

(19) Japan Patent Office (JP)

(12) Gazette of Unexamined Patent Applications (A)

(11) Publication Number
2008-117879
(P2008-117879A)

(43) Publication Date May 22, 2008 (2008.5.22)

(51) Int.Cl.		FI			Theme Codes (Reference)
H01L 33/00	(2006.01)	H01L 33/00		N	2H091
G02F 1/13357	(2006.01)	G02F 1/13357			2H191
F21V 8/00	(2006.01)	F21V 8/00		601A	3K243
F21S 8/04	(2006.01)	F21S 1/02		G	5F041
F21Y 101/02	(2006.01)	F21Y 101:02			
Examination Request Not Yet Received No. of Claims 7 OL (Total of 11 Pages)					

(21) Appl. No. 2006-298515 (P2006-298515)

(22) Filing Date Nov. 2, 2006 (2006.11.2)

(71) Applicant 000111672
Harison Toshiba Lighting Corporation
5-2-1, Asahi-machi, Imabari-shi, Ehime-ken

(74) Agent 100108062
Masahiko HYUGAJI, Patent Attorney

(74) Agent 100146592
Hiroshi ICHIKAWA, Patent Attorney

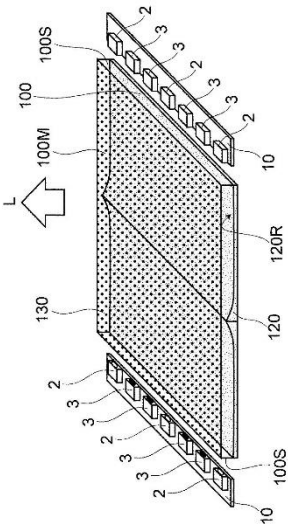
(72) Inventor
Junichi KINOSHITA
Harison Toshiba Lighting Corporation
5-2-1, Asahi-machi, Imabari-shi, Ehime-ken

F Terms (Reference)
2H091 FA01Z FA16Z FA23Z FA32Z FA45Z
FA46Z FB02 FC13 FD13 FD24 LA12
LA20

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(54) [Title of the Invention] Planar Light-Emitting Device

(57) [Abstract]
[Problem] To provide a planar light-emitting device that can stably obtain a specified chromaticity and luminance balance while holding down costs.
[Solution] Provided is a planar light-emitting device comprising: a light guide plate having a main surface and a side surface that emits light incident from the side surface via the main surface; a first light-emitting element that causes blue light to be incident on the side surface of the light guide plate; and a wavelength conversion sheet provided on the main surface of the light guide plate and containing a wavelength conversion material that absorbs light emitted from the first light-emitting element and emits green light.
[Selected Drawing] FIG. 1



[Claims]

[Claim 1]

A planar light-emitting device comprising: a light guide plate having a main surface and a side surface that emits light incident from the side surface via the main surface; a first light-emitting element that causes blue light to be incident on the side surface of the light guide plate; and a wavelength conversion sheet provided on the main surface of the light guide plate and containing a wavelength conversion material that absorbs light emitted from the first light-emitting element and emits green light.

[Claim 2]

10 The planar light-emitting device according to claim 1, wherein further comprising a second light-emitting element that emits red light toward the side surface of the light guide plate.

[Claim 3]

A planar light-emitting device comprising: a diffusion plate having a main surface and a back surface that makes uniform the intensity distribution of light incident from the back surface and emits the light via the main surface; a plurality of first light-emitting elements arranged two-dimensionally on the back surface of the diffusion plate, each emitting blue light; and a wavelength conversion sheet provided on the side of the main surface or the back surface of the diffusion plate and containing a wavelength conversion material that absorbs light emitted from the first light-emitting elements and emits green light.

[Claim 4]

20 The planar light-emitting device according to claim 3, further comprising a plurality of second light-emitting elements provided on the back surface side of the diffusion plate, each of which emitting red light.

[Claim 5]

The planar light-emitting device according to any one of claims 1 to 4, wherein further comprising a third light-emitting element that emits blue light with a wavelength shorter than that of the blue light emitted from the first light-emitting element.

[Claim 6]

The planar light-emitting device according to any one of claims 1 to 5, wherein the luminance of the green light emitted to the outside is five times or more the luminance of the blue light emitted to the outside.

[Claim 7]

30 The planar light-emitting device according to any one of claims 1 to 6, wherein the wavelength of the red light is in the range of 590 to 670 nanometers, the wavelength of the blue light is in the range of 420 to 480 nanometers, and the wavelength of the green light is in the range of 520 to 560 nanometers.

[Detailed Description of the Invention]

[Technical Field]

[0001]

The present invention relates to a planar light-emitting device that can be used, for example, as a backlight for a liquid crystal display (LCD) or as an area lighting source.

[Background Art]

[0002]

40 Backlighting for LCD displays has been provided by cold cathode fluorescent lamps (CCFLs), which have a fluorescent material coated on the inside. However, solid-state light-emitting devices such as light-emitting diodes (LEDs) are now gaining attention as a light source. The reason is that LEDs can select narrow emission wavelength bands that match the wavelengths of the three primary colors (RGB: red, green, and blue) of the color filters. In cold cathode fluorescent lamps, there is room for improvement in color reproduction due to limitations in the characteristics of the phosphors. In particular, red color reproduction is poor.

[0003]

In contrast, the wavelength band of LEDs can be controlled by changing the material and crystal composition of the active layer (light-emitting layer) of the LED chip. For yellow-green to red, a quaternary alloy of aluminum, gallium, indium, and phosphorus ((Al_xGa_{1-x})_{0.5}In_{0.5}P) is used, and the Al composition x is varied.

For blue to green, gallium indium nitride ($\text{In}_x\text{Ga}_{1-x}\text{N}$) and a ternary crystal mixture of nitride compounds are used, and the indium composition x can be varied to adjust the emission wavelength. In this way, LED-based backlights for LCDs can improve color reproduction and produce beautiful red images.

[0004]

10 The spectrum of natural light such as sunlight is green in the center of the visible range and red at the ends of the visible range. Human visual sensitivity is also high for green. Therefore, in order to reproduce colors, high luminosity is required in the green wavelength band. In general, green requires more than five times the luminance of red or blue. However, in LEDs, green (InGaP-based) LEDs have lower luminous efficiency than red (AlInGaP-based) and blue (InGaP-based) LEDs due to their material characteristics. In other words, the opposite of these characteristics is actually required. Therefore, when covering all three RGB primary colors with direct LED emission, two or more green LEDs are used (the RRGB method). In general, InGaP-based (B and G) LEDs are more expensive than AlInGaP-based (R) LEDs. Therefore, three of the four LEDs are expensive LEDs, making this method costly.

[0005]

20 In contrast, there is a method of obtaining white light by exciting a phosphor with a blue LED. Specifically, a yellow phosphor such as YAG (yttrium aluminum garnet) is mixed into the LED package. The phosphorescence spectrum of YAG is broad, but the red phosphorescence is weak. In addition, the phosphorescence wavelengths are not optimized for green filters used in LCDs, making them unsuitable for LCD backlights. Furthermore, once the phosphor is mixed in, it becomes impossible to adjust the color and spectral balance.

[0006]

However, a light-emitting device that incorporates blue and red LEDs in a single package and has a green phosphor mixed in has been disclosed (Patent Document 1). For example, if a green phosphor that matches the color filter of the LCD is selected and the concentration of the green phosphor in the package is properly adjusted, color reproducibility can be achieved.

[0007]

30 However, in the case of this light-emitting device, once the phosphor is mixed in, the green luminous intensity/blue luminous intensity ratio is fixed and cannot be subsequently adjusted by current control. It is also difficult to mix phosphors stably in each package at the specified distribution and concentration. In other words, the ratio of green luminance to blue luminance varies from package to package. For this reason, it is currently difficult to use all packages as manufactured to control the specified luminance ratio (5:1), resulting in yield losses and the need for sorting.

[Patent Document 1] JP 2005-317873 A

[Disclosure of the Invention]

[Problem to Be Solved by the Invention]

[0008]

It is an object of the present invention to provide a planar light-emitting device that can stably obtain a specified chromaticity and luminance balance while holding down costs.

[Means for Solving the Problem]

40 [0009]

One aspect of the present invention is a planar light-emitting device comprising: a light guide plate having a main surface and a side surface that emits light incident from the side surface via the main surface; a first light-emitting element that causes blue light to be incident on the side surface of the light guide plate; and a wavelength conversion sheet provided on the main surface of the light guide plate and containing a wavelength conversion material that absorbs light emitted from the first light-emitting element and emits green light.

[0010]

Another aspect of the present invention is a planar light-emitting device comprising: a diffusion plate having a main surface and a back surface that makes uniform the intensity distribution of light incident from the

back surface and emits the light via the main surface; a plurality of first light-emitting elements arranged two-dimensionally on the back surface of the diffusion plate, each emitting blue light; and a wavelength conversion sheet provided on the side of the main surface or the back surface of the diffusion plate and containing a wavelength conversion material that absorbs light emitted from the first light-emitting elements and emits green light.

[Effect of the Invention]

[0011]

The present invention is able to provide a planar light-emitting device that can stably obtain a specified chromaticity and luminance balance while holding down costs.

10 [Best Mode for Carrying Out the Invention]

[0012]

Embodiments of the present invention will now be described with reference to the drawings. FIG. 1 is a perspective view of the planar light-emitting device in the first embodiment of the present invention.

[0013] This planar light-emitting device comprises a light guide plate 100 and red light-emitting elements 2 and blue light-emitting elements 3 disposed in close proximity to the side surfaces 100S of the plate. The red light-emitting elements 2 and blue light-emitting elements 3 are prepared and mounted on a substrate 10 so that their numbers are in a ratio of 1:2, for example. The light-emitting elements 2, 3, can be, for example, LEDs or LDs (laser diodes). In addition, their structure may be surface-emitting or edge-emitting. However, they are mounted on each substrate 10 so that their light emission is transverse to the main surface of the substrate 10, that is, incident on the side surfaces 100S of the light guide plate 100.

20

[0014]

The peak wavelength of the light emitted by red light-emitting elements 2 is preferably in the range of 590 to 670 nanometers. Such light-emitting elements can be realized, for example, using InGaAlP compound semiconductors. By adjusting the composition of the InGaAlP active layer of the red light-emitting elements 2, the most desirable peak wavelength can be obtained within this wavelength range for various applications.

[0015]

Meanwhile, the peak wavelength of the light emitted from the blue light-emitting elements 3 is preferably in the range of 420 to 480 nanometers. Such semiconductor light-emitting elements can be realized, for example, using InGaAlN compound light emission. In this case as well, by adjusting the composition of the InGaAlN active layer of the blue light-emitting elements 3, the most desirable peak wavelength can be obtained within this wavelength range for various applications.

30

[0016]

In this way, an light-emitting element array mounted on a substrate 10 is arranged for two side surfaces 100S of the light guide plate 100. However, the present invention is not limited to the configuration of the present embodiment. For example, a light-emitting element array can be arranged on only one side surface, or a light-emitting element array can be arranged on three or four side surfaces.

[0017]

A reflector plate 120 is provided on the lower surface of the light guide plate 100. The light emitted from light-emitting elements 2, 3 is reflected by the reflective surface 120R of the reflector plate 120 and extracted from the main surface 100M of the light guide plate 100 as indicated by arrow L. Here, the reflector plate 120 has a convex reflective surface 120R at the center of the light guide plate 100, which is separated from the light-emitting elements 2, 3. In this way, the luminance near the center of the main surface 100M of the light guide plate 100, which has high luminance at the edges that weakens toward the center, can be compensated for by changing the reflection angle according to the direction of light emitted from light-emitting elements 2, 3, thereby improving luminance uniformity.

40

[0018]

In the present embodiment, a wavelength conversion sheet 130 containing a green wavelength conversion material is disposed on the main surface 100M of the light guide plate 100. The phosphor in wavelength conversion sheet 130 absorbs blue light emitted from blue light-emitting elements 3 and emits green light.

The peak wavelength of green light is preferably in the range of 520 to 560 nanometers. Examples of such phosphor materials include ZnS with added Cu or Al, and (Ba·Mg)Al₁₀O₁₇ with added Eu or Mn.

[0019]

The wavelength conversion sheet 130 can be formed, for example, using a resin. Specifically, the wavelength conversion sheet 130 may be formed by dispersing a phosphor in a resin and molding it into a sheet, or by coating a phosphor on the front surface (or back surface) of a transparent film.

[0020]

FIG. 2 shows views of the cross-sectional structure of various wavelength conversion sheets 130. Specifically, as shown in FIG. 2 (a), a phosphor layer 130f can be formed on the surface of a film-like base material 130c, such as a resin, using, for example, a coating method.

[0021]

Also, as shown in FIG. 2 (b), a phosphor may be dispersed in a base material 130 such as a resin. In addition, as shown in FIG. 2 (c), sheets of translucent film 130c may be laminated, and a layer 130s containing a phosphor material may be coated or dispersed between these sheets. Furthermore, the wavelength conversion sheet 130 does not have to be an integral sheet, and may, for example, be a laminate of a plurality of sheets of film 130s, each containing a phosphor, as shown in FIG. 2 (d).

[0022]

The wavelength conversion sheet 130 and the light guide plate 100 may be separate or formed as an integrated unit. Specifically, the wavelength conversion material may be coated on the main surface 100M of the light guide plate 100, or dispersed in some or all of the light guide plate 100.

[0023]

In the present embodiment, the wavelength of green light can be adjusted by adjusting the material and composition of the phosphor in the wavelength conversion sheet 130. For example, when used as a backlight for an LCD, light that matches the transmission characteristics of the green color filter of the LCD can be obtained by selecting the proper material and composition for the phosphor to be included in the wavelength conversion sheet 130. This eliminates the need for inefficient green LEDs. As a result, high luminance and color reproduction can be achieved while reducing overall costs.

[0024]

In the present embodiment, green light emission is obtained from the light guide plate 100 via the wavelength conversion sheet 130. This makes it possible to eliminate the variation in characteristics caused by individual differences in green light emitting elements when green light emitting elements are used. Because the wavelength conversion sheet 130 is excited by blue light whose uniformity has been improved by the reflector plate 120, the concentration distribution of the green wavelength conversion material does not have to be adjusted in the in-plane direction of the main surface 100M of the light guide plate 100. However, the concentration of the wavelength conversion material may be adjusted uniformly across the entire surface of the wavelength conversion sheet 130 so that the luminance of the green wavelength conversion light is five times greater than that of the blue excitation light. In this way, white light corresponding to human visual sensitivity can be obtained. If the luminance distribution in the in-plane direction of the main surface 100M is uneven, the in-plane distribution of the wavelength conversion material in the wavelength conversion sheet 130 may be adjusted accordingly.

[0025]

In addition, the luminance of the red light can also be controlled to be approximately one-fifth that of the green light in the present embodiment, by independently controlling the current value applied to the red light-emitting elements 2. Similarly, because the blue light to red light luminance ratio can also be controlled, the color temperature can be adjusted within a certain range. In this case, the control circuit is simpler than adjusting three LEDs in the so-called RGGB method.

[0026]

FIG. 3 is a perspective view of the planar light-emitting device in a comparative example. In the comparative example, light-emitting elements 4 are provided, which is similar to those in the light-emitting device

disclosed in Patent Document 1, in that a red LED, a blue LED, and a phosphor that absorbs blue light and emits green light are sealed in the same package. Specifically, three colors of light (RGB) are emitted from the light-emitting elements 4. However, once the phosphor is mixed into these light-emitting elements 4, the green brightness/blue brightness ratio is fixed and cannot be adjusted subsequently. It is also difficult to mix phosphors stably in each package with the specified distribution and concentration. Thus, the ratio of green brightness to blue brightness often varies from package to package. For this reason, it is difficult to use all packages as manufactured to control the specified luminance ratio (5:1), resulting in yield losses and the need for sorting.

[0027]

10 In contrast, the blue light-emitting elements 3 and the sheet 130 containing the phosphor are configured as separate units in the present embodiment. Therefore, by combining these units as appropriate, the balance between the blue light and green light luminance can be easily adjusted. For example, the balance between blue light and green light can be optimally adjusted by preparing a plurality of wavelength conversion sheets 130 with different amounts of green phosphor, and selecting and using one of these wavelength conversion sheets 130 based on the luminance of the blue light emitted from the light guide plate 100.

[0028]

20 These wavelength conversion sheets 130 can also be obtained by adopting a laminated structure in which a plurality of phosphor-containing films are laminated, as shown in FIG. 2 (d). In this way, the amount of phosphor can be easily changed. In other words, by laminating the required number of sheets based on the luminance of the blue light emitted from the blue light-emitting elements 3, the optimum balance of green and blue light required for a given application is easy to obtain.

[0029]

FIG. 4 is a perspective view of the planar light-emitting device in the second embodiment of the present invention. In FIG. 4 and subsequent figures, elements that have already been explained in the previous drawings are denoted by the same reference numbers, and a detailed description of these elements has been omitted.

[0030]

30 In the present embodiment, a diffusion plate 110 is provided on top of the wavelength conversion sheet 130. The diffusion plate 110 can be configured as a translucent plate with fine irregularities formed on its surface, for example, to scatter light so as to make the distribution of light uniform. The distribution of luminance and distribution of color in the in-plane direction of the main surface 100M of the light guide plate 100 can be made more uniform by providing such a diffusion plate 110.

[0031]

Note that in FIG. 4, the diffusion plate 110 and the wavelength conversion sheet 130 are shown as separate units, but the present invention is not limited to this configuration. In other words, the diffusion plate 110 and the wavelength conversion sheet 130 may be integrally formed to have both light diffusion and wavelength conversion functions.

[0032]

40 FIG. 5 is a perspective view of the planar light-emitting device in the third embodiment of the present invention. In this specific example, red light-emitting elements 2 and blue light-emitting elements 3 are arranged two-dimensionally on a substrate 10 on the back surface of a diffusion plate 110 having a main surface and a back surface. The space between the light-emitting elements 2, 3 and the diffuser plate 110 may be left open, or filled with a translucent material such as a resin.

[0033]

In this case, the red light-emitting elements 2 and the blue light-emitting elements 3 can be mounted on the substrate at a ratio of approximately 1:2. In the present embodiment, inefficient green light-emitting elements are omitted, and a wavelength conversion sheet 130 containing a green wavelength conversion material matching the color filter of the LCD is disposed on the surface of the diffusion plate 110. As in the first and second embodiments, the overall cost and efficiency can be held down by eliminating inefficient green LEDs.

[0034]

Green light emission is obtained using the wavelength conversion sheet 130. As a result, the variation in characteristics caused by individual differences in green LEDs when green LEDs are used can be eliminated. By arranging the red light-emitting elements 2 and blue light-emitting elements 3 in an alternating pattern two-dimensionally, color unevenness can be suppressed and uniform color distribution can be easily obtained. In addition, a diffusion plate 110 may be provided on top of the wavelength conversion sheet 130.

[0035]

FIG. 6 is a perspective view of the planar light-emitting device in the fourth embodiment of the present invention. In this specific example, a red light-emitting elements 2, first blue light-emitting elements 3, and second blue light-emitting elements 3' are arranged two-dimensionally on a substrate 10 on the back surface of a diffusion plate 110 having a main surface and a back surface. The peak wavelength of the first blue light-emitting elements 3 can be, for example, approximately 470 nm, and the peak wavelength of the second blue light-emitting elements 3' can be, for example, approximately 455 nm.

[0036]

The green phosphor in wavelength conversion sheet 130 generally has higher excitation efficiency when excited by blue light at 470 nm. Meanwhile, the transmission wavelength of blue color filters used in LCDs is generally around 455 nm. Therefore, the luminance ratio between blue light and green light can be controlled if the luminous intensity ratio between the first blue light-emitting elements 3 with a peak wavelength of 470 nm and the second blue light-emitting elements 3' with a peak wavelength of 455 nm can be controlled. In addition, the luminance of the red, green, and blue light can be freely controlled if the output of the red light-emitting elements 2 can be independently controlled.

[0037]

In the comparative example shown in FIG. 3, it is difficult to control the luminance ratio between blue and green, but the luminance ratio between these colors can be controlled in the present embodiment. This effect cannot be achieved by mixing a wavelength conversion material into a light-emitting element package. By independently controlling light-emitting elements with different excitation efficiencies, control color becomes possible.

[0038]

FIG. 7 is a diagram of an example of a drive circuit for the light-emitting element in the embodiments. Here, the red light-emitting elements 2, the first blue light-emitting elements 3, and the second blue light-emitting elements 3' are connected in series and can be independently controlled by the drive unit 200. In this way, the luminance of red, green, and blue light can be freely controlled. Note that while FIG. 7 shows a specific example in which light-emitting elements of each color are connected in series, light-emitting elements of each color may also be connected in parallel.

[0039]

FIG. 8 is a perspective view of the planar light-emitting device in the fifth embodiment of the present invention. In this specific example, red light-emitting elements 2, first blue light-emitting elements 3, and second blue light-emitting elements 3' are arranged two-dimensionally on a substrate 10 on the back side of the diffusion plate 110. However, instead of a uniform wavelength conversion sheet 130, a wavelength conversion sheet 131 is used in which a wavelength conversion material that absorbs blue light and emits green light is distributed locally. In other words, the wavelength conversion sheet 131 is composed of wavelength conversion portions 131A containing the wavelength conversion material and translucent portions 131B not containing the wavelength conversion material.

[0040]

Wavelength conversion materials that absorb blue light and emit green light not only absorb blue light, but also scatter red light. In this case, because hardly any is converted to green light, the red light is lost. In contrast, by providing translucent portions 131B in the wavelength conversion sheet 131 of the present embodiment, the scattering of red light in these portions can be prevented and red loss reduced. In this case, the color of the light emitted from wavelength conversion portions 131A and the color of the light

emitted from the translucent portions 131B are different, but color unevenness can be suppressed by providing a diffusion plate 110.

[0041]

Note that in the specific example shown in FIG. 8, the wavelength conversion portions 131A are provided in the form of stripes, but the present invention is not limited to this pattern. Specifically, by forming the wavelength conversion portions 131A and the translucent portions 131B with a finer pattern, color unevenness as seen from the light extraction surface can be more reliably suppressed. In this case, the pattern for the wavelength conversion portions 131A or the translucent portions 131B may be, for example, a two-dimensional array pattern, such as a mesh pattern or a dot pattern.

[0042]

The embodiments described above can eliminate low-efficiency green LEDs and the resulting increase in cost and generated heat due to the high number of expensive green LEDs used in a system provided with LEDs for all RGB colors. In addition, the need for sorting individual packages based on variations in color and luminance can be eliminated, as well as the poor controllability of low yield color and the decrease in yield of individual packages, when phosphors are mixed into packages containing light-emitting elements. In other words, a planar light-emitting device such as a LCD backlight can be provided with excellent color and luminance control and good in-plane uniformity at low cost.

[0043]

The embodiments of the present invention were described above with reference to specific examples. The present invention, however, is not limited to these specific examples. For example, the light-emitting elements, light guide plates, diffusion plates, wavelength conversion materials, etc., constituting the semiconductor light-emitting device of the present invention, even if they have been modified where appropriate by those skilled in the art, are included in the scope of the present invention as long as they have the characteristics of the present invention. In addition, combinations of the specific examples described above, within the range of technical feasibility, are also included in the scope of the present invention.

[Brief Description of the Drawings]

[0044]

[FIG. 1] FIG. 1 is a perspective view of the planar light-emitting device in the first embodiment of the present invention.

[FIG. 2] FIG. 2 shows views of the cross-sectional structure of various wavelength conversion sheets 130.

[FIG. 3] FIG. 3 is a perspective view of the planar light-emitting device in a comparative example.

[FIG. 4] FIG. 4 is a perspective view of the planar light-emitting device in the second embodiment of the present invention.

[FIG. 5] FIG. 5 is a perspective view of the planar light-emitting device in the third embodiment of the present invention.

[FIG. 6] FIG. 6 is a perspective view of the planar light-emitting device in the fourth embodiment of the present invention.

[FIG. 7] FIG. 7 is a diagram of an example of a drive circuit for the light-emitting element in the embodiments.

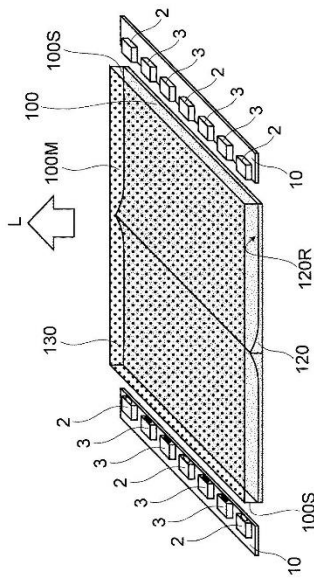
[FIG. 8] FIG. 8 is a perspective view of the planar light-emitting device in the fifth embodiment of the present invention.

[Reference Numbers]

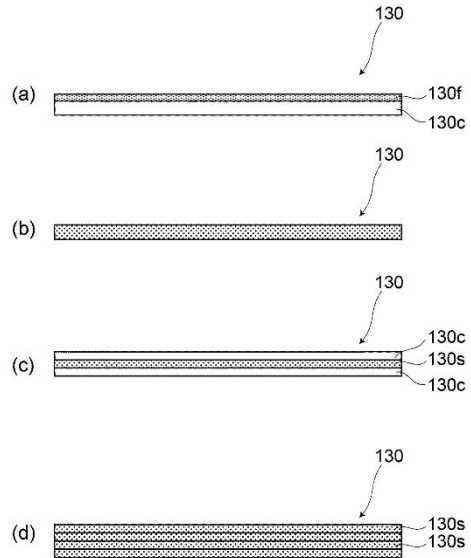
[0045]

2 ... Red light-emitting element, 3 ... blue light-emitting element, 4 ... light-emitting element, 10 ... substrate, 100 ... light guide plate, 100M ... main surface, 100S ... side surface, 110 ... diffusion plate, 120 ... reflector plate, 130 ... wavelength conversion sheet, 130c ... base material, 130c ... translucent film, 130f ... phosphor layer, 130s ... film, 131 ... wavelength conversion sheet, 131A ... wavelength conversion portion, 131B ... translucent portion, 200 ... drive unit

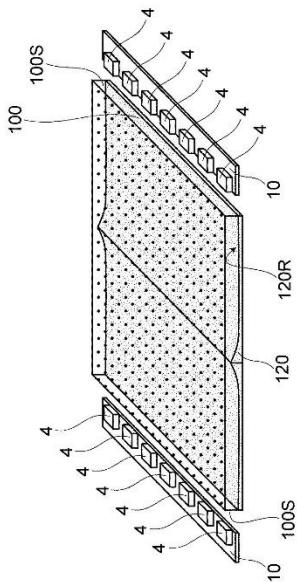
[FIG. 1]



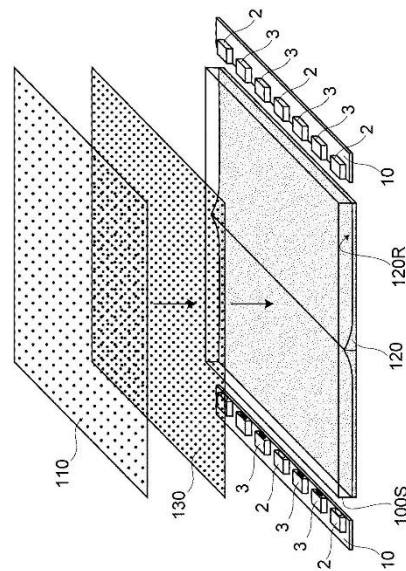
[FIG. 2]



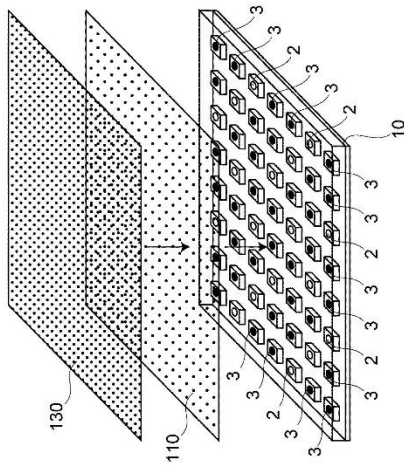
[FIG. 3]



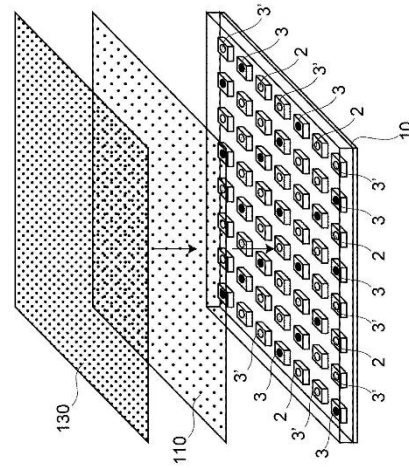
[FIG. 4]



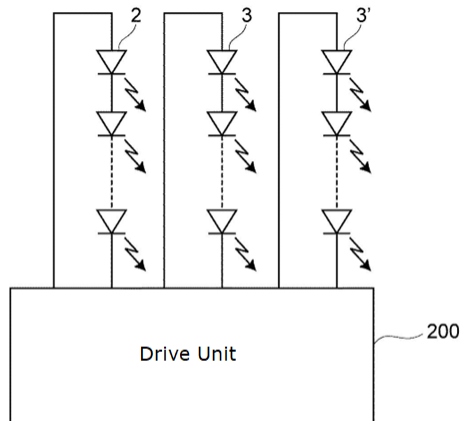
[FIG. 5]



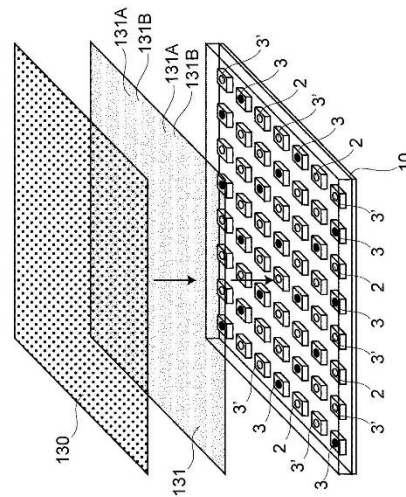
[FIG. 6]



[FIG. 7]



[FIG. 8]



Continued From Front Page

F Terms (Reference) 2H191 FA01Z FA34Z FA42Z FA71Z FA85Z FA86Z FB02 FC14 FD33 FD44 LA13
 LA27
 3K243 MA01
 5F041 AA05 AA11 AA14 AA41 CA34 DA14 DA20 DA82 DB07 DB08 EE23 EE25
 FF11

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE PATENT TRIAL AND APPEAL BOARD**

Affidavit of Frank McGee

I, Frank McGee, hereby declare as follows:

I am a citizen of the United States of America and I am over 18 years of age. I have personal knowledge of the matters stated in this affidavit, all of which are true and correct.

I am a Translator for Sun IP.

I submit this declaration to certify the accuracy of the translation I performed relating to JP2008117879A (hereinafter "Kinoshita").

I am qualified to translate Japanese technical documents into English, including translating Japanese patent documents into English. My qualifications include an MA in East Asian Languages from the University of Chicago and 30 years of experience as a full-time Japanese-to-English IP translator.

Attached as **Exhibit 1020** is a true and accurate copy of Kinoshita.

Attached as **Exhibit 1005** is a true and accurate copy of an English translation of Kinoshita, which I prepared based on **Exhibit 1020** and my personal knowledge of the Japanese and English languages.

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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.



Date: August 20, 2025

By: Frank McGee