming a transparent core inside the dome.

4. A method according to Claim 2 further comprising:

forming a transparent outer shell outside the dome.

5. A method according to Claim 3 further comprising:

forming a transparent outer shell outside the dome.

6. A method according to Claim 2 wherein the filling is preceded by forming a transparent core and wherein the filling comprises filling a dome-shaped mold that includes the transparent core with a molten liquid that comprises a transparent plastic and a phosphor additive.

7. A method according to Claim 1 wherein the transmissive optical element is a keypad key through which a light emitting device emits light and wherein the filling comprises filling a keypad key-shaped mold with a molten liquid that comprises a transparent plastic and a phosphor additive.

8. A method according to Claim 1 wherein the transmissive optical element is a keypad key face, through which a light emitting device emits light, the method further comprising:

Savant Technologies LLC - 1004.421

forming a keypad key wall that is attached to the keypad key face.

9. A transmissive optical element comprising:

a shell that comprises a transparent plastic including a phosphor dispersed therein.

10. A transmissive optical element according to Claim 9 wherein the phosphor is uniformly dispersed in the shell.

11. A transmissive optical element according to Claim 9 wherein the phosphor is nonuniformly dispersed in the shell.

12. A transmissive optical element according to Claim 9 wherein the shell is a dome-shaped shell, the transmissive optical element further comprising a transparent inner core inside the dome-shaped shell.

13. A transmissive optical element according to Claim 9 wherein the shell is a dome-shaped shell, the transmissive optical element further comprising a transparent outer core outside the dome-shaped shell.

14. A transmissive optical element according to Claim 12 wherein the shell is a dome-shaped shell, the transmissive optical element further comprising a transparent outer core outside the dome-shaped shell.

15. A transmissive optical element according to Claim 12 wherein the transparent inner core fills the dome-shaped shell.

16. A transmissive optical element according to Claim 12 in combination with a semiconductor light emitting device that is configured to emit light into and through the transparent inner core and through the dome-shaped shell, to emerge from the dome-shaped shell.

17. A transmissive optical element according to Claim 16 in further combination with a mounting substrate that is adjacent the semiconductor light

Savant Technologies LLC - 1004.422

emitting device such that the semiconductor light emitting device is between the mounting substrate and the transparent inner core.

18. A transmissive optical element according to Claim 17 in further combination with an encapsulant between the semiconductor light emitting device and the transparent inner core.

19. A transmissive optical element according to Claim 9 wherein the shell is a keypad key shell, including a keypad key face and a keypad key wall that extends from the keypad key face.

20. A transmissive optical element according to Claim 19 wherein the phosphor is uniformly dispersed in the keypad key shell.

21. A transmissive optical element according to Claim 19 wherein the phosphor is uniformly dispersed in the keypad key face and is not included in the keypad key wall.

22. A transmissive optical element according to Claim 19 wherein the phosphor is nonuniformly dispersed in the keypad key face.

23. A light emitting device comprising:

a mounting substrate;

a semiconductor light emitting device on the mounting substrate;

a dome-shaped shell that comprises a transparent plastic including a phosphor dispersed therein, on the mounting substrate that at least partially surrounds the semiconductor light emitting device; and

a transparent inner core inside the dome-shaped shell.

24. A light emitting device according to Claim 23 further comprising:

an encapsulant between the semiconductor light emitting device and the transparent inner core.

Savant Technologies LLC - 1004.423

25. A light emitting device according to Claim 24 wherein the mounting substrate includes therein a cavity, wherein the semiconductor light emitting device is at least partially in the cavity, wherein the dome-shaped shell is on the mounting substrate surrounding the cavity and wherein the encapsulant is in the cavity.

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26. A light emitting device according to Claim 23 further comprising:
a transparent outer shell outside the dome-shaped shell.

Savant Technologies LLC - 1004.424

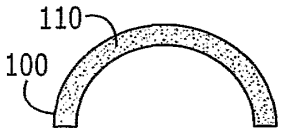


FIG. 1A

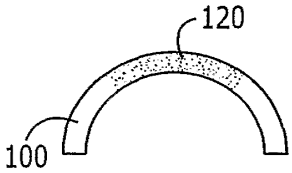


FIG. 1B

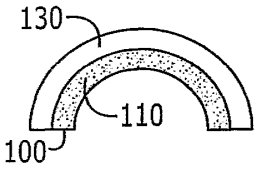


FIG. 1C

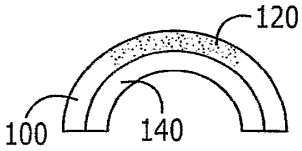


FIG. 1D

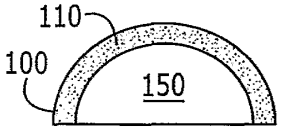


FIG. 1E

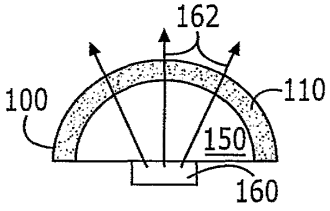


FIG. 1F

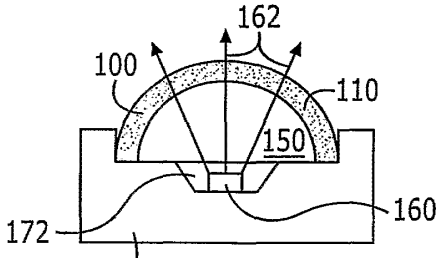


FIG. 1G

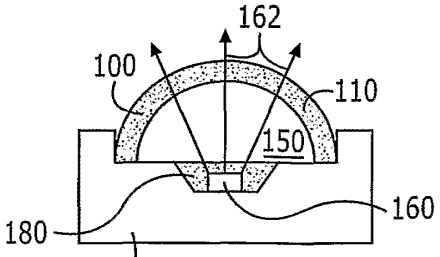


FIG. 1H

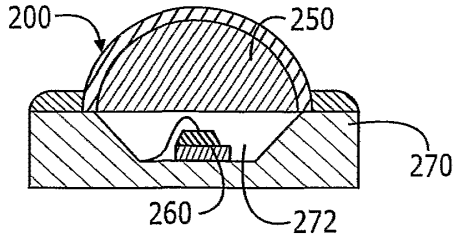


FIG. 2A

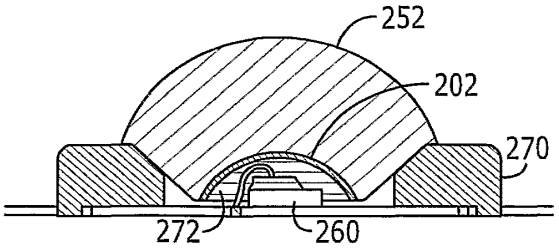


FIG. 2B

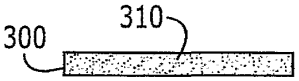


FIG. 3A

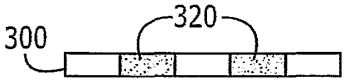


FIG. 3B

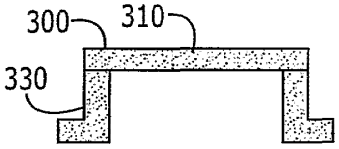


FIG. 3C

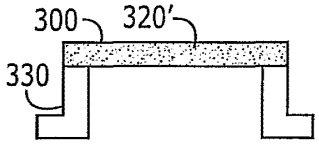


FIG. 3D

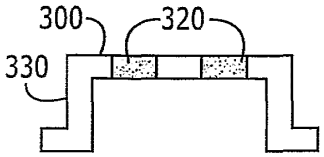


FIG. 3E

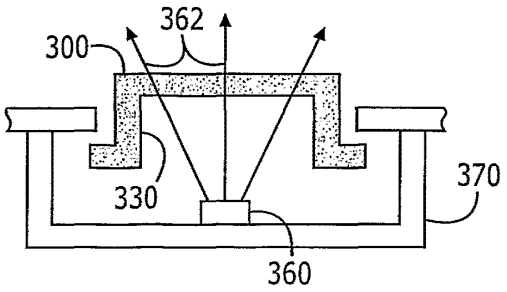


FIG. 3F

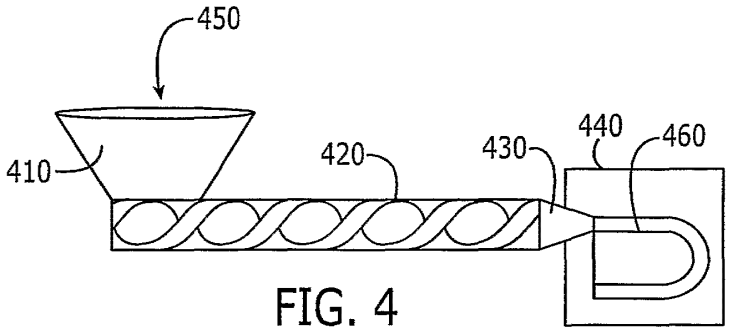


FIG. 4

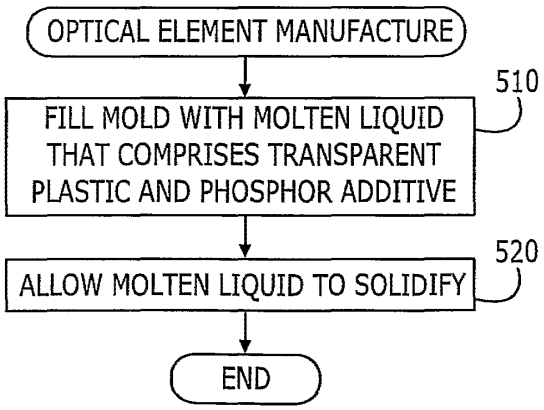


FIG. 5

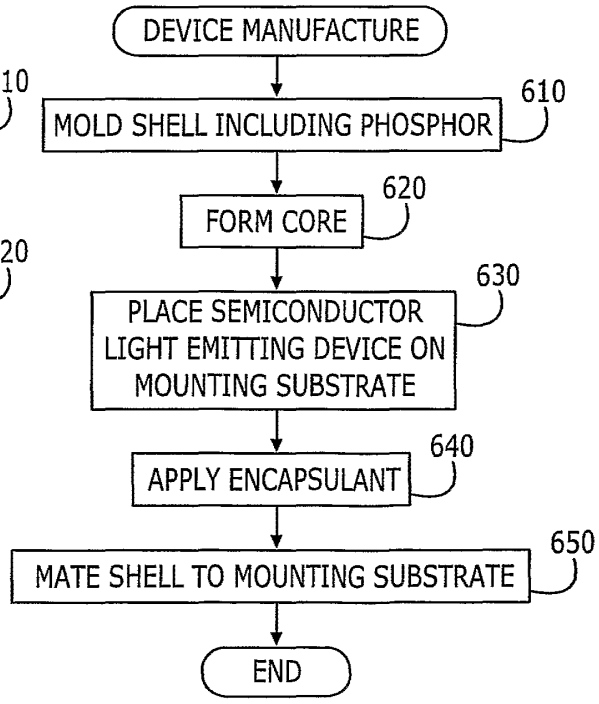


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
/US2004/017325

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C45/00 B29C39/00 H01H13/70

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 066 861 A (SCHNEIDER JUERGEN ET AL) 23 May 2000 (2000-05-23) column 9, line 15 - line 28; claim 1; figure 4	1-26
X	US 2003/153861 A1 (ROYER GEORGE R) 14 August 2003 (2003-08-14) column 5, paragraph 66-69; figures 9-11	1-26

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 September 2004	28/09/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Roberts, P

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Information on patent family members

International Application No
/US2004/017325

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WO 2006/022792 A2

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C09K 3/00 (2006.01) *H01F 1/28* (2006.01)

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10/912,741 4 August 2004 (04.08.2004) US
10/948,764 22 September 2004 (22.09.2004) US

(71) Applicant *(for all designated States except US)*: **INTEMATIX CORPORATION** [US/US]; 351 Rheem Blvd., Moraga, California 94556 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **WANG, Ning** [US/US]; 47 Fountainhead Court, Martinez, California 95376 (US). **DONG, Yi** [CN/US]; 1765 Hoops Court, Tracy, California 95676 (US). **CHENG, Shifan** [CN/US]; 344 Rheem Blvd., #3, Moraga, California 94556 (US). **LI, Yi-qun** [US/US]; 311 Downham Court, Walnut Creek, California 94598 (US).

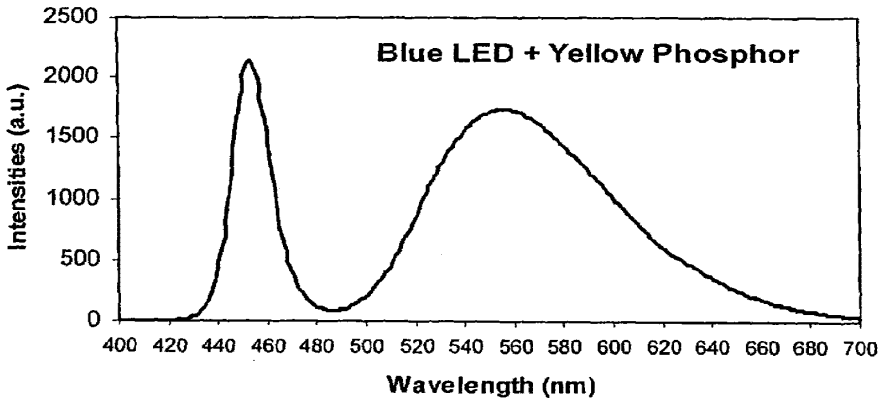
(74) Agent: **POWELL, Stephen, F.**; Burns Doane Swecker & Mathis, L.L.P., P.O. Box 1404, Alexandria, VA 22313-1404 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: NOVEL SILICATE-BASED YELLOW-GREEN PHOSPHORS



(57) Abstract: Novel phosphor systems are disclosed having the formula $A_2SiO_4:Eu^{2+}D$, where A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S and N. In one embodiment, the novel phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2SiO_4$: $Eu^{2+}F$ (where M is one of Ca, Mg, Zn, or Cd in an amount ranging from $0<y<0.5$). The phosphor is configured to absorb visible light from a blue LED, and luminescent light from the phosphor plus light from the blue LED may be combined to form white light. The novel phosphors can emit light at intensities greater than either conventionally known YAG compounds, or silicate-based phosphors that do not contain the inventive dopant ion.

WO 2006/022792 A2

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Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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NOVEL SILICATE-BASED YELLOW-GREEN PHOSPHORS

BACKGROUND OF THE INVENTION

Reference to Related Application

The present application is a continuation-in-part of U.S. patent application serial number 10/912,741, filed August 4, 2004, and titled "Novel phosphor systems for a white light emitting diode (LED)," by inventors Yi Dong, Ning Wang, Shifan Cheng, and Yi-Qun Li. U.S. patent application 10/912,741 is hereby incorporated by reference in its entirety.

Field of the Invention

Embodiments of the present invention are directed in general to novel silicate-based yellow and/or green phosphors (herein referred to as yellow-green phosphors) for use in a white light illumination system such as a white light emitting diodes (LED). In particular, the yellow-green phosphors of the present invention comprise a silicate-based compound having at least one divalent alkaline earth element and at least one anion dopant, wherein the optical performance of the novel phosphors is equal to or exceeds that of either known YAG:Ce compounds or known silicate-based compounds that do not take advantage of the benefits of including an anion dopant.

State of the Art

White LED's are known in the art, and they are relatively recent innovations. It was not until LED's emitting in the blue/ultraviolet region of the electromagnetic spectrum were developed that it became possible to fabricate a white light illumination source based on an LED. Economically, white LED's have the potential to replace incandescent light sources (light bulbs), particularly as production costs fall and the technology develops further. In particular, the potential of a white light LED is believed to be superior to that of an incandescent bulbs in lifetime, robustness, and efficiency. For example, white light illumination sources based on LED's are expected to meet industry standards for operation lifetimes of 100,000 hours, and efficiencies of 80 to 90 percent. High brightness LED's have already made a substantial impact on such areas of society as traffic light signals, replacing incandescent bulbs, and so it is not surprising that they will soon provide

Savant Technologies LLC - 1004.432

generalized lighting requirements in homes and businesses, as well as other everyday applications.

There are several general approaches to making a white light illumination system based on light emitting phosphors. To date, most white LED commercial products are fabricated based on the approach shown in FIG. 1, where light from a radiation source does affect the color output of the white light illumination. Referring to the system 10 of FIG. 1, a radiation source 11 (which may be an LED) emits light 12, 15 in the visible portion of the electromagnetic spectrum. Light 12 and 15 is the same light, but is shown as two separate beams for illustrative purposes. A portion of the light emitted from radiation source 11, light 12, excites a phosphor 13, which is a photoluminescent material capable of emitting light 14 after absorbing energy from the source 11. The light 14 can be a a substantially monochromatic color in the yellow region of the spectrum, or it can be a combination of green and red, green and yellow, or yellow and red, etc. Radiation source 11 also emits blue light in the visible that is not absorbed by the phosphor 13; this is the visible blue light 15 shown in FIG. 1. The visible blue light 15 mixes with the yellow light 14 to provide the desired white illumination 16 shown in the figure.

A known yellow phosphor that has been used in the art according to the scheme illustrated in FIG. 1 is a YAG–based phosphor having a main emission peak wavelength that varies in the range of about 530 to 590 nm depending on the composition, especially the amount of gadolinium (Gd) atoms substituting yttrium (Y) atoms constituting the YAG-based phosphor. Another factor that influences the main emission peak wavelength is the amound of the Ce^{3+} added as a luminescent center. It is known that the peak emission wavelength shifts to longer wavelengths as either the substitution amount of Gd or the amount of Ce^{3+} is increased. Color control of the white light may be accomplished by changing the output ratio between the blue light emitted by the blue LED and the yellow light emitted by the YAG-based phosphor.

U.S. Pat. 5,998,925 to Shimizu et al. discloses the use of a 450nm blue LED to excite a yellow phosphor comprising a yttrium-aluminum-garnet (YAG) fluorescent material. In this approach a InGaN chip functions as a visible, blue-light emitting LED, and a cerium doped yttrium aluminum garnet (referred to as "YAG:Ce") serves as a single phosphor in the system. The phosphor typically has the following stoichiometric formula: $Y_3Al_5O_{12}:Ce^{3+}$. The blue light emitted by the blue LED excites the phosphor, causing it to emit yellow light, but not all the blue light emitted by the blue LED is absorbed by the phosphor; a portion is

Savant Technologies LLC - 1004.433

transmitted through the phosphor, which then mixes with the yellow light emitted by the phosphor to provide radiation that is perceived by the viewer as white light.

The YAG:Ce phosphors of the prior art have known disadvantages. One disadvantageis that when used in an illumination system it may contribute to production of white light with color temperatures ranging from 6,000 to 8,000 K, which is comparable to sunlight, and a typical color rendering index (CRI) of about 70 to 75. These specifications are viewed as a disadvantage because in some instances white light illumination systems with a lower color temperature are preferred, such as between about 3000 and 4100 K, and in other cases a higher CRI is desired, such as above 90. Although the color temperature of this type of prior art system can be reduced by increasing the thickness of the phosphor, the overall efficiency of the system decreases with such an approach.

Another yellow phosphor that has been used in the art according to the scheme illustrated in FIG. 2 is a silicate-based phosphor described by T. Maeda et al. in U.S. Patent Application Publication 2004/0104391 A1, published June 3, 2004. In this publication, T. Maeda et al. describe a silicate-based phosphor according to the formula $(Sr_{1-a1-b1-x}Ba_{a1}Ca_{b1}Eu_x)_2SiO_4$, where $0 \leq a1 \leq 0.3$; $0 \leq b1 \leq 0.8$; and $0 < x < 1$. This yellow-yellowish phosphor emits a fluorescence having a main emission peak in the wavelength range from 550 to 600 nm, inclusive, with a wavelength range 560 to 590 nm being preferred. Still more preferable was a phosphor emitting a fluroescence having a main emission peak in the wavelength range 565 to 585 nm, both inclusive.

That the YAG-based phosphors exemplified by U.S. Pat. 5,998,925 to Shimizu et al., or the silicate-based phosphors of T. Maeda et al. in U.S. Patent Application Publication 2004/0104391 A1, can produce white light according to the visible excitation source scheme of FIG. 1, may be understood in part by studying an excitation spectra shown in FIG. 2, taken from the Maeda et al. patent application. FIG. 2 is a graph showing the excitation and emission spectra of Maeda et al.'s silicate phosphor and a YAG-based phosphor. Maeda et al.'s silicate based phosphor is a yellow (or yellow/yellowish, as they describe it) phosphor which has an excitation peak around 250 to 300 nm, and absorbs light in a wavelength range of 100 to 500 nm to emit a yellow/yellowish fluorescence having an emission peak in the 550 to 600 nm range; i.e., from yellow-green to yellow to orange. Accordingly, if light from the yellow/yellowish phosphor of Maeda et al. is combined with the blue light from a blue-light-emitting device, the resulting light is substantially white in nature.

Savant Technologies LLC - 1004.434

Maeda et al. concede in FIG. 2 that their silicate phosphor has a low luminous efficacy, the luminous efficacy of their silicate-based phosphor being only half of that of a YAG-based phoshpor under 470 nm excitation when the silicate-based phosphor is excited by blue light in the wavelength range greater than 430 nm and less than or equal to 500 nm. This necessitates the use of a larger amount of Maeda et al.'s phosphor relative to a YAG-based phosphor in order to obtain the same color of light according to the scheme of FIG. 2. In a description provided by Maeda et al., the luminescent layer is "relatively thick" compared to that which would have been used had the luminescent been a YAG-based phosphor. In this case the blue light intensity used as a part of white illumination will be significantly reduced by relative thick layer of Maeda et al's yellow phosphors.

What is needed is an improvement over the silicate-based, yellow phosphors of the prior art where the improvement is manifestated at least in part by an equal or greater conversion efficiency from blue to yellow. The enhanced yellow phosphor with low gravity density and low cost may be used in conjunction with a blue LED to generate light whose color output is stable, and whose color mixing results in the desired uniform, color temperature and color rendering index.

SUMMARY OF THE INVENTION

Embodiments of the present invention are directed to novel silicate-based yellow and/or green phosphors (herein referred to as yellow-green phosphors) for use in a white light illumination system such as a white light emitting diodes (LED). In particular, the yellow-green phosphors of the present invention comprise a silicate-based compound having at least one divalent alkaline earth element and at least one anion dopant, wherein the optical performance of the novel phosphors is equal to or exceeds that of either known YAG:Ce compounds or known silicate-based compounds that do not take advantage of the benefits of including an anion dopant.

In one embodiment of the present invention, the novel silicate-based yellow-green phosphor has the formula $A_2SiO_4:Eu^{2+}D$, where A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S and N, wherein D is present in the phosphor in an amount ranging from about 0.01 to 20 mole percent. This silicate-based phosphor is configured to absorb radiation in a wavelength ranging from about 280 nm to 490 nm, and emits visible light having a wavelength ranging from about 460 nm to 590 nm.

Savant Technologies LLC - 1004.435

In an alternative embodiment, the silicate-based phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4$: $Eu^{2+}D$, where M is at least one of an element selected from the group consisting of Ca, Mg, Zn, and Cd, and where

$0 \leq x \leq 1$;

$0 \leq y \leq 1$ when M is Ca;

$0 \leq y \leq 1$ when M is Mg; and

$0 \leq y \leq 1$ when M is selected from the group consisting of Zn and Cd.

In one embodiment, the "D" ion in the silicate-based phosphor is fluorine.

In an alternative embodiment, the silicate-based has the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4$: $Eu^{2+}F$, where M is at least one of an element selected from the group of Ca, Mg, Zn,Cd, and where

$0 \leq x \leq 0.3$;

$0 \leq y \leq 0.5$ when M is Ca;

$0 \leq y \leq 0.1$ when M is Mg; and

$0 \leq y \leq 0.5$ when M is selected from the group consisting of Zn and Cd.

This phophor emits light in the yellow region of the electromagnetic spectrum, and has a peak emission wavelength ranging from about 540 to 590 nm.

In an alternative embodiment, the silicate-based phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4$: $Eu^{2+}F$, where M is at least one of an element selected from the group consisting of Ca, Mg, Zn, and Cd, and where

$0.3 \leq x \leq 1$;

$0 \leq y \leq 0.5$ when M is Ca;

$0 \leq y \leq 0.1$ when M is Mg; and

$0 \leq y \leq 0.5$ when M is selected from the group consisting of Zn and Cd.

This silicate-based phosphor emits light in the green region of the electromagnetic spectrum, and has a peak emission wavelenth ranging from about 500 to 530 nm. The silicate-based phosphor emits light in the green region of the electromagnetic spectrum, and has a peak emission wavelenth ranging from about 500 to 530 nm.

In an alternative embodiment, a white light LED is disclosed, the white light LED comprising a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm; a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with a peak intensity in a wavelength ranging from about 530 to 590 nm.

Savant Technologies LLC - 1004.436

In an alternative embodiment, the white LED may comprise a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm; a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 530 to 590 nm; and a green phosphor according to claim 9, the green phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 500 to 540 nm.

In an alternative embodiment, the white LED may comprise a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm; a green phosphor according to claim 9, the green phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 500 to 540 nm; and a red phosphor selected from the group consisting of $CaS:Eu^{2+}$, $SrS:Eu^{2+}$, $MgO*MgF*GeO:Mn^{4+}$, and $M_xSi_yN_z:Eu^{+2}$, where M is selected from the group consisting of Ca, Sr, Ba, and Zn; Z=2/3x+4/3y, wherein the red phosphor is configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 590 to 690nm.

n an alternative embodiment, the white LED may comprise a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm; a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with a peak intensity in a wavelength ranging from about 540 to 590 nm; and a red phosphor selected from the group consisting of $CaS:Eu^{2+}$, $SrS:Eu^{2+}$, $MgO*MgF*GeO:Mn^{4+}$, and $M_xSi_yN_z:Eu^{+2}$, where M is selected from the group consisting of Ca, Sr, Ba, and Zn; and Z=2/3x+4/3y, wherein the red phosphor is configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 590 to 690nm.

Further embodiments of the composition comprise a silicate-based yellow phosphor having the formula $A_2SiO_4:Eu^{2+}D$, wherein A is at least one divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is an ion that is present in the yellow phosphor in an amount ranging from about 0.01 to 20 mole percent; and a blue phosphor; wherein the yellow phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 540 nm to 590 nm; and the blue phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 480 to 510 nm. The blue phosphor of the composition is selected from the group consisting of silicate-based

Savant Technologies LLC - 1004.437

phosphors and aluminate-based phosphors. The composition of the silicate-based blue phosphor may have the formula $Sr_{1-x-y}Mg_xBa_ySiO_4:Eu^{2+}F$; and where

$0.5 \leq x \leq 1.0$; and

$0 \leq y \leq 0.5$.

Alternatively, the composition of the aluminate-based blue phosphor may have the formula $Sr_{1-x}MgEu_xAl_{10}O_{17}$; and where

$0.01 < x \leq 1.0$.

In an alternative embodiment, a composition comprises a silicate-based green phosphor having the formula $A_2SiO_4:Eu^{2+}H$, wherein A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and H is a negatively charged halogen ion that is present in the yellow phosphor in an amount ranging from about 0.01 to 20 mole percent; a blue phosphor; and a red phosphor; wherein the green phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 500nm to 540 nm; the blue phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 480 to 510 nm; and the red phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 775 to 620 nm.

In an alternative embodiment, methods are provided for preparing a silicate-based yellow phosphor having the formula $A_2SiO_4:Eu^{2+}D$, wherein A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S and N, wherein D is present in the phosphor in an amount ranging from about 0.01 to 20 mole percent, the method selected from the group consisting of a sol-gel method and a solid reaction method.

Methods for preparing the novel phosphors include sol-gel methods, which comprises the steps of:

a) dissolving a desired amount of an alkaline earth nitrate selected from the group consisting of Mg, Ca, Sr, and Ba-containing nitrates with a compound selected from the group consisting of Eu_2O_3 and BaF_2 or other alkaline metal halides, in an acid, to prepare a first solution;

b) dissolving corresponding amount of a silica gel in de-ionized water to prepare a second solution;

c) stirring together the solutions produced in steps a) and b), and then adding ammonia to generate a gel from the mixture solution;

Savant Technologies LLC - 1004.438

d) adjusting the pH of the solution produced in step c) to a value of about 9, and then stirring the solution continuously at about 60°C for about 3 hours;

e) drying the gelled solution of step d) by evaporation, and then decomposing the resulting dried gel at 500 to 700°C for about 60 minutes to decompose and acquire product oxides;

f) cooling and grinding the gelled solution of step e) with NH_4F or other ammonia halides when alkaline earth metal halides are not used in step a) to produce a powder;

g) calcining/sintering the powder of step f) in a reduced atmosphere for about 6 to10 hours, wherein the sintering temperature ranged from about 1200 to 1400°C.

In a method that involves a solid reaction method, the steps comprise:

a) wet mixing desired amounts of alkaline earth oxides or carbonates (Mg, Ca, Sr, Ba), dopants of Eu_2O_3 and/or BaF_2 or other alkaline earth metal halides, corresponding SiO_2 and/or NH_4F or other ammonia halides with a ball mill.

b) after drying and grinding, calcining and sintering the resulting powder in a reduced atmosphere for about 6 to10 hours, wherein the calcining/sintering temperature ranged from about 1200 to 1400°C.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a general scheme for constructing a white light illumination system, the system comprising a radiation source that emits in the visible, and a phosphor that emits in response to the excitation from the radiation source, wherein the light produced from the system is a mixture of the light from the phosphor and the light from the radiation source;

FIG. 2 is an excitation spectrum plotted as a function of wavelength for a prior art YAG-based phosphor and a prior art silicate-based phosphor; included in the graph is an emission spectra measured from each of two prior art yellow phosphors, where both have been excited with radiation having a wavelength of 470 nm;

FIG. 3 shows a collection of emission spectra of exemplary phosphors according to the embodiments of the present invention, the compositions varying in fluroine content but conforming to the formula $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{4-x}F_x$, where the wavelength of the excitation radiation used in the experiment was about 450 nm;

Savant Technologies LLC - 1004.439

FIG. 4 is a graph of emission intensities versus doping concentration of the ion (D) for exemplary compositions having the formula $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{4-x}D_x$, where D in this experiment is F, Cl, or P;

FIG. 5 is a graph of the peak wavelength position versus doping concentration of the anion (D) for exemplary compositions having the formula $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{4-x}D_x$, where D in this experiment is F, Cl, or P;

FIG. 6 is a graph of the excitation spectra comparing fluorine containing silicates and non-fluorine containing silicates, further confirming the role that fluorine plays in the present embodiments;

FIG. 7 shows a collection of emission spectra for exemplary phosphors having the formula $[(Sr_{1-x}Ba_x)_{0.98}Eu_{0.02}]_2SiO_{4-y}D_y$, illustrating how both peak intensity and wavelength position change as a function of the ratio of the two alkaline earths Sr and Ba;

FIG. 8 is a graph of emission intensity as a function of wavelength for compounds having similar CIE color, including novel phosphors prepared by mixing 40% $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$ and 60% $[(Sr_{0.9}Ba_{0.05}\ Mg_{0.05})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$;

FIG. 9 is a collection of emission spectra of the exemplary phosphor $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$ tested as a function of temperature, which ranged from 25 to 120°C;

FIG. 10 is a graph of the maximum intensities of the spectra plotted as a function of temperature, where the maximum intensity of the exemplary yellow phosphor $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$ is shown compared with a YAG:Ce compound and a (Y,Gd)AG compound;

FIG. 11 is a graph of the maximum emission wavelengths of the spectra shown in FIG. 8 plotted as a function of temperature for the exemplary yellow phosphor $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$;

FIG. 12 is a graph of the maximum emission intensity as a function of humidity for the exemplary yellow-green phosphor $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$;

FIG. 13 relates to fabrication of the novel yellow-green phosphor, and is a graph of the fluorine concentration of a starting material in an exemplary sintered phosphor as a function of the mole percent of fluorine that actually ends up in the phoshor, the fluorine content in the sintered phosphor measured by secondary ion emisson spectroscopy (SIMS);

FIG. 14 shows the location of the inventive yellow-green phosphors on a CIE diagram, along with an exemplary YAG:Ce phosphor for comparison;

Savant Technologies LLC - 1004.440

FIG. 15 is an emission spectrum from an exemplary white LED comprising yellow light from an exemplary $(Sr_{0.7}Ba_{0.3}Eu_{0.02})_{1.95}Si_{1.02}O_{3.9}F_{0.1}$ phosphor in combination with blue light from a blue LED (used to provide excitation radiation to the exemplary yellow-green phosphor), the excitation wavelength of the blue LED about 450 nm;

FIG. 16 is an emission spectrum from an exemplary white LED comprising yellow light from the exemplary $(Sr_{0.7}Ba_{0.3}Eu_{0.02})_{1.95}Si_{1.02}O_{3.9}F_{0.1}$ phosphor in combination with green light from an exemplay green phosphor having the formula $(Ba_{0.3}Eu_{0.02})_{1.95}Si_{1.02}O_{3.9}F_{0.1}$, with blue light from the blue LED as before in FIG. 14, the excitation radiation from the blue LED again having a wavelength of about 450 nm;

FIG. 17 is an emission spectrum from an exemplary white LED comprising a blue LED (emitting at a peak wavelength of about 450 nm), the inventive yellow-green phosphor this time adjusted to emit more in the green at about 530 nm, and a red phosphor having the formula CaS:Eu;

FIG. 18 is a chromaticity diagram showing the positions of an exemplary red, green and yellow phosphor, and the position of the resulting white light created by mixing light from the individual phosphors.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the present invention will be described in the following order: first, a general description of the novel silicate-based phosphor will be given, particularly with respect to selection of the dopant anion and reasons for its inclusion, and benefits especially in terms of enhanced emission intensity; the alkaline earths present in the phosphor, and the effect their content ratios has on luminescent properties; and the effects that temperature and humidity have on the phosphor. Next, phosphor processing and fabrication methods will be discussed. Finally, the white light illumination that may be produced using the novel yellow-green phosphor will be disclosed by first discussing the general characteristics of a blue LED, followed by a discussion of other phosphors that may be used in tandom with the novel yellow-green phosphor, such as, in particular, a red phosphor.

The novel yellow phosphors of the present embodiments

According to embodiments of the present invention, a yellow phosphor having the formula $A_2SiO_4:Eu^{2+}D$ is disclosed, wherein A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is a negatively charged ion,

Savant Technologies LLC - 1004.441

present in the phosphor in an amount ranging from about 0.01 to 20 mole percent. There may be more than one of the divalent metal A present in any one phosphor. In a preferred embodiment, D is a dopant ion selected from the group consisting of F, Cl, Br, and I, but D can also be an element such as N, S, P, As, Sb, P, As, and Sb. The silicate-based phosphor is configured to absorb an excitation radiation having a wavelength ranging from about 280 nm to 520 nm, and particularly from wavelengths in the visible portion of that range such as from 430 to 480 nm. For example, the present silicate-based phosphor is configured to emit visible light having a wavelength ranging from about 460 nm to 590 nm, and has the formula $(Sr_{1-x-y}Ba_xCa_yEu_{0.02})_2SiO_{4-z}D_z$; and where $0<x\leq1.0$, $0<y\leq0.8$., and $0<z\leq0.2$. An alternative formula is $(Sr_{1-x-y}Ba_xMg_yEu_{0.02})_2SiO_{4-z}D_z$, where $0<x\leq1.0$, $0<y\leq0.2$, and $0<z\leq0.2$. In an alternative embodiment, the phosphor may be described by the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4$: $Eu^{2+}D$, where $0\leq x\leq1$, and M is one or more of Ca, Mg,Zn,Cd. In this embodiment, the condition $0\leq y\leq0.5$ applies when M is Ca; $0\leq y\leq0.1$ when M is Mg; and $0\leq y\leq0.5$ when M is either Zn or Cd. In a preferred embodiment, the component D is the element fluorine (F).

Exemplary phosphors were fabricated according to the present embodiments, and characterized optically in a variety of ways. First, and perhaps most revealing, were tests conducted to evaluate the intensity of the light emitted from the phosphor as a function of wavelength, wherein the test was carried out on a series of phosphor compositions that varied in the content of the D anion. From this data, it is useful to construct a graph of peak emission intensities, as a function of D anion content. Also useful is the construction of a graph of peak emission wavelength, again as a function of D anion content. Finally, it is possible to investigate the role that the divalent metal plays in phosphor performance; specifically, a series of compositions may be fabricated that contain two alkaline earth elements A_1 and A_2, sometime with an additional (or third) alkaline earth element A_3, and emission spectra as a function of wavelength may be measured for the different alkaline earths. In the case of two alkaline earths, in other words, the ratio of A_1/A_2 content may be varied.

Exemplary data is shown in FIGS. 3-6. The phosphor chosen to illustrate the inventive concept was a yellow-green phosphor of the family $[(Sr_{1-x}Ba_x)_{0.98}Eu_{0.02}]_2SiO_{4-y}D_y$. In other words, it will be understood by those skilled in the art that the alkaline earth components (A_1 and A_2) in these exemplary compositions are Sr and Ba; that it is an Eu^{2+} activated system, and that the D anions chosen for these compositions are F and Cl. Although "D" has been consistently referred to as an anion in this disclosure, it is possible

Savant Technologies LLC - 1004.442

for a cation to be incorporated into the structure. The results of such a composition are shown as well in FIG. 5, where the inclusion of phosphorus is compared to the results obtained for chlorine and fluorine.

The effect of the inclusion of the D anion dopant into the phosphor, where D is fluroine (F) in an exemplary composition, is seen in FIGS. 3-5. Referring to FIG. 3, the emission spectra was taken of a series of six compositions for the composition $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{4-x}D_x$, where the mole percent (mol%) of the fluorine was 0, 3.2, 13.5, 9.0, 16.8, and 19.0, respectively. The wavelength of the excitation radiation in this experiment was 450 nm, and so light from this blue LED may be considered to contribute to the subsequently produced white light illumination. The results of FIG. 3 show that the emission intensity from this phosphor is significantly increased by doping the compositions with fluorine for concentrations up to about 10 mol%, at which point the intensity begins to fall off as the fluorine concentration is increased further.

The data from FIG. 3 may be plotted in a slightly different way: the value of the emission intensity at the maximum of each of the peaks may be plotted as a function of fluorine content, as shown for F using the triangle symbols in FIG. 4. For example, since the curve in FIG. 3 exhibiting the highest intensity occurred for the composition having a fluorine content of 9 mol%, the highest point of the F-ion curve in FIG. 4 occurs at a location on the x-axis also at 9 mol%. What makes FIG. 4 interesting (and the reason for plotting the data in this manner), is that such a plot allows different D anions to be compared. Referring to FIG. 4, normalized peak emission intensities have been plotted as a function of doping concentration of the anions fluorine (triangles), chlorine (circles), and phosphorus (squares), again where the host phosphor comprised a silicate with Sr and Ba alkaline earth components in mole ratio 0.7 and 0.3, respectively.

The data in FIG. 4 shows that the fluorine anion is most capable of increasing emission intensity, relative to P and Cl, and in this particular system under study. It is interesting to note that the F and P compositions both peaked at about 9 mol%, whereas the Cl emission intensity was relatively constant over the range 9 to 17 mol%, and may even have shown a slight increase over the 9 to 17 mol% range. It should also be noted that whereas the increase offered by the Cl and P compositions is significant, being about a 40 to 50% in normalized intensity at an optimized concentration, the advantage may not appear to be significant only because of the huge increase of 100% that the F composition displayed. Furthermore, there may be advantages offered by the relatively flat curve of the Cl

Savant Technologies LLC - 1004.443

composition, in this instance, where fabrication difficulties and/or inconsistencies in content tolerances may be ignored because of the relative constant nature of the emission over a range of compositions (e.g., Cl content ranging from 9 to 17 mol%).

Just as normalized peak emission intensity may be plotted as a function of doping concentration for a series of D anion or cation (in this case, F, Cl, or P) compositions, so too may the wavelength at which that peak emission occurs be plotted as a function of wavelength. This data is shown in FIG. 5, again for the family of compositions $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{4-x}D_x$, where D is either an F, Cl, or P anion. As before, the wavelength of the excitation radiation was about 450 nm. The results of FIG. 5 show that the peak emission wavelength does not significantly vary with concentration for P, but does decrease for F and Cl with increasing dopant concentration to a value between about 2 and 4 mol%, steadily increasing thereafter. FIG. 6 is an example of excitation (absorption) spectra from an exemplary phosphor, tested with an excitation wavelength of about 450nm, affected by fluorine content in the inventive silicate based phosphors. It showed clearly again that the fluorine dramatically changed the excitation spectra of silicate phosphors, in particular for the wavelength range from about 400nm to 500nm. This has a tremendous impact on white LED applications, since the 100 percent increase in excitation intensity at the excitation wavelength 430 to 490nm of blue LED was achieved with only about 10 percent increase (mole percent) in fluorine concentration.

The effects that the inclusion of the D anion component into the phosphor have been discussed in FIGS. 3-5. Before preceeding to a disclosure of the effects of the alkaline earth component, a brief discussion of the role that the D anion plays in the composition will be given.

The role that the ion dopant (D) plays in the yellow phosphor

The effect of the inclusion of the anion D into the phosphor is highlighted by FIG. 3, which shows a collection of emission spectra of exemplary yellow phosphors varying in fluroine content. The wavelength of the excitation radiation used in the experiment was about 450 nm. In one embodiment, fluorine is added to the phosphor composition in the form of a NH_4F dopant. The present inventors have found that when the NH_4F dopant amount is very small (about 1%), the position of the peak emission is located at shorter wavelengths, and as more NH_4F is added, the wavelength increases with dopant amount. The luminescence of the Eu doped phosphor is due to the presence of the Eu^{2+} in the

Savant Technologies LLC - 1004.444

compound, which undergoes an electronic transition from $4f^6 5d^1$ to $4f^7$. The wavelength positions of the emission bands depend very much on the host's material or crystal structure, changing from the near-UV to the red region of the spectrum. This dependence is interpreted as due to the crystal field splitting of the 5d level. With increasing crystal field strength, the emission bands shift to longer wavelength. The luminescence peak energy of the 5d-4f transition is affected most by crystal parameters denoting electron-electron repulsion; in other word, the distance between Eu^{2+} cation and surrounding anions, and the average distance to distant cations and anions.

In the presence of small amounts of NH_4F, the fluorine anion dopant functions predominantly as a flux during sintering processing. Generally, a flux improves sintering processing in one of two ways: the first is to promote crystal growth with the liquid sintering mechanism, and the second is to absorb and collect the impurities from the crystal grains and improve the phase purity of the sintered materials. In one embodiment of the present invention, the host phosphor is $(Sr_{1-x}Ba_x)_2SiO_4$. Both Sr and Ba are very large cations. There may be present smaller cations such as Mg and Ca, which may be considered to be impurities. Therefore, further purification of host lattice will lead to more perfect symmetric crystal lattice and a larger distance between cations and anions, with a result of a weakening of the crystal field strength. This is the reason that small amount doping of NH_4F moves the emission peak to shorter wavelength. The emission intensity increases with this small amount of F doping attributes to a higher quality crystal with fewer defects.

When the amounts of NH_4F are increased even further, some of the F^- anions will replace O^{2-} anions, and become incorporated into the lattice. Cation vacancies will be created in order to maintain an electrical charge neutrality. Since the vacancies in the cation positions reduce the average distance between cations and anions, the crystal field strength will be increased. Therefore, the peak of the emission curves will move to longer wavelength as the NH_4F content increases due to the increased number of cation vacancies. The emission wavelength is directly related to the energy gap between ground and excitation states which is determined only by the crystal field strength. The result of emission wavelength increases with the fluorine and chlorine is strong evidence of fluorine or chlorine incorporating into the host lattice, most likely in substitute of oxygen sites. On the other hand, the addition of a phosphate ion does not substantially change the emission wavelength, as expected. This is again evidence that phosphate acts as a cation, will not replace oxygen, and thus will not be easily incorporated into the lattice to change the host material's crystal

Savant Technologies LLC - 1004.445

field strength. This is particularly true of the crystal field surrounding the Eu^{2+} ions, which consist essentially of oxygen sites. The improvement in the emission intensity gained by adding $NH_4H_2PO_4$ indicates that it works a flux agent as discussed above.

The excitation spectra comparing fluorine containing silicates and non-fluorine containing silicates, as shown in FIG. 6, further confirmed the critical role that fluorine plays in the present embodiments of the present halide containing silicate phosphors. The excitation spectra shown in FIG. 6 is obtained by plotting the emission intensity at the wavelength of 540nm verses an excitation wavelength. The excitation intensity is directly related to the absorption and determined by excitation and transmission probability between excitation level and ground level. The dramatic increase in excitation intensity above 400nm by introduction of fluorine into the silicate phosphor indicates again strongly that fluorine incorporates into the silicate lattice and changed dramatically the symmetrical surrounding of Eu^{+2} to nonsymmetrical structure, which directly increases the probability of emission and transmission between emission sate to ground state. From FIG. 6 one skilled in the art may see that about 10 mol% fluorine in silicate phosphor can increase about 100% emission intensity of non-fluorine contained silicate phosphor in the excitation wavelength from 450 to 480nm which is the most important for white LED applications.

The emission intensity decreases or levels off when the halide concentration increases more than 10 mol% as shown in FIG.3. This can be explained by Eu emission quenching due to the fact that more defects introduced in associated with the fluorine incorporation into the lattice, the more non-radiation centers will be created to reduce the absorbed energy transferring to Eu^{2+} effective emission centers. The result in FIG 3 indicates the maximum intensity increase by fluorine without Eu emission quenching is about 10 mol%.

Effect of the alkaline earth component

The optical properties of the inventive yellow phosphor may be controlled, in addition to the methods discussed above, by adjusting the ratio of the alkaline earth elements contained within the phosphor. An exemplary data set that puts this embodiment of the inventive concept into place is illustrated in FIG. 7. Before turning to FIG. 7, however, it may be useful to discuss the general effects of typical alkaline earths on the crystal structure of the phosphor, which in turn will affect optical properties, where the alkaline earths under consideration are Sr, Ba, Ca, and Mg.

Savant Technologies LLC - 1004.446

T. Maeda et al. do not teach the benefits of the present dopant ion D in U.S. Patent Application 2004/0104391. Many of the principles pertaining to the alkaline earth content, however, still apply. Maeda et al. teach that when the content of Ba and Ca in a silicate phosphor is very small; in other words, when the content of the alkaline earths in the phosphor is mostly Sr, then the phosphor is likely to assume a monoclinic structure, or a structure comprising a mixture of monoclinic and orthorhombic crystal structures. When Ba is put into the phosphor at higher values than desired with little or no Ca, the crystal field around Eu^{2+} ions is weak. If the Ba content is low and the Ca content is higher than desired, the crystal structure is again likely to be monoclinic. Finally, if both the Ba and Ca contents are larger than desired, relative to the amount of Sr in the phosphor, then the silicate-based phosphor is likely to have a hexagonal structure. In each of these cases, according to Maeda et al., the phosphor is expected to be greener, and emits light with a low color purity for yellow.

T. Maeda et al. teach that in order to obtain yellow light from the phosphor, which may be defined as light having a wavelength ranging from about 550 to 600 nm, the desired Ba content in the phosphor should be in a mole fraction from about 0 to 0.3. With regard to the Ca content, the desired condition for obtaining yellow wavelengths lies from about 0 to 0.6, although they conjecture that yellow wavelengths may also be obtained from a compound in which the Ca substitution (for Sr) has a mole fraction of about 0.7. Maeda et al. note that compounds that do not contain any Sr do not emit yellow light.

The present inventors have completed an investigation of the composition space $(Sr_{1-x-y-z}Ba_xCa_yMg_z)_2SiO_4$ (where x+y+z=1) to enhance luminescent properties. In this case the particular interest was to optimize the material configured to emit green to yellow color light by blue excitation. The effects of stoichiometric ratio of calcium, strontium and barium on luminescent properties were found in consistent with Maeda et al's results disclosed in their patent. However, the present invention is more focused on the improvements of emission intensity while controlling the emission wavelength in the desired green to yellow region. FIG. 7 is a graph of the emission spectra of exemplary yellow-green phosphors belonging to the family $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$, where the value of the strontium content in the series varies from 0 to 12, 25, 37, 50, 60, 65, 70, 80, 90, and 100 percent. Plotted another way, the value of x in the formula $Sr_{1-x}Ba_x$ ranges from 0, 0.1, 0.2, 0.3, 0.35, 0.4, 0.5, 0.63, 0.75, 0.87, and 1.0. Also plotted for comparison is a prior art YAG:Ce phosphor. The

Savant Technologies LLC - 1004.447

present study of the effects of alkaline metals on luminescent properties of silicate phosphors may be summarized as follows:

(1) In $(Sr_{1-x}Ba_x)_2SiO_4$ phosphor materials, the emission peak wavelength changes from green at 500 nm for x=1 (100%Ba) to yellow at 580 nm for x=0 (100%Sr) as shown in FIG. 7. The conversion efficiency from the same light source at 450nm shows a continuous increase when the Ba increases from 0 to about 90%. The peak emission wavelength of 545nm obtained when Ba to Sr ratio is 0.3 to 0.7 is close to the pure YAG:Ce peak emission wavelength as compared in FIG.7.

(2) Calcium substitution of barium or strontium in the Sr-Ba based silicate phosphor system will in general reduce the emission intensity, even they can be favored for moving the emission to longer wavelength when calcium substitution is less than 40%.

(3) Magnesium substitution of barium or strontium in the Sr-Ba based silicate phosphors will in general reduce the emission intensity and move the emission to shorter wavelengths. However, the small amount of magnesium substitution of barium or strontium (<10%) will enhance the emission intensity and move the emission to longer wavelengths. For example, five percent of substitution of barium by magnesium in $(Sr_{0.9}Ba_{0.1})_2SiO_4$ will increase the emission intensity and move to a slightly longer wavelength, as shown in FIG. 7 for the curve labeled $[(Sr_{0.9}Ba_{0.075}Mg_{0.025})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$.

(4) To match or improve upon a YAG emission spectrum, it may be necessary in some embodiments of the present invention to mix the inventive silicate phosphors. FIG. 8 shows that a substantially identical CIE color of YAG can be prepared by mixing 40% $[(Sr_{0.7}Ba_{0.3})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$ and 60% $[(Sr_{0.9}Ba_{0.05}Mg_{0.05})_{0.98}Eu_{0.02}]_2SiO_{3.9}F_{0.1}$. The total brightness of the mixture is estimated to be nearly 90% as bright as the YAG composition.

Effects of temperature and humidity on the phosphor

Temperature and humidity effects on the luminescent properties are very important to phosphor-based illumination devices such as white LEDs, based on partial or total conversion of LED emission to other wavelength emissions by the selected phosphor material system. The operating temperature range for such phosphor-based radiation devices depends on the specific application requirements. Temperature stable up to 85°C are

Savant Technologies LLC - 1004.448

generally required for commercial electronic applications. However, temperatures up to 180°C are desired for high power LED applications. Stability over the entire humidity range of 0 to 100% is required for almost all commercial electronic applications.

FIGS. 9-11 are plots of maximum luminescent intensity either as a function of temperature, or of wavelength for various temperatures, for an exemplary fluorine containing silicate phosphor $(Sr_{0.7}Ba_{0.3}Eu_{0.02})_{1.95}Si_{1.02}O_{3.9}F_{0.1}$. This particular phosphor was derived from the series of emission spectra measured at different temperatures shown previously. The temperature stability of the phosphor of this invention behaves very similar to that of a commercial YAG phosphor, particularly up to 100°C. FIG. 12 shows graph of the stability of the phosphor of this invention for humidity ranging from about 20 to100%. Without being constrained to any one theory, the inventors believe that while the reason for the 3% increase in emission maximum intensity above 90% humidity is unknown at this time, such a phenomena is reversible when the humidity oscillates between a value of about 90% to 100%.

Phosphor fabrication processes

Methods of fabricating the novel silicate-based phosphor of the present embodiments are not limited to any one fabrication method, but may, for example, be fabricated in a three step process that includes: 1) blending starting materials, 2) firing the starting material mix, and 3) various processes to be performed on the fired material, including pulverizing and drying. The starting materials may comprise various kinds of powders, such as alkaline earth metal compounds, silicon compounds, and europium compounds. Examples of the alkaline earth metal compounds include alkaline earth metal carbonates, nitrates, hydroxides, oxides, oxalates, and halides. Examples of silicon compounds include oxides such as silicon oxide and silicon dioxide. Examples of europium compounds include europium oxide, europium fluoride, and europium chloride. As a germanium material for the germanium-containing novel yellow-green phosphors of the present invention, a germanium compound such as germanium oxide may be used.

The starting materials are blended in a manner such that the desired final composition is achieved. In one embodiment, for example, the alkaline-earth, silicon (and/or germanium), and europium compounds are bended in the appropriate ratios, and then fired to achieve the desired composition. The blended starting materials are fired in a second step, and to enhance the reactivity of the blended materials (at any or various stages of the firing),

Savant Technologies LLC - 1004.449

a flux may be used. The flux may comprise various kinds of halides and boron compounds, examples of which include strontium fluoride, barium fluoride, calcium fluoride, europium fluoride, ammonium fluoride, lithium fluoride, sodium fluoride, potassium fluoride, strontium chloride, barium chloride, calcium chloride, europium chloride, ammonium chloride, lithium chloride, sodium chloride, potassium chloride, and combinations thereof. Examples of boron-containing flux compounds include boric acid, boric oxide, strontium borate, barium borate, and calcium borate.

In some embodiments, the flux compound is used in amounts where the number of mole percent ranges from between about 0.1 to 3.0, where values may typically range from about 0.1 to 1.0 mole percent, both inclusive.

Various techniques for mixing the starting materials (with or without the flux) include using a motar, mixing with a ball mill, mixing using a V-shaped mixer, mixing using a cross rotary mixer, mixing using a jet mill and mixing using an agitator. The starting materials may be either dry mixed or wet mixed, where dry mixing refers to mixing without using a solvent. Solvents that may be used in a wet mixing process include water or an organic solvent, where the organic solvent may be either methanol or ethanol.

The mix of starting materials may be fired by numerous techniques known in the art. A heater such as an electric furnace or gas furnace may be used for the firing. The heater is not limited to any particular type, as long as the starting material mix is fired at the desired temperature for the desired length of time. In some embodiments, firing temperatures may range from about 800 to 1600°C. The firing time may range from about 10 minutes to 1000 hours. The firing atmosphere may be selected from among air, a low-pressure atmosphere, a vacuum, an inert-gas atmosphere, a nitrogen atmosphere, an oxygen atmosphere, an oxidizing atmosphere, and/or a reducing atmosphere. Since Eu^{2+} ions need to be included in the phosphor at some stage of the firing, it is desired in some embodiments to provide a reducing atmosphere using a mixed gas of nitrogen and hydrogen.

Exemplary methods of preparing the present phosphors include a sol-gel method and a solid reaction method. The sol-gel method may be used to produce powder phosphors. A typical procedure comprised the steps of:

1. a) Dissolving certain amounts of alkaline earth nitrates (Mg, Ca, Sr, Ba), and Eu_2O_3 and/or BaF_2 or other alkaline earth metal halides in dilute nitric acid; and

   b) Dissolving corresponding amount of silica gel in de-ionized water to prepare a second solution.

Savant Technologies LLC - 1004.450

2. After the solids of the two solutions of steps 1a) and 1b) above were totally dissolved, the two solutions were mixed and stirred for two hours. Ammonia was then used to generate a gel in the mixture solution. Following formation of the gel, the pH was adjusted to about 9.0, and the gelled solution stirred continuously at about 60°C for 3 hours.
3. After drying the gelled solution by evaporation, the resulted dry gel was decomposed at 500 to 700°C for about 60 minutes to decompose and acquire oxides.
4. After cooling and grinding with certain amount of NH_4F or other ammonia halides when alkaline earth metal halides are not used in step 1a), the powder was sintered in a reduced atmosphere for about 6 to10 hours. The calcining/sintering temperature ranged from about 1200 to 1400°C.

Alternatively, the solid reaction method was also used for silicate-based phosphors. The steps of a typical procedure used for the solid reaction method are as following:

1. Desired amounts of alkaline earth oxides or carbonates (Mg, Ca, Sr, Ba), dopants of Eu_2O_3 and/or BaF_2 or other alkaline earth metal halides, corresponding SiO_2 and/or NH_4F or other ammonia halides were wet mixed with a ball mill.
2. After drying and grinding, the resulting powder was calcined/sintered in a reduced atmosphere for about 6 to10 hours. The calcining/sintering temperature ranged from 1200 to 1400°C.

In a specific example relating to the preparation of the present phosphors, the concentration of fluorine in the sintered phosphor $[(Sr_{1-x}Ba_x)_{0.98}Eu_{0.02}]_2SiO_{4-y}F_y$ was measured using secondary ion emisson spectroscopy (SIMS), and the results are shown in FIG. 13. In this experiment, the fluorine was added to the phosphor as NH_4F. The results show that for a mol% of fluorine of about 20 mol% in the starting material, the sintered phosphor ends up with about 10 mol%. When the content of fluorine in the raw material is about 75 mol%, the content of fluorine in the sintered phosphor is about 18 mol%.

Production of white light illumination

The white light illumination that may be produced using the inventive, novel yellow-green phosphor will be discussed in this final portion of the disclosure. The first section of this final portion will begin with a description of exemplary blue LED's that may be used to excite the inventive yellow-green phosphor. That the present yellow-green phosphors are capable of absorbing, and be excited by, light over a large range of wavelengths, including

Savant Technologies LLC - 1004.451

the blue portion of the visible, is demonstrated by the excitation (absorption) spectra of FIG. 6. Next, a generalized description of the CIE diagram will be provided, along with the location of the inventive yellow-green phosphor on the diagram, as shown in FIG 14. According to the general scheme of FIG. 1, light from the inventive yellow-green phosphor may be combined with light from the blue LED to make white illumination; the results of such an experiment are shown in an emission intensity versus wavelength plot for this system in FIG. 15. The color rendering of the white light may be adjusted with the inclusion of other phosphors in the system, as exemplified by the spectrum of FIG. 16. Alternatively, the inventive phosphor may be adjusted to emit more in the green, and combined with a red phosphor to make up the phosphor system, which together with the blue light from the blue LED produces the spectrum in FIG. 17. To conclude, the CIE diagram of the resulting white light is shown in FIG. 18.

The blue LED radiation source

According to the present embodiments, the blue light emitting LED emits light having a main emission peak in the wavelength range greater than or equal to about 400 nm, and less than or equal to about 520 nm. This light serves two purposes: 1) it provides the excitation radiation to the phosphor system, and 2) it provides blue light which, when combined with the light emitted from the phosphor system, makes up the white light of the white light illumination.

In an alternative embodiment, the blue LED emits light greater than or equal to about 420 nm, and less than or equal to about 500 nm. In yet another embodiment, the blue LED emits light greater than or equal to about 430 and less than or equal to about 480 nm. The blue LED wavelength may be 450 nm.

The blue light emitting device of the present embodiments is herein described generically as a "blue LED," but it will be understood by those skilled in the art that the blue light emitting device may be at least one of (wherein it is contemplated to have several operating simultaneously) a blue light emitting diode, a laser diode, a surface emiting laser diode, a resonant cavity light emitting diode, an inorganic electroluminescence device and an organic electroluminescence device. If the blue light emitting device is an inorganic device, it may be a semiconductor selected from the group consisting of a gallium nitride based compound semiconductor, a zinc selenide semiconductor and a zinc oxide semiconductor.

Savant Technologies LLC - 1004.452

FIG. 6 is an excitation spectrum of the present yellow-green phosphors, showing that these novel phosphors are capable of absorbing radiating over a range of about 280 to 520 nm, and relevant to the present embodiments, over a range of about 400 to 520 nm. In preferred embodiments of the present invention, the novel yellow-green phosphors absorb radiation (in other words, are capable of being excited by radiation) ranging from 430 to 480 nm. In yet another embodiment, the phosphor absorbs radiation having a wavelength of about 450 nm.

Next, a generalized description of the CIE diagram will be given, along with a description of where the present yellow-green phosphors appear on the CIE diagram.

Chromaticity coordinates on a CIE diagram, and the CRI

White light illumination is constructed by mixing various or several monochromatic colors from the visible portion of the electromagnetic spectrum, the visible portion of the spectrum comprising roughly 400 to 700 nm. The human eye is most sensitive to a region between about 475 and 650 nm. To create white light from either a system of LED's, or a system of phosphors pumped by a short wavelength LED, it is necessary to mix light from at least two complementary sources in the proper intensity ratio. The results of the color mixing are commonly displayed in a CIE "chromaticity diagram," where monochromatic colors are located on the periphery of the diagram, and white at the center. Thus, the objective is to blend colors such that the resulting light may be mapped to coordinates at the center of the diagram.

Another term of art is "color temperature," which is used to describe the spectral properties of white light illumination. The term does not have any physical meaning for "white light" LED's, but it is used in the art to relate the color coordinates of the white light to the color coordinates achieved by a black-body source. High color temperature LED's versus low color temperature LED's are shown at www.korry.com.

Chromaticity (color coordinates on a CIE chromaticity diagram) has been described by Srivastava et al. in U.S. Pat. 6,621, 211. The chromaticity of the prior art blue LED-YAG:Ce phosphor white light illumination system described above are located adjacent to the so-called "black body locus," or BBL, between the temperatures of 6000 and 8000 K. White light illumination systems that display chromaticity coordinates adjacent to the BBL obey Planck's equation (described at column 1, lines 60-65 of that patent), and are desirable because such systems yield white light which is pleasing to a human observer. **[0001]** The

Savant Technologies LLC - 1004.453

color rendering index (CRI) is a relative measurement of how an illumination system compares to that of a black body radiator. The CRI is equal to 100 if the color coordinates of a set of test colors being illuminated by the white light illumination system are the same as the coordinates generated by the same set of test colors being irradiated by a black body radiator.

Turning now to the present yellow-green phosphors, various exemplary compositions of the novel phosphors were excited with 450 nm radiation, and the positions of their emissions on a CIE diagram are shown in FIG. 14. The position of the 450 nm excitation light is also shown, as well as the position of a YAG:Ce phosphor for comparison.

The yellow to yellow-green color of these exemplary phosphors may advantageously be mixed with blue light from the blue LED described above (wherein the blue light has a wavelength ranging from about 400 to 520 nm in one embodiment, and 430 to 480 nm in another embodiment) to construct the white light illumination desired for a multiplicity of applications. FIG. 15 shows the results of mixing light from a blue LED with an exemplary yellow phosphor, in this case the yellow phosphor having the formula $(Sr_{0.7}Ba_{0.3}Eu_{0.02})_{1.95}Si_{1.02}O_{3.9}F_{0.1}$.

It will be understood by those skilled in the art that the present yellow-green phosphor may be used in conjunction with other phosphors, as part of a phosphor system, whereupon the light emitted from each of the phosphors of the phosphor system may be combined with the blue light from the blue LED to construct white light with alternative color temperatures and color renderings. In particular, green, orange and/or red phosphors disclosed previously in the prior art may be combined with the present yellow-green phosphor.

For example, U.S. Pat. 6,649,946 to Bogner et al. disclosed yellow to red phosphors based on alkaline earth silicon nitride materials as host lattices, where the phosphors may be excited by a blue LED emitting at 450nm. The red to yellow emitting phosphors uses a host lattice of the nitridosilicate type $M_xSi_yN_z$:Eu, wherein M is at least one of an alkaline earth metal chosen from the group Ca, Sr, and Ba, and wherein $z = 2/3\ x + 4/3\ y$. One example of a material composition is $Sr_2Si_5N_8:Eu^{2+}$. The use of such red to yellow phosphors was disclosed with a blue light emitting primary source together with one or more red and green phosphors. The objective of such a material was to improve the red color rendition R9 (adjust the color rendering to red-shift), as well as providing a light source with an improved overall color rendition Ra.

Savant Technologies LLC - 1004.454

Another example of a disclosure of supplementary phosphors, including red phosphors, that may be used with the present yellow-green phosphor are found in U.S. Patent Application 2003/0006702 to Mueller-Mach, which disclosed a light emitting device having a (supplemental) fluorescent material that receives primary light from a blue LED having a peak wavelength of 470 nm, the supplemental fluorescent material radiating light in the red spectral region of the visible light spectrum. The supplementary fluorescent material is used in conjunction with a main fluorescent material to increase the red color component of the composite output light, thus improving the white output light color rendering. In a first embodiment, the main fluorescent material is a Ce activated and Gd doped yttrium aluminum garnet (YAG), while the supplementary fluorescent material is produced by doping the YAG main fluorescent material with Pr. In a second embodiment, the supplementary fluorescent material is a Eu activated SrS phosphor. The red phosphor may be, for example, $(SrBaCa)_2Si_5N_8$: Eu^{2+}. The main fluorescent material (YAG phosphor) has the property of emitting yellow light in response to the primary light from the blue LED. The supplementary fluorescent material adds red light to the blue light from the blue LED and the yellow light from the main fluorescent material.

U.S. Pat. 6,504,179 to Ellens et al. disclose a white LED based on mixing blue-yellow-green (BYG) colors. The yellow emitting phosphor is a Ce-activated garnet of the rare earths Y, Tb, Gd, Lu, and/or La, where a combination of Y and Tb was preferred. In one embodiment the yellow phosphor was a terbium-aluminum garnet (TbAG) doped with cerium ($Tb_3Al_5O_{12}$-Ce). The green emitting phosphor comprised a CaMg chlorosilicate framework doped with Eu (CSEu), and possibly including quantities of further dopants such as Mn. Alternative green phosphors were $SrAl_2O_4$:Eu^{2+} and $Sr_4Al_{14}O_{25}$:Eu^{2+}.

The novel yellow-green phosphor may be used in a combination of green and yellow phosphors ($Tb_3Al_5O_{12}$-Ce).

Although a prior art method disclosed in U.S. Pat. 6,621,211 to Srivastava et al was designed to emit white light using a non-visible UV LED, this patent is relavent to the present embodiments because of the supplementary green, orange, and/or red phosphors used in the phosphor system. The white light produced in this method was created by non-visible radiation impinging on three, and optionally a fourth, phosphor, of the following types: the first phosphor emitted orange light having a peak emission wavelength between 575 and 620 nm, and preferably comprised a europium and manganese doped alkaline earth pyrophosphate phosphor according to the formula $A_2P_2O_7$:Eu^{2+}, Mn^{2+}. Alternatively, the

Savant Technologies LLC - 1004.455

formula for the orange phosphor could be written $(A_{1-x-y}Eu_xMn_y)_2P_2O_7$, where $0 < x \leq 0.2$, and $0 < y \leq 0.2$. The second phosphor emits blue-green light having a peak emission wavelength between 495 and 550 nm, and is a divalent europium activated alkaline earth silicate phosphor $ASiO:Eu^{2+}$, where A comprised at least one of Ba, Ca, Sr, or Mb. The third phosphor emitted blue light having a peak emission wavelength between 420 and 480 nm, and comprised either of the two commercially available phosphors "SECA," $D_5(PO_4)_3Cl:Eu^{2+}$, where D was at least one of Sr, Ba, Ca, or Mg, or "BAM," which may be written as $AMg_2Al_{16}O_{27}$, where A comprised at least one of Ba, Ca, or Sr, or $BaMgAl_{10}O_{17}:Eu^{2+}$. The optional fourth phosphor emits red light having a peak emission wavelength between 620 and 670 nm, and it may comprise a magnesium fluorogermanate phosphor $MgO*MgF*GeO:Mn^{4+}$.

The inventive yellow phosphor in combination with other phosphors

In one embodiment of the present invention, a white illumination device can be constructed using a GaN based blue LED having a emission peak wavelength ranging about 430nm to 480nm, in combination with the inventive yellow phosphor with an emission peak wavelength ranging from about 540nm to 580nm. FIG. 15 is a combination spectra measured from a white illumination device, which consists of a blue LED and the inventive yellow phosphor layer. The conversion efficiency and the amount of the phosphor used in the device directly determines the color coordination of the white illumination devices in CIE diagram. In this case, a color temperature of about 5,000 to 10,000 K with a color coordination where X ranges from 0.25 to 0.40 and Y ranges from 0.25 to 0.40 can be achieved by combining light from the blue LED with light from the inventive yellow phosphor.

In another embodiment, a white illumination device may be constructed using a GaN based blue LED having an emission peak wavelength ranging from about 430 nm to 480 nm; the inventive yellow phosphor has an emission peak wavelength ranging from about 540 nm to 580 nm; and an inventive green phosphor having an emission peak wavelength ranging from about 500 nm to 520 nm. The color rendering of the resulting white light has been improved with this solution of mixing green and yellow phosphors. FIG. 16 is a combination spectra measured from a white illumination device comprising the light from a blue LED, and the light from a mixture of the inventive yellow and green phosphors. The conversion efficiency and the amounts of the phosphors used in the device directly

Savant Technologies LLC - 1004.456

determine the color coordination of the white illumination devices in CIE diagram. In this case, a color temperature of 5,000 to 7,000 K with a color rendering greater than 80 was achieved by combining light from the blue LED with light from a mixture of the inventive yellow and green phosphors.

In another embodiment, a white illumination device may be constructed by using a GaN based blue LED having an emission peak wavelength ranging from about 430 nm to 480 nm; the inventive green phosphor having an emission peak wavelength ranging from about 530 nm to 540 nm; and a commercially available red phosphor such as Eu doped CaS having an emission peak wavelength ranging from 600 nm to 670 nm. The color temperature may be adjusted to 3,000 K, and color rendering may be enhanced to a value greater than about 90 using the presently disclosed green and red phosphors. FIG. 17 is a combination spectra measured from a white illumination device comprising a blue LED and the mixture of the inventive green and CaS:Eu phosphors. The conversion efficiency and amount of the phosphor used in the device directly determines the color coordination of the white illumination devices in CIE diagram. In this case the color temperature of 2,500 to 4,000 K with color rendering greater than 85 can be achieved by combining light from the blue LED with light from a mixture of the inventive red and green phosphor system. FIG. 18 shows the position of the resultant white light illumination on a CIE diagram.

Many modifications of the exemplary embodiments of the invention disclosed above will readily occur to those skilled in the art. Accordingly, the invention is to be construed as including all structure and methods that fall within the scope of the appended claims.

Savant Technologies LLC - 1004.457

WHAT IS CLAIMED IS:

1. A silicate-based yellow-green phosphor having the formula $A_2SiO_4:Eu^{2+}D$, wherein:

A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and

D is a dopant selected from the group consisting of F, Cl, Br, I, P, S and N, wherein D is present in the phosphor in an amount ranging from about 0.01 to 20 mole percent.

2. The silicate-based phosphor of claim 1, wherein the phosphor is configured to absorb radiation in a wavelength ranging from about 280 nm to 490 nm.

3. The silicate-based phosphor of claim 1, wherein the phosphor emits visible light having a wavelength ranging from about 460 nm to 590 nm.

4. The silicate-based phosphor of claim 1, wherein the phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4: Eu^{2+}D$, where M is at least one of an element selected from the group consisting of Ca, Mg, Zn, and Cd, and where

$0 \leq x \leq 1$;

$0 \leq y \leq 1$ when M is Ca;

$0 \leq y \leq 1$ when M is Mg; and

$0 \leq y \leq 1$ when M is selected from the group consisting of Zn and Cd.

5. The silicate-based phosphor of claim 1, wherein D is F.

6. The silicate-based phosphor of claim 1, wherein the phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2\ SiO_4: Eu^{2+}F$, where M is at least one of an element selected from the group of Ca, Mg, Zn,Cd, and where

$0 \leq x \leq 0.3$;

$0 \leq y \leq 0.5$ when M is Ca;

$0 \leq y \leq 0.1$ when M is Mg; and

$0 \leq y \leq 0.5$ when M is selected from the group consisting of Zn and Cd.

Savant Technologies LLC - 1004.458

7. The silicate-based phosphor of claim 6, wherein the phosphor emits light in the yellow region of the electromagnetic spectrum, and has a peak emission wavelength ranging from about 540 to 590 nm.

8. The silicate-based phosphor of claim 1, wherein the phosphor has the formula $(Sr_{1-x-y}Ba_xM_y)_2 SiO_4: Eu^{2+}F$, where M is at least one of an element selected from the group consisting of Ca, Mg, Zn, and Cd, and where

$0.3 \leq x \leq 1$;

$0 \leq y \leq 0.5$ when M is Ca;

$0 \leq y \leq 0.1$ when M is Mg; and

$0 \leq y \leq 0.5$ when M is selected from the group consisting of Zn and Cd.

9. The silicate-based phosphor of claim 8, wherein the phosphor emits light in the green region of the electromagnetic spectrum, and has a peak emission wavelenth ranging from about 500 to 530 nm.

10. A white LED comprising:

a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm;

a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with a peak intensity in a wavelength ranging from about 530 to 590 nm.

11. A white LED comprising:

a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm;

a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 530 to 590 nm; and

a green phosphor according to claim 9, the green phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 500 to 540 nm.

Savant Technologies LLC - 1004.459

12. A white LED comprising:

a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm;

a green phosphor according to claim 9, the green phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 500 to 540 nm;

a red phosphor selected from the group consisting of $CaS:Eu^{2+}$, $SrS:Eu^{2+}$, $MgO*MgF*GeO:Mn^{4+}$, and $M_xSi_yN_z:Eu^{+2}$, where M is selected from the group consisting of Ca, Sr, Ba, and Zn; Z=2/3x+4/3y, wherein the red phosphor is configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 590 to 690nm.

13. A white LED comprising:

a radiation source configured to emit radiation having a wavelength ranging from about 410 to 500 nm;

a yellow phosphor according to claim 7, the yellow phosphor configured to absorb at least a portion of the radiation from the radiation source and emit light with a peak intensity in a wavelength ranging from about 540 to 590 nm;

a red phosphor selected from the group consisting of $CaS:Eu^{2+}$, $SrS:Eu^{2+}$, $MgO*MgF*GeO:Mn^{4+}$, and $M_xSi_yN_z:Eu^{+2}$, where M is selected from the group consisting of Ca, Sr, Ba, and Zn; and Z=2/3x+4/3y, wherein the red phosphor is configured to absorb at least a portion of the radiation from the radiation source and emit light with peak intensity in a wavelength ranging from about 590 to 690nm.

14. A composition comprising:

a silicate-based yellow phosphor having the formula $A_2SiO_4:Eu^{2+}D$, wherein A is at least one divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is an ion that is present in the yellow phosphor in an amount ranging from about 0.01 to 20 mole percent; and

a blue phosphor;

wherein the yellow phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 540 nm to 590 nm; and the blue phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 480 to 510 nm.

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15. The composition of claim 10, wherein the blue phosphor is selected from the group consisting of silicate-based phosphors and aluminate-based phosphors.

16. The composition of claim 11, wherein the silicate-based blue phosphor has the formula $Sr_{1-x-y}Mg_xBa_ySiO_4:Eu^{2+}F$; and where

$0.5 \leq x \leq 1.0$; and

$0 \leq y \leq 0.5$.

17. The composition of claim 11, wherein the aluminate-based blue phosphor has the formula $Sr_{1-x}MgEu_xAl_{10}O_{17}$; and where

$0.01 < x \leq 1.0$.

18. A composition comprising:

a silicate-based green phosphor having the formula $A_2SiO_4:Eu^{2+}H$, wherein A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and H is a negatively charged halogen ion that is present in the yellow phosphor in an amount ranging from about 0.01 to 20 mole percent;

a blue phosphor; and

a red phosphor;

wherein the green phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 500nm to 540 nm; the blue phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 480 to 510 nm; and the red phosphor is configured to emit visible light with a peak intensity in a wavelength ranging from about 775 to 620 nm.

19. A method of preparing a silicate-based yellow phosphor having the formula $A_2SiO_4:Eu^{2+}D$, wherein A is at least one of a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd; and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S and N, wherein D is present in the phosphor in an amount ranging from about 0.01 to 20 mole percent, the method selected from the group consisting of a sol-gel method and a solid reaction method.

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20. The method of claim 19, wherein the sol-gel method comprises:

a) dissolving a desired amount of an alkaline earth nitrate selected from the group consisting of Mg, Ca, Sr, and Ba-containing nitrates with a compound selected from the group consisting of Eu_2O_3 and BaF_2 or other alkaline metal halides, in an acid, to prepare a first solution;

b) dissolving corresponding amount of a silica gel in de-ionized water to prepare a second solution;

c) stirring together the solutions produced in steps a) and b), and then adding ammonia to generate a gel from the mixture solution;

d) adjusting the pH of the solution produced in step c) to a value of about 9, and then stirring the solution continuously at about 60°C for about 3 hours;

e) drying the gelled solution of step d) by evaporation, and then decomposing the resulting dried gel at 500 to 700°C for about 60 minutes to decompose and acquire product oxides;

f) cooling and grinding the gelled solution of step e) with NH_4F or other ammonia halides when alkaline earth metal halides are not used in step a) to produce a powder;

g) calcining/sintering the powder of step f) in a reduced atmosphere for about 6 to10 hours, the sintering temperature ranging from about 1200 to 1400°C.

21. The method of claim 19, wherein the solid reaction method comprises:

a) wet mixing desired amounts of alkaline earth oxides or carbonates (Mg, Ca, Sr, Ba), dopants of Eu_2O_3 and/or BaF_2 or other alkaline earth metal halides, corresponding SiO_2 and/or NH_4F or other ammonia halides with a ball mill; and

b) after drying and grinding, calcining and/or sintering the resulting powder was in a reduced atmosphere for about 6 to10 hours, wherein the calcining/sintering temperature ranged from about 1200 to 1400°C.

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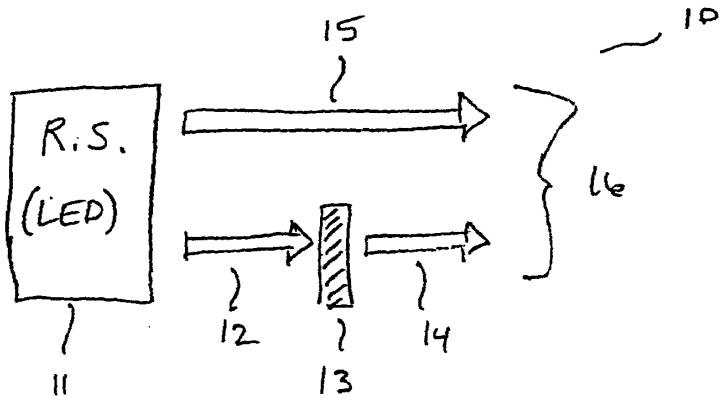


Fig. 1

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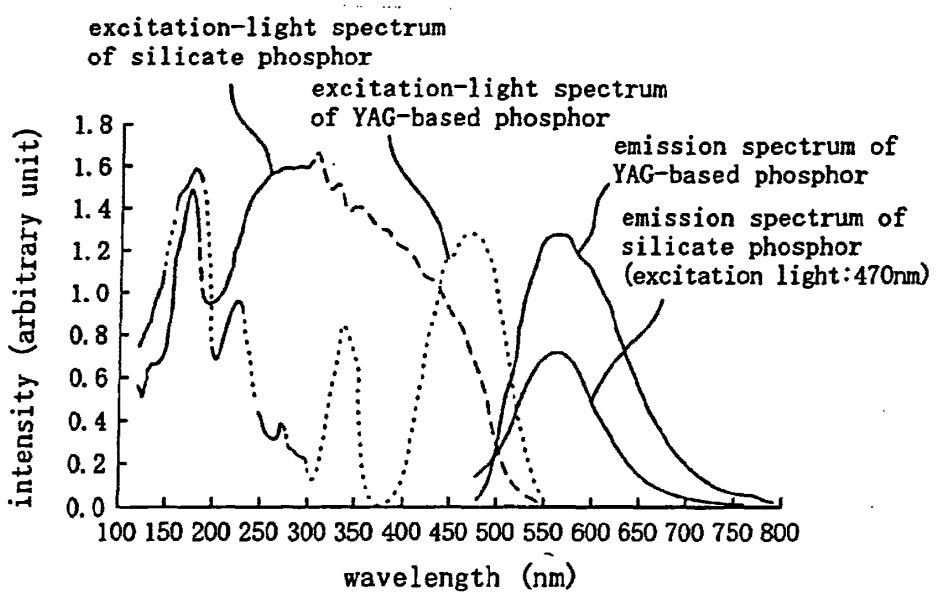


Fig. 2

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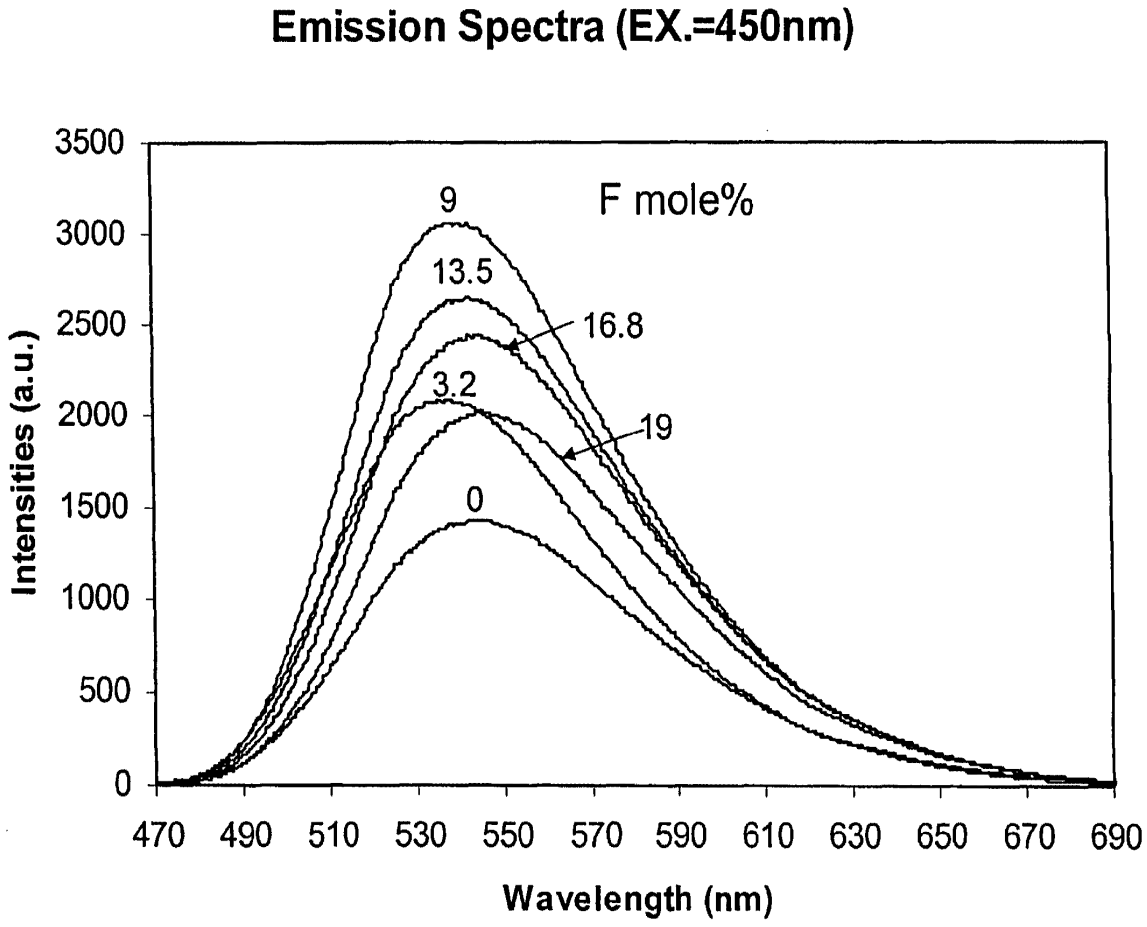

Emission Spectra (EX.=450nm)
Intensities (a.u.)
3500
3000
2500
2000
1500
1000
500
0
470
490
510
530
550
570
590
610
630
650
670
690
Wavelength (nm)
F mole%
9
13.5
16.8
3.2
19
0

FIG. 3

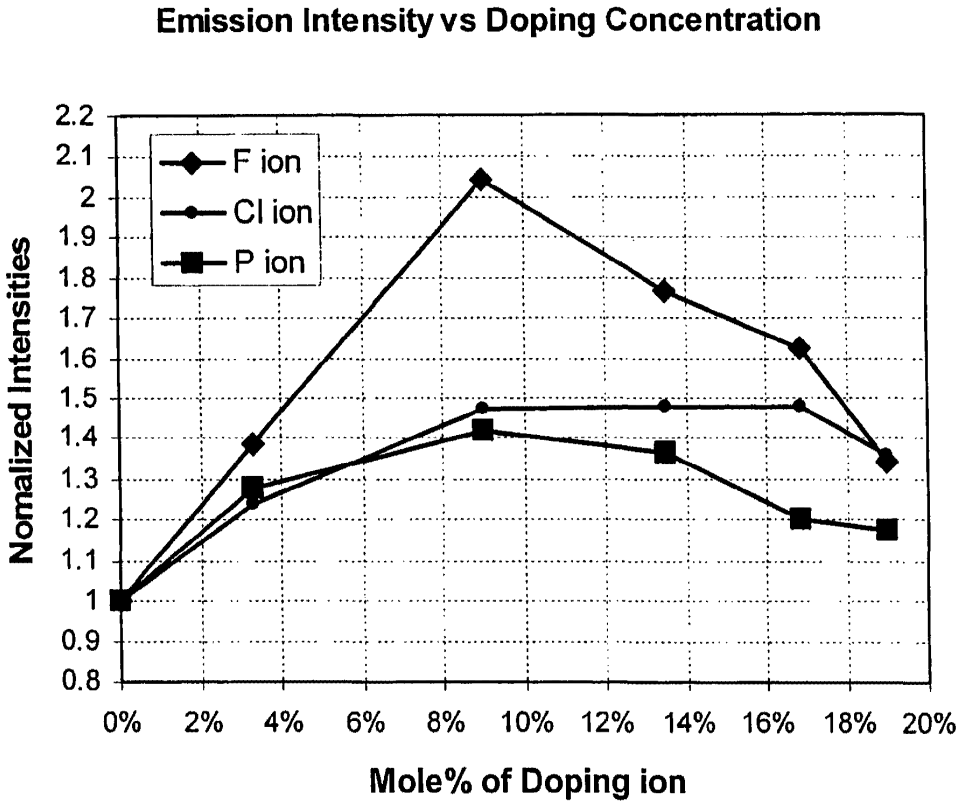

Emission Intensity vs Doping Concentration
Nomalized Intensities
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
F ion
Cl ion
P ion
0%
2%
4%
6%
8%
10%
12%
14%
16%
18%
20%
Mole% of Doping ion

FIG. 4

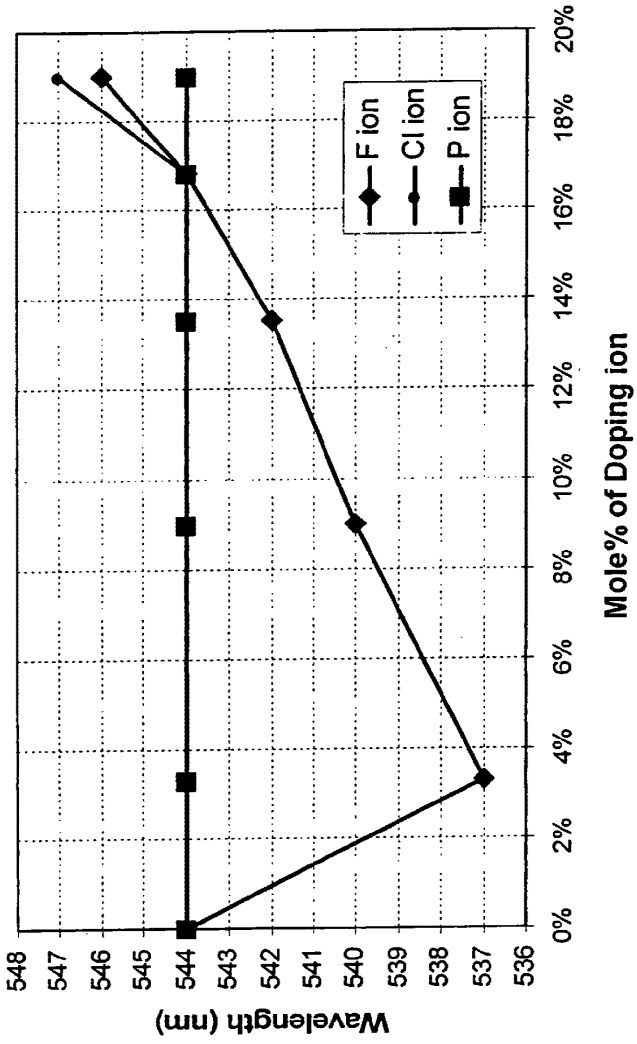


FIG. 5

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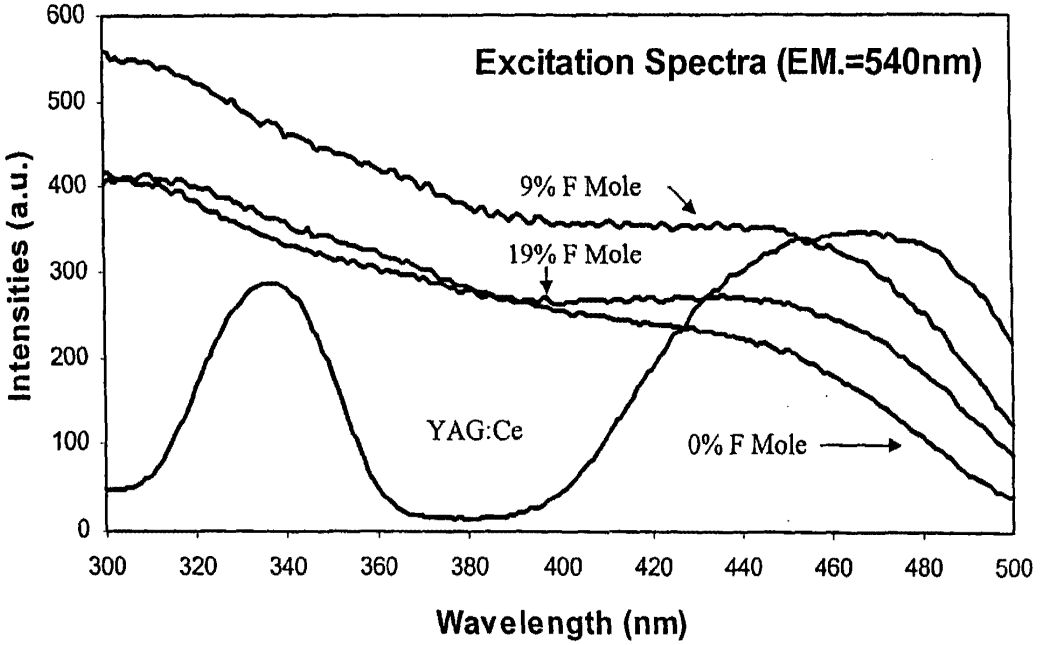

Excitation Spectra (EM.=540nm)
Intensities (a.u.)
Wavelength (nm)
9% F Mole
19% F Mole
0% F Mole
YAG:Ce
600
500
400
300
200
100
0
300
320
340
360
380
400
420
440
460
480
500

FIG. 6

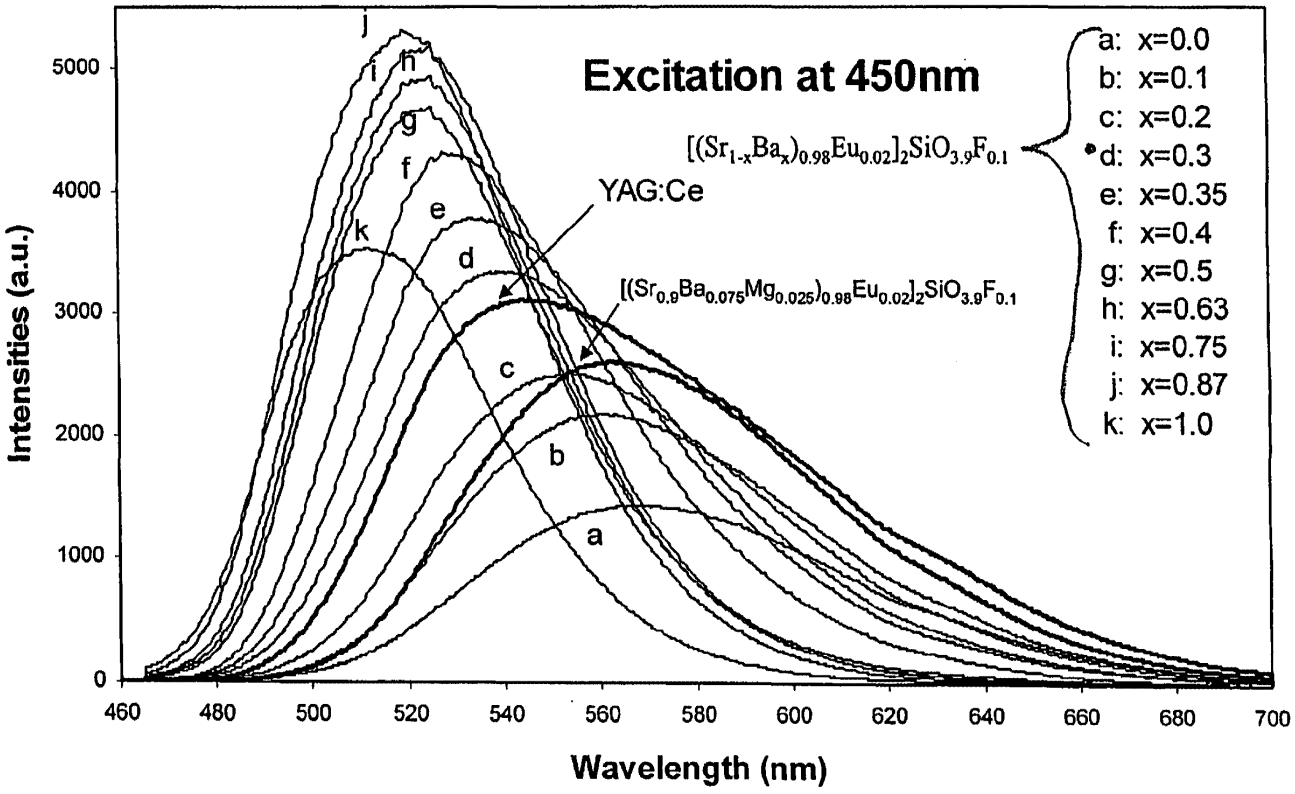


FIG. 7

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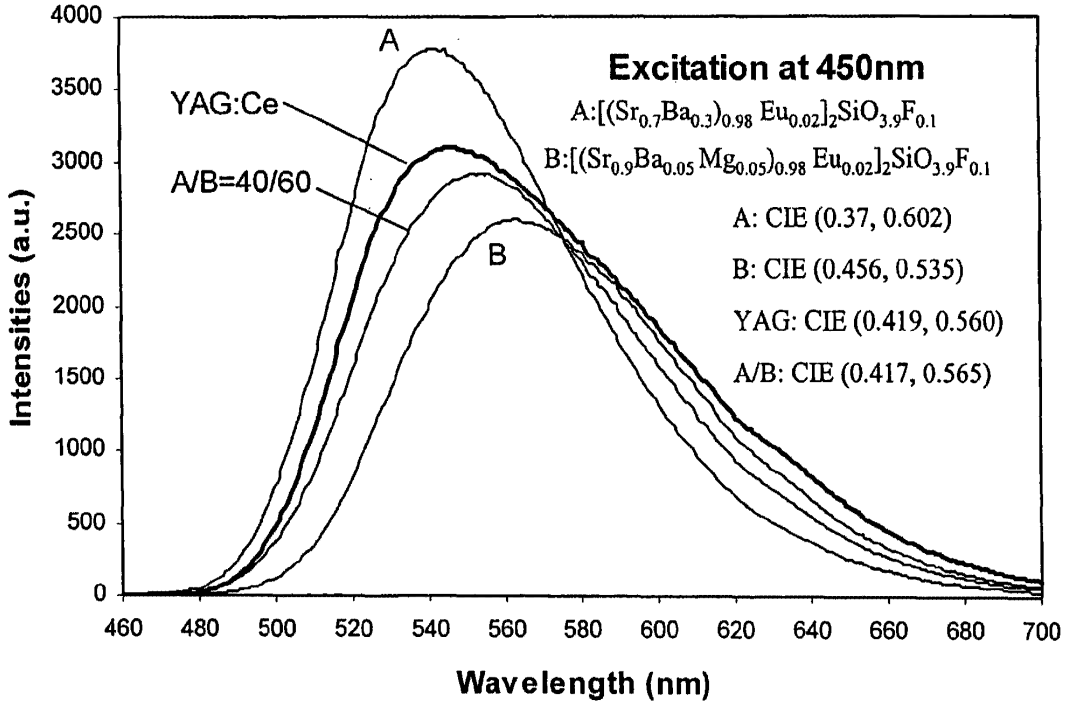

Excitation at 450nm
A:[(Sr0.7Ba0.3)0.98 Eu0.02]2SiO3.9F0.1
B:[(Sr0.9Ba0.05 Mg0.05)0.98 Eu0.02]2SiO3.9F0.1
A: CIE (0.37, 0.602)
B: CIE (0.456, 0.535)
YAG: CIE (0.419, 0.560)
A/B: CIE (0.417, 0.565)
YAG:Ce
A/B=40/60
A
B
Intensities (a.u.)
Wavelength (nm)
0
500
1000
1500
2000
2500
3000
3500
4000
460
480
500
520
540
560
580
600
620
640
660
680
700

FIG. 8

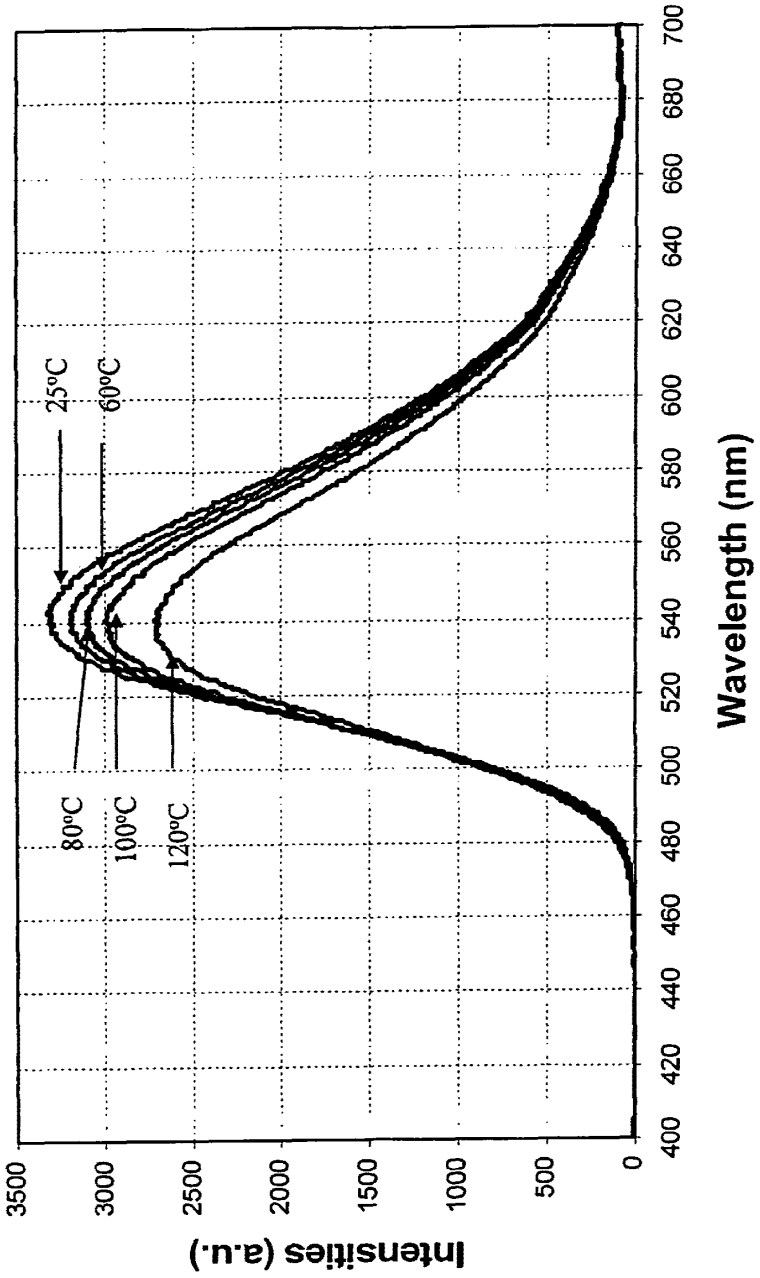


FIG. 9

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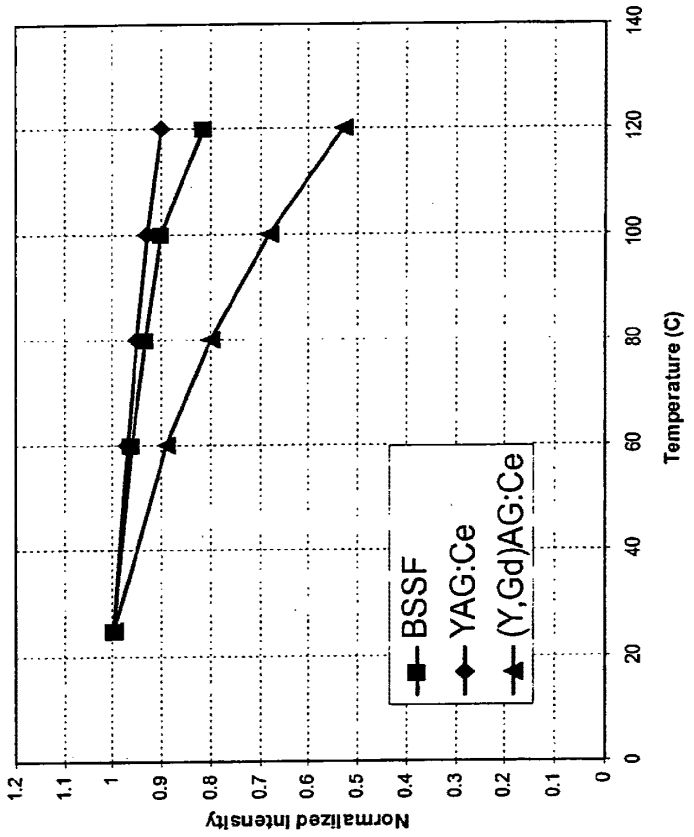


FIG. 10

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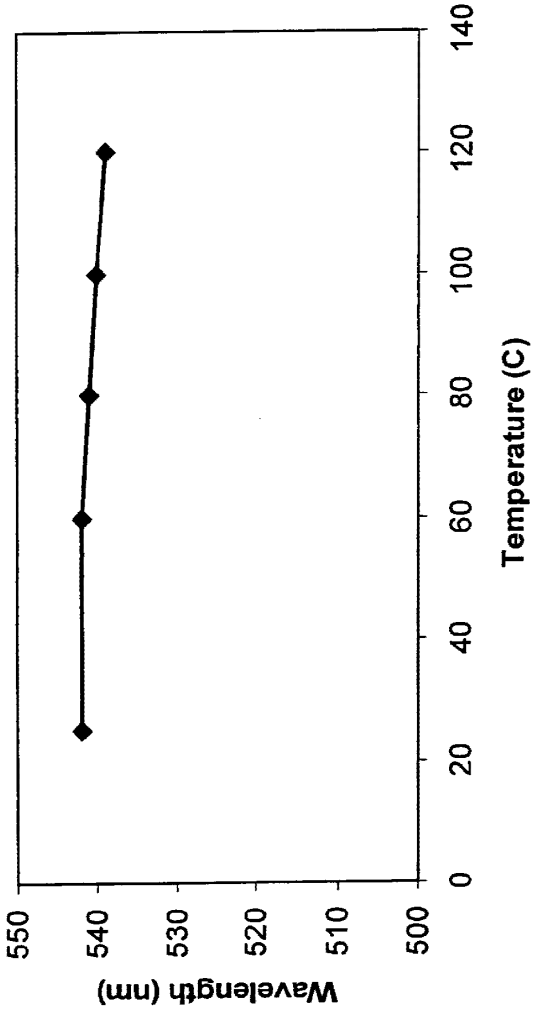


FIG. 11

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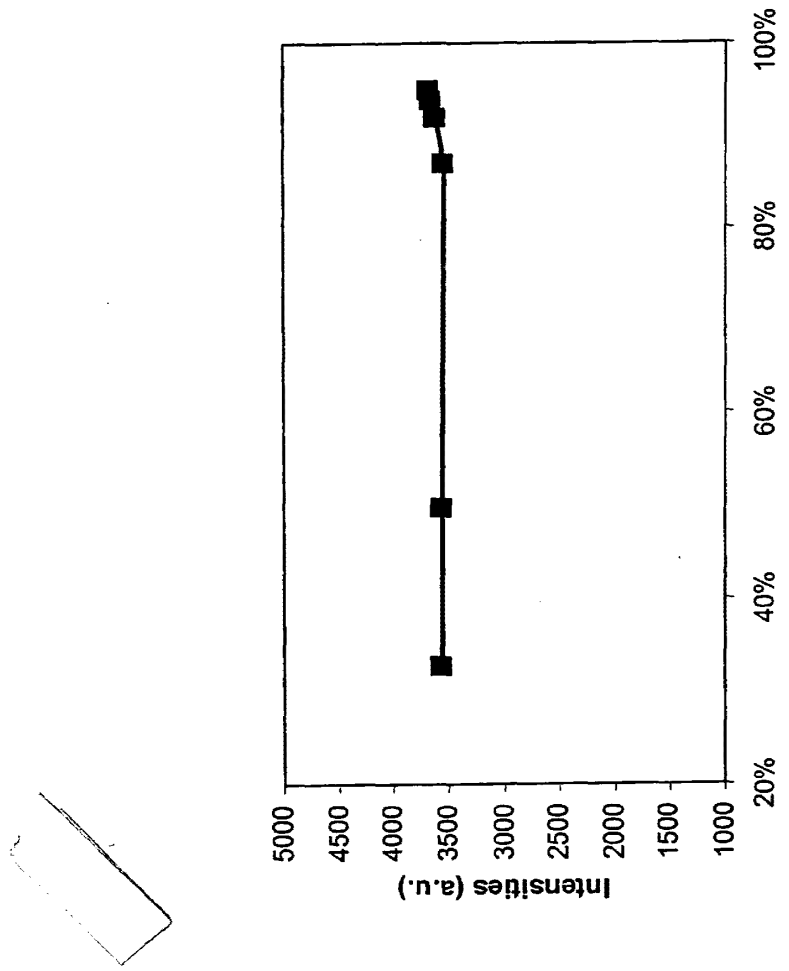


FIG. 12

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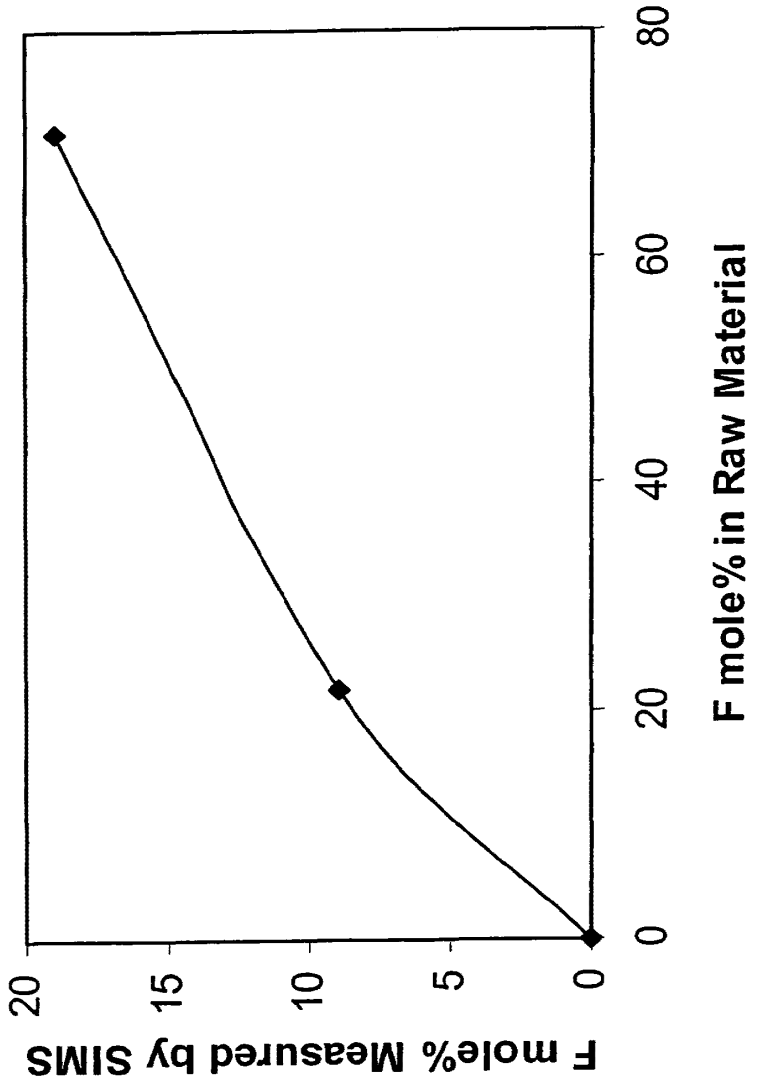


FIG. 13

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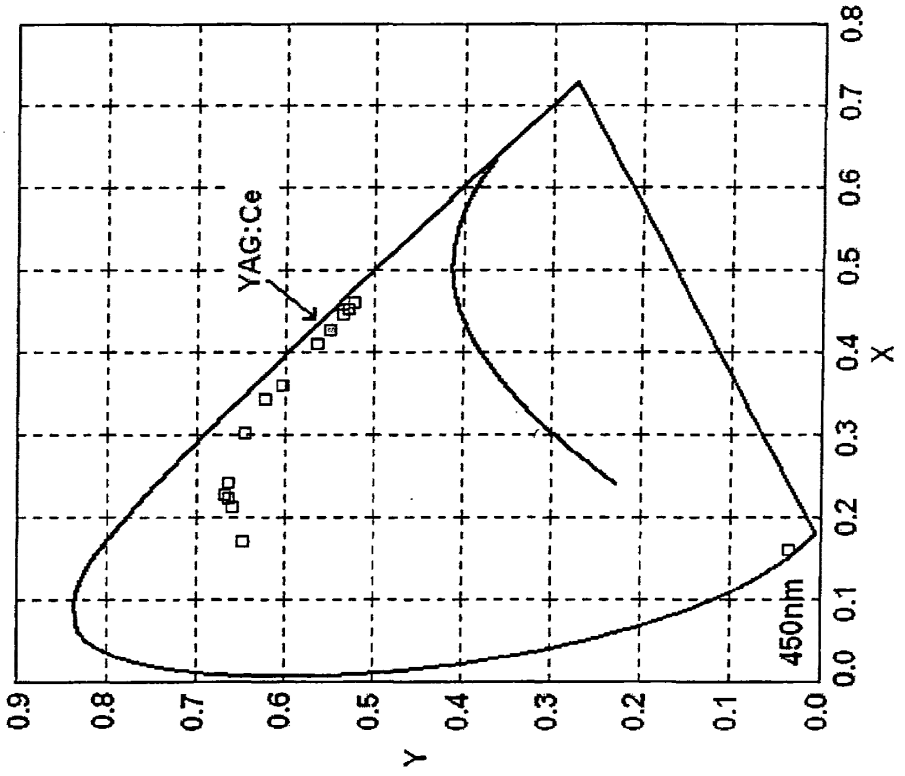


FIG. 14

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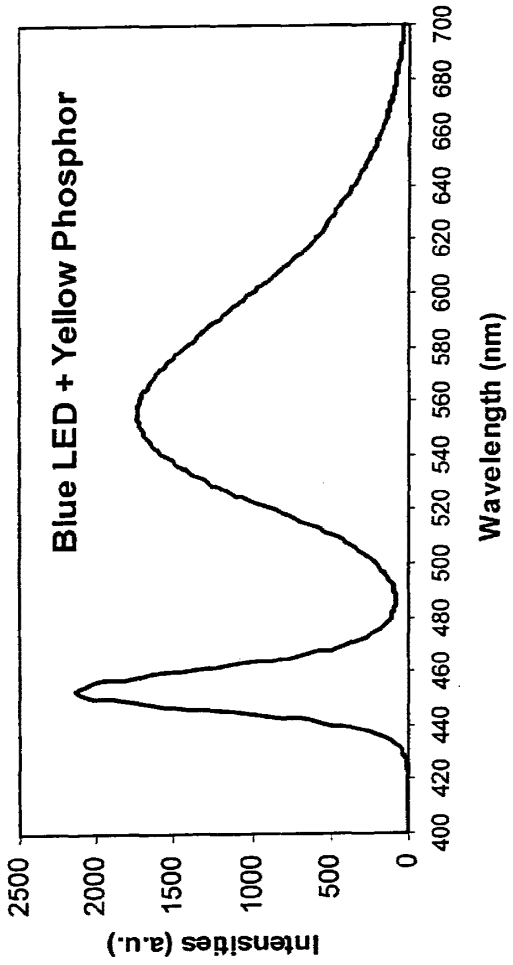


FIG. 15

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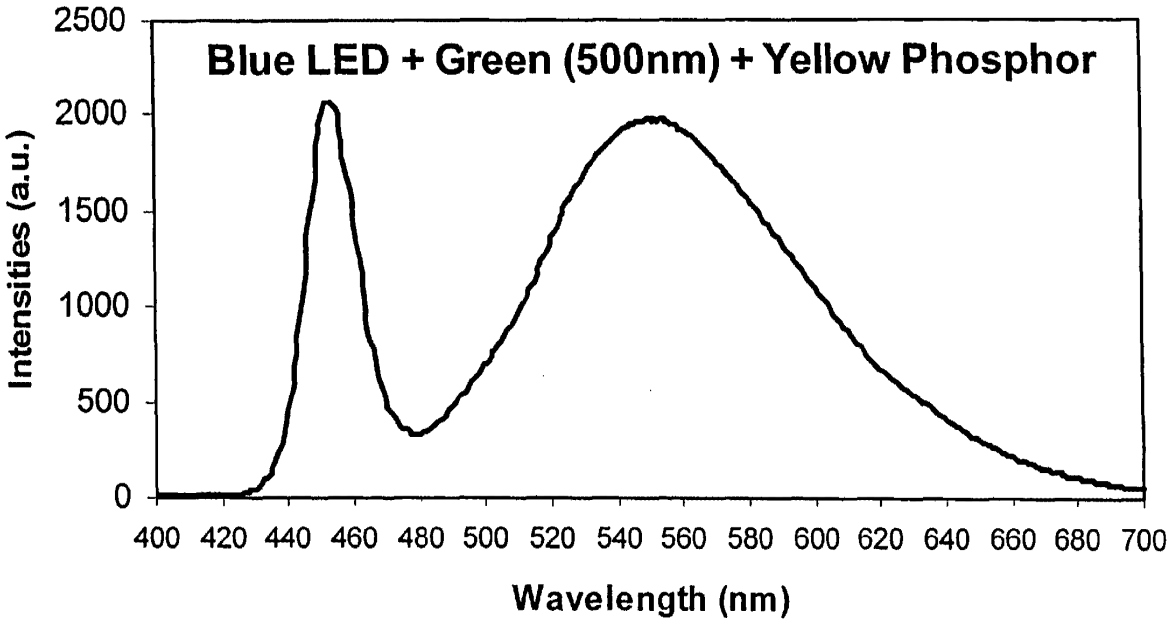

Blue LED + Green (500nm) + Yellow Phosphor
Intensities (a.u.)
2500
2000
1500
1000
500
0
400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700
Wavelength (nm)

FIG. 16

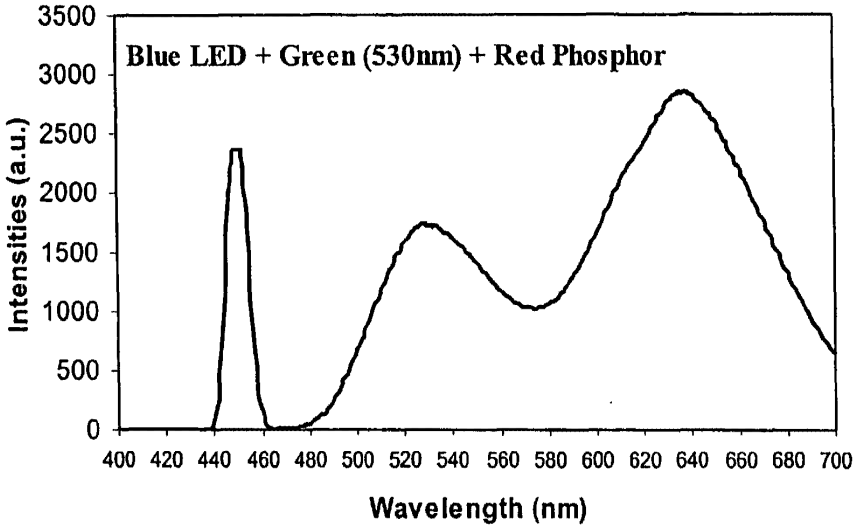

Blue LED + Green (530nm) + Red Phosphor
Intensities (a.u.)
3500
3000
2500
2000
1500
1000
500
0
400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700
Wavelength (nm)

FIG. 17

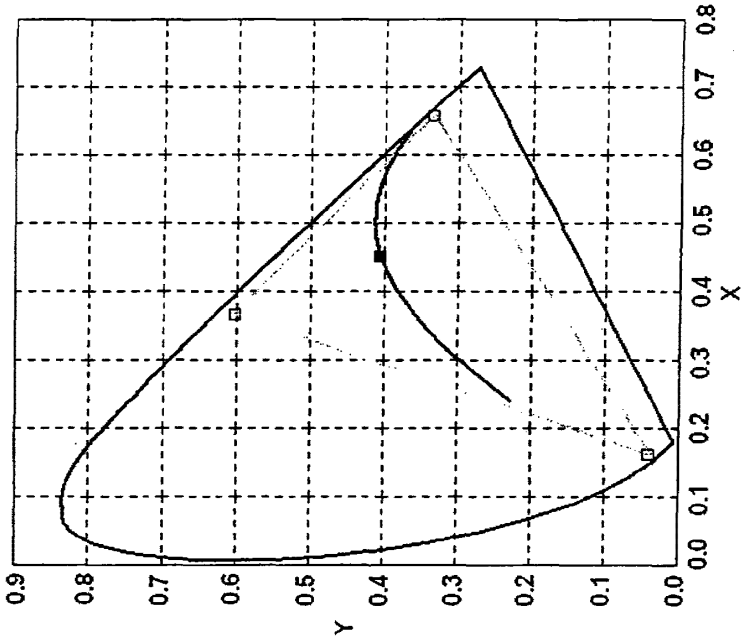


FIG. 18

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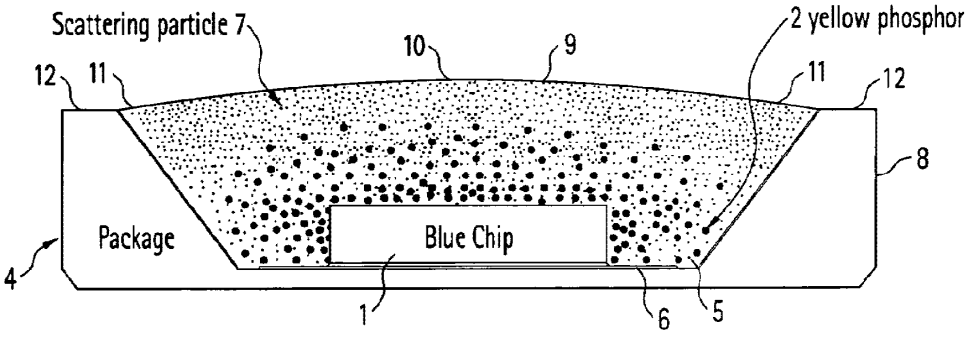
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(54) Title: PHOSPHOR-CONVERTED LIGHT EMITTING DIODE



(57) Abstract: A semiconductor light-emitting device, said device comprising a semiconductor chip light source that emits light of a first peak wavelength in the blue wavelength range, and at least a first layer comprising a transparent matrix material, wherein at least one of the layers contains one or more wavelength-converting substances dispersed in the matrix material and converting the blue light from the chip at least partially into light of a second wavelength, such that a mix of light of the first and second wavelength is emitted from the device, wherein the concentration gradient of the wavelength-converting substances is increasing in the downward direction.

WO 2008/043519 A1

Savant Technologies LLC - 1004.481

Phosphor-converted LEDs

The invention relates to so-called pc-LEDs (phosphor-converted LEDs), i.e. LEDs in which an emitted spectrum is converted by a so-called phosphor such that a mix of the original spectrum and the converted spectrum is emitted from the pc-LED.

An example of a known LED device is shown in Figure 1 and contains a blue chip 1 and wavelength converting elements 2 (hence also called colour conversion layers or CCL). Such devices usually consist of a blue or UV chip inside a cavity and a colour conversion layer, which converts essentially all or part of the photons from the chip into photons of higher wavelength. The wavelength converting elements may contain one or more inorganic phosphors absorbing part of the light from the chip and re-emitting it, usually isotropically, in the yellow, green, orange and/or red.

The phosphors are suspended in a transparent matrix material, e.g. silicone, which may contain additives such as viscosity modifiers, scattering particles etc. Examples for widely used phosphors are YAG:Ce and BOSE. Colour uniformity and optical efficiency (lm/W) are important parameters for LEDs, which in many cases cannot be changed independently, i.e. the optimisation of colour uniformity entails a decrease in efficiency and vice versa.

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For instance, if the phosphor layer is directly surrounding the chip, efficiency usually decreases due to back-reflection into and re-absorption by, the chip. On the other hand, CCLs located near the chip in many cases lead to enhanced colour uniformity. However, colour uniformity can be increased almost without sacrificing efficiency by optimisation of the location of the phosphor relative to the chip and surface of the package 3 as well as by use of multiple layer designs (several colour converting layers of different phosphor concentration and/or alternating converting and non-converting layers with flat/shaped surfaces/interfaces. Shaped surfaces/interfaces of silicone or of the colour converting elements are used in a number of patent applications, for instance in JP2005-93896, US2006/0073625, etc., to increase colour uniformity and/or efficiency.

Achieving high colour uniformity practically without sacrificing efficiency has been the main target of this invention.

Contrary to LEDs where the light emitted from the chip is either converted by the phosphor completely and/or where excess light from the chip must be removed for safety reasons (e.g. green and white LEDs using UV-chips), colour variance (also referred to as the halo-effect) is one of the severe problems of those types of pc-LEDs where the colour conversion layer converts only part of the light from the chip into light of higher wavelength. The different radiation pattern of the chip light and the converted light plays a crucial role in colour variance. The chip light that is not converted, though it may be

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scattered, reflected or otherwise deviated from its original direction, still has a more narrow radiation pattern than the converted light, which is emitted from the phosphor isotropically. Therefore, the light in the centre of the light-cone has a blue shift, while the light in the boundaries of the light-cone is red-shifted, i.e. there is a bluish centre surrounded by a yellow ring. One way out could be a high concentration of scattering particles (oxides, sulphates of Al, Ti, Ba, etc.), but the use of scattering particles only without any other appropriate measures, while yielding high colour uniformity, leads to a considerable decrease in optical efficiency.

EP 1 357 610 A1 teaches a LED comprising a LED chip having a light emitting layer made of a nitride compound semiconductor and a light transmitting resin that includes a fluorescent material which absorbs at least a part of light emitted by the LED chip and emits light of a different wavelength. The fluorescent material includes fluorescent particles of small particle size and fluorescent particles of large particle size, the fluorescent particles of large particle size being distributed in the vicinity of the LED chip in the light transmitting resin to form a wavelength converting layer. The fluorescent particles of small particles size are distributed on the outside of the wavelength converting layer in the light transmitting resin.

The size distribution according to EP 1 357 610 A1 is illustrated in figure 7. One can easily see that the particle size distribution shows two peaks, i.e. a first peak in a very small particle size and a second peak at a

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big particle size. Within the two peaks there are essentially no particles. Therefore, when sedimenting, practically all of the big particles will sedimentate and be located in the surroundings of the LED chip only, while the speed of sedimentation of particles of the small fraction will be so small that it can essentially be neglected.

US 2006/065906 A1 teaches a method for manufacturing a semiconductor light emitting device. When forming a wavelength conversion layer, a first resin with little or no wavelength conversion material is filled inside a cavity such that the light emitting element surface is slightly exposed and a surface of a first resin is formed in a bole shape. Then, a second resin with wavelength conversion material contained therein can be filled inside the cavity over the bole-shaped first resin. These resins can be heated to be hardened. During heating the viscosities of the resins are reduced to cause the wavelength conversion material to migrate and deposit around the light emitting element.

It is the object of the present invention to propose a technique for improving the colour uniformity of LEDs.

This object is achieved by means of the features of the independent claims. The dependent claims develop further the central idea of the invention.

According to a first aspect of the invention a semiconductor light-emitting device comprises a semiconductor chip light source that emits light of a first peak wavelength in the blue wavelength range. All

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layers above the chip comprise a transparent matrix material such as e.g. silicone etc., wherein the upper surface/interface of at least one layer is non-flat such that the centre region of the upper surface/interface is higher than the edge portion thereof.

At least one of the layers contains one or more wavelength-converting substances dispersed in the matrix material, the vertical concentration of the substances being not constant and increasing in a downward direction.

At least one of the layers can contain scattering particles and/or viscosity-modifying materials.

At least two layers can be provided, wherein two adjacent layers differ in at least one of the following parameters: phosphor concentration, phosphor composition, and scattering particle concentration.

The first layer can have a curved surface and optionally contains wavelength-converting material(s).

The first layer can contain scattering particles.

Also a second layer can contain wavelength-converting material(s).

The second layer optionally contains scattering particles.

The top surface of the second layer can be flat or curved.

Savant Technologies LLC - 1004.486

Optionally a third layer is placed on top of the second layer.

The third layer may consist of transparent matrix material with or without wavelength-converting material(s) and/or scattering particles.

The third layer may have a curved surface.

According to another aspect of the invention a LED device can comprise a semiconductor chip light source that emits light of a first peak wavelength in the blue wavelength range. All layers above the chip comprise a transparent matrix material such as e.g. silicone, etc... At least one layer covers the upper surface and the side walls of the chips as a coating and contains wavelength-converting material(s).

The second layer optionally surrounds the first layer and has a curved surface and optionally contains wavelength-converting material(s) of lower concentration than the first layer.

A third layer can be placed on top of the second layer.

Preferably the surfaces of the second layer and/or the third layer are curved.

The second layer and/or the third layer can contain wavelength-converting material(s) of lower concentration than the first layer.

Savant Technologies LLC - 1004.487

At least one layer may contain scattering particles.

In the following preferred embodiments of the invention will be explained in order to illustrate further feature, objects and advantages of the present invention when taken in conjunction with the figures of the enclosed drawings.

Figure 1 shows a LED device according to the prior art,

Figure 2 shows a first embodiment of the invention,

Figure 3 shows a second embodiment of the invention,

Figure 4 shows a third embodiment of the invention,

Figure 5 shows a fourth embodiment of the invention,

Figure 6 shows a fifth embodiment of the invention,

Figure 7 shows the phosphor particle size distribution of EP 1 357 610 A1, and

Figure 8 shows the one-peak size distribution of the phosphor particles according to the present invention.

The subject of the present invention encompasses the aspects of using (1) a process of selective sedimentation

Savant Technologies LLC - 1004.488

of phosphor particles optionally in combination with (2) shaped surfaces/interfaces and (3) scattering particles. The aspect can be combined in any order.

The invention comprises the following aspects:

- Above the LED chip there is one or more layer, all of which base on a transparent matrix material,
- at least one layer may contain an additive such as e.g. a viscosity modifier,
- at least one layer contains wavelength-converting substances ('phosphors'),
- at least one layer may contain scattering particles.

In the following examples, ΔCIEx and ΔCIEy are defined as the difference between the maximum and the minimum CIEx and CIEy-values, respectively, measured in an area of hemispherical shape surrounding the front side of the LED. A colour variance of $\Delta CIEx,y < 0.01$ can hardly be perceived by the human eye, and LEDs with such a low colour variance show excellent colour uniformity.

In the following examples, data are given for 6500K devices containing a blue die emitting at about 460nm and a yellow BOSE-based phosphor. However, the invention is in no way limited, but can be applied to other systems as well, including a large range of phosphor materials and concentrations covering the whole white region from 2800-7000K. Though excellent colour uniformity is achieved for 6500K in the following examples, even better results can be achieved for lower colour temperatures due to a higher degree of scattering as a consequence of higher phosphor concentration.

Savant Technologies LLC - 1004.489

It is to be understood that in all shown examples the package 13 can be made from silicon. Preferably the side walls 16 of the cavity housing the LED chip can be metallised.

Embodiment 1 (Figure 2)

The LED device 8 comprises a casing 4 with a concave-shaped cavity 5, a light-emitting element (a die) 1 located at the bottom 6 of the cavity 5, a resin for filling the cavity 5, and electrodes and electrical wiring for power supply to the device, which are not shown. The LED device 8 is filled with a colour conversion layer (CCL) containing the phosphor 2, small scattering particles 7 preferably in the sub-micron range, and small amounts of additives. After dispensing, the LED device 8 is submitted to a temperature treatment. The temperature is chosen in a way to achieve a compromise between minimum viscosity for efficient deposition of the phosphor and a low cure rate; the matrix material should not cure to any considerable extent before deposition of the phosphor. After deposition, the temperature is raised to achieve complete cure of the colour conversion layer. The major effects of this treatment are as follows:

- Due to the much larger particle size of the phosphor particles 2 compared to the scattering particles 7, the phosphor deposits, while there is no considerable deposition of the scattering particles 7.

Savant Technologies LLC - 1004.490

- Furthermore, due to the particle size distribution of the phosphor 2, smaller phosphor particles do not sediment as quickly as bigger ones, which results in an accumulation of big phosphor particles 2 near the chip 1. The average size of the phosphor particles 2 is the bigger the closer to the chip 1.

ΔCIEx,y-values of about 0.005 can be achieved in such a configuration (In a standard device as depicted in Figure 1, ΔCIEx,y is about 0.015-0.030 for a yellow BOSE phosphor).

The useful lumen loss due to scattering effects, increased back-reflection into the chip 1 and re-absorption by the chip is <5% compared to the standard device. In devices without scattering particles, colour uniformity decreases, but is still better than in the known device as depicted in figure 1.

In all further examples, ΔCIEx,y-values of below 0.01 are achieved.

Preferably in the embodiment of Figure 2 the top surface 9 of the filling extends in a curved shape at least in its centre 10 beyond the level of the adjacent top surface 12 of the package 3. The edge portion 11 of the filling flushes with the level of the top surface 12 of the package 3.

Example 2 (Figure 3)

Into a device similar to the one described above, the lower portion 13 of the cavity is filled with clear

Savant Technologies LLC - 1004.491

silicone 14. The upper portion 14 is subsequently filled with colour conversion layer containing the phosphor 2, scattering particles 7 and a small amount of additives (Figure 3a). After dispensing, the LED device 8 is submitted to a temperature treatment as described above. The phosphor 2 sediments to the lower portion of the cavity (Figure 3b), while scattering particles 7 stay in the upper portion 14 of the device.

The particle distribution is similar to that in Figure 1, but there is less phosphor at the boundaries than in the centre which has a positive effect on colour uniformity.

Again, the top surface 9 of the filling extends in a curved shape at least in its centre 10 beyond the level of the top surface 12 of the package 3. The edge portion 11 of the filling flushes with the level of the top surface 12 of the package 3.

The interface 15 between the upper portion 14 and the lower portion 13 of the filling of the cavity is set such it essentially flushes with the level of the top surface of the chip 1. It is slightly raised towards the edges, i.e. where it joins the slanted side walls 16 of the cavity.

Example 3 (Figure 4)

The lower part of the LED is filled with colour conversion layer with or without scattering particles. There is no temperature treatment and no sedimentation of the phosphor. The upper part of the device is filled with a scattering particle layer. The viscosity of both layers

Savant Technologies LLC - 1004.492

is higher than in examples 1 and 2 so that both the interface 14 between the two portions 13, 14 and the top surface 12 are slightly curved upwards. This curvature can increase light output and enhance colour uniformity.

Preferably the level of the interface 14, both in its centre and edge portions is set higher than the level of the top surface 17 of the chip 1.

Again, the top surface 9 of the filling extends in a curved shape at least in its centre 10 beyond the level of the top surface 12 of the package 3. The edge portion 11 of the filling flushes with the level of the top surface 12 of the package 3.

Example 4 (Figure 5)

A pre-fabricated colour conversion element (e.g. a foil) CCL1, comprising phosphor and scattering particles, is placed directly onto the chip 1. The top surface 18 of the pre-fabricated colour conversion element CCL1 can be curved upwards.

The side walls 19 of the pre-fabricated colour conversion element (e.g. a foil) CCL1 can flush with the side walls 20 of the chip 1. Thus the CCL1, when seen from above, can have the same contours as the chip 1.

The remaining cavity is filled with a second colour conversion layer CCL2 with lower phosphor concentration. The phosphor concentration is $0 \leq CCL2 < CCL1$. Both the surface of the foil and that of CCL2 can have different degrees of curvature depending on the package geometry.

Savant Technologies LLC - 1004.493

The curvature increases light output and enhances colour uniformity.

Again, the top surface 9 of the filling extends in a curved shape at least in its centre 10 beyond the level of the top surface 12 of the package 3. The edge portion 11 of the filling flushes with the level of the top surface 12 of the package 3.

Example 5 (Figure 6)

A pre-fabricated colour conversion foil is placed directly onto the chip (CCL1). The top surface 18 of the pre-fabricated colour conversion element (e.g. a foil) CCL1 can be flat.

The side walls 19 of the pre-fabricated colour conversion element (e.g. a foil) CCL1 can flush with the side walls 20 of the chip 1. Thus the CCL1, when seen from above, can have the same contours as the chip 1.

The remaining cavity is filled with a second colour conversion layer (CCL2) with lower phosphor concentration. The phosphor concentration is $0 \leq CCL2 < CCL1$. After dispensing of CCL2, the device is submitted to temperature treatment as described in Example 1. The phosphor of CCL2 thereby sediments while the distribution of scattering particles in the cavity remains essentially unaltered by the sedimentation process.

Again, the top surface 9 of the filling extends in a curved shape at least in its centre 10 beyond the level of the top surface 12 of the package 3. The edge portion

Savant Technologies LLC - 1004.494

11 of the filling flushes with the level of the top surface 12 of the package 3.

Figure 8 shows the particle size distribution of the colour conversion particles according to the present invention.

As can be seen from figure 8, this is a "normal" particle size distribution having one peak only. According to the invention, smaller particles will sediment very slowly, while the bigger particles will sediment faster. In view of the continuous particle size distribution of figure 8, this will result in two continuous gradients:

Gradient 1: The average particle size increases continuously from the top to the bottom, and

Gradient 2: The average particle concentration of the colour conversion particles increases continually from the top to the bottom.

In view of the particle size distribution of figure 8, there will only be a low contribution to scattering from the phosphors (colour conversion particles) according to the invention.

Therefore preferably a different material will be used for the scattering.

As can be seen in figures 2 to 6, the scattering particles will preferably be distributed in the silicone matrix in a homogenous manner, i.e. without showing a

Savant Technologies LLC - 1004.495

concentration gradient from the top to the bottom of the chip arrangement.

This is in stark contrast to EP 1 357 610 according to which the small particle fraction of the phosphor (left peak in Fig. 7) contributes mainly to scattering with only minor effects on colour conversion, while the big particle fraction contributes mainly to colour conversion rather than to scattering (right peak in Fig. 7).

Savant Technologies LLC - 1004.496

Claims:

1. A semiconductor light-emitting device,
said device comprising a semiconductor chip that emits light of a first peak wavelength in the blue wavelength range,
and one or more layers comprising a transparent silicone matrix material,
wherein at least one of the one or more layers contains one or more wavelength-converting substances dispersed in the silicone matrix material and converting the blue light from the chip at least partially into light of a second wavelength, such that a mix of light of the first and second wavelength is emitted from the device,
wherein the concentration gradient of the wavelength-converting substances is continuously increasing in the downward direction, i.e. towards the base surface of said semiconductor chip.

2. The semiconductor light-emitting device according to Claim 1,
wherein the size distribution of the wavelength-converting substances is continuously distributed around a single peak.

3. The semiconductor light-emitting device according to Claim 1 or 2,
wherein the wavelength-converting substances are distributed in the matrix such that the average particle size of the wavelength-converting

Savant Technologies LLC - 1004.497

substances continuously increases in the downward direction.

4. The semiconductor light-emitting device according to any of the preceding claims, wherein
- one of said one or more layers covers the upper surface of the chip, and
- the upper surface of said layer is non-flat, such that the centre region of the upper surface/interface is higher vis-à-vis the semiconductor chip than the edge portion thereof.

5. The semiconductor light-emitting device according to any of the preceding claims, wherein at least one of the layers contains scattering particles, wherein the concentration gradient of the scattering particles is essentially zero.

6. The semiconductor light-emitting device according to any of the preceding claims, wherein at least two layers are provided and two adjacent layers differ in at least one of the following parameters: phosphor concentration, phosphor composition, and scattering particle concentration.

7. The semiconductor light-emitting device according to any of the preceding claims, wherein the first layer has a curved surface and

Savant Technologies LLC - 1004.498

optionally contains wavelength-converting material(s).

8. The semiconductor light-emitting device according to any of the preceding claims, wherein the first layer contains scattering particles.

9. The semiconductor light-emitting device according to any of the preceding claims, wherein also a second layer contains wavelength-converting material(s).

10. The semiconductor light-emitting device according to any of the preceding claims, wherein a second layer contains scattering particles.

11. The semiconductor light-emitting device according to any of the preceding claims, wherein the top surface of the second layer is flat.

12. The semiconductor light-emitting device according to any of the preceding claims, wherein the surface of the second layer is curved.

13. The semiconductor light-emitting device according to any of the preceding claims, wherein a third layer is placed on top of the second layer.

14. The semiconductor light-emitting device according to claim 13,

Savant Technologies LLC - 1004.499

wherein the third layer consists of transparent matrix material with or without wavelength-converting material(s) and/or scattering particles.

15. The semiconductor light-emitting device according to any of the claims 13 or 14, wherein the third layer has a curved surface.

16. The semiconductor light-emitting device according to any of the preceding claims, wherein it comprises a package made from silicon, the package having a cavity for housing the light source.

17. The semiconductor light-emitting device according to claim 16, wherein side walls defining the cavity are metallised.

18. A semiconductor light-emitting device, said device comprising a semiconductor chip light source that emits light of a first peak wavelength in the blue wavelength range, and at least a first layer made from a transparent matrix material and which covers the upper surface and the sidewalls of the chips as a coating and contains wavelength-converting material(s), wherein the upper surface/interface of at least one layer above the chip is non-flat such that the centre region of the upper surface/interface is higher than the edge portion thereof.

Savant Technologies LLC - 1004.500

19. The semiconductor light-emitting device according to claim 18, wherein a second layer surrounds the first layer and has a curved surface and optionally contains wavelength-converting material(s) of lower concentration than the first layer.

20. The semiconductor light-emitting device according to claim 19, wherein a third layer is placed on top of the second layer.

21. The semiconductor light-emitting device according to claim 20, wherein the surfaces of the second layer and/or the third layer are curved.

22. The semiconductor light-emitting device according to claim 20 or 21, wherein the second layer and/or the third layer contain(s) wavelength-converting material(s) of lower concentration than the first layer.

23. The semiconductor light-emitting device according to any of claims 20 to 22, wherein at least one layer contains scattering particles.

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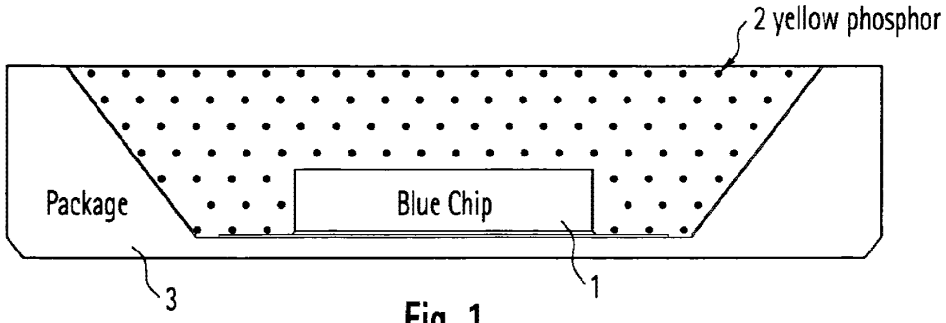


Fig. 1

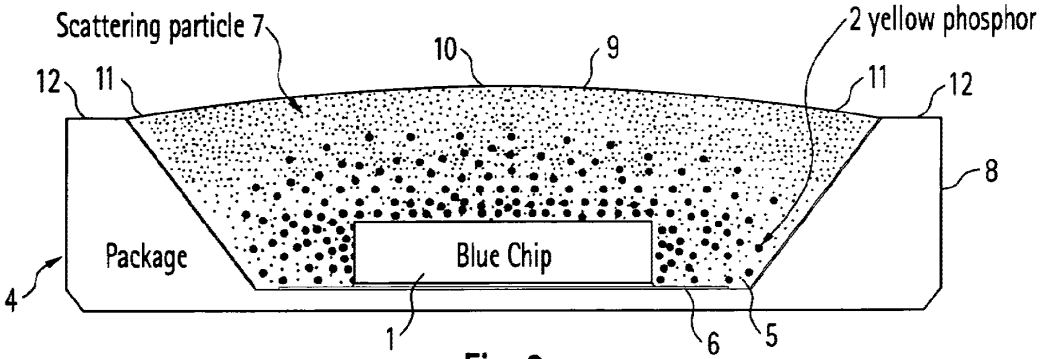


Fig. 2

Savant Technologies LLC - 1004.502

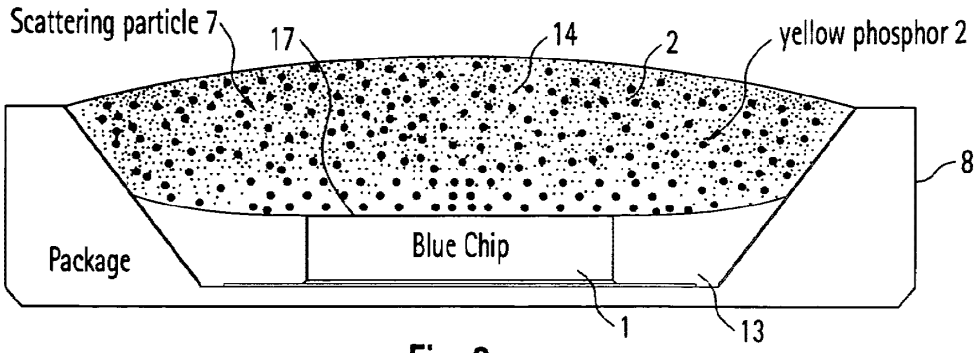


Fig. 3a

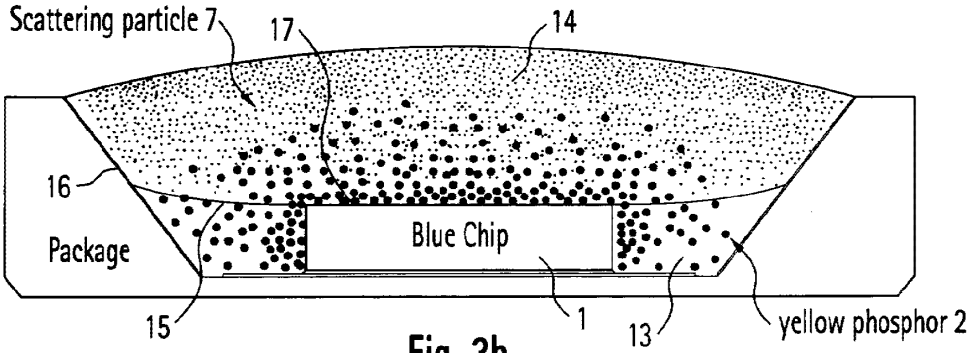


Fig. 3b

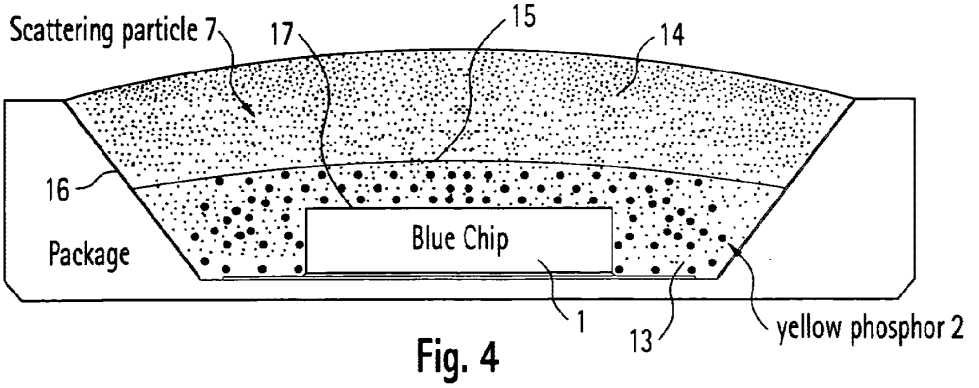


Fig. 4

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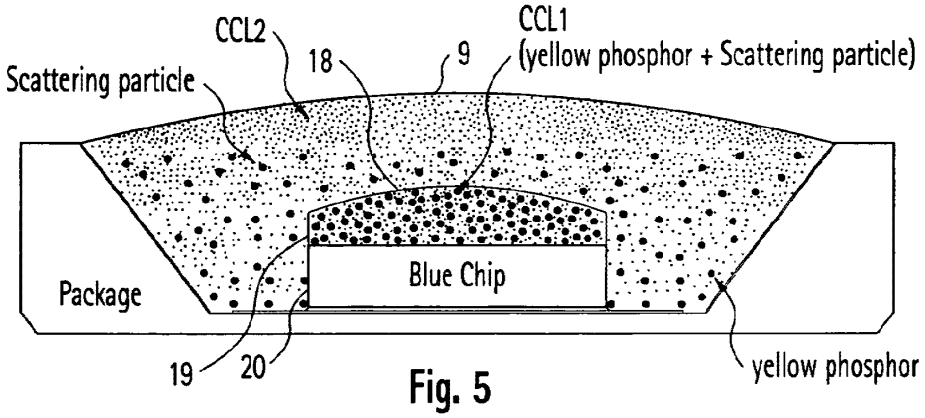


Fig. 5

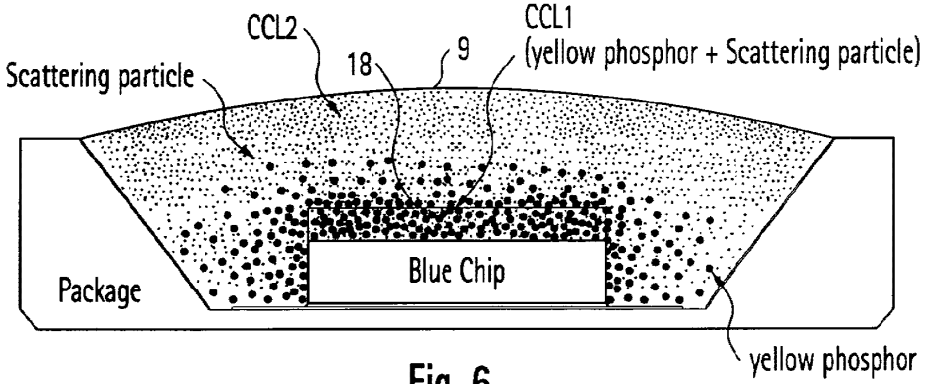


Fig. 6

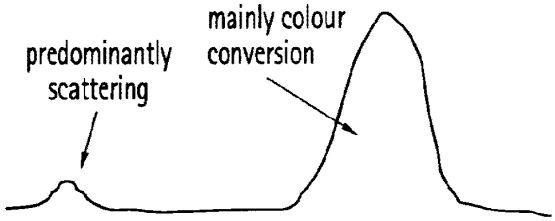


Fig. 7

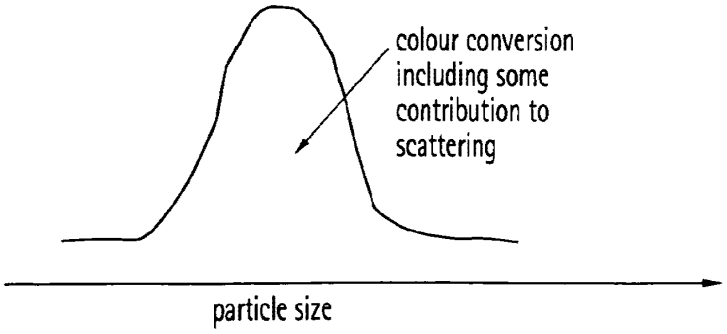


Fig. 8

Savant Technologies LLC - 1004.504

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2007/008765

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 2002/043926 A1 (TAKAHASHI Y ET AL) 18 April 2002 (2002-04-18) paragraphs [0046] - [0104]	1-23
X	WO 2005/119797 A (PHILIPS IP) 15 December 2005 (2005-12-15) page 8, paragraph 3 page 9, paragraph 2	1-18

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 February 2008	12/02/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	VAN DER LINDEN, J

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Savant Technologies LLC - 1004.505

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (continuation of second sheet) (April 2005)

Savant Technologies LLC - 1004.506

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2007/008765

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(74) Agents: **FLIESLER, Martin C.** et al.; Fliesler Meyer LLP, 650 California Street, 14th Floor, San Francisco, California 94108 (US).

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Published:

— *with international search report (Art. 21(3))*

(54) **Title**: NITRIDE-BASED RED-EMITTING PHOSPHORS IN RGB (RED-GREEN-BLUE) LIGHTING SYSTEMS

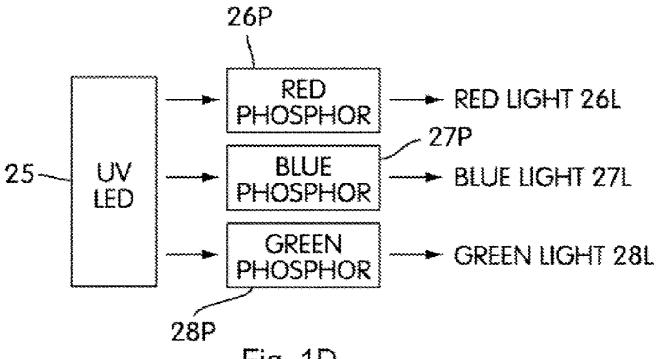


Fig. 1D

(57) **Abstract**: Embodiments of the present invention are directed to nitride-based, red-emitting phosphors in red, green, and blue (RGB) lighting systems, which in turn may be used in backlighting displays and warm white-light applications. In particular embodiments, the red-emitting phosphor is based on $CaAlSiN_3$ type compounds activated with divalent europium. In one embodiment, the nitride-based, red emitting compound contains a solid solution of calcium and strontium compounds $(Ca,Sr)AlSiN_3:Eu^{2+}$, wherein the impurity oxygen content is less than about 2 percent by weight. In another embodiment, the $(Ca,Sr)AlSiN_3:Eu^{2+}$ compounds further contains a halogen in an amount ranging from about zero to about 2 atomic percent, where the halogen may be fluorine (F), chlorine (Cl), or any combination thereof. In one embodiment at least half of the halogen is distributed on 2-fold coordinated nitrogen (N2) sites relative to 3-fold coordinated nitrogen (N3) sites.

WO 2010/074963 A1

Savant Technologies LLC - 1004.508

NITRIDE-BASED RED-EMITTING PHOSPHORS IN RGB (RED-GREEN-BLUE) LIGHTING SYSTEMS

Inventors: Shengfeng Liu, Dejie Tao, Xianglong Yuan, Yi-Qun Li

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Non-provisional application 12/632,550 by Shengfeng Liu, et al., filed December 7, 2009 and entitled "Nitride-based red-emitting phosphors in RGB (Red-Green-Blue) Lighting Systems." This application also claims priority to U.S. provisional application 61/122,569 by Shengfeng Liu, et al., filed December 15, 2008 and entitled "Nitride-based red phosphors." This application also claims priority to U.S. patent application 12/250,400 by Shengfeng Liu, et al., filed October 13, 2008 and entitled "Nitride-based red phosphors", which claims priority to U.S. provisional application 61/054,399 by Shengfeng Liu, et al., filed May 19, 2008 and entitled "Nitridosilicate-based red phosphors." U.S. provisional applications 61/054,399 and 61/122,569 and U.S. patent application 12/250,400 are each incorporated herein in their entirety.

FIELD OF THE INVENTION

[0002] Embodiments of the present invention are directed to nitride-based, red-emitting phosphors, which may be used in red, green, and blue (RGB) lighting systems, which in turn may be used in backlighting displays and warm white-light applications. In particular embodiments, the red-emitting phosphor is based on (Ca, Sr, Ba)$AlSiN_3$ type compounds activated with divalent europium.

BACKGROUND OF THE INVENTION

[0003] There is a need in the field(s) of optical engineering for red, green, and blue lighting systems in various devices, applications, and technologies. Among these technologies are backlighting sources for display systems, such as plasma displays, and warm-white light sources in general lighting.

[0004] Various configurations of LED light sources and light-emitting phosphors are possible in the design of such RGB systems. The conventional one, shown schematically in FIG. 1A, employs three light emitting diodes (LEDs). Each of the three LEDs is a

Savant Technologies LLC - 1004.509

semiconductor-based integrated circuit, or "chip", and there is one chip for each of the red, green, and blue colors. A disadvantage of the conventional system is that a separate electrical current controller is needed for each LED, like in many situations, it is better to have as few current controllers in the system as is possible. The prior art system of FIG. 1A requires three circuit controllers.

[0005] The RGB systems depicted in FIGS. 1B-D differ from that of FIG. 1A in that they have at least one photoluminescent substance (a "phosphor") substituting for at least one of the red, green, or blue LEDs of the system. The progression from FIGS. 1A-1D shows the effect of replacing LEDs with phosphors; in no particular order regarding color, first the green LED is replaced with a green phosphor (going from FIG. 1A to 1B); then the red LED is replaced with a red phosphor along with the green (going from FIG. 1B to 1C); finally, all three visible light emitting LEDs are replaced in FIG. 1D with phosphors, although a UV-emitting LED has been added to this system to provide excitation radiation to the phosphors. Thus, FIG. 1D depicts a strategy that is in a sense somewhat opposite to that of FIG. 1A, in that each of the RGB colors in FIG. 1D is provided by a phosphor, and therefore the excitation source is a non-visible, UV emitting LED. The practice of technologies based on a UV excitation source are somewhat further away from commercialization than those based on blue LEDs, but nonetheless, the configuration of FIG. 1D is still one in which the present nitride-based red phosphors may be used.

[0006] This means that no blue phosphors are used in the embodiments of FIGS. 1B and 1C because the blue LED provides the blue component of the light needed in various applications like backlighting and warm-white light general lighting. In this regard the blue LED is unique in the system because it serves a dual role; in addition to providing blue light to the final light product, it provides excitation to either or both of the red or green phosphors in the system. Systems such as those depicted in FIGS. 1C and 1D are the subject of the present disclosure; these configurations are particularly suited for silicon nitride based red-emitting phosphors.

[0007] Since earlier versions of these red phosphors were based on nitrides of silicon, they may be generically referred to as "nitride-based" silicates, or nitridosilicates. Newer versions have included aluminum such that the resulting compounds are referred to as "nitridoaluminosilicate nitrides." The deliberate inclusion of oxygen into these crystals in a desired stoichiometric manner gives rise to a certain class of red-emitting phosphors, and compounds known as "SiAlONs" can also be in some cases sources of green and yellow-

Savant Technologies LLC - 1004.510

green illumination. When oxygen substitutes for nitrogen the resulting compound may be described as an "oxynitrides."

[0008] As alluded to earlier, a combination of LED-generated blue light, and phosphor-generated green and red light, may be used to generate the white light from a so-called "white LED." Previously known white light generating systems used a blue LED in conjunction with a yellow emitting, cerium-doped, yttrium aluminum garnet known as "YAG," having the formula $Y_3Al_5O_{12}:Ce^{3+}$. Such systems have correlated temperatures (CCTs) of greater than about 4,500 K, and color rendering indexes (CRIs) ranging from about 75 to 82. The blue emitting LED provides excitation radiation ranging from about 400 to 480 nm.

[0009] One way of achieving a flexibility of design in blue LED-based devices involves creating a wider separation between the yellow and/or green phosphors, and the red phosphors, the phosphors relative to one another in CIE space. CIE coordinates will be discussed further later in this disclosure, but suffice it to say for now that "CIE space" means the area in a triangle mapped by two vertices of a triangle defined by phosphors, and the third by the blue LED. A yellow and/or green apex widely separated from that of the blue LED create a rich diversity of components for white light generation.

[0010] As described in U.S. Pat. 7,252,787 to D. Hancu et al., red sources were used with YAG and TAG-based yellow sources to produce a high color rendering index have included nitrides having the formula $(Ba,Sr,Ca)_xSi_yN_z:Eu^{2+}$, where each of the x, y, and z parameters was greater than zero. A disadvantage of such phosphors used with YAG/TAG was that they reabsorb emissions from those phosphors due to overlapping of the Eu^{2+} absorption bands with the emission of the $(Tb,Y)_3Al_5O_{12}:Ce^{3+}$) phosphors. Thus, there is a need for red phosphors having a redder emission than these nitrides to produce white light illumination with high CRI.

[0011] Host lattices for new red-emitting phosphors based on nitridosilicate compounds were introduced in the mid-1990's. Such phosphors have desirable mechanical and thermal properties due to a three dimensional network of cross-linked SiN_4 tetrahedra in which alkali earth ions (M=Ca, Sr, and Ba) are incorporated. The formula used in U.S. Pat. 6,649,946 to Bogner et al. to describe such phosphors was $M_xSi_YN_z$, where M was at least one of an alkaline earth metal, and where $z=2/x+4/3y$. The nitrogen of these nitrides increased the content of colvalent bonding, and thus ligand-field splitting. This lead to a pronounced shift of excitation and emission bands to longer wavelengths in comparison to oxide lattices.

[0012] The effect of the alkaline earth component of such nitridosilicates when y is 5 was investigated by Y.Q. Li et al. in "Luminescence properties of red-emitting $M_2Si_5N_8:Eu^{2+}$

Savant Technologies LLC - 1004.511

(M=Ca, Sr, Ba) LED conversion phosphors," *J. of Alloys and Compounds* **417** (2006), pp. 273-279. Polycrystalline powders were prepared by a solid state reaction mechanism. The crystal structure of the Ca-containing member of this family was monoclinic with space group Cc, whereas the Sr and Ba members were isostructral with orthorhombic space group $Pmn2_1$. There was a formation of a complete solid solution between the Sr and Ba end-members in the latter compound(s).

[0013] As taught by Li et al., the excitation spectra are not substantially dependent on the type of alkaline earth, but the position of the emission bands are. The peak emission bands for a 1 mole percent activator concentration were 605, 610, and 574 nm, for M = Ca, Sr, and Ba. The shift in the emission band with the nature of the alkaline earth is due to a difference in the Stokes shift for each of the members, where the Stokes shift gradually increases with the sequence Ca > Sr > Ba, and this trend is predictable if one observes that the relaxation of the $4f^6 5d^1$ state becomes less restricted when the size of the alkaline-earth ion decreases. Further, the Stokes shift increases for as the Eu concentration is increased in all cases.

[0014] US 2007/0040152 elucidated the difficulties in producing a nitridosilicate based compound such as $M_2Si_5N_8$, MSi_7N_{10}, and $MSiN_2$, where M is at least one element selected from Mg, Ca, Sr, and Ba, etc., and where the compound contains substantially no oxygen. This may be achieved, it is taught, by using as starting materials the nitrides of the alkaline-earth elements and the rare earth elements, but these nitrides are difficult to obtain, expensive, and difficult to handle. These factors conspire to make nitridosilicate-based phosphors difficult to produce industrially. As stated by the reference: "the conventional nitridosilicate-based compound has the following problems: (1) low purity due to the presence of a large amount of impurity oxygen, (2) low material performance of a phosphor caused by the low purity; (3) high cost; and the like." The problems included low luminous flux and brightness.

[0015] What is needed in the art are red-emitting phosphors in red, green, and blue (RGB) lighting systems for use in backlighting displays and warm white-light applications, where the red phosphors have high luminous flux and brightness. The present disclosure describes improvements in red-emitting phosphor based on $CaAlSiN_3$ type compounds activated with divalent europium. In conjunction with phosphors emitting at other wavelengths, it is believed the present embodiments provide general illumination sources having higher CRIs and lower CCTs than those currently available.

Savant Technologies LLC - 1004.512

SUMMARY OF THE INVENTION

[0016] Embodiments of the present invention are directed to nitride-based, red-emitting phosphors, which may be used in red, green, and blue (RGB) lighting systems. These RBG systems may in turn be used in backlighting displays and warm white-light applications. In particular embodiments, the red-emitting phosphor is based on (Ca,Sr,Ba)$AlSiN_3$ activated with divalent europium, where the (Ca,Sr,Ba) nomenclature means any of these alkaline earths may be used, in any proportion one relative to the others. Strontium (Sr) may substitute for Ca in the formula, in any combination of amounts; in one embodiment a complete solid solution of calcium and strontium containing compounds (Ca,Sr)$AlSiN_3$ compounds are disclosed where the impurity oxygen content is less than about 2 percent by weight. The present nitride-based, red emitting compounds may further comprise a halogen, whose content ranges from greater than about zero to about 2 atomic percent, which halogen in one embodiment may be selected from the group consisting of F and Cl. It is believed the halogen may provide some sort of a gettering effect during synthesis, and this may be the mechanism by which the oxygen impurity content is kept to low levels. In one embodiment of the present invention, at least half of the halogen is distributed on 2-fold coordinated nitrogen (N2) sites relative to 3-fold coordinated nitrogen (N3) sites.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIGS. 1A-1D show various configurations and ways of arranging LEDs and phosphors to provide RGB light for use in white LED and backlighting situations;

[0018] FIGS. 2A and 2B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the fluorine content x supplied by NH_4F is increased above various halogen baseline levels; the three compounds being $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_{0.04+x}$ when the europium source is EuF_3; $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_{0.04}F_x$ when the europium source is $EuCl_3$; and $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_x$ when the europium source is Eu_2O_3;

[0019] FIGS. 3A and 3B are graphs showing the effects on the CIE coordinates x and y with the same additions of NH_4F to the three compounds of FIGS. 2A and 2B;

[0020] FIGS. 4A and 4B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the chlorine content x supplied by NH_4Cl is increased above various halogen baseline levels; the three compounds being $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_{0.04}Cl_x$ when the europium source is EuF_3;
$Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_{0.04+x}$ when the europium source is $EuCl_3$;

Savant Technologies LLC - 1004.513

and $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_x$ when the europium source is Eu_2O_3;

[0021] FIGS. 5A and 5B are graphs showing the effects on the CIE coordinates x and y with the same additions of NH_4F to the three compounds of FIGS. 4A and 4B;

[0022] FIGS. 6A and 6B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the fluorine content x supplied by NH_4F is increased above various halogen baseline levels; the three compounds being

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_{0.04+x}$ when the europium source is EuF_3;

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_{0.04}F_x$ when the europium source is $EuCl_3$; and

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_x$ when the europium source is Eu_2O_3;

[0023] FIGS. 7A and 7B are graphs showing the effects on the CIE coordinates x and y with the same additions of NH_4F to the three compounds of FIGS. 6A and 6B;

[0024] FIGS. 8A and 8B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the fluorine content x supplied by NH_4Cl is increased above various halogen baseline levels; the three compounds being

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_{0.04}Cl_x$when the europium source is EuF_3;

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_{0.04+x}$ when the europium source is $EuCl_3$; and

$Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_x$ when the europium source is Eu_2O_3;

[0025] FIGS. 9A and 9B are graphs showing the effects on the CIE coordinates x and y with the same additions of NH_4F to the three compounds of FIGS. 8A and 8B;

[0026] FIGS. 10A and 10B are graphs of photoluminescence as a function of emission wavelength for both the R630 and R640 type of compounds, respectively, when no additional halogen is provided by a flux such as NH_4F or NH_4Cl;

[0027] FIG. 10C is a collection of emission spectra comparing the R630 and R640 nitride-based red phosphors (the numbers in the designations indicating roughly the peak emission wavelength of that particular phosphor), having formulas $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$ (R630), $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$, (R640), to the phosphor $Ca_{0.157}Sr_{0.808}AlSiN_3Eu_{0.035}$ (R645), where EuF_3 was used as the source of europium in each of the three compositions;

[0028] FIGS. 11A-B are graphs of emission wavelength and photoluminescence as a function of Sr content for the phosphors having the formula $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$, where Eu_2O_3 is the europium source;

[0029] FIGS. 12A-B are the normalized emission spectra of $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$ and $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$ with x=0.82 and x=0, respectively, plotted in this way to show the effect of a wavelength shift to shorter wavelengths with the Sr doping, and a greater brightness with Sr doping;

Savant Technologies LLC - 1004.514

[0030] FIG. 13 shows the effect of doping the present nitride-based red phosphors with further amounts of an alkaline earth metal; specifically, Ca, Sr, and Ba replacing a portion of the Ca/Sr mix discussed in previous paragraphs: here the compound under study had the formula $Ca_{0.2}Sr_{0.74}AlSiM_{0.05}N_3Eu_{0.01}$, where M was Ca, Sr, Ba, respectively;

[0031] FIGS. 14A-B provide a collection of emission wavelengths, the raw data shown in FIG. 14A and a normalized version shown in FIG. 14B, for a nitride-based red phosphor with a 5% level of a group IIIA (of the periodic table) metal M, where M is in this example either boron or gallium;

[0032] FIGS. 15A-B are graphs showing peak emission wavelength and photoluminescent changes as a function of Eu source and content, where Eu sources include the oxide, fluoride, and chloride salts of the europium metal; the compound chosen for this study being $Ca_{0.2}Sr_{0.8-x}AlSiN_3Eu_x$, where x ranged from 0.005 to 0.015;

[0033] FIG. 16 is a collection of excitation spectra for the R630 composition having the formula $Ca_{0.2}Sr_{0.8}AlSiN_3Eu_{0.01}$, and the R640 composition having the formula $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$;

[0034] FIG. 17 is an x-ray diffraction (XRD) pattern of one of the typical compositions of the present embodiments; the particular compound examined was $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$:F;

[0035] FIGS. 18A-18E are exemplary spectra of light intensity versus wavelength emitted by warm white luminescent systems.

DETAILED DESCRIPTION OF THE INVENTION

[0036] An introduction to the field of nitride-based, red emitting phosphors has been provided by K. Uheda et al. in "Luminescence properties of a red phosphor, $CaAlSiN_3:Eu^{2+}$, for white light-emitting diodes," published in *Electrochemical and Solid-State Letters*, **9** (4) H22-H25 (2006). This reference explains how white light-emitting diodes (LEDs) are attracting increasing attention due to their high efficiencies and long lifetimes. The earliest "white light LEDs," consisting of a blue LED as an excitation source and provider of blue light, and a yellow-emitting $YAG:Ce^{3+}$ phosphor, suffered from low color rendering because of the lack of a red component. An earlier attempt at providing the desired red component was made with an Eu^{2+} activated alkaline earth sulfide, which had the advantage of being excitable by blue light, but which also suffered from the potential to be degraded by atmospheric moisture due to its hygroscopic nature. The next generation of red phosphors exhibited an improvement in properties: these materials were alkaline earth silicon nitrides such as $CaSiN_2:Eu^{2+}$ (present nomenclature = "1-1-2," after the stoichiometric amounts of the

Savant Technologies LLC - 1004.515

Si and N, respectively) and $Ca_2Si_5N_8:Eu^{2+}$ ("2-5-8"), where, at least in the latter case, other alkaline earth metal elements may be substituted for Ca. The state of the art in red nitrides is the compound $CaAlSiN_3:Eu^{2+}$ ("1-1-1-3"), where again Ca can be any alkaline earth or mixture of alkaline earths. These compounds have greater chemical stability and optical efficiency than their 1-1-2 and 2-5-8 counterparts. K. Uheda et al. were the first to discover the benefits of the 1-1-1-3 compound as a phosphor, where interestingly, the host material $CaAlSiN_3$ was already known from the CaO, AlN, and Si_3N_4 phase diagram.

[0037] The position of the 5d excitation bands of the Eu^{2+} ions in these $CaAlSiN_3$ compounds at low energies is attributable to the influence of the highly covalent nature of the europium on an alkaline earth metal site with nitrogen atoms, leading to a large crystal field splitting, as well, also due to the presence of nitrogen. The covalency of the Eu-N bond and the resultant crystal field strength around the Eu^{2+} ions is similar in each of the members of this series (e.g., Ca, Sr, and Ba-based), despite the fact there are two M sites with different symmetries. Of particular importance to white LEDs is the fact these compounds have efficient excitation in the same spectral region (400 to 470 nm), matching the radiative blue light from an InGaN-based LED, which emits around 465 nm. Their broad-band emissions are due to a $4f^65d^1 \rightarrow 4f^7$ transition within the Eu^{2+} ion, with the Ca compound emitting at wavelengths ranging from about 605-615 nm, Sr at 609-680 nm, and Ba at 570-680 nm. For $M_2Si_5N_8:Eu^{2+}$ with M restricted to Sr and Ba, the emission band of Eu^{2+} successively shifts from orange when M is Sr, and yellow when M is Ba at low Eu concentrations, to red (up to 680 nm) for high concentrations of Eu.

[0038] While the advent of new red nitrides was crucial to the evolution of the state of the art of backlighting and warm white light (specifically, their ability to impart a high color rendering to the product white light), their inclusion in a mix of light from other phosphors has be developing over a period of time. The assignee of the present application has been involved in this field for some time, and has contributed a number of innovations to the art. The following table lists several patents and published applications directed RGB systems, each patent (or published application) being incorporated herein in its entirety. Table 1 is provided for the purpose of summarizing the red and green phosphor compositions that have contributed to the present state of the art, and also to show the progression towards adoption of an $CaAlSiN_3:Eu^{2+}$-type compounds in the present art.

[0039] U.S. Pat. 7,311,858, titled "Silicate-based yellow-green phosphors," filed September 22, 2004, discloses the combination of a blue LED, a green phosphor that includes (but is not limited to) compositions having the formula $M_2SiO_4:Eu^{2+}D$, where M is a divalent

Savant Technologies LLC - 1004.516

metal that includes the alkaline earths, and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S, and N, and a red phosphor that includes (but is not limited to) the nitridosilicate $(Sr,Ba,Ca)_2Si_5N_8:Eu^{2+}$.

[0040] U.S. Pat. 7,575,679, titled "Silicate-based green phosphors," November 8, 2005, discloses the combination of a blue LED and the nitridosilicate $(SrBaCa)_2Si_5N_8:Eu^{2+}$ (among other compounds) as the red phosphor, but this patent discloses a slightly different green phosphor from that of the patent in the paragraph above. The green phosphors of U.S. Pat. 7,575,679 may be described by the formula $(Sr,M^{2+})_x(Si,P)(O,F,Cl)_{2+x}:Eu^{2+}$, where M^{2+} again includes the alkaline earth metals. These green phosphors may be undoped; in other words, the amounts of P, F, and/or Cl in the phosphor may be zero.

[0041] U.S. Application No. 2008/0116786, title "Novel silicate-based yellow-green phosphors," filed December 24, 2007 and a Continuation-in-part of U.S. Pat. 7,311,858, discloses the combination of a blue LED and green phosphor having the formula $M_2SiO_4:Eu^{2+}D$ (where M is a divalent metal that includes the alkaline earths, and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S, and N), as in U.S. Pat. 7,311,858, but the red phosphor of the RGB solution includes the aluminonitridosilicate $(Sr,Ba,Ca)AlSiN_3:Eu^{2+}$. The present embodiments are directed to a more thorough disclosure of the use of these aluminonitridosilicate-based red phosphors (which may also be called nitride-based red phosphors).

[0042] A further disclosure filed by the assignee of the present application contributing to the RGB art is U.S. Application No. 12/250,400, titled "Nitride-based red phosphors," and filed October 13, 2008, but based on a provisional U.S. Application No. 61/054,399, title "Nitridosilicate-based red phosphors," filed May 19, 2008. The yellow-green phosphors of these two disclosures were based on the general formula $M_2SiO_4:Eu^{2+}$, which may be undoped, and used in combination with the blue LED and red phosphors of the nitridosilicate-based family of the type $(Sr,Ba,Ca)AlSiN_3:Eu^{2+}$ discussed above.

[0043]

Case ID	Filing date	Green phosphor	Red phosphor
U.S. Pat. 7,311,858	9-22-04	$M_2SiO_4:Eu^{2+}D$ M includes alkaline earths D=F, Cl, Br, I, P, S, and N	Includes $(Sr,Ba,Ca)_2Si_5N_8:Eu^{2+}$
U.S. Pat. 7,575,697	11-8-05	$(Sr,M^{2+})_x(Si,P)(O,F,Cl)_{2+x}:Eu^{2+}$ M^{2+} includes alkaline earths (can be undoped; the amounts of P, F, Cl zero)	Includes $(Sr,Ba,Ca)_2Si_5N_8:Eu^{2+}$
U.S. Pub. 2008/0116786	12-24-07	$M_2SiO_4:Eu^{2+}D$ M includes alkaline earths D=F, Cl, Br, I, P, S, N and B	Includes $(Sr,Ba,Ca)AlSiN_3:Eu^{2+}$

Savant Technologies LLC - 1004.517

U.S. Appl. No. 61/054,399 U.S. Appl. No. 12/250,400	5-19-08 10-13-08	$M_2SiO_4:Eu^{2+}$ M includes alkaline earths	Includes $(Sr,Ba,Ca)AlSiN_3:Eu^{2+}$

Table 1

[0044] The present disclosure will be divided into the following sections: first, a chemical description of the present red nitrides (stoichiometric formulas) will be given, followed by a description of the synthesis, focusing on the starting materials. The structure of the present nitride-based red phosphors will then be discussed in detail, although further reference to structure will be made later in the disclosure with experimental x-ray diffraction (XRD) data. Experimental data comprising wavelength and photoluminescent changes upon inclusion of halogen will be presented, and reference will be made to the lowering of the oxygen content as a result of halogen inclusion. Finally, the role the present red nitrides may play in white light illumination and backlighting applications will be presented with exemplary data.

[0045] Chemical description of the present red nitrides

[0046] There are several ways to describe the formula of the present phosphors. In one embodiment, the present phosphors have the form M-A-B-(N,D):Z, where M, A, and B are three cationic metals and/or semimetals with divalent, trivalent, and tetravalent valences, respectively; N is nitrogen (a trivalent element), and D is a monovalent halogen that along with the nitrogen contributes to the anionic charge balance. Thus, these compounds may be thought of as halogen-containing nitrides. The element Z is an activator in the host crystal, providing the photoluminescent centers. Z may be a rare earth or transition metal element.

[0047] The present nitride-based red phosphors may be described in a slightly different format, to emphasize the approximate ratios of the constituent elements. This formula takes the form $M_mM_aM_b(N,D)_n:Z_z$, where the stoichiometry of the constituent elements (m+z):a:b:n follows the general ratios 1:1:1:3, although deviations from these integer values are contemplated, and n may range from about 2.5 to about 3.5, endpoints inclusive. It is noted the formula shows that the activator Z substitutes for the divalent metal M_m in the host crystal, and that the host material of the phosphor contains substantially no oxygen (or at least, less than about 2 percent by weight, according to the present embodiments).

[0048] Embodiments of the present invention are directed to nitride-based, red phosphors having the formula $M_aM_bM_c(N,D)_n:E_z$, where M_a may be a single divalent element, or it may be a combination of two or more divalent elements (or two divalent elements used simultaneously). Divalent elements include elements from the second column of the periodic table, the alkaline earth metals. The two divalent metals may be, for example, Ca and Sr. In

Savant Technologies LLC - 1004.518

this formula, n may range from about 2.5 to about 3.5, endpoints inclusive, and charge compensation may be accomplished by a redistribution of cationic content, changes in numbers of vacancies, inclusion of impurities, and the like. In the present phosphors, M_a may be a combination of at least two divalent alkaline earth metals selected from the group consisting of Mg, Ca, Sr, Ba; M_b is a trivalent metal such as Al, Ga, Bi, Y, La, and Sm; and M_c is a tetravalent element such as Si, Ge, P, and B; N is nitrogen, and D is a halogen such as F, Cl, or Br. The following description contains first a disclosure of how the starting materials containing the alkaline earth metals may be prepared, then a description of the process by which the present nitride-based phosphors may be prepared, and then concludes with testing results. The preparation of some of the starting materials appears to be novel, as the inventors do not believe that one of the, strontium nitride, is commercially available.

[0049] The present nitride-based red phosphors may be described in yet another manner, this format emphasizing the stiochiometric relationship between the amounts of the metals and halogen(s) present relative to the amount of nitrogen present in the nitride host. This representation has the form $M_mM_aM_bD_{3w}N_{[(2/3)(m+z)+a+(4/3)b-w]}Z_z$. The parameters m, a, b, w, and z fall within the following ranges: $0.01 \leq m \leq 1.5$; $0.01 \leq a \leq 1.5$; $0.01 \leq b \leq 1.5$; $0.0001 \leq w \leq 0.6$, and $0.0001 \leq m \leq 0.5$.

[0050] The metal M_m may be an alkaline earth or otherwise divalent metal such as Be, Mg, Ca, Sr, Ba, Zn, Cd, and/or Hg. Different combinations are possible, and M_m may be a single one of these elements, or a mixture of any or all of them. In one embodiment, the metal M_m is Ca.

[0051] M_a is a trivalent metal (or semimetal) such as B, Al, Ga, In, Y, Sc, P, As, La, Sm, Sb, and Bi. Again, different combinations and contents of these metals/semimetals are possible, and in one embodiment, the metal M_a is Al.

[0052] M_b is a tetravalent element such as C, Si, Ge, Sn, Ni, Hf, Mo, W, Cr, Pb, Ti, and Zr. In one embodiment, the tetravalent element M_b is Si.

[0053] The element D is a halogen such as F, Cl, or Br in this nitride-based compound, and may be contained within the crystal in any of a number of configurations: for example, it may be present in a substitutional role (substituting for nitrogen) in the crystalline host; it may be present interstitially in the crystal, and/or perhaps within grain boundaries that separate crystalline grains, regions, and/or phases. The amount of the halogen may range from about zero to about 2 atomic percent. In other embodiments, the amount of the halogen ranges from about zero to about 0.2, 0.5, 1, and 5 atomic percent, respectively.

Savant Technologies LLC - 1004.519

[0054] Z is an activator comprising at least one or more of the rare earth elements and/or transition metal elements, and include Eu, Ce, Mn, Tb, and Sm. In one embodiment the activator Z is europium. According to one embodiment of the present invention the activator is divalent, and substitutes for the divalent metal M_m in the crystal. The relative amounts of the activator and the divalent metal M_m may be described by the molar relationship z/(m+z), which falls within the range of about 0.0001 to about 0.5. Keeping the amount of the activator within this range may substantially avoid the so-called quenching effect manifested by a decrease in emission intensity caused by an excessive concentration of the activator. The desired amount of the activator may change with the particular choice of activator.

[0055] Starting materials for the present synthesis

[0056] Prior art starting materials have typically consisted of the nitrides and oxides of the metals. For example, to produce the phosphor $CaAlSiN_3:Eu^{2+}$ in U.S. Pat. 7,252,788, it is taught that the nitride starting materials for the calcium, aluminum, and silicon sources may be Ca_3N_2, AlN, and Si_3N_4, respectively. The source of the europium in this disclosure was the oxide Eu_2O_3. In contrast, the sources of the metals in the present phosphors may be at least in part the halides of the metals, and typical examples include MgF, CaF, SrF, BaF, AlF, GaF, BF, InF, and $(NH_4)_2SiF_6$. The europium may be supplied by either of the two fluorides EuF_2 and EuF_3. The use of halides of the divalent, trivalent, and tetravalent metals is not the only way to supply the halogen to the phosphor: an alternative method is to use a flux such as NH_4F or LiF.

[0057] Specifically, compounds of the divalent metal M_m appropriate as raw materials in the synthesis of the present phosphors include nitrides, oxides, and halides; e.g., Mm_3N_2, MmO, MmD_2, where again D is F, Cl, Br, and/or I. Analogous raw material compounds of the trivalent metal M_a are MaN, Ma_2O_3, and MaD_3. The tetravalent metal starting compounds include Mb_3N_4, and $(NH_4)_2MbF_6$. Compounds of the halide anion D include NH_4D and AeD, where Ae is an alkaline metal such as Li, Na, and MD_2, where Me is an alkaline earth metal such as Mg, Ca, etc.

[0058] Prior art references have disclosed the oxide of europium, Eu_2O_3, as the source of the europium activator, as this material is a readily available commercial compound. The present inventors have discovered, however, that the oxygen in this compound has a deleterious effect on the photoluminescent properties of the phosphor. One way of eliminating this problem is to use a europium source that does not contain oxygen, such as the substantially pure Eu metal, but this is a very expensive approach that is difficult to

Savant Technologies LLC - 1004.520

implement. One embodiment of the present invention is to use a Eu halide, such as EuF_3 and/or $EuCl_3$ as europium-containing starting materials. The present inventors have found that when a europium halide such as EuF_3 is used as the europium source, the emission efficiency of the phosphor increases, and the emission wavelength of the phosphor shifts to a longer wavelength. Thus one embodiment of the present invention is to use a europium compound EuD_3 (D=F, Cl, Br, I), and not Eu_2O_3, as the europium source. These concepts will be illustrated, and discussed more fully, in conjunction with the accompanying figures.

[0059] The strontium nitride starting material bay be synthesized by nitriding Sr metal under a nitrogen atmosphere at temperature of about 600-850°C for about 5-12 hours. The resulting Sr nitride is pulverized in a glove box within an inert atmosphere, such as a nitrogen atmosphere. The chemical reaction used to prepare the Sr nitride starting material may be represented by the following equation:

$$3Sr+N_2 \rightarrow Sr_3N_2$$

[0060] Ca nitride may be either obtained commercially or specially prepared. If it is desired to prepare one's own Ca nitride, then a similar procedure may be used as that described above to prepare strontium nitride: calcium metal is nitrided under a nitrogen atmosphere at temperature of about 600-950°C for about 5-12 hours. Note that the upper temperature of the heating step is slightly higher in the Ca case than it was for the Sr case. The Ca nitride that is obtained from that step is pulverized in a glove box under an inert atmosphere such as a nitrogen atmosphere. The chemical reaction may be represented by the following equation:

$$3Ca+N_2 \rightarrow Ca_3N_2$$

[0061] The synthesis process of the new phosphors containing two or more of the divalent element (such as Ca and Sr) is similar to that which was describe in co-pending application titled "Nitride-based red phosphors," filed October 13, 2008, having application number 12/250,400. Application 12/250,400 is incorporated herein in its entirety. In the present case, the raw materials Sr_3N_2, Ca_3N_2, AlN, Si_3N_4, and the Eu-containing materials such as EuF_3, $EuCl_3$, Eu_2O_3, and/or their combinations, were sealed under an inert atmosphere such as nitrogen and the like. A glove box containing an inert atmosphere may be used. These raw materials are weighed, and then mixed using any of the methods known in the art, such as mixing with an ordinary ball mill.

Savant Technologies LLC - 1004.521

[0062] The raw material mixture is then fired at an elevated temperature in an inert atmosphere; a convenient way to perform this firing step is to place the raw material mixture in a crucible, and then to place the crucible in a tube furnace. The raw material mixture within the crucible is heated to a temperature of about 1400-1700°C using a heating rate of about 10°C per minute, again, the entire procedure carried out in an inert atmosphere such as nitrogen or the like. Once at temperature, the mixture is maintained at 1400-1700°C for about 2-10 hours to sinter the raw material mixture. After the sintering is complete, the sintered material is cooled to about room temperature, and then pulverized using any pulverizing means known in the art such as pulverizing with a mortar or ball mill. The pulverizing step produces a phosphor in powder form having the desired composition.

[0063] Structure of the present nitride-based red phosphors

[0064] Aluminonitridosilicates may be derived from nitridosilicates by substitutions of aluminum for silicon. A new red phosphor having the formula $CaAlSiN_3$ has been described by K. Uheda et al. in the reference alluded to earlier: "Luminescence properties of a red phosphor, $CaAlSiN_3:Eu^{2+}$, for white light-emitting diodes," in *Electrochemical and solid-state letters*, **9** (4) (2006), pages H22-H25. The crystal structure of the $CaAlSiN_3:Eu^{2+}$ family of compounds was found to be orthorhombic with a $Cmc2_1$ space group, where the unit cell volume expanded linearly with an increase in Eu concentration up to at least 20 mole percent. The structure is made up of tetrahedra of $[SiN_4]$ and $[AlN_4]$ forming corner sharing six-member rings; rings are combined to form sheets, of which there are two types, overlaid in an alternate fashion to form the three dimensional network. The Ca^{2+} ions accommodated in cavities in the overlaid planes, and the Eu^{2+} ions substitute for the Ca^{2+} ions. The overlay of the two sheets, rotated 180 degrees one to the other, forms the basis for the existence of two types of nitrogen sites, which significance to the present embodiments will be made apparent from the next several paragraphs.

[0065] Figure 2 of the Uheda et al. reference shows that in any one of the two sheets, either Sheet-A or Sheet-B as labeled in the figure, a nitrogen site at any particular vertex (corner) of either a $[SiN_4]$ or $[AlN_4]$ tetrahedron is shared by only one other tetrahedron (again, either $[SiN_4]$ or $[AlN_4]$ tetrahedra), when the two-dimensional sheets are viewed as separate structures. But when the two types of sheets are overlaid, and bonding between the sheets is considered, there is created a second type of nitrogen site in which that vertex is corner shared with two other tetrahedrons. The nature of the corner sharing is such that two thirds of the nitrogen sites are coordinated with three other Si/Al tetrahedron, and the

Savant Technologies LLC - 1004.522

remaining one third of the N sites are coordinated with two other Si/Al tetrahedron. Uheda et al. point out that this is to be contrasted with the nitridosilicate phosphor $CaSiN_2:Eu^{2+}$ described earlier, where all the N atoms are coordinated with only two Si tetrahedra. As a result, $CaAlSiN_3:Eu^{2+}$ has a more rigid structure than $CaSiN_2:Eu^{2+}$.

[0066] Determination of just where the halogen atoms are located in the present red nitrides, whether the halogen is a Cl, F atom, or combination of both Cl and F in the same phosphor, is best understood by considering the atomic arrangements of all the atoms within the $CaAlSiN_3$ crystal structure. This topic has been reviewed by R-J Xie et al. in "Silicon-based oxynitride and nitride phosphors for white LEDs—a review," published in *Science and Technology of Advanced Materials* **8** (2007), pp. 588-600. The atomic arrangements in the materials, particularly as they pertain to a halogen in a $CaAlSiN_3$ crystal, will be covered in the next several paragraphs of the present disclosure. CaAlSiN3 itself has an orthorhombic crystal structure having the space group $Cmc2_1$, and unit cell parameters of a = 9.8007 Å, b = 5.6497 Å, c = 5.0627 Å.

[0067] The structure of the present $CaAlSiN_3$-based halogen-containing materials is built up corner sharing SiN_4 and AlN_4 tetrahedra, linked in two different ways: one third of the nitrogen atoms in so-called N2 sites are linked to two SiN_4 or AlN_4 tetrahedral neighbors, and the remaining two thirds of the nitrogen atoms in N3 sites are connected to three SiN_4 or AlN_4 tetrahedral neighbors. The Si^{4+} and Al^{3+} cations are randomly distributed within the tetrahedral sites formed by four nitrogen atoms. Tetrahedra display corner sharing to form vertex-linked M6N18 rings, where M represents the aluminum and silicon cations. The Ca atoms reside in the tunnels surrounded by six corner-sharing Al/Si occupied tetrahedral, and are coordinated to two to four nitrogen atoms, where the average Ca-N bond length is 2.451 Å.

[0068] Effects of halogen content on optical properties

[0069] That halides of europium may be used as the source of the europium has been taught by Hirosaki et al. (US 2007/0007494). Their disclosure states that: "...from the viewpoint of good reactivity with other nitride materials, oxides, nitrides, and halides of [europium] are preferred, and oxides are particular preferred since the raw materials are available at a low cost and the temperature for phosphor synthesis can be lowered. This patent application goes on to disclose that Eu halides such as EuF_2, EuF_3, $EuCl_2$, and $EuCl_3$ are [also] preferred since they have an effect of accelerating crystal growth. Eu_2O_3 is particularly preferred, because it is an inexpensive raw material, has a low degree of

Savant Technologies LLC - 1004.523

deliquescency, and enables a synthesis of a high-luminance phosphor at a relatively low temperature. The amounts of the halogen from this source that end up inside the crystal, if any, are not discussed, and certainly the benefits of such a halogen content (such as the potential to getter contaminant oxygen) are not given.

[0070] The effect of the halogen content in the family of $CaAlSiN_3$ phosphors on photoluminescence and chromaticity has not, to the present inventors' knowledge, been disclosed in the literature. In the ensuing discussion, photoemission intensity, peak emission wavelength, and the chromaticity parameters x and y were measured as a function of halogen content, this content providing a baseline level supplied by a halogenated europium source. A control was run for each experiment, for which the phosphor was synthesized using Eu_2O_3 as the europium source, and thus the control samples had no baseline halogen content. In each of the graphs of FIGS. 2-9 there are three curves, one for each of the three europium sources Eu_2O_3, $EuCl_3$, and EuF_3. Thus, the curve from the Eu_2O_3 synthesized phosphor has no baseline halogen; the curve from the $EuCl_3$ synthesized phosphor has a starting level of chlorine of x equal to about 0.04.

[0071] Additional halogen "x" (see formulas) was supplied in the form of NH_4F (FIGS. 2, 3, 6, 7) or NH_4Cl (FIGS. 4, 5, 8, 9), the halogen from this source being the independent variable in the experiment. It was increased from zero to about 0.3, stoichiometrically, to see what effect this had on the optical properties mentioned above. By this method, a particular red nitride of the present embodiments may contain both the halogens F and Cl in its composition, one or the other, or neither of each.

[0072] The first set of data (FIGS. 2-5) is for an exemplary phosphor having the formula $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}(F,Cl)_{0.04+x}$ when the europium source is EuF_3 and $EuCl_3$, respectively, and $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}(F,Cl)_x$ when the europium source (Eu_2O_3) provides no halogen. The phosphors in this family may collectively be designated R630 for their emission color (R = red) and wavelength (in nm). The second set of data (FIGS. 5-8) was generated by analogous experiments on the exemplary phosphors $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}(F,Cl)_{0.04+x}$ and $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}(F,Cl)_x$, again where the composition contains F if the europium source was EuF_3; Cl if the europium source was $EuCl_3$; and no halogen when the europium source was the oxide of europium (Eu_2O_3). The phosphors in this family may collectively be designated R640, again for their red emission color, this time centered at a wavelength of about 640 nm. The oxygen content of the R630 group of phosphors was about 1 weight percent, whereas that for the R640 family about 1.35 weight percent.

Savant Technologies LLC - 1004.524

[0073] FIGS. 2A and 2B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the fluorine content x supplied by NH_4F is increased above various halogen baseline levels; the three R30 compounds being $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_{0.04+x}$ when the europium source is EuF_3; $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_{0.04}F_x$ when the europium source is $EuCl_3$; and $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_x$ when the europium source is Eu_2O_3. It may been seen that for this particular set of compounds, emission wavelength increased as more and more fluorine was added from the NH_4F source, and thus the emission became more red in color. This property is viewed as being especially beneficial when the user is attempting to engineer phosphors having a desired chromaticity with particular color rendering properties. The effect of an increase in wavelength with additional halogen is the same no matter what the nature of the baseline halogen: F, Cl, or no initial halogen in the case of the control (Eu_2O_3). This beneficial effect comes at the expense of a slight loss of photoluminescent intensity (PL decreases as additional halogen above the baseline is incorporated into the crystal), although it is noted that this decrease is not substantial, and many situations are contemplated where it is well worth tolerating in order to achieve the desired chromaticity and color rendering.

[0074] FIGS. 3A and 3B are graphs showing the effects on the CIE coordinates x and y with the same additions of NH_4F to the same three compounds as in FIGS. 2A and 2B. Because of the importance the present embodiments has on chromaticity, it is viewed appropriate to provide a short discussion of what is meant by chromaticity, and the implications of that property on other issues affecting optical performance, such as color temperature and color rendering.

[0075] As described by K. Narisada et al. in "Color Vision," Chapter 17, Section One of the *Phosphor Handbook* (CRC Press, New York, 1999), pp. 799-818, the CIE colorimetric system is derived from three imaginary reference color stimuli (called tristimulus values), generated by comparing a reference (monochromatic wavelength) color with a test color made by the mixing of three primary colors. Test light source colors are specified from the tristimulus values, and used to define the chromaticity coordinates x and y of the light sources. A plot of the x and y coordinates of every color designated by the Intersociety Color Council-National Bureau of Standard (ISCC-NBS) is called the CIE chromaticity diagram, shown in the Phosphor Handbook at page 809.

[0076] K. Narisada et al. further teach the concept of chromatic adaptation, the function of vision that minimizes the influence of the (variable) color of the illumination on the perception of the object being illuminated. Variable color illumination means that the

Savant Technologies LLC - 1004.525

chromaticity coordinates of the light illuminating the object do not always correspond to the perceived colors. One method (proposed by the CIE) of correcting for this lack of correspondence is to objectively define the color of light by "color temperature," the absolute temperature of a black body radiator radiating light with a color the same as the light source. The color of the light source changes from a reddish to a bluish color as the color temperature increases. The "correlated color temperature" is the absolute temperature of a black body radiator closest to the light source when the chromaticity coordinates of the light source do not precisely match the radiator.

[0077] A final property of color vision useful in describing the present nitride-based red phosphors is color rendering, a property of the light source that changes the colors of the object illuminated by that source. The "color rendering index," represented by the parameter R_a, indicates the extent of the color rendering properties of a light source. It is calculated by taking the average of the differences in distance between chromaticity points of the sample and the reference light source for eight different selected object colors. The maximum value of R_a is 100, which means there is no difference between sample and reference source for any of the eight selected colors.

[0078] The color temperature and color rendering index values of exemplary nitride-based phosphors of the present embodiments will be discussed later in a section addressing white light illumination, but the effects of halogen addition the CIE coordinates x and y will be addressed at this time. FIGS. 3A and 3B are graphs showing the effects on the CIE coordinates x and y (respectively) with the same additions of halogen from NH_4F to the same three compounds as in FIGS. 2A and 2B. It will be observed that the x coordinate increases, and they y coordinate decreases, confirming the shift to longer wavelengths and a deeper red color when viewing the CIE chromaticity diagram of the *Phosphor Handbook*.

[0079] FIGS. 4A and 4B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the chlorine content x supplied by NH_4Cl is increased above various halogen baseline levels; the three compounds being $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:F_{0.04}Cl_x$ when the europium source is EuF_3; $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_{0.04+x}$ when the europium source is $EuCl_3$; and $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}:Cl_x$ when the europium source is Eu_2O_3. The trends are the same as those for FIGS. 2A and 2B; that is to say, emission wavelength increased as more and more fluorine was added from the NH_4F source, and thus the emission became more red in color.

[0080] FIGS. 5A and 5B are graphs showing the effects on the CIE coordinates x and y (respectively) with the same additions of halogen from NH_4Cl to the same three compounds

Savant Technologies LLC - 1004.526

as in FIGS. 4A and 4B. It will be observed that, as in the case with the R630 compounds for which NH_4F was added, the x coordinate increases, and they y coordinate decreases, confirming the shift to longer wavelengths and a deeper red color when viewing the CIE chromaticity diagram.

[0081] An analogous set of experiments was carried out with a family of R640 compounds; these results are shown in FIGS. 6-9. FIGS. 6A and 6B are graphs of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the fluorine content x supplied by NH_4F is increased above various halogen baseline levels; the three compounds being $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_{0.04+x}$ when the europium source is EuF_3; $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_{0.04}F_x$ when the europium source is $EuCl_3$; and $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_x$ when the europium source is Eu_2O_3. It may been seen that for this particular set of compounds, emission wavelength again increases as more fluorine is added from the NH_4F source, and thus the emission becomes more red in color. The photoluminescence graph shows that photoluminescence is not affected as adversely as it was in the case of the R630 compound. CIE changes for those compounds are shown in FIGS. 7A and 7B.

[0082] FIGS. 8A and 8B are of the emission wavelength and photoluminescence (PL), respectively, of the changes that occur when the chlorine content x supplied by NH_4Cl is increased above various halogen baseline levels; the three compounds being $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:F_{0.04}Cl_x$ when the europium source is EuF_3; $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_{0.04+x}$ when the europium source is $EuCl_3$; and $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}:Cl_x$ when the europium source is Eu_2O_3. Following the trend set by the R630 compounds, these R640 compounds show an increase in emission wavelength as chlorine is added, and photoluminescent intensity decreases somewhat as well. CIE changes for those compounds are shown in FIGS. 9A and 9B.

[0083] Photoluminescence as a function of emission wavelength for both the R630 and R640 type of compounds, when no additional halogen is provided by a flux such as NH_4F or NH_4Cl, is shown in FIGS. 10A-B. In both cases (R630 and R640) the fluorinated versions demonstrated the highest intensities, followed by the chlorinated versions. The non-halogenated versions (provided by synthesizing R630 and R640 with the oxide of europium, Eu_2O_3, so that no halogen was added) showed the lowest intensities. The order of the compounds exhibiting the longest emission wavelength was different, however, with the non-halogenated compound having the longest wavelength in R630, and the shortest of the respective series in R640.

Savant Technologies LLC - 1004.527

[0084] Since fluorine doping of R630 and R640 was shown to provide the highest photoluminescent intensity (FIGS. 10-A-B), the two were compared on the same graph, in FIG. 10C (notwithstanding a slight variation in the R640 formula), along with another nitride-based phosphor having the formula $Ca_{0.157}Sr_{0.808}AlSiN_3Eu_{0.035}$, designated R645. This nomenclature comes from the phosphor emitting at 645 nm; the reader will note in FIG. 10C that it also had the lowest intensity when compared to R630 and R640. FIG. 10C is a collection of emission spectra of the nitride-based red phosphors having the designations R630, R640, and R645, the numbers in the designations indicating roughly the peak emission wavelength of that particular phosphor. The formulas of those three phosphors are, respectively, $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$ (R630), $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$, (R640), and $Ca_{0.157}Sr_{0.808}AlSiN_3Eu_{0.035}$ (R645), where EuF_3 was used as the source of europium in each of the three compositions. This data set shows that photoluminesce intensity decreases with increasing peak emission wavelength.

[0085] In the experiments described above that investigated the influence of a halogen inclusion, one will have observed that, to various degrees, strontium (Sr) was used to substitute for calcium (Ca). The effect of strontium substitution in a $CaAlSiN_3$ host will be investigated more thoroughly in the next section, along with a few other elemental substitutions and inclusions.

[0086] Optical properties of compositions having Sr substitute for Ca

[0087] The effect of varying the ratio of the two divalent elements, when those elements are strontium and calcium, is shown in FIG. 11. In FIG. 11 the inclusion of the second divalent metal Sr is shown increasing from left to right along the x-axis of the graph, from a value of no strontium (x=0) to a value of 100% (where there is no calcium at x=1).

[0088] FIG. 11 contains two parts: the first is peak emission wavelength shown in FIG. 11A, and the second is photoluminescent (PL) value shown in FIG. 11B. The tested samples are compounds having the general formula $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$. Thus, the two divalent elements that are simultaneously present in this phosphor are calcium and strontium, with the exceptions of the endpoints, shown for comparison where only one metal is present. The results in FIG. 1 show that as the strontium content "x" is increased from 0 to 1, the wavelength of the peak emission first increases slightly, meaning that the emission is becoming more red (where the longest wavelength occurs at x=0.2); then decreases gradually, from a maximum of about 660 nm (x=0.2) to final value of about 637 nm (at x=1). The

Savant Technologies LLC - 1004.528

photoluminescence in FIG. 11B is generally about constant between x=0 to x=0.8, but then decreases substantially as the strontium content is increased from x=0.8 to x=0.9.

[0089] FIG. 12 is a collection of normalized emission spectra (FIG. 12A), to show the effect of maximum emission wavelength of a high ratio of Sr to Ca in the present phosphors; and emission spectra that has not been normalized (Fig. 12B) of the same two compounds having the formula $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$ with x=0.82 and x=0, respectively, to show relative brightness. The emission peak wavelength changed as much as about 20 nm, from 658nm to 638 nm for x=0 and x=0.82, respectively, but the x=0.82 strontium content doped samples are brighter as well.

[0090] FIG. 13 shows the effect of doping the present nitride-based red phosphors with further amounts of an alkaline earth metal; specifically, Ca, Sr, and Ba replacing a portion of the Ca/Sr mix discussed in previous paragraphs. Here the compound under study had the formula $Ca_{0.2}Sr_{0.74}AlSiM_{0.05}N_3Eu_{0.01}$, where M was Ca, Sr, Ba, respectively, with M as 0 being used as a control for the experiment. The europium source was the fluorinated EuF_3; likewise, alkaline earth fluorides were used as the sources of the Ca, Sr, and the Ba. This data set shows that the peak emission wavelength shifts to longer wavelengths with the addition of the 5% alkaline earth metal. The order of the wavelength increase was Ca, then, Sr, and finally Ba.

[0091] FIGS. 14A and 14B are a collection of emission wavelengths, the raw data shown in FIG. 14A, and a normalized version shown in FIG. 14B, for a nitride-based red phosphor with a 5% level of a group IIIA (of the periodic table) metal M, where M is in this example either boron or gallium. These doping metals (semiconductors and/or semi-metals) are shown in the following formula as substituting for the trivalent metal aluminum: $Ca_{0.2}Sr_{0.79}Al_{0.95}SiM_{0.05}N_3Eu_{0.01}$:F. Again, EuF_3 was used as the source of both the activator europium, as well as the halogen dopant that substitutes for nitrogen. Here, the peak emission wavelength shifted to longer wavelengths (shown best in the normalized data set of FIG. 14B), and the photoluminescence decreased (shown best in the non-normalized data set of FIG. 14A), with the addition of the 5% alkaline earth metal, in the order of boron and gallium.

[0092] <u>The activator</u>

[0093] FIG. 15A is a graph showing peak emission wavelength changes as a function of Eu source and content, where Eu sources include the oxide, fluoride, and chloride salts of the europium metal. The compound chosen for this study was $Ca_{0.2}Sr_{0.8-x}AlSiN_3Eu_x$, where the parameter "x" represents the amount of the Eu activator present; its value ranging from 0.005

Savant Technologies LLC - 1004.529

to 0.015 in this experiment. The data shows that the peak emission wavelength shifts to longer wavelengths (a deeper red color) as the Eu content is increased, with the phosphors synthesized from the fluoride of europium showing the longest wavelengths of the group. The phosphors synthesized from the chlorides of europium demonstrated the shortest wavelengths with the oxides in the middle of the data set: this set shows that a particularly desired emission wavelength may be achieved via the proper selection of starting materials (in this case, the nature of the europium source).

[0094] Not only do the EuF_3 generated samples emit at longer wavelengths than Eu_2O_3 based samples having the same europium content, but the EuF_3 generated samples are brighter as well. This is illustrated in FIG. 15B. The data in FIG. 15B is in a format that is similar to that of FIG. 15A, but this time photoluminescence (PL) is plotted as a function of europium content. Again, data was collected for three types of compounds; those synthesized from the fluorides, chlorides, and oxides of the europium metal. Here, the photoluminescence first increased as the europium content was increased, reaching a maximum at a content of about 0.01. Higher than values of 0.01, values to 0.015, the photoluminescence either leveled off, or decreased slightly for the three variations of $Ca_{0.2}Sr_{0.8-x}AlSiN_3Eu_x$. While it is not precisely known whether this is due to the inclusion of halogen or absence of oxygen (by a halogen-instigated oxygen gettering effect), it is recognized that either way, the effect is advantageous.

[0095] Activators that may be used in conjunction with the present red nitrides, in particular the rare earths, include Mn, La, Ce, Pr, Nd, Pm, Sm, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu. These activators may be used in any combination, and in the desired amounts, up to and including 5 atomic percent.

[0096] <u>Excitation spectra of the present nitride-based red phosphors</u>

[0097] FIG. 16 is a collection of excitation spectra for the R630 composition having the formula $Ca_{0.2}Sr_{0.8}AlSiN_3Eu_{0.01}$, and the R640 composition having the formula $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$. Excitation spectra are taken by measuring the photoluminescence at a chosen wavelength, in this case around 630 to 640 nm, as a function of the wavelength of the incoming excitation radiation used to cause the phosphor(s) to photoluminesce. In this experiment, the wavelength of the excitation radiation was increased from about 400 nm, which lies in the UV to visible purple range of the electromagnetic spectrum, to about 600 nm, which is orange and approaching red. The data shows that the exemplary phosphors of

Savant Technologies LLC - 1004.530

the present embodiments are efficient at photoluminescing when the wavelength of the excitation radiation ranges from about 400 to about 550 nm (yellow).

[0098] The present phosphors may also be activated in the ultraviolet and near-ultraviolet, at wavelengths ranging from about 250 to 400 nm.

[0099] X-ray diffraction (XRD) pattern of the present nitride-based red phosphors

[0100] An x-ray diffraction (XRD) pattern of one of the typical compositions of the present embodiments is shown in FIG. 17. The particular compound examined was $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$:F. It may be seen that this compound has the $CaAlSiN_3$-type structure by comparing its x-ray diffraction pattern (FIG. 17 of the present disclosure) with the patterns of a $CaAlSiN_3$ host, and $CaAlSiN_3$ host activated with Eu (FIGS. 1-1 and 1-2 of US 2007/000749, respectively).

[0101] Nitride-based, red-emitting phosphors of the present embodiments, even with large amounts of Sr present and replacing Ca, may be identified by the presence of what is perhaps the highest intensity diffraction peak at a 2θ of about 36 degrees, representing diffraction from the (311) plane; another high intensity at about 35 degrees from the (002) peak; a peak at about 32 degrees from the (310) plane; a set of peaks at 40-41 degrees from the (221) plane; and a set of peaks at 48 degrees from the (312) and/or (022) planes. That the intensities of the peaks in FIG. 17 of the present disclosure differ from those of US 2007/000749, with respect to the (hkl) planes identified above, is indicative of a slight shifting of the atomic positions within the unit cell as a result of the substitutions and inclusions of the present compounds.

[0102] Distribution of halogen on nitrogen sites, oxygen gettering by halogen, and oxygen content

[0103] Embodiments of the present invention are directed to the fluorescence of a nitride-based deep-red phosphor having at least one of the following novel features: 1) an oxygen content less than about 2 percent by weight, and 2) a halogen content of virtually any amount. Such phosphors are particularly useful in the white light illumination industry, which utilizes the so-called "white LED," as well as in backlighting applications, which also utilize white light. The selection and use of a rare earth halide as a raw material source of not only the rare earth activator for the phosphor, but also the halogen, is a key feature of the present embodiments. While not wishing to be bound by any particular theory, it is believed the halogen may play a dual role in enhancing the properties of these phosphors: by reducing the

Savant Technologies LLC - 1004.531

oxygen content in addition to causing an increase in photoluminescent intensity and spectral emission.

[0104] Apart from an advantage of mechanical rigidity there is another consequence of the $CaAlSiN_3:Eu^{2+}$-type structures of the present embodiments with two types of nitrogen sites; and that is that the distribution of halogen dopants and/or and oxygen impurities is not random. Hirosaki et al. describe in U.S. Publication No. 2007/0007494 how in such a situation the "N is replaced with one or two or more elements selected from the group consisting of O and F." But Hirosaki et al. do not say *how* the O and F replace N, and they do not teach the gettering abilities of the halogen that are believed by the present inventors to reduce oxygen contamination. Using a nomenclature whereby a nitrogen site corner-shared by two Al/Si tetrahedral is designated as N2, and a nitrogen vertex corner-shared by three Al/Si tetrahedra as N3, the present inventors propose that, in at least some situations, the oxygen impurity occupies an N2 site because the O^{2-} valence (2-) is lower than that of the N^{3-} valence (3-). If this is so, then it stands to reason that the monovalent halogen ions F^- and Cl^- also prefer to occupy N2 sites, rather than N3 sites, for the same reasons of free energy minimization. In one embodiment of the present invention, oxygen and halogen compete for the same atomic positions in the unit cell. Another way of describing the two types of nitrogen sites is that the N2 site is 2-fold coordinated, and the N3 site is 3-fold coordinated.

[0105] According to embodiments of the present invention, at least half (50 percent) of the halogen content (either by weight or by number) resides on N2 sites rather than N3 sites. In another embodiment, at least 80 percent of the halogen content (either by weight or by number) resides on N2 sites as opposed to N3 sites. In some embodiments, the desired distribution of halogen on the N2 relative to N3 sites may be achieved by synthesizing the phosphor according to liquid mixing methods, including liquid precipitation, and the sol gel technique. But regardless of the synthetic method, which means that including solid state reaction mechanisms, the present inventors believe that their method of halogen inclusion is related to a low oxygen impurity content. "Low oxygen impurity content" means less than about 2 weight percent oxygen. In some embodiments, low oxygen impurity means less than about 1.9 weight percent oxygen, and less than about 1.8 weight percent oxygen.

[0106] Oxygen impurity has been discussed by the present inventors in a co-pending application titled "Nitride-based red phosphors," filed October 13, 2008, having application serial number 12/250,400. Application 12/250,400 is hereby incorporated herein in its entirety. That application discussed U.S. Pat. 7,252,788 to Nagatomi et al., who discovered and disclosed in U.S. Pat. 7,252,788 that when the oxygen content in the phosphor is large,

Savant Technologies LLC - 1004.532

the emission efficiency decreased (not desirable), and the emission wavelength of the phosphor also tended to shift to a shorter wavelength side. This latter observation is also undesirable because most (if not all) manufacturers are attempting to add a phosphor that is deeper in the red region (i.e., less orange or yellow) for the color rendering benefits a red phosphor offers to the white LED industry. Nagatomi et al. continue: the phosphor they provided includes no oxygen in the host material, with the benefits of exhibiting a higher emission efficiency, and avoiding the shift of the emission wavelength to the shorter wavelength side [of the spectrum].

[0107] But this is more easily stated than accomplished. Oxygen contamination was addressed by Nagatomi et al. in US 2006/0017365, where it is taught that the source is believed to be the oxygen adhering to the surface of the raw materials, and thus introduced at the start of the synthesis; oxygen added as a result of oxidation of the surface of the raw materials at the time of preparation for firing, and the actual firing, and the oxygen adsorbed onto the surface of the phosphor particles after firing.

[0108] A discussion of oxygen measurements, and an analysis of the possible causes for a discrepancy between measured and calculated values, was also given by Nagatomi et al. in US 2006/0017365. The oxygen content that was measured in their sample was 2.4 percent by weight, to be contrasted with a calculated oxygen concentration of 0.3 percent by weight. The origin of this approximately 2 percent by weight difference between the measured value (with its so-called "excessive oxygen") versus the calculated amount was attributed to oxygen originally adhering to the surface of the raw materials at the time of preparation of the firing and at the time of firing, and the oxygen adsorbed onto the surface of the phosphor specimen after the firing.

[0109] The oxygen content in Nagatomi et al.'s samples of U.S. Pat. 7,252,788 similarly show a 2 plus percent by weight value: 2.2, 2.2, and 2.1 in Tables 1 and 3.

[0110] Hirosaki et al. (US 2007/0007494) teach a $CaAlSiN_3$ family of crystal phases, where the "N is replaced with one or two or more elements selected from the group consisting of O and F." In the case of oxygen, its content in a $CaAlSiN_3$:Eu phosphor was measured. A synthesized compound having the intended formula $Eu_{0.008}Ca_{0.992}AlSiN_3$ was pulverized and a compositional analysis performed by ICP emission spectrometry. The oxygen and nitrogen in the sample were measured in a LECO model TC-436 oxygen and nitrogen analyzer. The oxygen content was determined to be 2.0 ± 0.1 % by weight, and its presence was attributed to oxygen impurities contained in the nitrides of the metals (Si, Al, Ca) used as starting materials. Thus the composition of the synthesized inorganic compound,

Savant Technologies LLC - 1004.533

calculated from the analytical results, is $Eu_{0.0078}Ca_{0.9922}Si_{0.9997}Al_{0.9996}N_{2.782}O_{0.172}$. The fluorine content was not measured in any of the samples.

[0111] Measured oxygen content of the present R630 phosphors, whose formulas have been given in preceeding sections, are about 1 weight percent. The measured oxygen content of the R640 phosphors was about 1.35 weight percent.

[0112] Application in backlighting and white light illumination systems

[0113] According to further embodiments of the present invention, the present red phosphors may be used in white light illumination systems, commonly known as "white LEDs," and in backlighting configurations for display applications. Such white light illumination systems comprise a radiation source configured to emit radiation having a wavelength greater than about 280 nm; and a halide anion-doped red nitride phosphor configured to absorb at least a portion of the radiation from the radiation source, and emit light with a peak intensity in a wavelength range greater than or equal to about 630 nm. Exemplary spectra of light intensity versus wavelength emitted by these warm white luminescent systems are shown in FIGS. 18A-18E. The properties of the present nitride-based, red phosphors are also suitable as components of a backlighting illumination system.

[0114] For these applications, the present nitride-based red phosphor may combined with any of a yellow, green, or orange emitting phosphor, used either singly or in any variety of combinations as desired, in a phosphor mix or package. The yellow, green, or orange phosphors may be either aluminate or silicate-based. Exemplary yellow, yellow-green, and green silicate-based phosphors may be of the form M_2SiO_4, where M is a divalent metal such as an alkaline earth (e.g., Mg, Ca, Sr, and Ba, singly or in combinations), or other such elements such as Zn. Exemplary orange silicate-based phosphors may be of the form M_3SiO_5, where M is defined as above in this paragraph. These silicate-based orange and/or green phosphors may additionally contain a halogen such as F or Cl, and in some embodiments, this halogen anion substitutes for oxygen and may reside on oxygen lattice sites in the crystal.

[0115] Exemplary silicate-based yellow-green phosphors that are particularly suitable for combination with the present nitride-based red phosphors have been described by the present inventors in U.S. Pat. 7,311,858 to Wang et al. The phosphors disclosed in the patent have the formula $M_2SiO_4:Eu^{2+}D$, where M is a divalent metal selected from the group consisting of Sr, Ca, Ba, Mg, Zn, and Cd, and D is a dopant selected from the group consisting of F, Cl, Br, I, P, S, and N. The dopant D is present in the phosphor in amounts ranging from about 0.01 to about 20 mole percent, and at least some of the dopant anions substitute for oxygen

Savant Technologies LLC - 1004.534

anions. These silicate-based phosphors are configured to absorb radiation in a wavelength ranging from about 280 nm to about 490 nm, and to emit visible light in wavelengths ranging from about 460 to about 590 nm. U.S. Pat. 7,311,858 is incorporated herein in its entirety.

[0116] Exemplary silicate-based green emitting phosphors suitable for use with the present red nitrides have been described by the present inventors in the Patent Application Publication US 2006/0145123 to Cheng et al. These phosphors are also of the M_2SiO_4 form, specifically having the formula $(Sr,A_1)_x(Si,A_2)(O,A_3)_{2+x}:Eu^{2+}$, where A_1 is at least one divalent cation selected from the group consisting of Mg, Ca, Ba, or Zn, or a combination of 1+ and 3+ cations; A_2 is a 3+, 4+, or 5+ cation, including at least one of B, Al, Ga, C, Ge, N, and P; A_3 is a 1-, 2-, or 3- anion, including any of F, Cl, Br, and S. In this formulation, x is any value between 1.5 and 2.5, both inclusive. The formula is written to indicate that the A_1 cation replaces Sr; the A_2 cation replaces Si, and the A_3 anion replaces O. The amounts of the A_1, A_2, and A_3 ions (whether cationic or anionic) each range from about 0 to about 20 mole percent. Patent Application Publication US 2006/0145123 is incorporated herein in its entirety.

[0117] Exemplary silicate-based orange emitting phosphors suitable for use with the present red nitrides have been described by the present inventors in the Patent Application Publication US 2007/0029526 to et al. These phosphors are also of the M_3SiO_5 form, specifically having the formula $(Sr_{1-x}M_x)_yEu_xSiO_5$, where M is at least one of a divalent metal selected from the group consisting of Ba, Mg, Ca, and Zn; $0<x<0.5$; $2.6<y<3.3$, and $0.001<z<0.5$. Patent Application Publication US 2007/0029526 is incorporated herein in its entirety.

[0118] Specific combinations of orange-emitting silicates and the present red emitting nitrides; green-emitting silicates and the present red emitting nitrides; various combinations thereof (meaning combinations of orange and green-emitting silicates with the present red emitting nitrides), for use in backlighting and warm white light illumination systems, will be described next. Exemplary data is shown in FIGS. 18A-18E, and the combinations are: a green phosphor emitting at about 525 nm (EG525) plus the R630 red phosphor previously described (FIG. 18A); the same green EG 525 nm phosphor in combination with the R640 phosphor previously described (FIG. 18B); a green phosphor emitting at about 540 and the R630 red nitride (FIG. 18C); the green EG540 phosphor in combination with the red R640 phosphor (FIG. 18D), and finally, a three-component system having a green phosphor EG540, an orange phosphor emitting at 586 nm (designated O586), and the red R640 nitride (FIG.

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18E). Each of the red nitride phosphor compositions may have oxygen contents that are less than or equal to about 2 weight percent.

[0119] The compositions of the red nitrides used in the examples of FIGS. 18A-18E are as follows: the R630 phosphor has the formula $Ca_{0.2}Sr_{0.8}AlSiN_3Eu_{0.01}$:F, and the R640 phosphor has the formula $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$:F. The green phosphor EG540 is the chlorinated version of an M_2SiO_4 silicate, and has the formula $Sr_{0.925}Ba_{1.025}Mg_{0.05}Si_{1.03}(O,Cl)_4:Eu^{2+}$. The EG540 green phosphor is also chlorinated, having the formula $Sr_{1.15}Ba_{0.8}Mg_{0.05}Si_{1.03}(O,Cl)_4:Eu^{2+}$. The O586 orange phosphor is a fluorinated version of the M_3SiO_5 silicate, and this particular phosphor has the formula $Sr_3Eu_{0.06}Si_{1.02}O_5F_{0.18}$.

[0120] Each of the figures gives the CIE x and y coordinates for the white light illumination resulting from these exemplary combinations, the color coordinated temperature (CCT), the brightness, and the color rendering index R_a. Although specific examples of yellow, green, and orange phosphors that may be used in conjunction with the present nitride-based red phosphors, this is not to say the present red nitrides are restricted to use with those phosphors. According to embodiments of the present invention, the present nitride-based red phosphors (having a desired distribution of the halogen over N2 and N3 sites, and/or having an oxygen content less than about 2 weight percent), may be used with virtually any blue, yellow, green, orange, or other type of red phosphor, regardless of structure or chemical makeup, in the white LED and backlighting display arts.

[0121] Many modifications of the exemplary embodiments of the invention disclosed above will readily occur to those skilled in the art. Accordingly, the invention is to be construed as including all structure and methods that fall within the scope of the appended claims.

Savant Technologies LLC - 1004.536

CLAIMS

WHAT IS CLAIMED IS:

1. A nitride-based, red emitting compound of the type $(Ca,Sr)AlSiN_3:Eu^{2+}$, wherein the impurity oxygen content is less than about 2 percent by weight.

2. A nitride-based, red emitting compound of the type $(Ca,Sr)AlSiN_3:Eu^{2+}$, further comprising a halogen whose content ranges from greater than about zero to about 2 atomic percent.

3. The compound of claim 2, wherein the halogen is selected from the group consisting of F and Cl.

4. The compound of claim 2, wherein at least half of the halogen is distributed on 2-fold coordinated nitrogen (N2) sites relative to 3-fold coordinated nitrogen (N3) sites.

5. An RGB lighting system for use in a white LED or backlighting display application, the RGB lighting system comprising:

the nitride-based, red-emitting phosphor according to claim 1,

a green phosphor, and

a blue LED emitting in a wavelength ranging from about 400 nm to about 550 nm.

6. An RGB lighting system for use in a white LED or backlighting display application, the RGB lighting system comprising:

the nitride-based, red-emitting phosphor according to claim 2,

a green phosphor, and

a blue LED emitting in a wavelength ranging from about 400 nm to about 550 nm.

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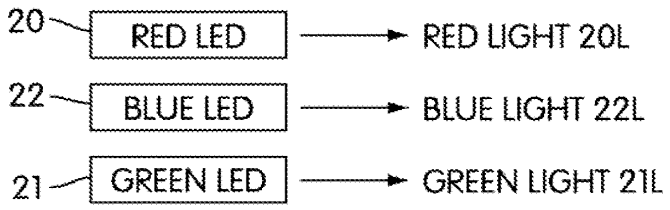

20
RED LED
RED LIGHT 20L
22
BLUE LED
BLUE LIGHT 22L
21
GREEN LED
GREEN LIGHT 21L

Fig. 1A

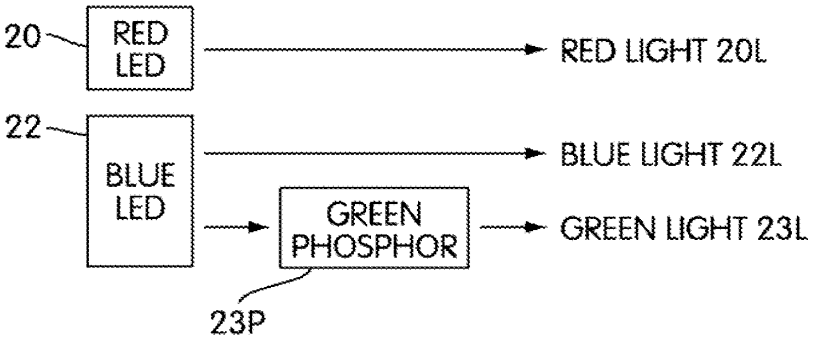

20
RED LED
RED LIGHT 20L
22
BLUE LED
BLUE LIGHT 22L
GREEN PHOSPHOR
GREEN LIGHT 23L
23P

Fig. 1B

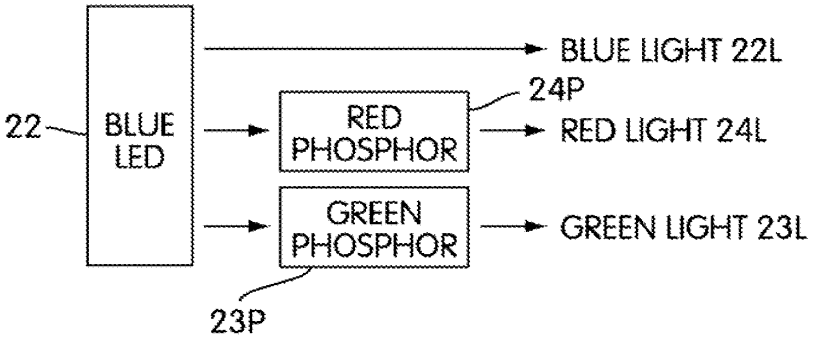

22
BLUE LED
BLUE LIGHT 22L
24P
RED PHOSPHOR
RED LIGHT 24L
GREEN PHOSPHOR
GREEN LIGHT 23L
23P

Fig. 1C

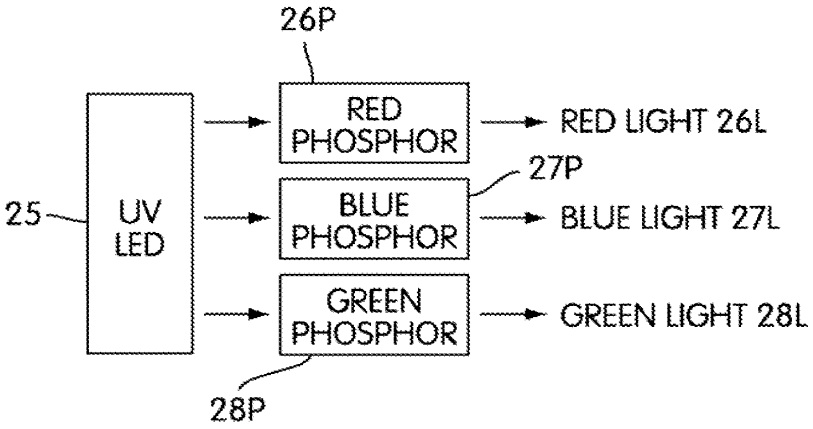
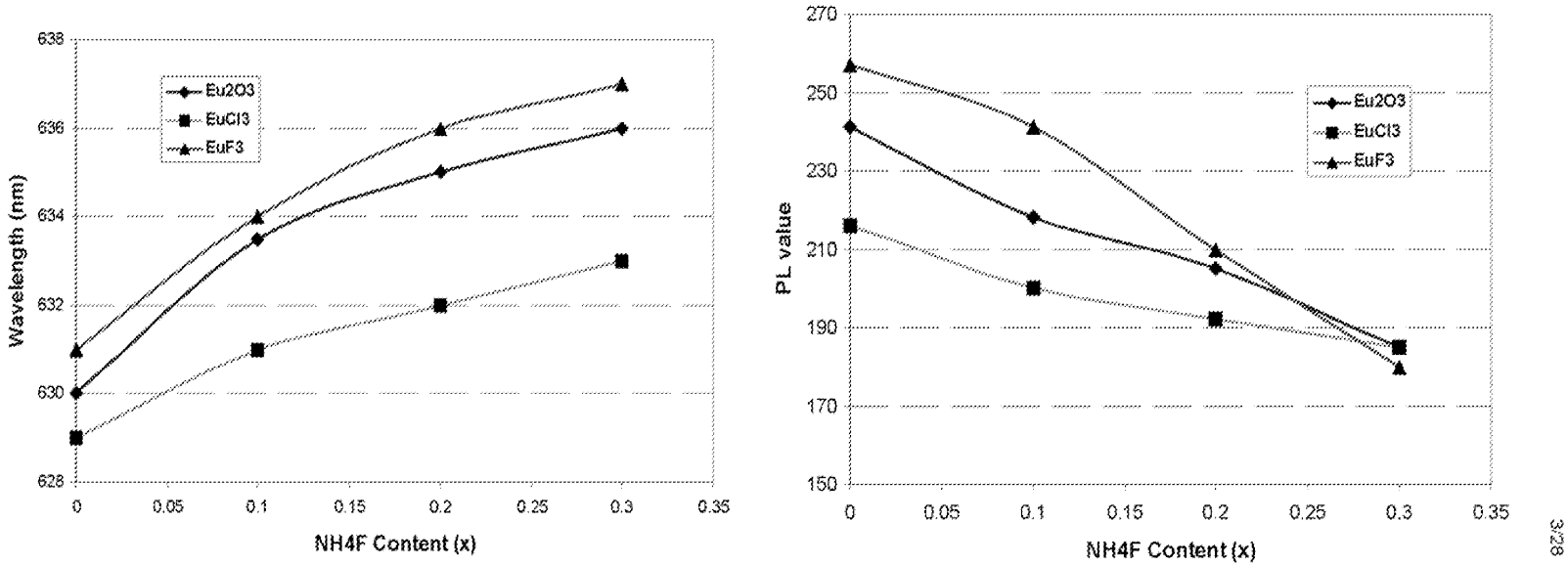

26P
RED PHOSPHOR
RED LIGHT 26L
25
UV LED
27P
BLUE PHOSPHOR
BLUE LIGHT 27L
GREEN PHOSPHOR
GREEN LIGHT 28L
28P

Fig. 1D



(a) (b)

Fig. 2 Wavelength (a) and PL Value (b) Changes with added NH4F content (x) in $Ca_{0.2}Sr_{0.79}Al\ SiN_3Eu_{0.01}F_x$ (R630), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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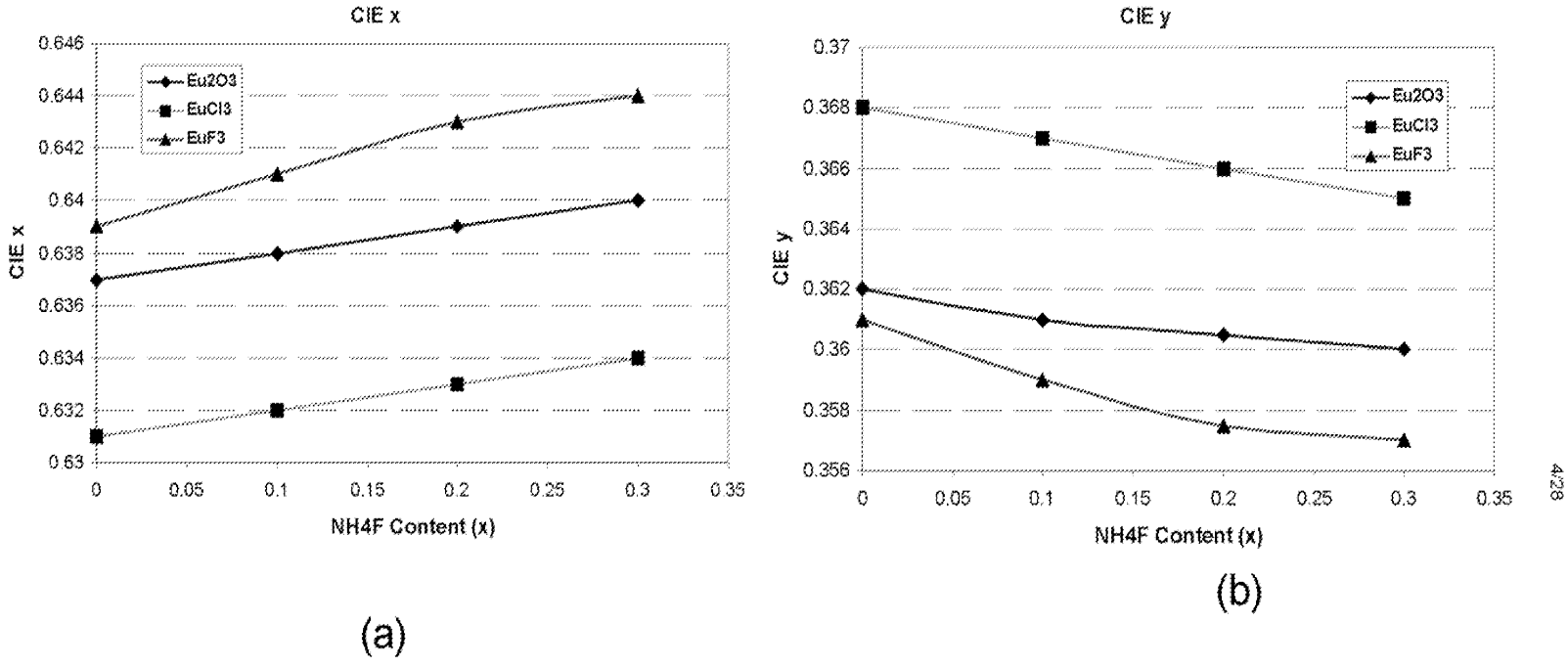
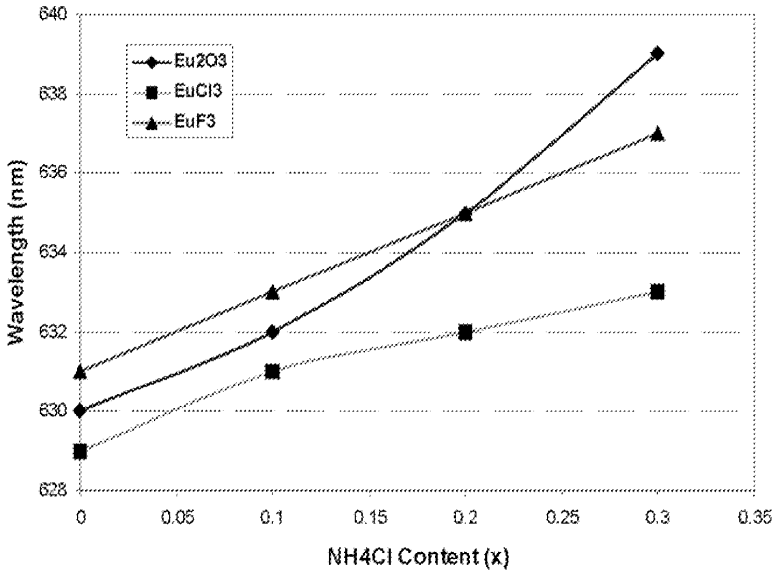
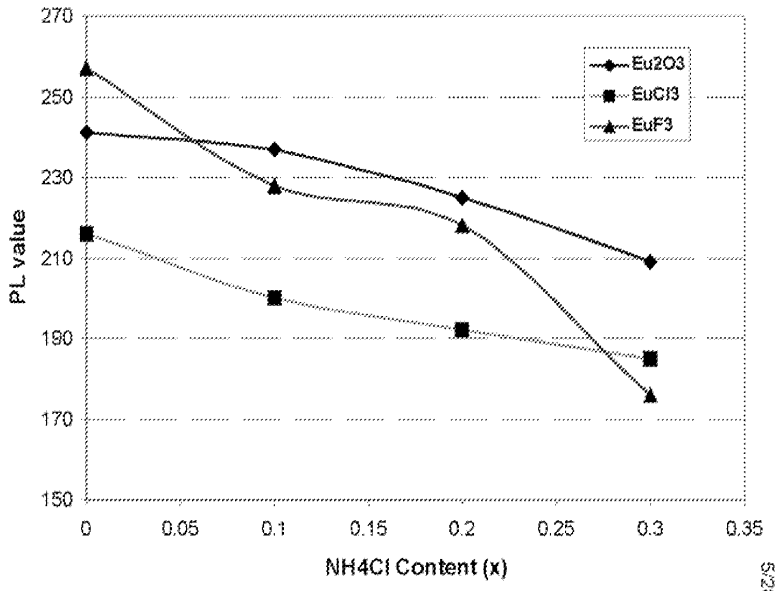


Fig. 3 CIE x (a) and CIE y (b) Changes with added NH4F content (x) in $Ca_{0.2}Sr_{0.79}Al\ SiN_3Eu_{0.01}F_x$ (R630), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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(a)



(b)

Fig. 4 Wavelength (a) and PL Value (b) Changes with added NH4Cl content (x) in $Ca_{0.2}Sr_{0.79}Al\ SiN_3Eu_{0.01}:Cl_x$ (R630), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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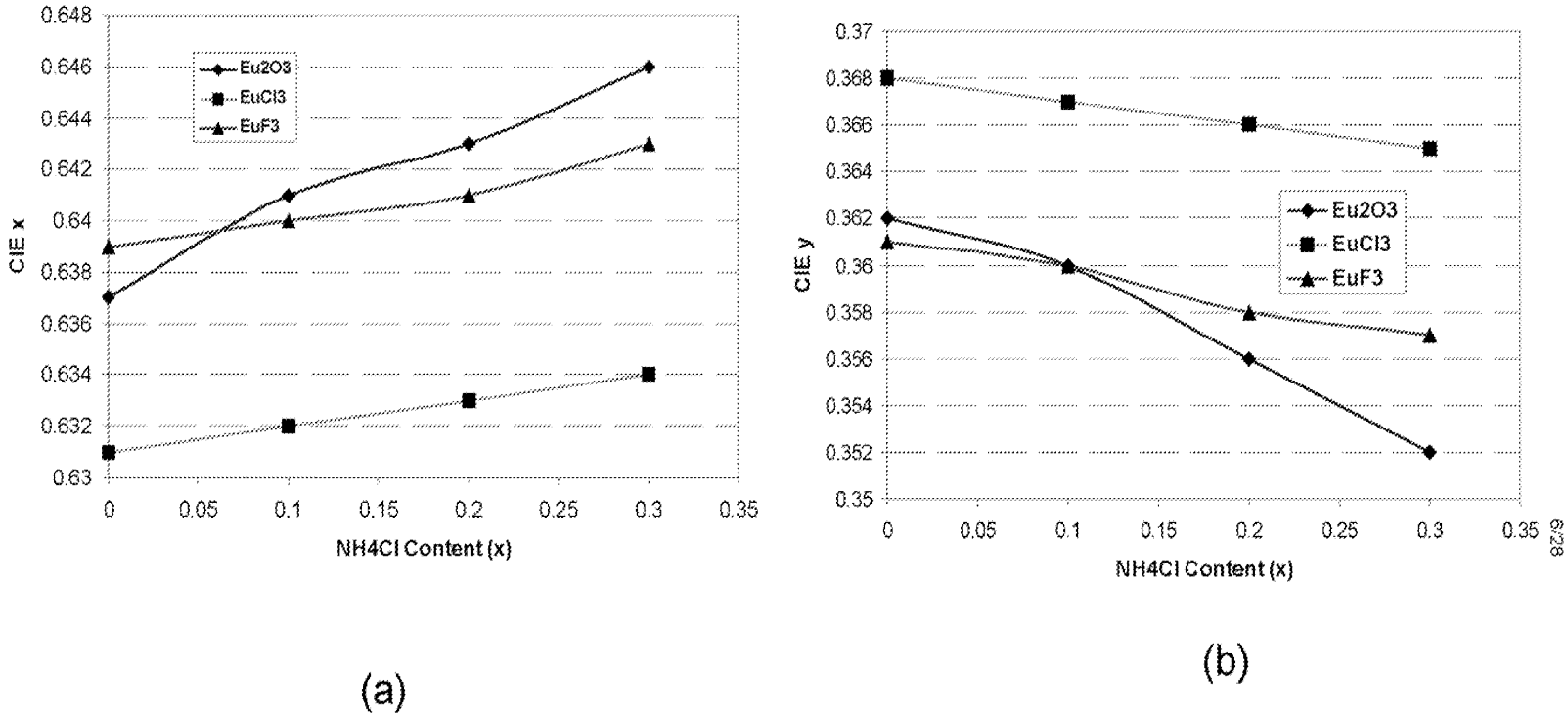
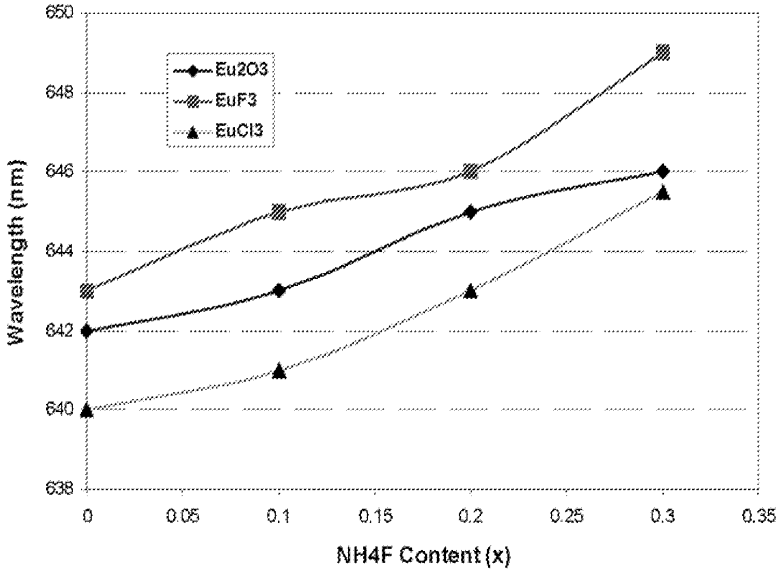
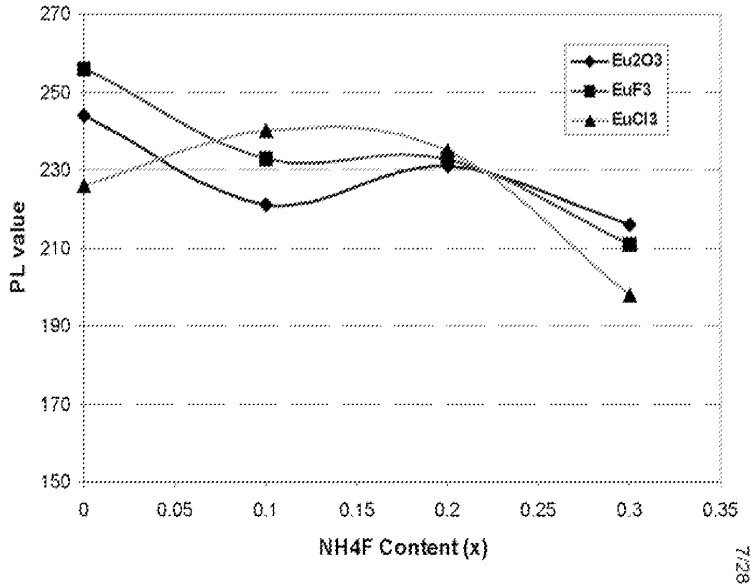


Fig. 5 CIE x (a) and CIE y (b) Changes with added NH4Cl content (x) in $Ca_{0.2}Sr_{0.79}Al\ SiN_3Eu_{0.01}Cl_x$ (R630), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)



(a)



(b)

Fig. 6 Wavelength (a) and PL Value (b) Changes with added NH4F content (x) in $Ca_{0.16}Sr_{0.82}Al\ SiN_3Eu_{0.02}:F_x$ (R640), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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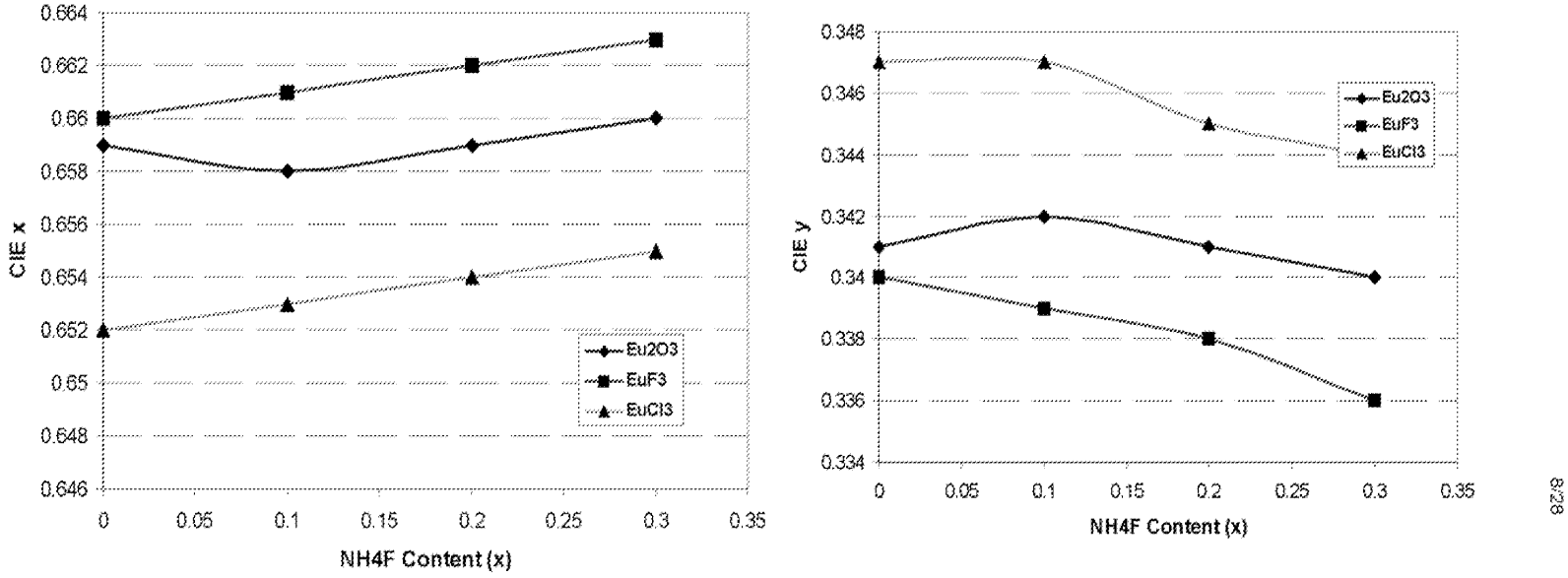


Fig. 7 CIE x (a) and CIE y (b) changes with added NH4F content (x) in $Ca_{0.16}Sr_{0.82}Al\ SiN_3Eu_{0.02}F_x$ (R640), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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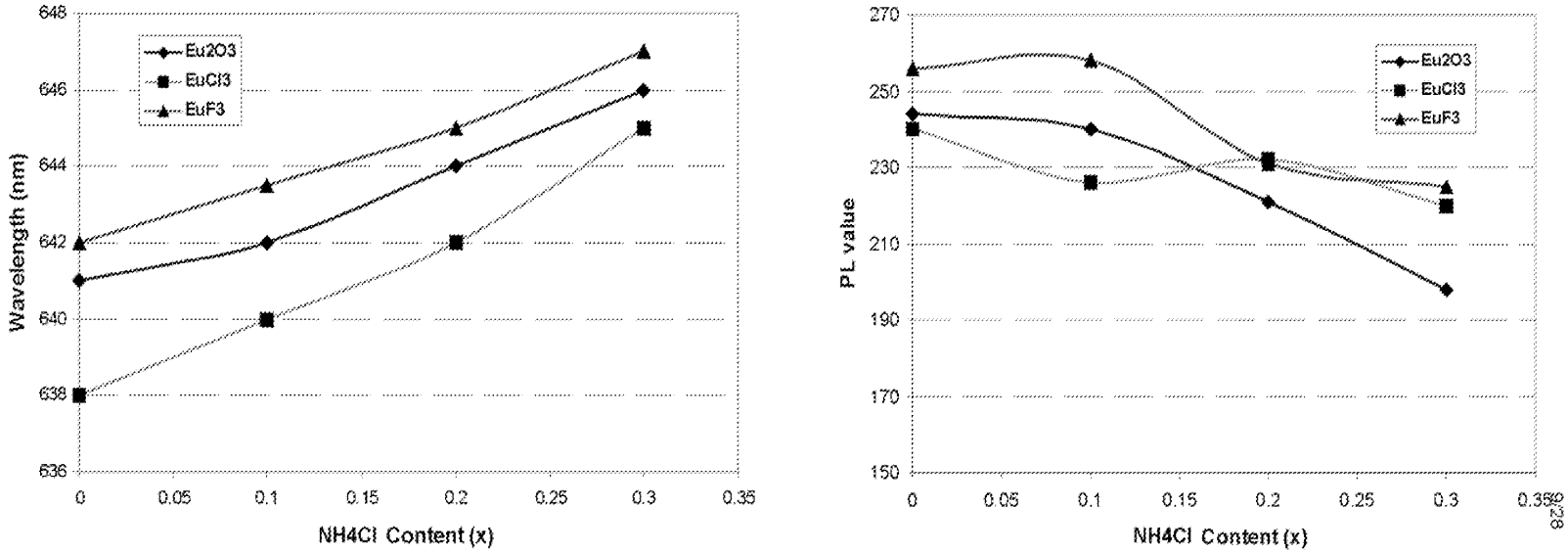


Fig. 8 Wavelength (a) and PL value (b) changes with added NH4Cl content (x) in $Ca_{0.16}Sr_{0.82}Al\ SiN_3Eu_{0.02}Cl_x$ (R640), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

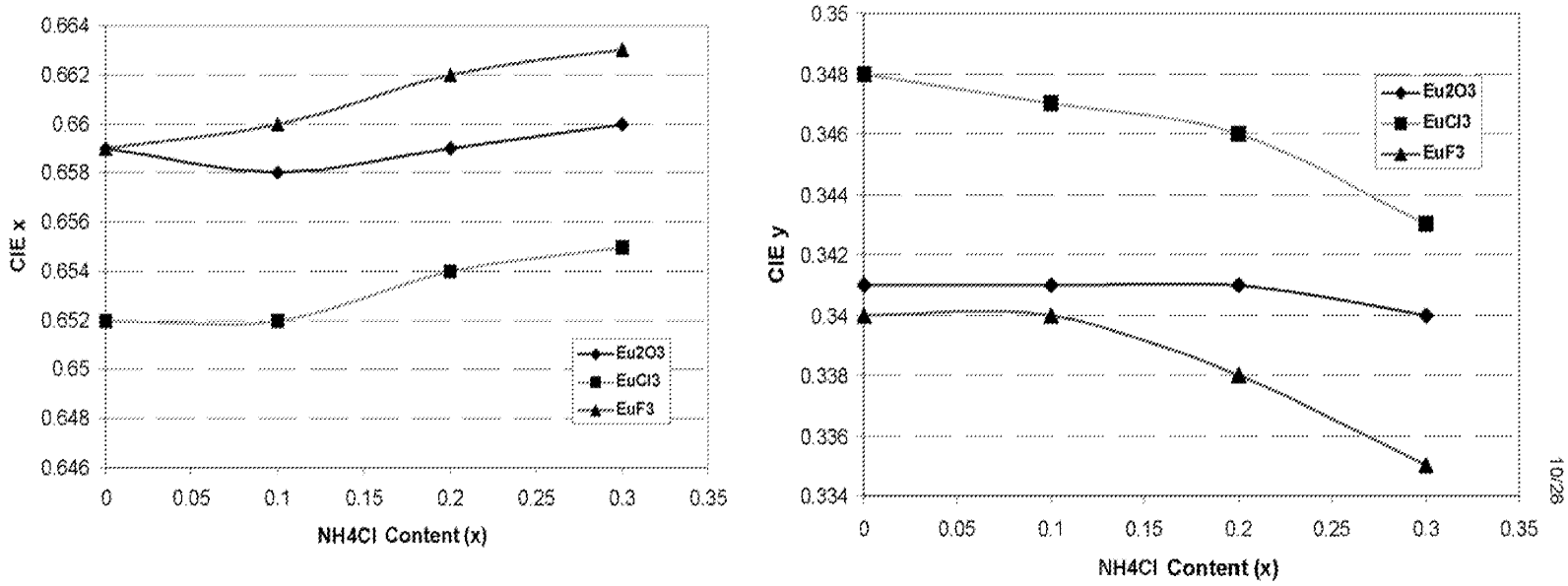


Fig. 9 CIE x (a) and CIE y (b) changes with added NH4Cl content (x) in $Ca_{0.16}Sr_{0.82}Al\ SiN_3Eu_{0.02}Cl_x$ (R640), respectively; (Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively)

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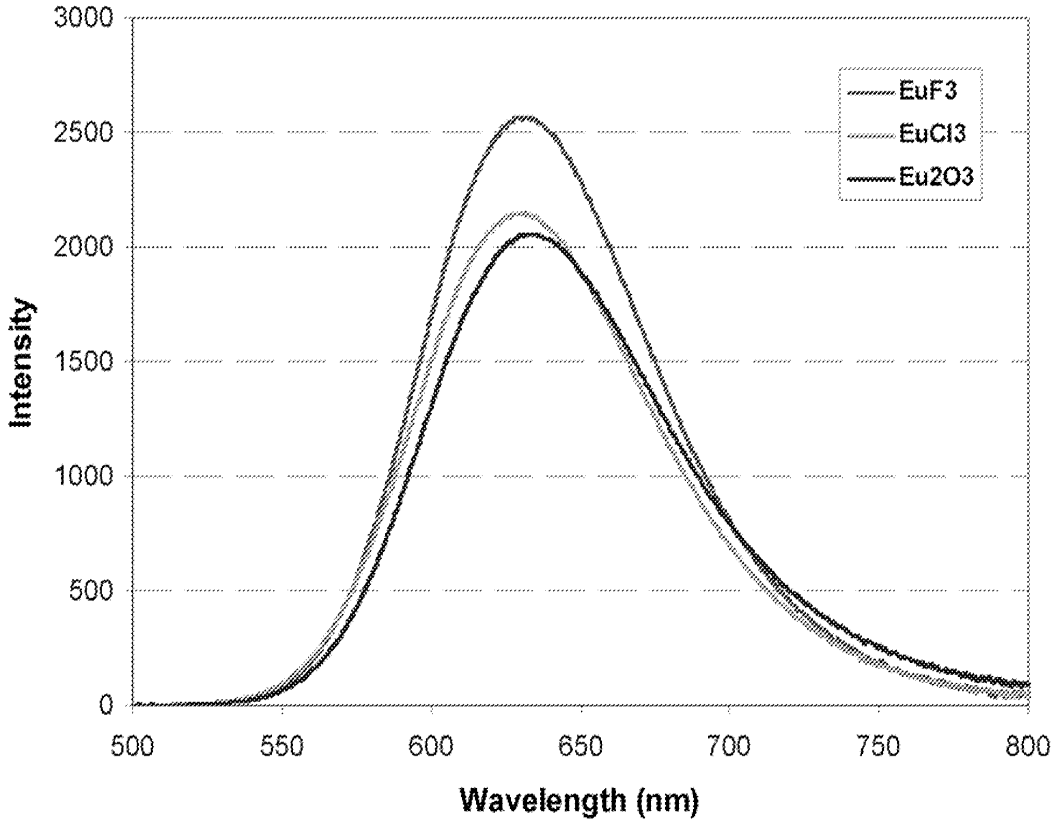


FIG. 10A is a collection of emission spectra of the present invention phosphors having the composition of $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$ (R630), where Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively.

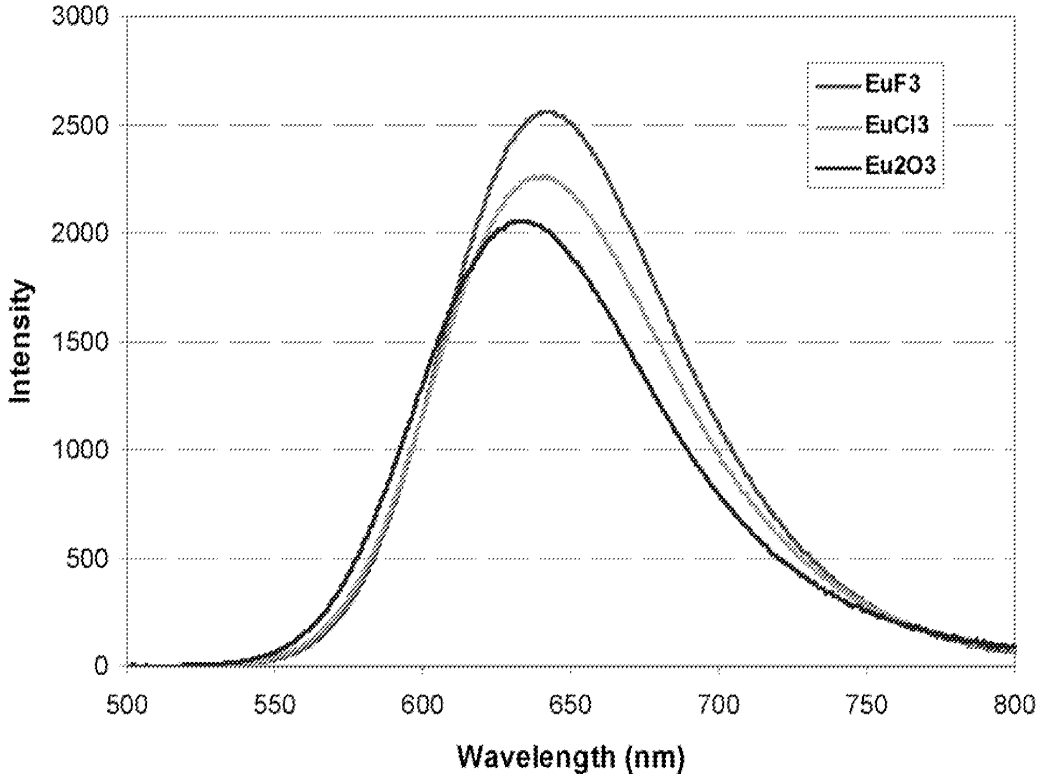


FIG. 10B is a collection of emission spectra of the present invention phosphors having the composition of $Ca_{0.16}Sr_{0.82}AlSiN_3Eu_{0.02}$ (R640), where Eu_2O_3, $EuCl_3$ and EuF_3 are used for Eu resource, respectively.

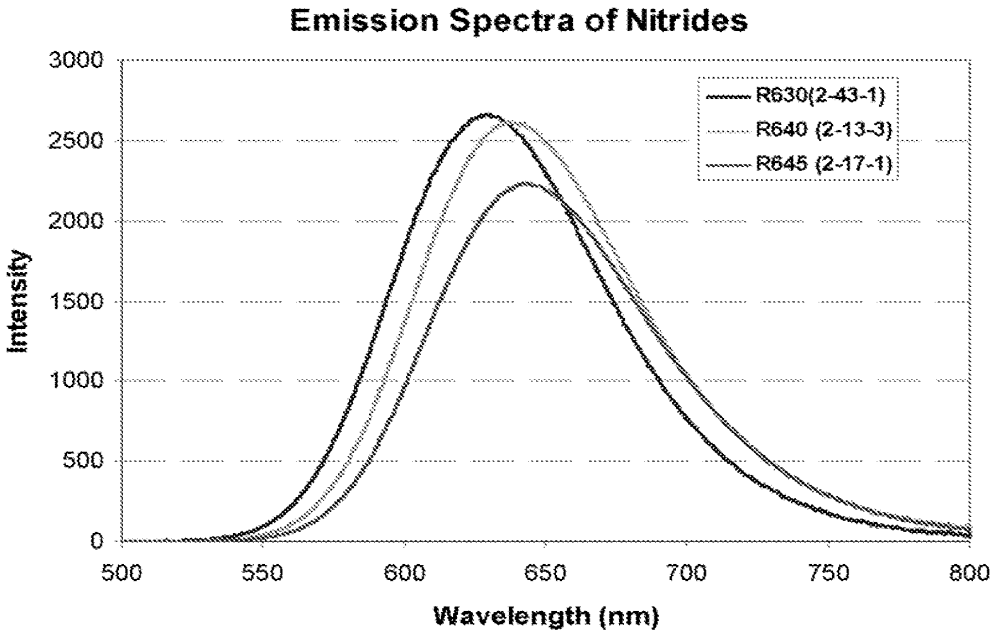


FIG. 10C is a collection of emission spectra of the present invention phosphors having the composition (1) $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$ (R630), (2) $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$ (R640), and (3) $Ca_{0.157}Sr_{0.808}AlSiN_3Eu_{0.035}$ (R645), respectively, where EuF_3 is used for Eu in the composition; the spectra showing that the PL value decreases with the wavelength increases.

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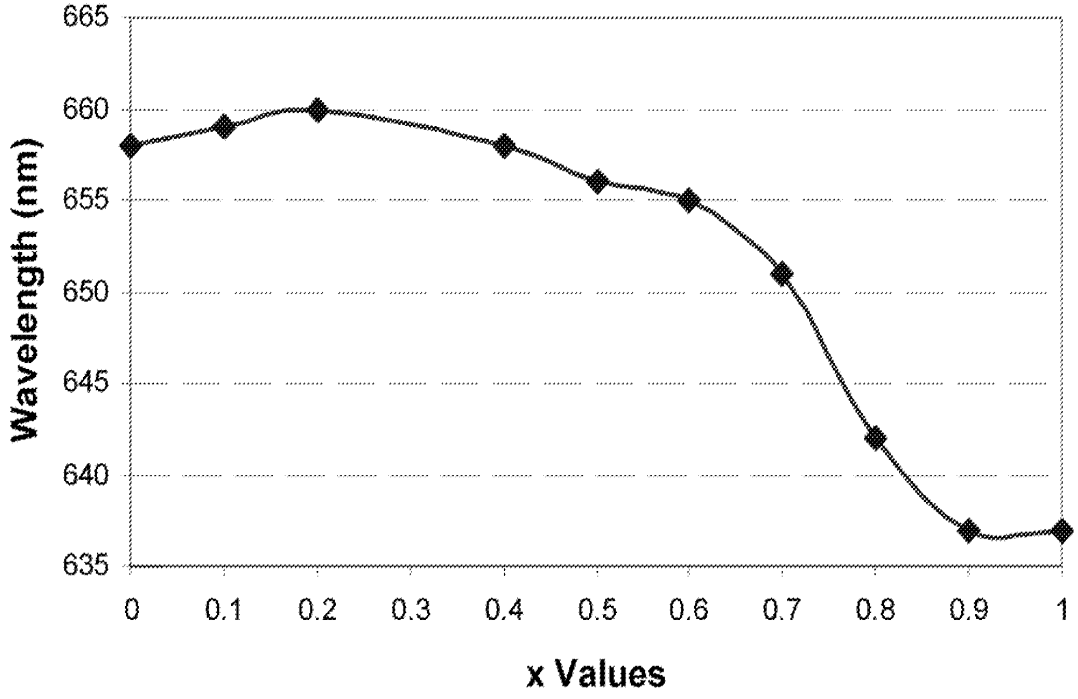


Fig. 11A Emission Wavelength Changes with Sr content (x) in $Ca_{0.98-x}Sr_xAl\ SiN_3Eu_{0.02}$ (Eu_2O_3 is used for Eu)

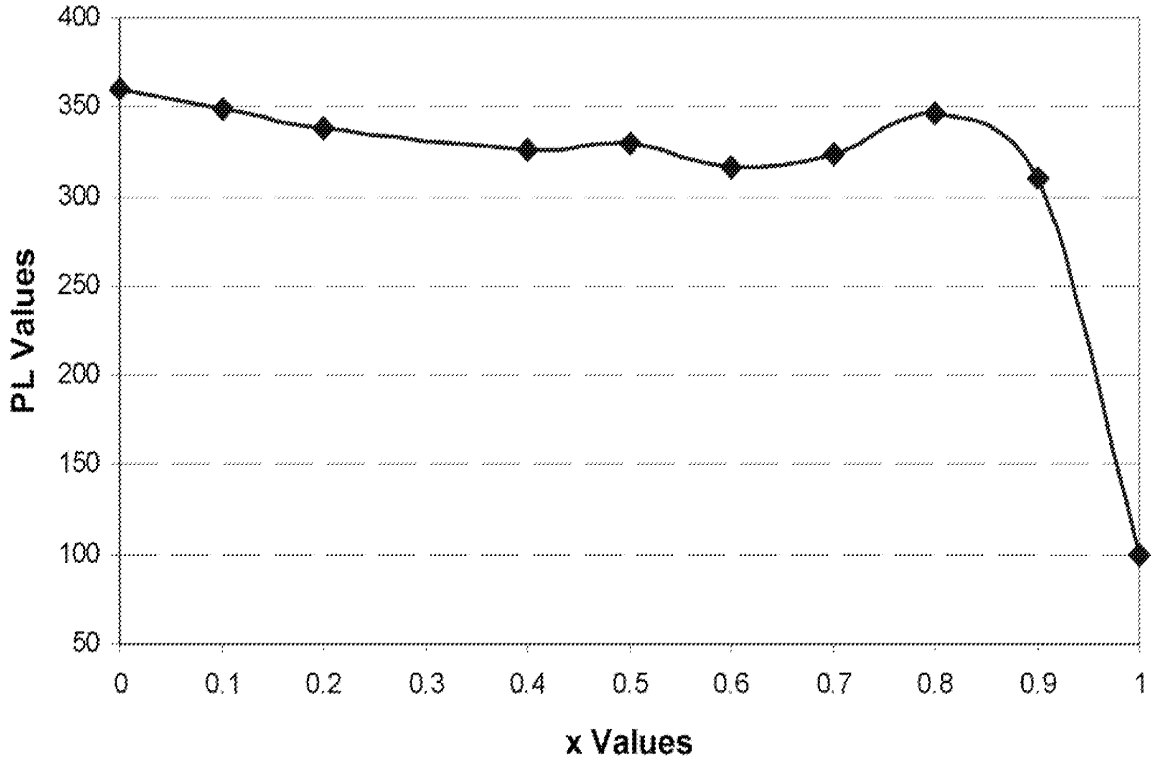


Fig. 11B PL Value Changes with Sr Content (x) in $Ca_{0.98-x}Sr_xAl\ SiN_3Eu_{0.02}$ (Eu_2O_3 is used for Eu)

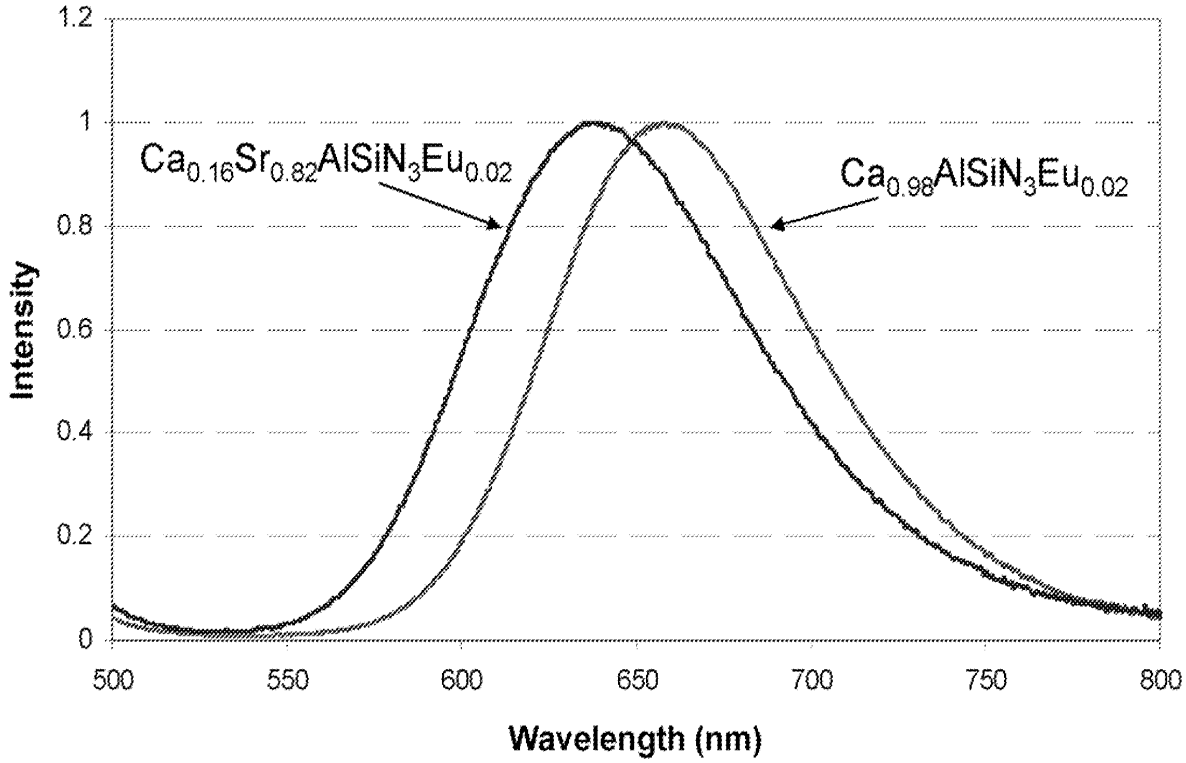


Fig. 12A Normalized Emission Spectra of $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$ with x=0.82 and x=0, respectively

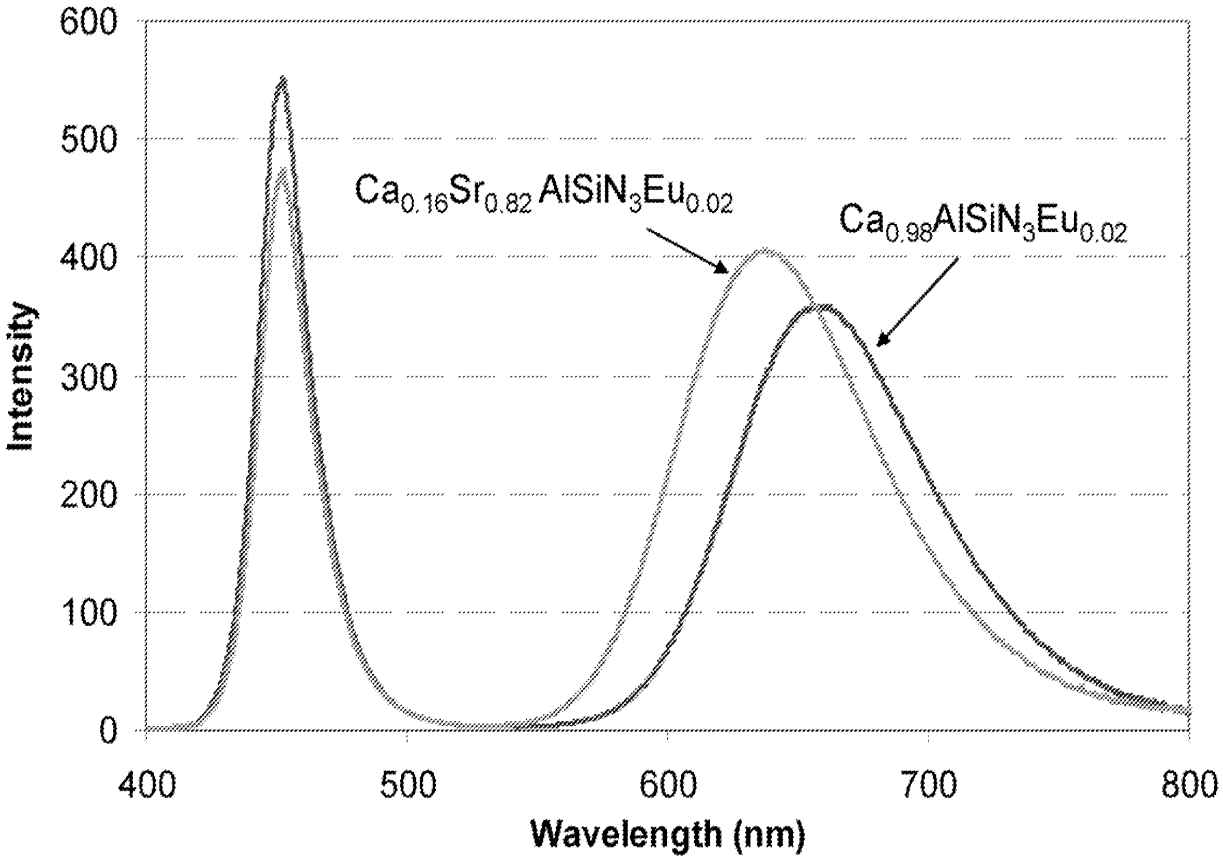


Fig. 12B Non-normalized Emission Spectra of $Ca_{0.98-x}Sr_xAlSiN_3Eu_{0.02}$ with x=0.82 and x=0, respectively

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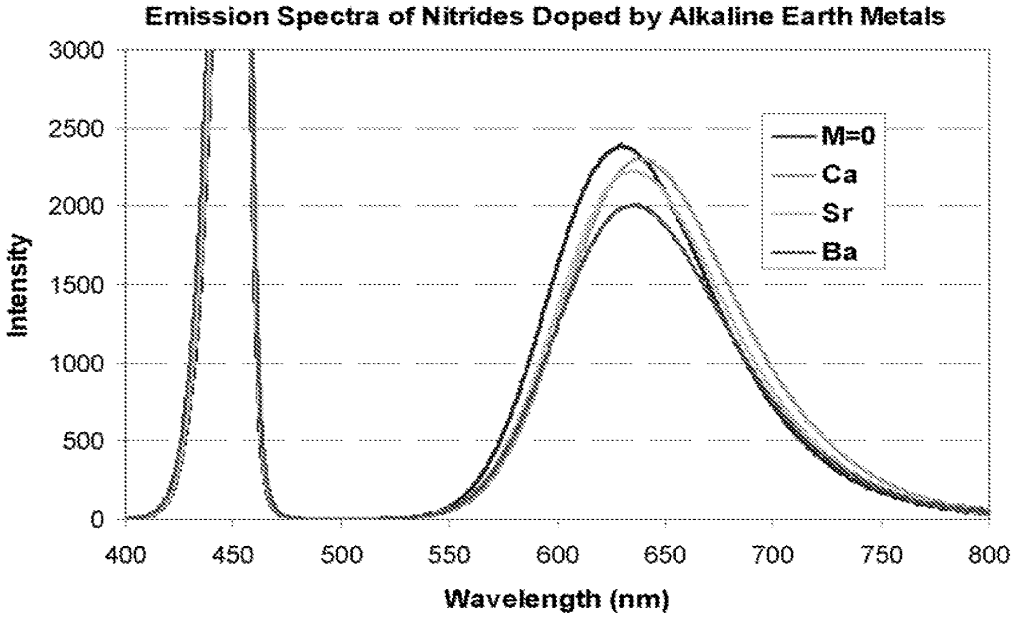
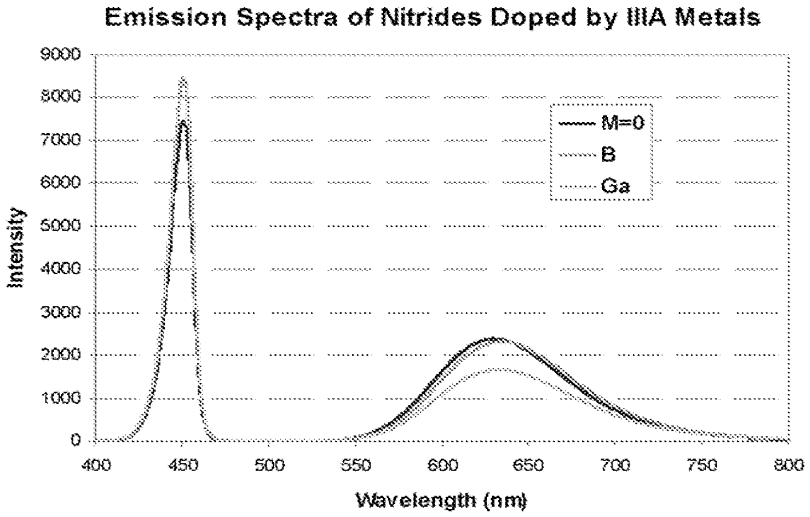
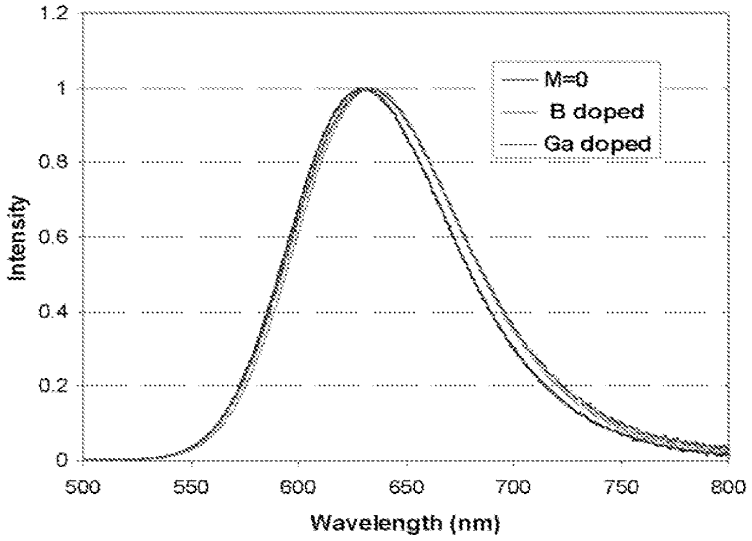


FIG. 13 is a collection of the emission wavelength changes with an alkaline earth metal M doped phosphor having the composition: $Ca_{0.2}Sr_{0.74}AlSiM_{0.05}N_3Eu_{0.01}$:F (M=0, Ca, Sr, and Ba, respectively); alkaline earth metal fluoride is used for doped Ca, Sr, and Ba, respectively, and EuF_3 is used for Eu in the composition, showing that the peak emission wavelength shifts to longer wavelength with the addition of the 5% alkaline earth metal in the order of Ca, Sr, and Ba.



(A)



(B)

FIG. 14 is a collection of the emission (Fig. 6a) and normalized (Fig.6 b) wavelength changes with an 5% IIIA metal M doped phosphor having the composition: $Ca_{0.2}Sr_{0.79}Al_{0.95}SiM_{0.05}N_3Eu_{0.01}$:F (M=B and Ga, respectively); EuF_3 is used for Eu in the composition, showing that the peak emission wavelength shifts to longer wavelength and PL values decrease with the addition of the 5% alkaline earth metal and in the order of B and Ga.

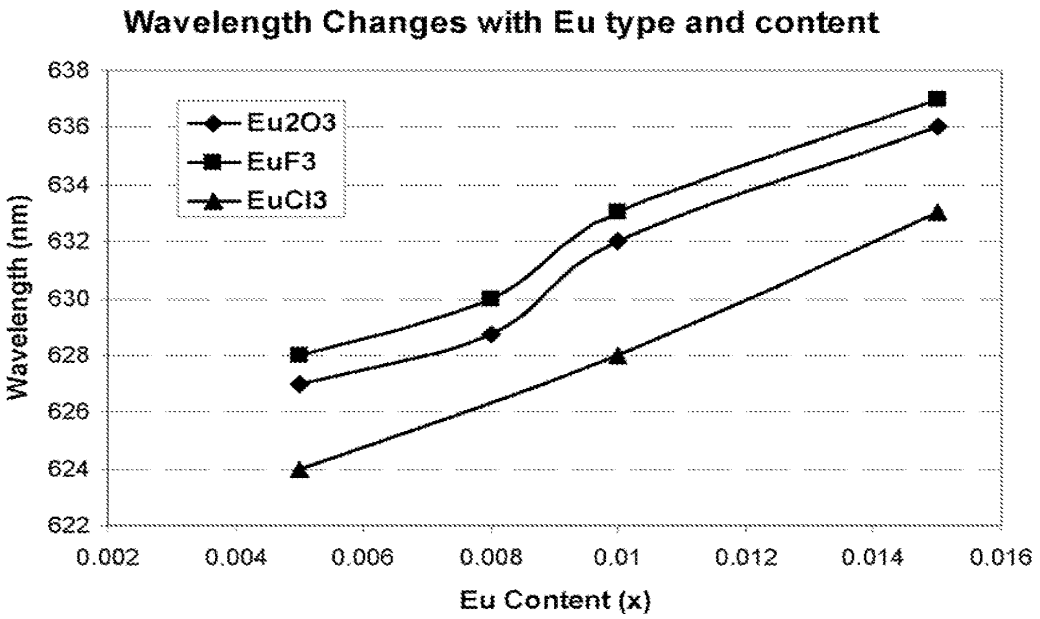


FIG. 15A is a graph of the wavelength (nm) changes with Eu content x in $Ca_{0.2}Sr_{0.8-x}AlSiN_3Eu_x$ (■: EuF_3 is used for Eu; ♦ $Eu_2O_3$is used for Eu; ▲: $EuCl_3$ is used for Eu)

(** when the EuF_3 is used for Eu materials of the phosphor, the emission wavelength of the phosphor tends to shift to a longer wavelength side.)

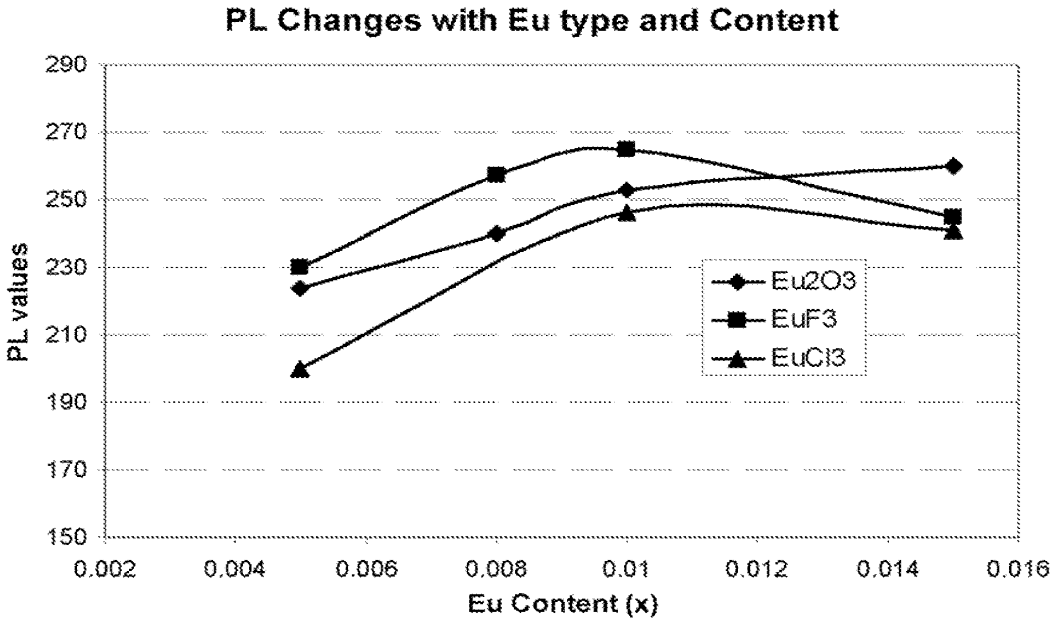


FIG. 15B is a graph of the emission PL value changes with Eu content x in $Ca_{0.2}Sr_{0.8-x}AlSiN_3Eu_x$ (■: EuF_3 is used for Eu; ♦ Eu_2O_3 is used for Eu; ▲: $EuCl_3$ is used for Eu;)

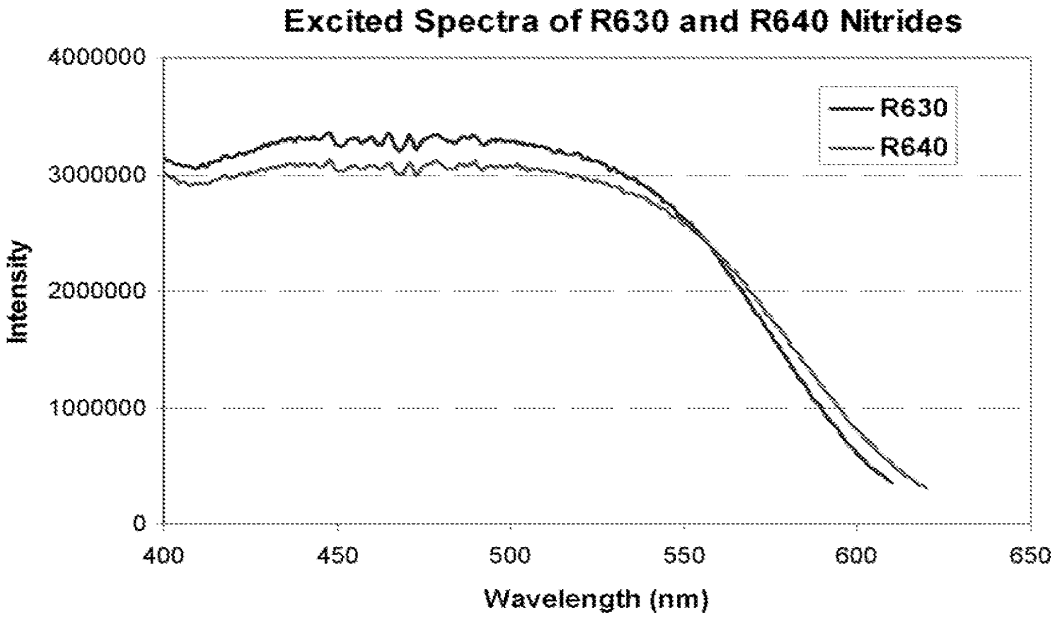


FIG. 16 shows the excitation spectra of R630 (composition: $Ca_{0.2}Sr_{0.8}AlSiN_3Eu_{0.01}$) and R640 (composition: $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$), the spectra showing that these phosphors are efficient at fluorescing when excited at wavelengths ranging from about 400 to about 600 nm.

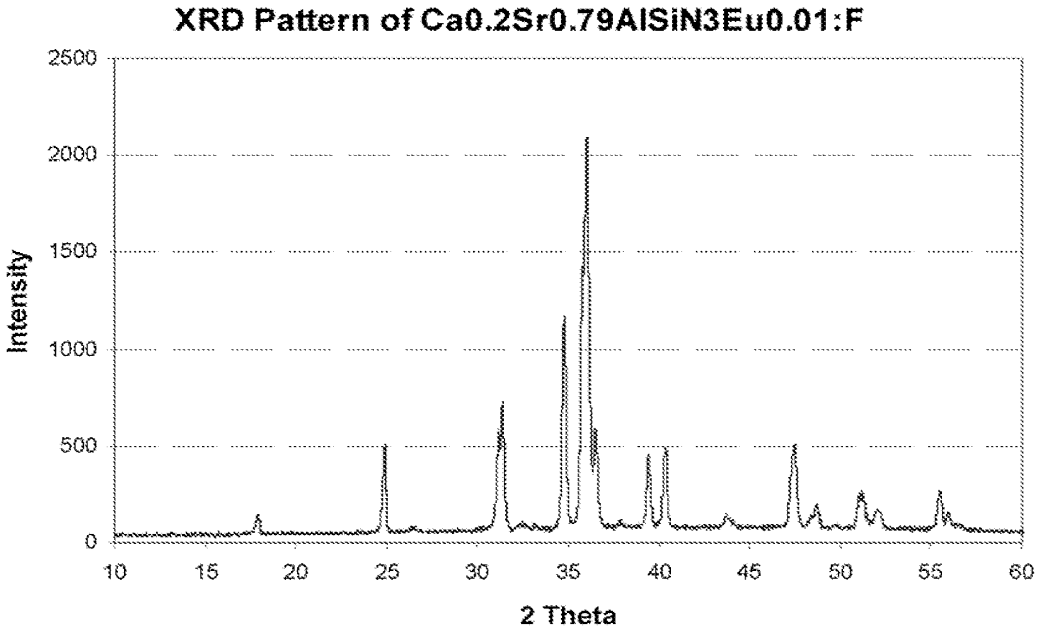
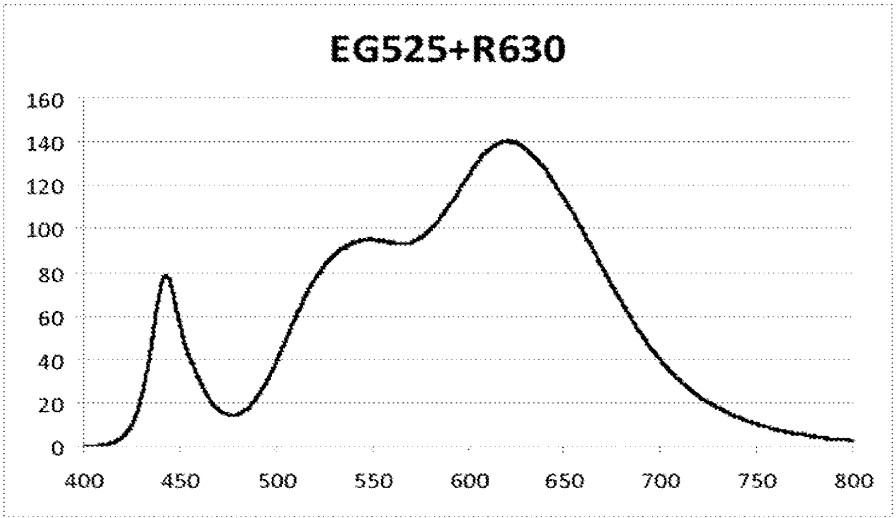


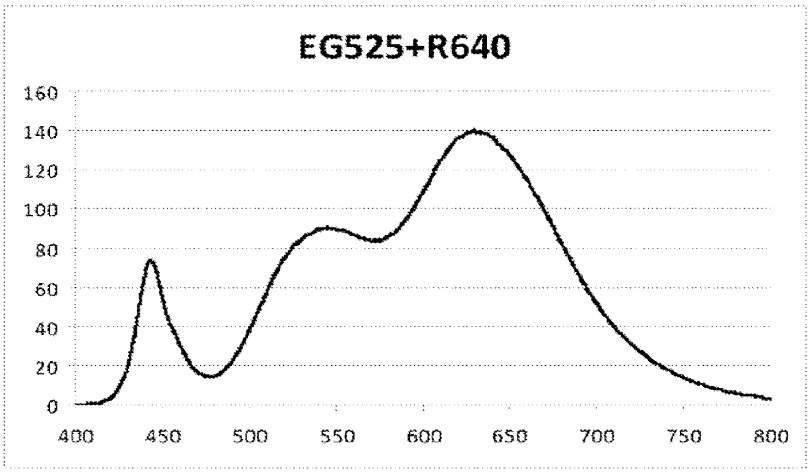
FIG. 17 is an x-ray diffraction pattern of an F anion doped nitride phosphor having the formula $Ca_{0.2}Sr_{0.79}AlSiN_3Eu_{0.01}$:F.



CIE x	CIE y	CCT	Brightness	Domi.	Purity	Ra	Rall	R9~12
0.437	0.406	3002	0.82	583	53	90	86	76

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
94	92	86	91	91	89	91	86	63	77	91	73	93	91	90

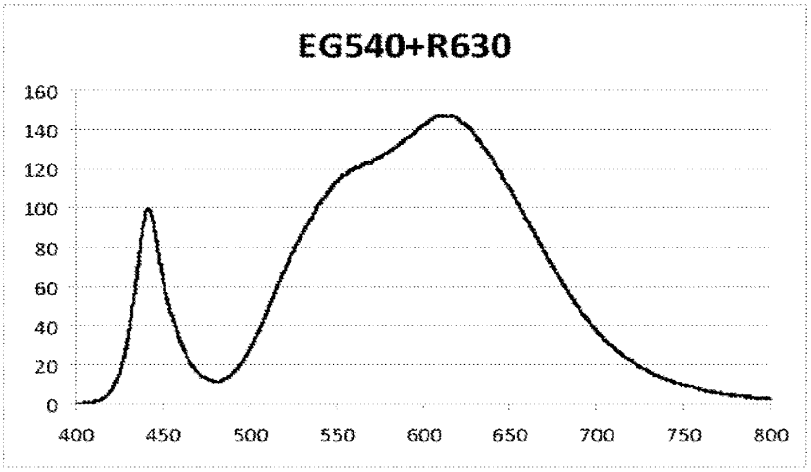
FIG. 18A



CIE x	CIE y	CCT	Brightness	Domi.	Purity	Ra	Ral	R9~12
0.437	0.404	2985	0.76	583	52	92	91	86

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
98	95	84	89	96	92	91	94	95	84	88	79	99	89	98

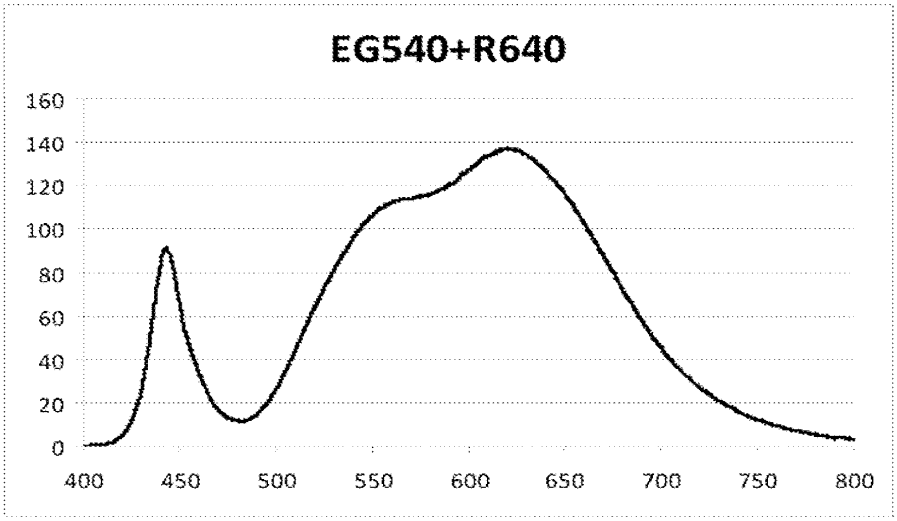
FIG. 18B



CIE x	CIE y	CCT	Brightness	Domi.	Purity	Ra	Rall	R9~12
0.437	0.402	2973	0.92	583	52	79	72	52

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
79	84	84	79	76	75	85	68	23	59	74	51	79	90	76

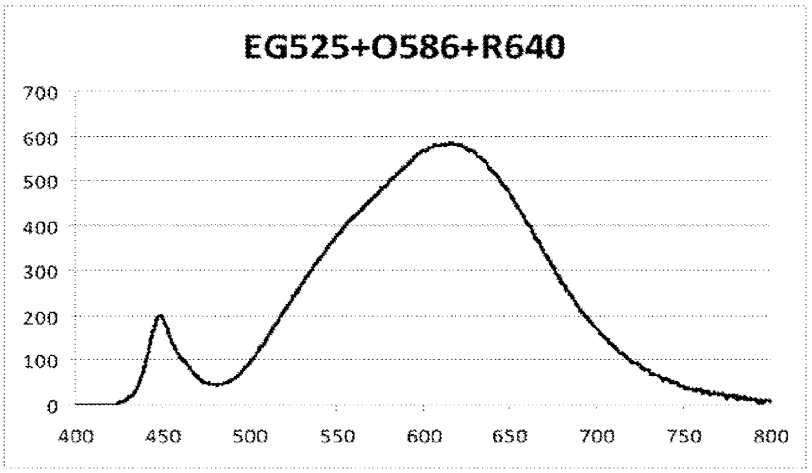
FIG. 18C



CIE x	CIE y	CCT	Brightness	Domi.	Purity	Ra	Rall	R9~12
0.437	0.402	2967	0.86	583	52	81	75	58

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
83	85	83	82	79	76	88	76	41	61	77	53	82	89	81

FIG. 18D



CIE x	CIE y	CCT	Brightness	Domi.	Purity	Ra	Rall	R9~12
0.477	0.426	2584	3.34	584	71	79	72	51

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
77	85	91	77	74	77	88	64	18	64	71	50	78	94	73

FIG. 18E

FIG. 18 is a collection of the emission intensity of a warm white light illumination system comprising an red phosphor of the present embodiments, a green phosphor, or an orange phosphor: EG 525+R630 (Fig. 10A), EG 525+R640 (Fig. 10B), EG 540+R630 (Fig. 10C), EG 540+R640 (Fig. 10D), EG 525+O586+R640 (Fig. 10E). the red phosphors having the formula: $Ca_{0.2}Sr_{0.8}AlSiN_3Eu_{0.01}$:F (R630) and $Ca_{0.158}Sr_{0.815}AlSiN_3Eu_{0.023}$:F (R640); the green phosphor having the formula $Sr_{0.925}Ba_{1.025}Mg_{0.05}Si_{1.03}(O,Cl)_4:Eu^{2+}$ (EG525) and $Sr_{1.15}Ba_{0.8}Mg_{0.05}Si_{1.03}(O,Cl)_4:Eu^{2+}$. (EG540); the orange phosphor having the formula: $Sr_3Eu_{0.06}Si_{1.02}O_5F_{0.18}$ (O586).

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/067178

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01J 1/62 (2010.01)
USPC - 313/483
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - H01J 1/62 (2010.01)
USPC - 313/483

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0257596 A1 (SHIMOMURA et al) 08 November 2007 (08.11.2007) entire document	2-4, 6
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Y		1,5
Y	US 3,207,583 A (BRAUTIGAM et al) 21 September 1965 (21.09.1965) entire document	1, 5
A	US 7,252,787 B2 (HANCU et al) 07 August 2007 (07.08.2007) entire document	1-6
A	US 2009/0243467 A1 (SHIMIZU et al) 01 October 2009 (01.10.2009) entire document	1-6

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2010	29 JAN 2010
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

Savant Technologies LLC - 1004.566

Electronic Patent Application Fee Transmittal	
Application Number:	13273212
Filing Date:	13-Oct-2011
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Filer:	Peter C. Mei/Tony Nguyen
Attorney Docket Number:	ITMX-00318US1
Filed as Small Entity	

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for Continued Examination	2801	1	600	600
		Total in USD ($)		**600**

Electronic Acknowledgement Receipt	
EFS ID:	15962202
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-00318US1
Receipt Date:	05-JUN-2013
Filing Date:	13-OCT-2011
Time Stamp:	19:58:00
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Payment was successfully received in RAM	$600
RAM confirmation Number	6322
Deposit Account	501105
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The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees) Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Continued Examination (RCE)	318US1_RCE.pdf	697787 6b8f4290b055c116bfbdfc11633115c2267d2158	no	3
Warnings:					
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2	Amendment Submitted/Entered with Filing of CPA/RCE	ITMX-00318US1_RCE_due_06062013.pdf	206485 d838a93184b0f19bd5bd31823e8bd8fd63935942	no	13
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3	Information Disclosure Statement (IDS) Form (SB08)	318US1_IDS-sb08-transmittal.pdf	222137 85c971db2e40eb7ba1755f2a557a34305bdc03e5	no	11
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4	Non Patent Literature	BARRY.pdf	1019926 cb9448db1f125cb26bfabf74d0075ba52654fc18	no	16
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5	Non Patent Literature	ITMX-00116CN0_OA_10-29-12.pdf	353913 ab3292599f090a78ed9d8d6e94c2f974526db9b2	no	16
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8	Non Patent Literature	ITMX-00116CN0_First_OA_3192010.pdf	1334243 b830210f5f0cfeb8bae0620c0d667a696459c129	no	15

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14	Non Patent Literature	ITMX-00116US6_NFOA_9_27_2012.pdf	367958 18b3d160e2831af8634390259c7c22174360c6c4	no	11
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15	Non Patent Literature	ITMX-00116US1_FOA_9_23_2011.pdf	472174 631ca8df025abbabdf42e439bb098b23eae4a5f1	no	12
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16	Non Patent Literature	ITMX-00116US1_NFOA_3_3_2011.pdf	510390 db24e932bde6e331d549a58ac2dd3dd418e849a8	no	13
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17	Non Patent Literature	ITMX-00116US1_FOA_9_9_2010.pdf	420147 8a237aeee63103a3b606811b91b86358d90e3ccf	no	11

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19	Non Patent Literature	ITMX-00116US1_FOA_6_23_2009.pdf	304900 6bbc0227fa54ac14477516294 3f73d97dd6ad1d3	no	8
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21	Non Patent Literature	ITMX-00116US2_NOA_9_26_2011.pdf	444414 1ab0d8703f978237c88faf7cddc7456c6a0d7edf	no	8
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22	Non Patent Literature	ITMX-00116US2_NOA_8_12_2011.pdf	167176 7d09df998d88b54283e1346b5c221ac67e4bf52a	no	5
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23	Non Patent Literature	ITMX-00116US3_FOA_1_11_2013.pdf	454646 d1759c75250612c0717a25f18065595fc42bdb2d	no	13
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24	Non Patent Literature	ITMX-00116US3_FOA_12_19_2011.pdf	416090 62201de443cad52ee6a5d9ca96c2dfbe7e6aae0a	no	12
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26	Non Patent Literature	ITMX-00116US3_NFOA_3_24_2011.pdf	353555 78482348ac2cbba94c832efe494e49550e2c07c5	no	11

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27	Non Patent Literature	ITMX-00116US4_FOA_1_30_2013.pdf	458268 635209db44b7ed5b7711946e75b309461edfc3bf	no	12
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32	Non Patent Literature	ITMX-00116US8_NFOA_9_19_2012.pdf	311508 1b25e5fcd2797ba21e0eb725e72d7c21afe9b04d	no	9
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33	Non Patent Literature	ITMX-00116WO0_ISR_08-15-08.pdf	542824 b9781ad6ba5eac4cee329d2e528d0e0eae99e0c4	no	13
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36	Non Patent Literature	ITMX-00318US2_Final_OA_03-01-13.pdf	457124 27cae0d8d4ed69e598580d459ace7136101d50f8	no	12
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37	Non Patent Literature	ITMX-00307WO0_Search-report-and-written-opinion_01-26-12.pdf	905003 446a7abba048883eae6961c7e94c04d97ee82b43	no	14
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Information:					
38	Non Patent Literature	ITMX-00318US3_FOA_03-01-13.pdf	456445 a9796da76bbc1d033d6832ecf1bae2b151364910	no	12
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Information:					
39	Non Patent Literature	ITMX-00318WO0_Search-report_03-28-13.pdf	247862 44d0ad07278a7c743d61141c2308b9f669503523	no	13
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40	Non Patent Literature	PARK.pdf	813681 7275b90d410c13bf57198f6bf6c44b09c90dbc02	no	15
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41	Non Patent Literature	ITMX-00116EP0_Search-Report_04-15-11.pdf	800052 6d27f2f411d936c69cd37fd562db224b6daa425d	no	15
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42	Non Patent Literature	JSYOO.pdf	883417 4b5553d3303f290f98c56bf45b8bd08b29881987	no	16
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Information:					
43	Foreign Reference	CA2466979A1.pdf	691320 418b94b2cfb7b6bc100fb372696ebc299d4c0071	no	14
Warnings:					
Information:					
44	Foreign Reference	JP07-094785.pdf	632789 da678bff1440fbb2e53198bdbd9c902529d0af49	no	5

Warnings:					
Information:					
45	Foreign Reference	JP2003101078A.pdf	584594 3cb949ee2fff72a7bc3c2733c398601b5f99a1ae	no	10
Warnings:					
Information:					
46	Foreign Reference	JP2005011953A.pdf	605424 a6ab1bb2cd51cea9e84764aceaa306aeb4f12bda	no	13
Warnings:					
Information:					
47	Foreign Reference	KR20070065486A.pdf	709320 c2f63ccd872e13f6931d15637e9ced4a9fb0731e	no	18
Warnings:					
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48	Foreign Reference	KR20090017346A.pdf	224758 097a4950eee2b34c72989b64055ade8b649675ea	no	6
Warnings:					
Information:					
49	Foreign Reference	RU2114492C1.pdf	344890 10f9a99b14ddbe7b4c3aa84ed339ef38d17ad213	no	8
Warnings:					
Information:					
50	Foreign Reference	TW200527664.pdf	16648174 3051aa6ce376a5715feafbe9acfd45ce7e4f8083	no	27
Warnings:					
Information:					
51	Foreign Reference	WO2002007228A1.pdf	576088 0c0e285af50192bdc7f4c115c034b82dafda2fef	no	15
Warnings:					
Information:					
52	Foreign Reference	WO2004077580A2.pdf	990878 27ef51c20796a2424e9116f2f626518018e4d131	no	35
Warnings:					
Information:					
53	Foreign Reference	WO2005025831A1.pdf	593808 4346b90591184339b662c30c77adc44af7572020	no	22

Warnings:					
Information:					
54	Foreign Reference	WO2006022792A2.pdf	2000869 cc35d2afc21210678cec38dcf08a4311fe712d48	no	51
Warnings:					
Information:					
55	Foreign Reference	WO2008043519A1.pdf	862717 6c4c642bc4e850029992a25ed87e862f5107eef9	no	27
Warnings:					
Information:					
56	Foreign Reference	WO2010074963A1.pdf	870409 8b9fa581fc31aaef30c33f6a12be953e9464a472	no	59
Warnings:					
Information:					
57	Fee Worksheet (SB06)	fee-info.pdf	30401 5e901bb763b7e228d67c6f32daa3e394b5607055	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	56893961	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	)	Group Art Unit: 2879
Bing Dai et al.	)	Examiner: Bowman, Mary Ellen
Serial No.: 13/273,212	)	Confirmation No.: 8795
Filed: October 13, 2011	)	
For: WAVELENGTH CONVERSION COMPONENT WITH DIFFUSING LAYER	)	

CONCISE EXPLANATION OF RELEVANCE

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In connection with the Information Disclosure Statement (PTO/SB/08a) filed on June 5, 2013, Applicants have identified non-English references as Foreign Patent Documents Nos. 1-8.

The relevance of Foreign Patent Documents Nos. 1-2 for submission is that they were cited in an International Search Report from related PCT Application No. PCT/US07/17299.

The relevance of Foreign Patent Documents Nos. 3-4 for submission is that they were cited in an office action from related Japanese Application No. 2009-522877.

The relevance of Foreign Patent Documents No. 5 for submission is that it was cited in an office action from related U.S. Application No. 11/640,533.

The relevance of Foreign Patent Documents No. 6 for submission is that it was cited in an office action from related Taiwanese. Application No. 96128666.

The relevance of Foreign Patent Documents Nos. 7-8 for submission is that they were cited in an International Search Report from related PCT Application No. PCT/US12/59892.

Savant Technologies LLC - 1004.577

Respectfully submitted,

DATE: 06-05-2013

By: /Peter C. Mei/
Peter C. Mei
Reg. No. 39,768

VISTA IP LAW GROUP LLP
2160 Lundy Drive, Suite 230
San Jose, California 95131
Telephone: (408) 321-8663
Facsimile: (408) 877-1662

Savant Technologies LLC - 1004.578

Electronic Acknowledgement Receipt

EFS ID:	15962227
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
Attorney Docket Number:	ITMX-00318US1
Receipt Date:	05-JUN-2013
Filing Date:	13-OCT-2011
Time Stamp:	20:01:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	ITMX-00318US1_IDS-Statement-of-Relevance.pdf	51980 63c3f7e16f0eac346fe3641bc6405c2d180cd695	no	2

Warnings:

Information:

Total Files Size (in bytes):	51980

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/273,212	Filing Date 10/13/2011	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	06/05/2013	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 29	Minus	** 29	= 0	X $40 =	0
	Independent (37 CFR 1.16(h))	* 5	Minus	***5	= 0	X $210 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/ZURIASHWORK ZENEBE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Savant Technologies LLC - 1004.581

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:	)	Group Art Unit: 2879
	)	
Bing Dai et al.	)	Examiner: Bowman, Mary Ellen
	)	
Serial No.: 13/273,212	)	Confirmation No.: 8795
	)	
Filed: October 13, 2011	)	
	)	
For: WAVELENGTH CONVERSION COMPONENT WITH DIFFUSING LAYER	)	
	)	
	)	

INFORMATION DISCLOSURE STATEMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In accordance with 37 CFR §§ 1.97 and 1.98, the items identified in this Information Disclosure Statement (IDS) are being brought to the attention of the Office. The Examiner is requested to make these documents of record.

The items identified in this IDS may or may not be "material" pursuant to 37 CFR § 1.56. The submission thereof by Applicant(s) is not to be construed as an admission that any such patent, publication or other information referred to therein is material or considered to be material (37 CFR § 1.97(h)), or even qualifies as "prior art" under 35 USC § 102 with respect to this invention unless specifically designated by Applicant(s) as such.

1. Fee:

☐ Charge the fee due under 37 CFR § 1.17(p) to the deposit account referenced below.

☐ The fee due under 37 CFR § 1.17(p) is being concurrently submitted with the filing of an electronic IDS submission. Thus, no additional fee is required.

Savant Technologies LLC - 1004.582

☒ Applicant believes that no fee is required for this submission. However, if Applicant is mistaken, then please charge the fee due under 37 CFR § 1.17(p) to the deposit account referenced below.

2. Statement Under 37 CFR § 1.97(e):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1); or

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

3. Copies of the Cited Items:

☒ Copies of all of the items listed under Foreign Patent Documents and/or Non Patent Literature Documents are enclosed.

☐ Copies of the following items listed under Item Nos. ___ under Foreign Patent Documents and Item Nos. ___ under Non Patent Literature Documents are enclosed.

☐ Copies of the following documents listed under Item Nos. ___ under Foreign Patent Documents and Item Nos. ___ under Non Patent Literature Documents are not supplied because they were previously cited by the Office or submitted in Information Disclosure Statements in parent U.S. Application No. _____, of which the current application is a _____ and relied upon in this application for an earlier filing date under 35 USC § 120. See 37 CFR § 1.98(d). The Examiner is requested to make these documents of record.

Savant Technologies LLC - 1004.583

4. Conclusion:

Citation of the above documents shall not be construed as:

1. an admission that the documents are necessarily prior art with respect to the instant invention;
2. a representation that a search has been made, other than as described above; and
3. an admission that the information cited herein is, or is considered to be, material to patentability as defined in § 1.56(b).

It is respectfully requested that the Examiner indicate consideration of the cited references by returning a copy of the attached form with initials or other appropriate marks. If the U.S. Patent Office determines that an extension and/or other relief is required, Applicant(s) petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 501105**, referencing **Docket No. ITMX-00318US1**. However, the Commissioner is not authorized to charge the cost of the issue fee to the Deposit Account.

Respectfully submitted,

Dated: 06-05-2013

By: /Peter C. Mei/
Peter C. Mei
Registration No. 39,768

Vista IP Law Group, LLP
2160 Lundy Ave., Ste. 230
San Jose, CA 95131
Telephone: (408) 321-8663 (Ext. 208)
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Savant Technologies LLC - 1004.584

PTO/SB/08a (07-09) (modified)
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Substitute for form 1449/PTO				***Complete if Known***	
				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	4	of	11	Attorney Docket Number	ITMX-00318US1

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	3290255	12-06-1966	Smith, I.	
	2	3593055	07-13-1971	Geusic, Joseph E., et al.	
	3	3670193	06-13-1972	Thorington, L., et al.	
	4	3676668	07-11-1972	Collins, N., et al.	
	5	3691482	09-01-1972	Pinnow et al.	
	6	3709685	01-09-1973	Hercock, R., et al.	
	7	3743833	07-01-1973	Martie et al.	
	8	3763405	10-02-1973	Mitsuhata, Teruhisa	
	9	3793046	02-01-1974	Wanmaker et al.	
	10	3819973	06-25-1974	Hosford, A.	
	11	3819974	06-25-1974	Stevenson, David A., et al.	
	12	3849707	11-19-1974	Braslau, N., et al.	
	13	3875456	04-01-1975	Kana, Tsuyoshi, et al.	
	14	3932881	01-13-1976	Mita, Yah, et al.	
	15	3937998	02-10-1976	Verstegen, J., et al.	
	16	3972717	08-03-1976	Wiedemann, W.	
	17	4047075	09-06-1977	Schober!, W.	
	18	4081764	03-28-1978	Christmann, M.H., et al.	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PTO/SB/08a (07-09) (modified)
Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO				Complete if Known	
				Application Number	13/273,212
				Filing Date	10-13-2011
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	5	of	11	Attorney Docket Number	ITMX-00318US1

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	19	4104076	08-01-1978	Pons, A.	
	20	4143394	03-06-1979	Schoeberl, W.	
	21	4176294	11-27-1979	Thornton, Jr., W.	
	22	4176299	11-27-1979	Thornton, W.	
	23	4211955	07-08-1980	Ray, S.	
	24	4305019	12-08-1981	Graff, E.A., et al.	
	25	4315192	02-09-1982	Skwirut, H., et al.	
	26	4443532	04-17-1984	Joy, David C., et al.	
	27	4559470	12-17-1985	Murakami, K. et al.	
	28	4573766	03-04-1986	Bournay, Jr. et al.	
	29	4618555	10-21-1986	Suzuki, T., et al.	
	30	4638214	01-20-1987	Beers, W., et al.	
	31	4667036	05-19-1987	Iden, Ruediger, et al.	
	32	4678285	07-07-1987	Ohta, W., et al.	
	33	4727003	02-23-1988	Ohseto, S. et al.	
	34	4772885	09-20-1988	Uehara, K., et al.	
	35	4845223	07-04-1989	Seybold, Guenther, et al.	
	36	4859539	08-22-1989	Tomko, Donna L., et al.	
	37	4915478	04-01-1990	Lenko et al.	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. 3 Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). 4 For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. 5Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. 6 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PTO/SB/08a (07-09) (modified)
Approved for use through 07/31/2012. OMB 0651-0031

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Substitute for form 1449/PTO				Complete if Known	
				Application Number	13/273,212
				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
				Examiner Name	Bowman, Mary Ellen
Sheet	6	of	11	Attorney Docket Number	ITMX-00318US1

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	38	4918497	04-01-1990	Edmond, John A.	
	39	4946621	08-07-1990	Fouassier, C. et al.	
	40	4992704	02-12-1991	Stinson, John W.	
	41	5077161	12-31-1991	Law, Kock-Yee	
	42	5110931	05-05-1992	Dietz, Erwin, et al.	
	43	5126214	06-30-1992	Tokailin, Hiroshi, et al.	
	44	5131916	07-21-1992	Eichenauer, Herbert, et al.	
	45	5143433	09-01-1992	Farrell, J.	
	46	5143438	09-01-1992	Giddens, L. et al.	
	47	5166761	11-24-1992	Olson, Jerry M., et al.	
	48	5208462	05-04-1993	O'Connor, James M., et al.	
	49	5210051	05-11-1993	Carter, Jr., C.	
	50	5211467	05-18-1993	Seder, Thomas A.	
	51	5237182	08-17-1993	Kitagawa, Masahiko, et al.	
	52	5264034	11-23-1993	Dietz, Erwin, et al.	
	53	5283425	02-01-1994	Imamura, M.	
	54	5369289	11-29-1994	Tamaki, M., et al.	
	55	5405709	04-11-1995	Littman, Jon E., et al.	
	56	5439971	08-08-1995	Hyche, K.W.	

Examiner Signature		Date Considered	

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				Filing Date	10-13-2011
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	7	of	11	Attorney Docket Number	ITMX-00318US1

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	31	January 29, 2007 Office Action in U.S. Patent Application No. 10/623,198, issued by Thao X. Le (Art Unit 2814)	
	32	January 30, 2006 Office Action in U.S. Patent Application No. 11/264,124, issued by Thao X. Le (Art Unit 2814)	
	33	January 7, 2011 Office Action in U.S. Patent Application No. 12/131,119, issued by Steven Y. Horikoshi (Art Unit 2879)	
	34	July 10, 2008 Office Action in U.S. Patent Application No. 11/264,124, issued by Abu I Kalam (Art Unit 2814)	
	35	July 14, 2005 Notice of Allowance, Notice of Allowability, and Examiner's Statement of Reasons for Allowance in U.S. Patent Application No. 10/623,198, issued by Thao X. Le (Art Unit 2814)	
	36	July 14, 2011 Office Action in U.S. Patent Application No. 12/131,119, issued by Steve Horikoshi (Art Unit 2879)	
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	38	June 14, 2006 Office Action in U.S. Patent Application No. 11/264,124, issued by Thao X. Le (Art Unit 2814)	
	39	June 26, 2007 Office Action in U.S. Patent Application No. 10/623,198, issued by Thao X. Le (Art Unit 2814)	

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				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	14	of	11	Attorney Docket Number	ITMX-00318US1

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	40	KIDO, J. ET AL. , "1,2,4-Triazole Derivative as an Electron Transport Layer in Organic Luminescent Devices", "Jpn. J. Appl. Phys. ", 7/1/1993, Page(s) L917-L920, Volume 32	
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	50	March 22, 2012 Office Action in U.S. Patent Application No. 12/131,119, issued by Steven Y. Horikoshi (Art Unit 2879)	
	51	March 28, 2006 Office Action in U.S. Patent Application No. 10/623,198, issued by Thao X. Le (Art Unit 2814)	

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				Application Number	13/273,212
INFORMATION DISCLOSURE STATEMENT BY APPLICANT				Filing Date	10-13-2011
				First Named Inventor	Bing Dai
				Art Unit	2879
(Use as many sheets as necessary)				Examiner Name	Bowman, Mary Ellen
Sheet	15	of	11	Attorney Docket Number	ITMX-00318US1

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	52	March 4, 2011 Notice of Allowance, Notice of Allowability, Examiner's Interview Summary, Examiner's Amendment/ Comment and Examiner's Statement of Reason for Allowance in U.S. Patent Application No. 11/264,124, issued by Abu I Kalam (Art Unit 2814)	
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EFS ID:	15973090
Application Number:	13273212
International Application Number:	
Confirmation Number:	8795
Title of Invention:	WAVELENGTH CONVERSION COMPONENT WITH A DIFFUSING LAYER
First Named Inventor/Applicant Name:	Bing Dai
Customer Number:	101130
Filer:	Peter C. Mei/Tony Nguyen
Filer Authorized By:	Peter C. Mei
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7	Non Patent Literature	April15_2009_Office_Action_in_US_Patent_Application_No_11264124_issued_by_Abu_I_Kalam_Art.pdf	645683 ed53e27499b8552a5ba29e1c8f36d5ab8521660a	no	13
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8	Non Patent Literature	ARMAROLI_N_ET_AL_Supramolecular_Photochemistry_and_Photophysics_J_Am_Chern_Soc_1994_Page.pdf	793396 89601ac599ef0dda546e63e4a454c2d3141eae1b	no	8
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9	Non Patent Literature	August_21_2006_Office_Action_in_US_Patent_Application_No_10623198_issued_by_Thao_X_Le_Art.pdf	337693 478bb90d94758d789b16af823c44730e0bf4a787	no	7
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10	Non Patent Literature	August_24_2007_Office_Action_in_US_Patent_Application_No_11264124_issued_by_Thao_X_Le_Art.pdf	855914 84074e62c242c3984b32d2fcf774c7aae92f8962	no	17

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11	Non Patent Literature	August_26_2010_Office_Action_in_US_Patent_Application_No_12131118_issued_by_Examiner_Abul.pdf	254085 e34f4422aa0c720d13379a87591f954f0d504374	no	5
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12	Non Patent Literature	BERGGREN_M_ET_AL_Light_emitting_diodes_with_variable_colours_from_polymer_blends_Nature_1.pdf	426990 8e8404805a35e842e606462796f57731099bea20	no	3
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13	Non Patent Literature	BERGGREN_M_ET_AL_White_light_from_an_electroluminescent_diode_made_from_poly34_octylpheny1.pdf	596663 952f9fdf64796f3d341bc42401a00928243a76ab	no	5
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14	Non Patent Literature	BOONKOSUM_W_ET_AL_Novel_Flat_Panel_display_made_of_amorphous_SiNHSiCH_thin_film_LED_Physi.pdf	975080 4e7e8ee903a1fc168c409938b1b1d8de30719f8e	no	15
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15	Non Patent Literature	BRADFIELD_PL_ET_AL_Eiectroluminescence_from_sulfur_impurities_in_a_p_n_junction_formed_in.pdf	309336 83fe4925a2a15e651993543563bcd0d902394d08	no	3
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16	Non Patent Literature	CHAO_ZHANG_JIN_ET_AL_White_light_emitting_glasses_Journal_of_Solid_State_Chemistry_1991_P.pdf	842280 78ed60f3d49dc4708c9b439d5707f212aaa6beb0	no	14
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17	Non Patent Literature	COMRIE_M_Full_Color_LED_Added_to_Lumexs_Lineup_EBN_6191995_Pages_28.pdf	143968 b8773682e24fbb636f11e18be9a4a49793738d7b	no	1
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18	Non Patent Literature	CRC-Handbook-63rd-Ed-1983-p-E-201-.pdf	129236 9222f64f12dbf5f7f75763e61f3a78c22e741e5a	no	2
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20	Non Patent Literature	December-16-2004-Office-Action-in-US-Patent-Application-No-10623198-issued-by-Thao-X-Le-A.pdf	232742 c27ee9384c570b5fd26ac98a977becf69dc38cb2	no	5
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21	Non Patent Literature	Dictionary-Definition-of-Phosphor-Oxford-English-Dictionary-Online-March-9-2012-Only-part.pdf	386037 a975342e609d71de74be76c3142abde69b378a6d	no	3
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24	Non Patent Literature	February-26-2008-Office-Action-in-US-Patent-Application-No-11264124-issued-by-Abu-I-Kalam.pdf	304230 4ae06ee7976ffc30f326cb3337a3d11232024eeb	no	7
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25	Non Patent Literature	February-4-2005-Office-Action-in-US-Patent-Application-No-10623198-issued-by-Thao-X-Le-Ar.pdf	509214 57cc0b22c1a548d45703d96047e930cc04f3fd85	no	11
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26	Non Patent Literature	February-7-2007-Office-Action-in-US-Patent-Application-No-11264124-issued-by-Thao-X-Le-Ar.pdf	1648229 b19c78853089be9d41c71ece6f8e18a33d1f0104	no	49
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27	Non Patent Literature	FORREST-S-ET-AL--Organic-emitters-promise-a-new-generation-of-displays-Laser-Focus-World-.pdf	912044 feb0c8ae1b2baa0dcc3b530c7d369092fc4bdafb	no	7
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29	Non Patent Literature	HAMAKAWA-YOSHIHIRO-ET-AL-Toward-a-visible-light-display-by-amorphous-SiCH-alloy-system-Op.pdf	779093 b098f5ac92d580300db99aa1c94569e64f653f69	no	14
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32	Non Patent Literature	January-29-2007-Office-Action-in-US-Patent-Application-No-10623198-issued-by-Thao-X-Le-Ar.pdf	541680 308668a21963d65b16047f43bba2d2d16519e21e	no	12
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33	Non Patent Literature	January-30-2006-Office-Action-in-US-Patent-Application-No-11264124-issued-by-Thao-X-Le-Ar.pdf	403550 f5625f85d2031358bd64d0985dbeb24933351867	no	9
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34	Non Patent Literature	January-7-2011-Office-Action-in-US-Patent-Application-No-12131119-issued-by-Steven-Y-Hori.pdf	1843104 d8069cd5e0dc97ce4c06e2520fb5fe0d5de2e38a	no	36
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35	Non Patent Literature	July-10-2008-Office-Action-in-US-Patent-Application-No-11264124-issued-by-Abu-I-Kalam-Art.pdf	439070 eac1cf87b656cbf12cba79af58c7a9d83e8ad934	no	9
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38	Non Patent Literature	July-7-2011-Office-Action-in-US-Patent-Application-No-12131118-issued-by-Abu-I-Kalam-Art-.pdf	1254500 0f3965313f64947b4229b040a2985e1c857fdced	no	29
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39	Non Patent Literature	June-14-2006-Office-Action-in-US-Patent-Application-No-11264124-issued-by-Thao-X-Le-Art-U.pdf	441824 6ab72d93615360e65110482b2079de963217dfa1	no	9
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41	Non Patent Literature	KIDO-J-ET-AL--1-24-Triazole-Derivative-as-an-Electron-Transport-Layer-in-Organic-Luminesc.pdf	391729 6391c0c01eddfb56aba64ae63a76d69b5da9549c	no	4
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42	Non Patent Literature	KIDO-J-ET-AL--Bright-blue-electroluminescence-from-polyN-vinylcarbazole-Appl-Phys-Letters.pdf	361571 bf4480bba2d0ce67432d834ad7c16777b106cfe0	no	3
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43	Non Patent Literature	KIDO-J-ET-AL-White-light-emitting-organic-electroluminescent-devices-using-the-polyN-viny.pdf	312321 edd1912ad411aa6243f02d50004096ab561d98b5	no	3
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44	Non Patent Literature	KRAMES-M-ET-AL-Status-and-Future-of-High-Power-Light-Emitting-Diodes-for-Solid-State-Ligh.pdf	2106883 99b0424ac2e6c2f4a66649bafc1b46de0cd3da22	no	16
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45	Non Patent Literature	KUDRYASHOV-V-ET-AL-Spectra-of-Superbright-Blue-and-Green-InGaNAlGaNGaN-Light-Emitting-dio.pdf	492760 d860f343c6040ebb125b6d364df60abf218f9e95	no	5
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46	Non Patent Literature	LARACH-S-ET-AL-Blue-emitting-luminescent-phosphors-Review-and-status-Intl-Workshop-on-Ele.pdf	416902 3e3728e770f58535d5d1ad8e932ef160498-6ca17	no	7

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47	Non Patent Literature	LEDs-and-Laser-Diodes-Electus-Distribution-copyright-2001.pdf	461853 f98e7512beb860cef19873045b407fdbb28e6e53	no	3
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48	Non Patent Literature	LESTER-S-ET-AL-High-dislocation-densities-in-high-efficiency-GaN-based-light-emitting-dio.pdf	440955 312d6b9c4654dc13d202130fe21f4c63a1785b8d	no	4
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51	Non Patent Literature	March-22-2012-Office-Action-in-US-Patent-Application-No-12131119-issued-by-Steven-Y-Horik.pdf	2984837 ca4cca712df84701006a59cc5f0c9b86098f23f9	no	43
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52	Non Patent Literature	March-28-2006-Office-Action-in-US-Patent-Application-No-10623198-issued-by-Thao-X-Le-Art-.pdf	526477 b3652dce6c92b960c9d92e2b06499cc68bc77e9c	no	12
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53	Non Patent Literature	March-4-2011-Notice-of-Allowance-Notice-of-Allowability-Examiners-Interview-Summary-Exami.pdf	707687 ed59c9b263cbd5fbd63584041da98a63b296792c	no	10
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55	Non Patent Literature	MARUSKA-HP-ET-AL-Violet-luminescence-of-Mg-doped-GaN-Appl-Phys-Lett-March-15-1973-Pages-3.pdf	263519 df6dbb58d5c23bcf7fa552f74a076a1dcd2f991b	no	3

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57	Non Patent Literature	May-4-2010-Office-Action-in-US-Patent-Application-No-12131119-issued-by-Examiner-Steven-H.pdf	1374466 29fe6219bf75eb15d75bae1850c0b6faefefd688	no	25
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58	Non Patent Literature	MCGRAW-HILL-McGraw-Hill-Dictionary-of-Scientific-and-Technical-Terms-Third-Edition-McGraw.pdf	412707 846ca9a996486c9173bfc49690b28a06f338d49f	no	4
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59	Non Patent Literature	MCGRAW-HILL-McGraw-Hill-Encyclopedia-of-Science-and-Technology-Sixth-Edition-McGraw-Hill-.pdf	504341 86d2373c6106ee0db0054436554b872ef79ccc95	no	6
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60	Non Patent Literature	MIMURA-HIDENORI-ET-AL-Visible-electroluminescence-from-uc-SiCporous-Sic-Si-p-n-junctions-.pdf	398963 8ec6a85c191cae2951210cb47ef7ea7be3135966	no	6
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(54) **ORGANIC ELECTROLUMINESCENT ELEMENTS.**

(57) The first organic electroluminescent element is provided with a low-molecular 1,2,4-triazole derivative layer; the second element has a carrier transport control layer for selectively transporting holes or electrons, which layer is interposed between an electron transport layer and a hole transport layer; the third element comprises a laminate of an electron transport with a hole-transport luminescent layer wherein a coloring matter is dispersed in a polymer on the molecular level; the fourth element is provided with a layer containing a high-molecular 1,2,4-triazole derivative as the hole transport material; and the fifth element is provided with a layer wherein a hole transport material is dispersed in a high-molecular 1,2,4-triazole derivative on the molecular level. These elements are excellent in luminous efficacy, luminance and stability, and permit blue luminescence, primary multi-color luminescence, and white luminescence.

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TECHNICAL FIELD

The present invention relates to organic electroluminescent (EL) elements.

BACKGROUND ART

It is considered that the light emission of an organic electroluminescent element is caused by a phenomenon where holes and electrons injected from electrode are recombined within a luminescent layer to generate excitons, and the excitons excite molecules of luminescent materials constituting the luminescent layer. By employing fluorescent dye as a luminescent material, there can obtain an emission spectrum, as an electroluminescence, being equivalent to photoluminescence of the dye molecules.

Tang and Vanslyke recently proposed an element comprising two layers of a hole-transport layer and an electron-transport luminescent layer which efficiently emits green light at a lower voltage of about 10 V compared with a conventional organic electroluminescent element of a single-layer structure [C.W. Tang and S.A. Vanslyke; Appl. Phys. Lett., 51 (1987) 913]. This element's structure is, as shown in Fig. **19 (a)**, composed of an anode **91**, a hole-transport layer **92**, an electron-transport luminescent layer **93** and a cathode **94**, which are formed in this order on a glass substrate **90**.

In this element, the hole-transport layer **92** not only allows holes to be injected from the anode **91** into the electron-transport luminescent layer **93**, but prevents electrons injected from the cathode **94** from escaping into the anode **91** without recombining with the holes, so that the electrons are contained into the electron-transport luminescent layer **93**. Thus, the electron containment effect due to the hole-transport layer **92** facilitates the recombination of the holes and the electrons compared with the conventional single-layer structure element, resulting in a substantial decrease in drive voltage.

Saito et al. showed that not only the electron-transport layer but hole-transport layer can become the luminescent layer in the two-layer structure element [C. Adachi, T. Tsutsui and S. Saito; Appl. Phys. Lett., 55 (1989) 1489].

Saito et al. also proposed a three-layer structure organic electroluminescent element wherein an organic luminescent layer is interposed between a hole-transport layer and an electron transport layer [C. Adachi, S. Tokito, T. Tsutsui and S. Saito; Jpn. J. Appl. Phys., 27 (1988) L269].

The two-layer structure element of Saito et al. is, as shown in Fig. **19 (b)**, composed of an anode **91**, a hole-transport luminescent layer **95**, an electron-transport layer **96** and a cathode **94**, which are formed in this order on a glass substrate **90**. In contrast to the previous element, the electron-transport layer **96** not only allow electrons to be injected from the cathode **94** into the hole-transport luminescent layer **95**, but prevents the holes injected from the anode **91** from escaping into the cathode **94** avoiding the recombination with the electrons, so that the holes are contained into the hole-transport luminescent layer **95**. This hole containment effect due to the electron-transport layer **96** realizes a substantial decrease in drive voltage likewise in the previous element.

The three-layer structure element of Saito et al. was attained by a further improvement in the element of Tang et al. As shown in Fig. **19 (c)**, this element is composed of an anode **91**, a hole-transport layer **92**, a luminescent layer **97**, an electron-transport layer **96** and a cathode **94**, which are formed in this order on a glass substrate **90**. The hole-transport layer **92** contains electrons into the luminescent layer **97**, and the electron-transport layer **96** contains holes into the luminescent layer **97**, so that the recombination of the electrons and the holes in the luminescent layer **97** is more efficient than the two-layer structure element.

Further, the electron-transport layer **96** and the hole-transport layer **92** prevent excitons generated by the above recombination from escaping into either an anode or a cathode. Therefore, the three-layer structure element of Saito et al. increases luminous efficiency furthermore.

Examples of hole-transport material which constitute the above organic electroluminescent elements are aromatic tertiary amines such as triphenylamine. Examples of electron-transport material are oxadiazoles. Examples of luminescent material are tetraphenybutadiene derivatives, tris(8-quinolinolato)aluminum (III) complex, distyrylbenzene derivatives, distyrylbiphenyl derivatives.

Advantages of the above organic electroluminescent elements are that they can emit light of high luminance at a lower voltage than a conventional electroluminescent element employing inorganic luminescent material, and that they can easily increase the surface area because the respective layers can be formed not only by vacuum deposition but solution application, and that they can emit light of multi-color depending upon molecular design for organic molecule. Each element, however, has the disadvantage that luminance decrease significantly with a long-term emission. It is therefore the urgent problems to improve stability and to extend the life.

Savant Technologies LLC - 1004.609

In the meantime, the conventional electroluminescent elements have the disadvantage that it is difficult to emit blue light irrespective of organic/inorganic or single/plural layer.

For example, the inorganic element has a problem that an inorganic light emission material with a wide band gap required for blue light emission is limited. Moreover, such a material is often accompanied by technical difficulties in crystal growth or thin film production, thereby making it difficult to produce an element from this material.

On the other hand, in the organic material, although multi-color due to molecular design can be obtained as described above, there are small number of material capable of emitting blue light. The known examples are merely anthracene and distyrylbenzene derivative of which luminous efficiency is insufficient. Accordingly, for practical applications they are far from adequate.

Further, every conventional electroluminescent element is for a single color light emission. It is therefore impossible at present to realize, by using one element, light emission of more than two mutually different spectrums which enables a multi-color display due to three primary color emissions: R (Red); G (Green); and B (Blue), and white light emission.

In order to solve the above problem, Ogura et al. proposed a three-layer structure element employing a bis-di(p-tolyl)aminophenyl-1,1-cyclohexane as a diamine derivative for a hole-transport layer, a 1,1-di(p-methoxyphenyl)-4,4-diphenylbutadiene as a tetraphenylbutadiene derivative for a luminescent layer and a 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole as an oxadiazole derivative for an electron-transport layer [Sharp Technical Journal, 52 (3), 15-18 (1992)].

This element has a peak of emission spectrum at wavelengths of 480 nm and 590 nm, and emits white light. The light having the wavelength of 480 nm is due to the luminescent layer having hole-transport properties, while that having a wavelength of 590 nm is due to the hole-transport layer. Ogura et al. described that the mechanism of light emission from the hole-transport layer is based on diffusion of excitons from the luminescent layer.

Mori et al. proposed an organic electroluminescent element comprising a single luminescent layer, wherein luminescent material such as a coumarin 6 and a coumarin 7 being known as a laser dye, and an oxadiazole derivative as an electron-transport material are molecularly dispersed in a high-molecular poly-N-vinyl carbazol which serves as a hole-transport material and a resin binder. It is their opinion that various color light emissions are available by selecting the kind of dye to be molecularly dispersed in the luminescent layer [Oyo Buturi 61(10), 1044-1047 (1992)].

This element may realize a multi-color display due to three primary colors of R, G and B or white light emission by selecting the dye kind and the dye combination.

In contrast, the three-layer structure element of Ogura has the disadvantage of being unstable due to a large drop in luminescent intensity during the use. It appears that this instability is caused by deterioration, coagulation or crystallization due to heat release when the element emits light.

In the single-layer structure element of Mori, the recombination of the holes and the electrons is insufficient and its luminance is low because of being a single-layer.

It is one object of the present invention to provide an organic electroluminescent element which is excellent in luminous efficiency, luminance and stability.

It is another object of the present invention to provide an organic electroluminescent element capable of emitting such color light, particularly blue light, at sufficient efficiency, which has never been obtained or failed to emit light at high luminous efficiency.

It is still another object of the present invention to provide an organic electroluminescent element which can emit light of more than two mutually different emission spectrums, and which can emit color light such as multi-color display due to three primary colors and white light emission, which has never been obtained at sufficient efficiency or failed to emit it at high luminous efficiency.

DISCLOSURE OF THE INVENTION

The first organic electroluminescent element of the present invention comprises at least one layer of a 1,2,4-triazole derivative.

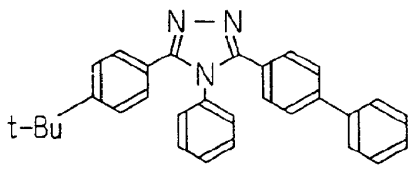
The low-molecular 1,2,4-triazole derivative (the term "low-molecular" used herein is not shown by molecular weight, but means that it has no main chain structure like a high-molecular 1,2,4-triazole derivative described later) have never been employed as an organic electroluminescent material until the present inventors do so.

Although the 1,2,4-triazole derivative is not valid for a hole-transport material, if employed it as an electron-transport material, it presents electron-transport properties and hole-blocking properties superior to those of other conventional materials. Thus the efficiency of the recombination of electron and holes

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increases and that of containment of excitons generated by the above combination increases, both contributing a further increase in luminous efficiency, luminance of the luminescent layer and stability accompanied thereby. Particularly, the combination of this derivative and a conventional luminescent layer for blue light emission which has high hole-transport properties, can raise luminous efficiency and luminance to a required level for practical applications. This realizes such blue light emission having high luminance as previously described.

For the low-molecular 1,2,4-triazole derivative, a 3-(4-biphenylyl)-4-phenyl-5-(4-tert-butylphenyl)-1,2,4-triazole (hereinafter referred to as "TAZ") expressed by the formula:



(1)

is preferred because it is excellent in both electron-transport properties and hole-blocking properties.

The second organic electroluminescent element of the present invention is characterized by a carrier-transport control layer for selectively transporting holes or electrons, which is interposed between a hole-transport layer and an electron-transport layer.

In this element, the exciton containment effect due to a carrier-transport control layer composed of material such as the low-molecular 1,2,4-triazole derivative, which selectively transports holes or electrons, provide the hole-transport layer or the electron-transport layer with high luminance and high luminous efficiency as a luminescent layer. It is therefore possible to increase luminous efficiency and luminance as well as stability accompanied thereby. Hence, the use of a hole-transport layer composed of material capable of emitting blue light emission(e.g. the poly-N-vinyl carbazole) along with an electron-transport layer promotes luminous efficiency and luminance for blue light emission to a required level for practical applications.

Besides, by selecting the material and film thickness for the carrier-transport control layer, it is possible to allow the hole-transport layer and/or electron-transport layer to emit light at high luminance and high luminous efficiency. Therefore, one element can emit more than two mutually different emission spectrums, by using different emission spectrum materials for the hole-transport layer and electron-transport layer. This might result in the practical use of light emission such as the multi-color display due to three primary colors of R, G and B, and white light emission.

The third organic electroluminescent element of the present invention is characterized in that at least one electron-transport layer and at least one hole-transport luminescent layer are provided and that the hole-transport luminescent layer is formed by molecularly dispersing at least one kind of dye in a polymer.

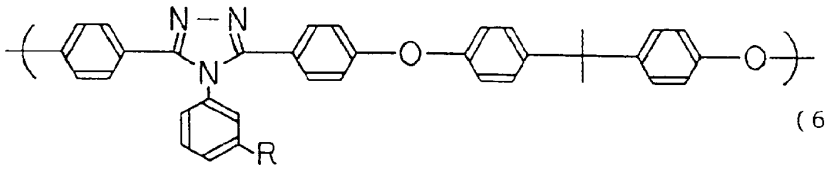
Specifically, the hole-transport luminescent layer has heat resistance superior to that of a conventional hole-transport layer of a low-molecular material, and is also excellent in adhesion to a substrate such as ITO glass and ITO film. It is therefore possible to form a hole-transport luminescent layer wherein there hardly occurs deterioration, aggregation, crystallization or the like due to heat release when the element emits light, resulting in an increase in stability.

Compared to a single-layer element, the combination of the aforesaid hole-transport luminescent layer and an electron-transport layer increases furthermore carrier injection efficiency and the recombination efficiency for holes and electrons, resulting in light emission having high luminous efficiency and high luminance.

Besides, a dye can be easily dispersed in a polymer by adjusting a solution. It is therefore possible to disperse plural dye in one hole-transport luminescent layer. This realizes a multi-color display having good color purity due to three primary color, white light emission and natural light emission, depending upon the dye kind or the dye combination.

The fourth organic electroluminescent element of the present invention is characterized in that there is provided with a hole-transport layer which contains, as a hole-transport material, a high-molecular 1,2,4-triazole derivative (hereinafter referred to as "PTAZ") of a repeating unit expressed by the general formula (6):

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(6)

wherein R denotes at least one member selected from the group consisting of a hydrogen atom, a methyl group and an ethyl group.

The fifth organic electroluminescent element of the present invention is characterized in that there is provided with a hole-transport layer which contains the PTAZ as a resin binder, and in the hole-transport layer a low-molecular hole-transport material is molecularly dispersed in the PTAZ.

The PTAZ used in these elements has never been employed as a material for organic electroluminescent elements until the present inventors do so.

As seen from its molecular structure, the PTAZ is applicable to a hole-transport material, and yet it is polymer. Accordingly, it has heat-resistance superior to that of a conventional low-molecular hole-transport material. It is therefore possible to form a hole-transport layer wherein there hardly occurs deterioration, crystallization due to heat release when the element emits light.

The PTAZ has a higher glass transition temperature (about 200 °C or more) than a normal polymer such as polycarbonate, and is excellent in optical characteristics. Therefore, if employed it as a resin binder for a so-called molecular-dispersion hole-transport layer wherein a low-molecular hole-transport material is molecularly dispersed in a resin binder, it is possible to prevent such a hole-transport material from causing aggregation or crystallization due to the aforesaid heat release.

Accordingly, the PTAZ is greatly useful in increasing stability, luminous efficiency and luminance for an element.

In the fifth element of the present invention, the PTAZ prevents a luminescent material being excited by the recombination of carriers from forming exciplex together with the hole-transport material. As a result, the luminescent material emits light at high efficiency, thus increasing luminous efficiency of the element. Particularly, the combination of the PTAZ and a conventional luminescent material for blue light emission whose luminous efficiency is low can raise the luminous efficiency to a required level for practical applications.

As described above, the first to fifth organic electroluminescent elements of the present invention can emit color light as previously mentioned, particularly blue one. Further, these organic electroluminescent elements can emit light of more than two mutually different emission spectrums, and can emit color light such as a multi-color display due to three primary colors and white light emission, which has never been produced with sufficient efficiency or has been failed to emit it at high luminous efficiency.

BRIEF DESCRIPTION OF DRAWINGS

Fig. **1(a)** is a vertical sectional view illustrating a preferred embodiment of the fist organic electroluminescent element of the present invention, and Fig. **1(b)** is a vertical sectional view illustrating one embodiment of the second organic electroluminescent element of the present invention.

Figs. **2(a) to 2(c)** are schematic diagrams illustrating the principle of light emission of an element wherein the film thickness of the TAZ layer as a carrier-transport control layer is sufficiently large, among the three-layer structure of the second organic electroluminescent element.

Fig. **3(a) to 3(c)** are schematic diagrams illustrating the principle of light emission of an element wherein the film thickness of the TAZ layer as the carrier-transport control layer is sufficiently small.

Fig. **4(a) to 4(c)** are schematic diagrams illustrating the principle of light emission of an element wherein the film thickness of the TAZ layer as a carrier-transport control layer is intermediate between those of Figs. **2** and **3**.

Fig. **5(a) to 5(c)** are schematic diagrams illustrating the principle of light emission of an element having a two-layer structure wherein no TAZ layer is interposed between the TPD layer as a hole-transport layer and the Alq layer as an electron-transport layer.

Fig. **6(a)** is a vertical sectional view illustrating an element whose electron-transport layer has a two-layer structure, among the third organic electroluminescent element, and Fig. **6(b)** is a vertical sectional view illustrating an element whose electron-transport layer is a single layer.

Savant Technologies LLC - 1004.612

Fig. **7** is a graph illustrating the measurement results of the relation, between drive voltage and luminance in the first organic electroluminescent element prepared in Example 1.

Fig. **8** is a graph illustrating the measurement results of the relation between drive voltage and luminance in the first organic electroluminescent element prepared in Example 2.

Fig. **9** is a graph illustrating the measurement results of an emission spectrum of the organic electroluminescent element prepared in Example 2.

Fig. **10** is a graph illustrating the measurement results of the relation between drive voltage and luminance in the second organic electroluminescent element prepared in Example 4.

Fig. **11** is a graph illustrating the measurement results of emission spectrums of the second organic electroluminescent element prepared in Examples **4**, 5 and 6.

Fig. **12** is a graph illustrating the measurement results of emission spectrums of the second organic electroluminescent element prepared in Examples 7 and 8.

Fig. **13** is a graph illustrating the measurement results of an emission spectrum of the third organic electroluminescent element prepared in Example 9.

Fig. **14** is a graph illustrating the measurement results of an emission spectrum of the third organic electroluminescent element prepared in Example 10.

Fig. **15** is a graph illustrating the measurement results of an emission spectrum of the third organic electroluminescent element prepared in Example 11.

Fig. **16** is a graph illustrating the measurement results of an emission spectrum of the third organic electroluminescent element prepared in Example 12.

Fig. **17** is a graph illustrating the measurement results of the relation between drive voltage and luminance in the fifth organic electroluminescent element prepared in Example 16.

Fig. **18** is a graph illustrating the measurement results of an emission spectrum of the organic electroluminescent element prepared in Example 16.

Figs. **19(a) to 19(c)** are vertical sectional views illustrating the conventional organic electroluminescent elements.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention will be described in detail.

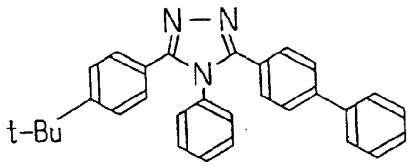
Followings are to describe the first organic electroluminescent element comprising at least one layer of a 1,2,4-triazole derivative.

The phrase "a layer of a 1,2,4-triazole derivative" used herein denotes a layer containing at least one kind of the low-molecular 1,2,4-triazole derivatives as previously described. There are, for example, a layer which solely comprises one or more kinds of the 1,2,4-triazole derivatives, and a layer wherein one or more kinds of the 1,2,4-triazole derivatives are dispersed in a suitable binder.

The 1,2,4-triazole derivative layer may contain other ingredients such as various additives, which do not inhibit its function.

The 1,2,4-triazole derivative layer can be formed by vapor phase deposition such as vacuum deposition, or solution application to apply, on a substrate or the other layer, a solution wherein a material constituting the layer is dissolved in a suitable solvent, followed by drying.

Various compounds can be employed for the 1,2,4-triazole derivative. Most preferred is a TAZ expressed by the formula:



(1)

because it is excellent in both electron-transport properties and hole-blocking properties.

The film thickness of this derivative layer is not specifically limited in the present invention. But if it is too thin, hole- block properties become insufficient and, therefore it requires a certain amount of thickness. Although its suitable range is not specifically limited, its lower limit is preferably a range from 100 to 200 Å

Savant Technologies LLC - 1004.613

for a vapor deposited film of the PAZ expressed by the formula (1), in order to hold a sufficient hole-blocking properties.

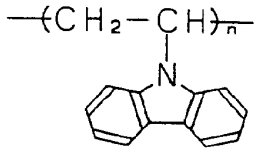
Although its upper limit is not specifically limited, if this layer is too thick, electron-transport properties decreases. For example, it is desired to be not more than 1000Å for the vapor deposited film of the TAZ.

The 1,2,4-triazole derivative layer is essential to the first organic electroluminescent element. There are no other construction restrictions. That is, it may be either a conventional single-layer structure or a multi-layer structure. In short, the construction of the first element is applicable to any layers irrespective of the construction kind.

In an element having the multi-layer structure, no particular restrictions to other layers than the 1,2,4-triazole derivative layer. There can employ various conventional materials used for the respective layers. Also, there are no restrictions for the film thickness of each layer constituting the element. Each layer can be formed by the aforesaid solution application and vapor phase deposition as in the 1,2,4-triazole derivative layer. Each layer may contain other ingredients such as resin binders and various additives, which do not directly affect the function of the layer.

In this element, since the layer of the 1,2,4-triazole derivative presents excellent electron-transport properties and hole-blocking properties as described above, it is possible to emit blue light emission at high luminance which has been difficult to realize by the combination of the 1,2,4-triazole derivative layer as an electron-transport layer and the hole-transport luminescent layer for blue light emission, which has high hole-transport properties.

Most preferred hole-transport luminescent layer for blue light is a layer of poly-N-vinylcarbazole (hereinafter referred to as "PVK") expressed by the formula:



(2)

wherein **n** is a polymerization degree.

The PVK layer has high hole mobility and, therefore holes injected into the layer escape into a cathode, thus normally failing to emit light. However, the blue light emission can be obtained by combing the PVK layer with the 1,2,4-triazole derivative layer which is excellent in the excitons containment and high hole-blocking properties.

Further, the PVK also performs the function of the hole-transport material as seen from its molecular structure, and has heat resistance superior to the conventional hole-transport materials such as the low-molecular aromatic tertiary amine compounds as previously described, because it is a polymer. Therefore, it is possible to form a hole-transport luminescent layer for blue light emission wherein there hardly occurs deterioration or crystallization due to heat release on storage or light emission of the element.

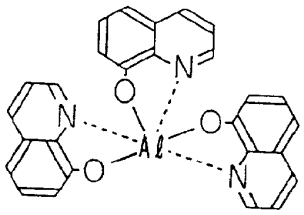
Moreover, the PVK layer is excellent in adhesion to substrates such as ITO glass and ITO film.

Hence, the combination of the PVK layer as a hole-transport luminescent layer and the 1,2,4-triazole derivative layer realizes an organic electroluminescent element for blue light emission that presents excellent luminous efficiency, luminance and stability and that can be put to practical use.

The polymerization degree **n** of the PVK is not specifically limited in the present invention, but it is preferably about 20 to 5000. If it is below this range, heat resistance and adhesion tend to be insufficient. On the other hand, if it is beyond this range, the layer formation by solution application might be difficult.

More preferred element of the combination of the 1,2,4-triazole derivative layer and the PVK layer (a hole-transport luminescent layer) is that having a three-layer structure wherein a layer of a tris(8-quinolinolato)aluminum (III) complex (hereinafter referred to as "Alq") expressed by the formula:

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(3)

is provided as an electron-transport layer. In this element, the action of the Alq layer promotes electron injecting properties to the hole-transport luminescent layer, thus obtaining blue light emission having high luminance at higher efficiency.

The layer construction of the three-layer structure element is not specifically limited. But, if consideration is given to the fact that the PVK layer is excellent in adhesion to substrates such as ITO glass and ITO film, and is formed exclusively by solution application, it is preferable to use an element wherein three layers: a hole-transport luminescent layer (a PVK layer) **10**, a layer of a 1,2,4-triazole derivative (a TAZ layer) **20** and an electron-transport layer (an Alq layer) **30** are laminated in this order on an anode **40** of a transparent conductive material such as ITO (indium-tin-oxide) being formed on a glass substrate **4**, as shown in Fig. **1(a)**. In Fig. **1(a)**, the reference numerals **5** and **B** denote a cathode of metal deposited film such as Mg/Ag and a power source for applying a drive voltage to the element, respectively.

The film thickness for the PVK layer **10** and the Alq layer **30** is not specifically limited in the present invention. There can set to an appropriate range depending upon the kind of the 1,2,4-derivative to be used and the film thickness of the layers.

Since the PVK layer is a polymer, the PVK layer **10** can be formed by the aforesaid solution application.

The Alq layer **30** contains at least the Alq. For example, there are a layer consisting the Alq alone or a layer wherein the Alq is dispersed in a suitable binder. The Alq layer **30** can be formed by the aforesaid solution application and vapor phase deposition.

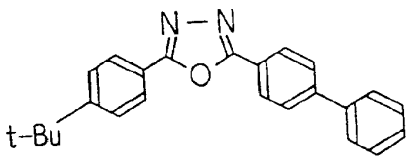
The PVK layer **10** and the Alq layer **30** may contain other ingredients such as various additives, which do not inhibit the functions of the PVK and the Alq.

Followings are to describe the second organic electroluminescent element having a three-layer structure comprising a carrier-transport control layer, which is interposed between a hole-transport layer and an electron-transport layer.

This element is, as shown in Fig. **1(b)**, composed of laminated three layers: a hole-transport layer **1**; a carrier-transport control layer **2** and an electron-transport layer **3**, which are formed in this order or in the reverse order, on an anode **40** of a transparent conductive material such as ITO (indium-tin-oxide) being formed on a glass substrate **4**. It is essential that the layer **2** is sandwiched between the layers **1** and **3**. In Fig. **1(b)**, reference numerals **5** and **B** denote a cathode of metal deposited film such as Mg/Ag and a power source for applying a drive voltage to the element, respectively, likewise in Fig. **1(a)**.

Most preferred carrier-transport control material for the carrier-transport control layer **2** is the 1,2,4-triazole derivative such as the TAZ.

There are, for example, a 1,3,4-oxadiazole derivative being known as an electron-transport material. There can employ various compounds for this derivative. More preferred is a 2-(4-biphenylyl)-5-(4-tert-butylphenyl)-1,3,4-oxadiazole (hereinafter referred to as "PBD") expressed by the formula:



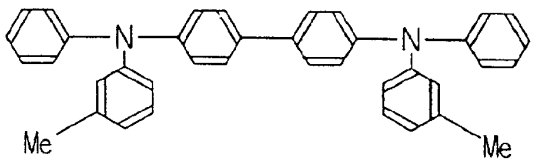
(4)

There can also employ various conventional compounds which have been used as an electron-transport material or hole-transport material.

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The carrier-transport control layer **2** functions such that either or both of the hole-transport layer **1** or/and electron-transport layer **3** emit light at high luminance and high efficiency depending upon its material and its film thickness as previously described.

The function of the carrier-transport control layer **2** will be described through an example where there employs a vapor deposited film of the TAZ (the TAZ layer) as a carrier-transport control layer **2**, a vapor deposited layer of a N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4-diamine (hereinafter referred to as "TPD") expressed by the formula:



(5)

(the TPD layer) as a hole-transport layer **1** and a vapor deposited film of the Alq (the Alq layer) expressed by the formula (3) as an electron-transport luminescence layer **3**.

In general, carrier injection into an organic insulating film is restricted by space charge. The current capacity that passes through the organic insulating film is proportional to the mobility of carriers and the square of the electric field strength, and is inversely proportional to the cubic of the film thickness of the organic insulating film. That is, the larger the electric field strength and mobility, the more carrier injection is accelerated. The larger the film thickness, the more carrier injection are restricted.

In an element of a two-layer structure (which corresponds to the element of Tang et al.) being composed of a TPD layer **1** and an Alq layer **3** as shown in Fig. **5**, when a bias voltage is applied between an anode **40** and a cathode **5**, holes are firstly injected into the TPD layer **1** and blocked on the TPD/Alq interface to form space charge (Fig. **5(a)**).

At this time, the electric field strength applied on the Alq layer **3** becomes larger than the apparent electric field strength applied between a couple of electrodes **40**, **5** because of the space charge on the TPD/Alq interface, thereby initiating an electron injection into the Alq layer **3** (Fig. **5(b)**).

Then, excitons are generated by the recombination of the holes and the electrons on the Alq layer **3** in the vicinity of the TPD/Alq interface (Fig. **5(c)**), and the Alq is excited to emit light.

When the TAZ layer is interposed between the TPD layer **1** and Alq layer **3**, the injection order for holes and electrons are the same. When the film thickness of the TAZ layer **2** is sufficiently large (for example, about 150Å or more) as shown in Fig. **2**, the TAZ layer **2** exhibits excellent hole-blocking properties similar to the first element, so that holes thus injected are blocked at the TPD/TAZ interface (Fig. **2(a)**).

Electrons which are being injected into the Alq layer **3** by the formation of the space charge due to the holes are transported to the TPD/TAZ interface because the TAZ layer **2** is excellent in electron-transport properties (Fig. **2(b)**), and excitons are generated by the recombination of the holes and the electrons (Fig. **2(c)**) and the TPD whose excitation energy level is lower than that of the TAZ is excited by the excitons thus generated to emit light.

On the other hand, when the film thickness of the TAZ layer **2** is sufficiently small (for example, about 50Å or less), as shown in Fig. **3**, holes injected into the TPD layer **1** by applying a bias voltage between a couple of electrodes **40**, **5** pass through the TAZ layer **2** and blocked at the TAZ/Alq interface to form space charge (Fig. **3(a)**). The reason why the holes pass through the TAZ layer **2** is that the injection amount of carriers (the holes in this case) is inversely proportional to the cubic of the film thickness of the TAZ layer **2** being the organic insulating film.

Then, electrons injects into the Alq layer **3** by the formation of the space charge due to holes (Fig. **3(b)**-), and excitons are generated by the recombination of the holes and the electrons on the TAZ/Alq interface (Fig. **3(c)**), and then the Alq whose excitation energy level is lower than that of the TAZ is excited by the excitons thus generated to emit light.

Still further, when the film thickness of the TAZ layer **2** is intermediate between the above value (in case of being in a range from about 50 to about 150Å), some of the holes which are injected into the TPD layer **1** by applying a bias voltage between a couple of electrodes **40**, **5** are blocked on the TPD/TAZ interface, the others pass through the TAZ layer **2** and are blocked on the TAZ/Alq interface (Fig. **4(a)**).

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