

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG DISPLAY CO., LTD.,
Petitioner,

v.

PICTIVA DISPLAYS INTERNATIONAL LTD.,
Patent Owner.

Case No. IPR2024-01093
Patent No. 8,723,164

**DECLARATION OF RUSSELL J. HOLMES, PH.D. IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 8,723,164**

TABLE OF CONTENTS

I.	Background and Qualifications	1
II.	Materials Considered	6
III.	Legal Principles	8
IV.	Background.....	11
A.	Technology Overview	11
1.	OLED Basics.....	11
2.	Mixed EML	17
B.	Overview of the '164 Patent.....	19
C.	Priority Date of the '164 Patent.....	23
D.	Prosecution History of the '164 Patent	24
E.	Challenged Claims	27
V.	Person of Ordinary Skill in the Art.....	32
VI.	Claim Construction.....	32
VII.	Overview of the Prior Art References	33
A.	Choulis (Ex. 1004)	33
B.	Sugiura (Ex. 1005/1006)	35
C.	Thompson (Ex. 1007).....	37
D.	Yong (Ex. 1008/1009).....	38
VIII.	Specific Grounds of Challenges	40
A.	Ground I: Claims 1–8 and 10–16 Are Anticipated By Or At A Minimum Rendered Obvious By Choulis.....	40
1.	Independent Claim 1	40

2. Dependent Claim 2: The electronic device according to claim 1, wherein the first matrix material has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material. 52
3. Dependent Claim 3: The electronic device according to claim 1, wherein the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material and a HOMO which is energetically higher than the HOMO of the third matrix material..... 55
4. Dependent Claim 4: The electronic device according to claim 1, wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials..... 56
5. Dependent Claim 5: The electronic device according to claim 1, wherein the second matrix material comprises a hole transport material. 58
6. Dependent Claim 6: The electronic device according to claim 1 wherein the third matrix material comprises an electron transport material. 58
7. Dependent Claim 7: The electronic device according to claim 1, wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers..... 59
8. Dependent Claim 8: The electronic device according to claim 1, wherein the emitter material in the emission layer has a concentration of ≤ 10 wt %..... 59
9. Dependent Claim 10: The electronic device according to claim 1, wherein the LUMO of the emitter material is energetically lower than the LUMO of the first, second,

	and third matrix materials, and the HOMO of the emitter material is energetically higher than the HOMO of the first, second, and third matrix materials.	60
10.	Dependent Claim 11: The electronic device according to claim 1, which is constructed as a radiation-emitting device.	62
11.	Dependent Claim 12: The electronic device according to claim 1 wherein the device is selected from a group which comprises an organic light-emitting device, a solar cell, and a transistor.	63
12.	Dependent Claim 13	63
13.	Dependent Claim 14: A method according to claim 13, wherein in the method step C), the first matrix material, the second matrix material and the third matrix material are applied by evaporation coating.	70
14.	Independent Claim 15	70
15.	Independent Claim 16	72
B.	Ground II: Claim 9 Is Obvious Based on Choulis and Yong	75
1.	Dependent Claim 9: The electronic device according [sic] claim 1, wherein the concentration of the emitter material in the emission layer has a gradient.	75
C.	Ground III: Claims 1, 3, 5–8, and 10–13 Are Anticipated By Or At A Minimum Rendered Obvious By Sugiura.....	78
1.	Independent Claim 1	78
2.	Dependent Claim 3: The electronic device according to claim 1, wherein the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material and a HOMO which is energetically higher than the HOMO of the third matrix material.....	88

3.	Dependent Claim 5: The electronic device according to claim 1, wherein the second matrix material comprises a hole transport material.	89
4.	Dependent Claim 6: The electronic device according to claim 1 wherein the third matrix material comprises an electron transport material.	90
5.	Dependent Claim 7: The electronic device according to claim 1, wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers.....	92
6.	Dependent Claim 8: The electronic device according to claim 1, wherein the emitter material in the emission layer has a concentration of ≤ 10 wt %.....	92
7.	Dependent Claim 10: The electronic device according to claim 1, wherein the LUMO of the emitter material is energetically lower than the LUMO of the first, second, and third matrix materials, and the HOMO of the emitter material is energetically higher than the HOMO of the first, second, and third matrix materials.	93
8.	Dependent Claim 11: The electronic device according to claim 1, which is constructed as a radiation-emitting device.	95
9.	Dependent Claim 12: The electronic device according to claim 1 wherein the device is selected from a group which comprises an organic light-emitting device, a solar cell, and a transistor.	95
10.	Dependent Claim 13	96
D.	Ground IV: Claims 15–16 Are Anticipated By Or At A Minimum Rendered Obvious By Thompson	100
1.	Independent Claim 15	100

2.	Independent Claim 16	112
IX.	Secondary Considerations of Non-obviousness	116
X.	Conclusion	116

I, Russell J. Holmes, Ph.D., declare and state, to the best of my knowledge, understanding, and belief, as follows:

1. I have been retained by counsel for Petitioner Samsung Display Co, Ltd. to provide my expert opinions concerning the validity of claims 1–16 of U.S. Patent No. 8,723,164 (“the ’164 patent”). For the reasons discussed below, it is my opinion that claims 1–16 of the ’164 patent would have been anticipated by the prior art or obvious to a person of ordinary skill in the art.

I. BACKGROUND AND QUALIFICATIONS

2. In this section, I summarize my qualifications for forming the opinions set forth in this declaration. Additional information is provided in my *curriculum vitae*, which is attached as Appendix A (“CV”). My *curriculum vitae* also includes a list of my publications, presentations, and patents, as well as previous patent proceedings in which I have served as an expert. CV at 4–25.

3. I have extensive experience in the research of organic electronic materials and devices, and more broadly in the areas of semiconductor physics and materials science. Since earning my Ph.D. in 2006, I have operated an independent research group in the Department of Chemical Engineering and Materials Science at the University of Minnesota. My group has consistently focused on the study of organic semiconductor materials and optoelectronic devices, with heavy emphasis on organic light-emitting devices (OLEDs), organic solar cells, and the study of

excitonic phenomena in organic thin films. Specific to the areas of OLEDs and excitonic phenomena, my research group has demonstrated novel architectures for phosphorescent OLEDs, elucidated mechanisms governing device efficiency and degradation, and worked to demonstrate methods to engineer exciton formation, recombination, and migration. My research group has been funded by federal funding agencies including the National Science Foundation, the Department of Energy, and the Department of Defense, in addition to several sponsored projects with industry.

4. In my capacity as an expert in semiconductor physics and materials science, I have taught courses in Introductory Materials Science, Electronic and Magnetic Properties of Materials, Thermodynamics, Transport and Kinetics, Solar Cell Physics, and Engineering Design.

5. I earned my Ph.D. in 2006 and Masters degree in 2002, both in Electrical Engineering, from Princeton University, and a Bachelor of Science (Honours) in Physics degree in 2000 from the University of Manitoba. The focus of my graduate study in Electrical Engineering was in understanding the luminescent properties of organic semiconductor thin films under optical and electrical excitation, with particular emphasis on applications in phosphorescent OLEDs. In particular, I carried out work in the design, fabrication, characterization, and analysis of phosphorescent blue OLEDs, realizing record efficiencies, as well as the first

phosphorescent blue OLEDs with exothermic host-guest energy alignment, and some of the earliest phosphorescent blue OLEDs capable of high efficiency and deep blue color purity. Realization of the latter required the development of the first OLEDs based on ultra-wide energy gap host (UGH) materials. I separately carried out spectroscopic studies of exciton energy transfer and quenching behavior in organic semiconductor materials and devices to elucidate device operating mechanisms and the interaction of molecular excited states with other excitons and electronic charges, especially under high current excitation. Finally, I led efforts to investigate the behavior of excitons in optical microcavities, leading to the first observations of microcavity polaritons in polycrystalline organic thin films, hybridization of vibronic transitions, and hybrid Wannier-Mott-Frenkel polaritons. I also contributed to work in the areas of white phosphorescent OLEDs, the elucidation of singlet-triplet exciton spin formation statistics, and the integration of phosphorescent OLEDs with flexible transistors to form display pixels. My graduate work led to numerous publications and granted patents, as listed in my *curriculum vitae*.

6. I am currently an active tenured full professor in the Department of Chemical Engineering and Materials Science (CEMS) at the University of Minnesota located in Minneapolis, MN. I am also a member of the Graduate Faculty in the Department of Electrical and Computer Engineering and in the Chemical

Physics Program in the Department of Chemistry. I have received several competitive academic appointments at the University of Minnesota; including the Distinguished McKnight University Professorship (2021), which is a university-wide honor recognizing outstanding faculty members who have recently achieved full professor status; the Ronald L. and Janet A. Christenson Chair in Renewable Energy (2020), an endowed Chair in the College of Science and Engineering; and a Distinguished University Teaching Professorship (2016), which comes with the Horace T. Morse-Minnesota Alumni Association Award for Outstanding Contributions to Undergraduate Education, representing the highest award offered by the University of Minnesota for excellence in undergraduate instruction.

7. I also hold additional positions at the University of Minnesota. For example, since 2014 I have served as Program Leader for the Optoelectronics and Metamaterials (formerly Flexible Electronics and Photovoltaics) program of the University of Minnesota Industrial Partnership for Research in Interfacial and Materials Engineering (IPRIME). I will also begin an appointment as the Department Executive Officer for Materials Science in July 2024. Also notable is my recently concluded service as Chair of the Department Head Search Committee (2023-2024) and prior appointment as Director of Graduate Studies for Materials Science program (2013-2020). Finally, since 2017, I have served as an Editor for the

Elsevier journal Synthetic Metals, which focuses on research on the physics, chemistry, and applications of organic and carbon electronic materials.

8. I have advised a number of graduate and undergraduate students in the Departments of Chemical Engineering and Materials Science, Electrical and Computer Engineering, and Chemistry at the University of Minnesota. This includes 18 completed Ph.D. graduate advisees (and an additional 7 current graduate advisees), 5 completed master's degree advisees, and 30 undergraduate advisees. Of my graduated Ph.D. students, several now work in the display and electronics industries.

9. Over the past 22 years, I have been an author on over 115 peer-reviewed publications, and given over 120 presentations, on topics in the general areas of semiconductors and materials science, with emphasis on organic semiconductor materials and devices. A long-term focus of my research, publications, and presentations has been on organic optoelectronic devices such as organic light-emitting devices (OLEDs), including the engineering of device architecture to manipulate exciton behavior, and the study of singlet and triplet exciton phenomena in organic semiconductors and in OLEDs. A complete list of my publications and presentations can be found in my *curriculum vitae*.

10. My research career has led to the filing of several patent applications. As listed in my *curriculum vitae*, there are currently six issued U.S. patents on which

I am an inventor. An additional five applications are listed that while published did not lead to issued patents. All of the listed patents and patent applications pertain to organic semiconductor materials and devices.

11. Additional details about my employment history, publications, and presentations can be found in my *curriculum vitae*.

12. In summary, I have extensive familiarity with organic light-emitting devices. At the time the '164 patent was filed, I was already leading an independent research group focused on organic semiconductor materials and devices. I am familiar with the development and state of this field around the time that the '164 patent was filed.

II. MATERIALS CONSIDERED

13. In forming my opinions, I have reviewed the documents in the following table. I have also relied on my education, knowledge, and experience gained by working in the field for more than 20 years.

Exhibit No.	Description
1001	U.S. Patent No. 8,723,164
1002	Certified File History for U.S. Patent No. 8,723,164
1004	U.S. Patent Application Publication No. 2007/0069636 (Choulis)
1005	Japanese Published Application No. 2001/110568 (Sugiura)
1006	Certified English Translation of Japanese Published Application No. 2001/110568 (Sugiura)
1007	U.S. Patent Application Publication No. 2004/0155238 (Thompson)

Exhibit No.	Description
1008	Chinese Published Application No. 1,582,073 (Yong)
1009	Certified English Translation of Chinese Published Application No. 1,582,073 (Yong)
1010	H.Y. Kang et al., <i>Electroluminescence Properties of Organic Light-Emitting Diodes with a Red Dye Doped into Alq3: Rubrene Mixed Host</i> , 45(3) J. Korean Physical Soc'y 756–760 (Sept. 2004) (Kang)
1011	Li et al., <i>Organic Long-Persistent Luminescence from a Thermally Activated Delayed Fluorescence Compound</i> , 32 Adv. Mater. 2003911 (2020) (Li)
1012	Wu et al., <i>Efficient tristable resistive memory based on single layer graphene/insulating polymer multi-stacking layer</i> , 104 Appl. Phys. Lett. 183105 (2014) (Wu)
1013	U.S. Patent Publication No. 2008/0116536 (Forrest)
1014	INTENTIONALLY LEFT BLANK
1015	Kim et al., <i>Relationship between host energy levels and device performances of phosphorescent organic light-emitting diodes with triplet mixed host emitting structure</i> , 91 Appl. Phys. Lett. 083511 (2007)
1016	Holmes et al., <i>Efficient, deep-blue organic electrophosphorescence by guest charge trapping</i> , 83 Appl. Phys. Lett. 3818–3820 (2003)
1017	Yang and Neher, <i>Polymer electrophosphorescence devices with high power conversion efficiencies</i> , 84 Appl. Phys. Lett. 2476–2478 (2004)
1018	Choulis et al., <i>The effect of interfacial layer on the performance of organic light-emitting diodes</i> , 87 Appl. Phys. Lett. 113503 (2005)
1019	INTENTIONALLY LEFT BLANK
1020	INTENTIONALLY LEFT BLANK
1021	Aziz et al., <i>Reliability and Degradation of Small Molecule-Based Organic Light-Emitting Devices (OLEDs)</i> , VOL. 8, NO. 2 IEEE JOURNAL ON SELECTED TOPICS IN QUANTUM ELECTRONICS 362 (2002)
1022	Choulis et al., <i>Highly efficient organic electroluminescent device with modified cathode</i> , 88 Appl. Phys. Lett. 203502 (2006)

Exhibit No.	Description
1023	Djobo et al., <i>Poly(N-vinylcarbazole) (PVK) deposited by evaporation for light emitting diodes thin films structures</i> , 122 Synthetic Metals 131–133 (2001)
1024	Hamada et al., <i>Red organic light-emitting diodes using an emitting assist dopant</i> , 75 Appl. Phys. Lett. 1682–1684 (1999)
1025	Kanno et al., <i>White Stacked Electrophosphorescent Organic Light-Emitting Devices Employing MoO3 as a Charge-Generation Layer</i> , 18 Adv. Mater. 339–342 (2006)

III. LEGAL PRINCIPLES

14. I am not an attorney. For the purposes of this declaration, I have been informed about certain aspects of the law that are relevant to forming my opinions. I have applied the following understanding of the law:

15. Petitioner’s counsel has informed me that a patent claim may be “anticipated” if each element of that claim is present either explicitly or inherently in a single prior art reference, and that the elements should be arranged in the reference as in the claim. Petitioner’s counsel has informed me that for a claimed limitation to be inherently present, the prior art need not expressly disclose the limitation, so long as the claimed limitation necessarily flows from a disclosure in the prior art.

16. Petitioner’s counsel has informed me that a patent claim can be considered to have been obvious to a person of ordinary skill in the art at the time the application was filed. This means that, even if all of the requirements of a claim are not found in a single prior art reference, the claim is not patentable if the

differences between the subject matter in the prior art and the subject matter in the claim would have been obvious to a person of ordinary skill in the art at the time the application was filed.

17. Petitioner's counsel has informed me that a determination of whether a claim would have been obvious should be based upon several factors, including, among others:

- the level of ordinary skill in the art at the time the application was filed;
- the scope and content of the prior art; and
- what differences, if any, existed between the claimed invention and the prior art.

18. Petitioner's counsel has informed me that a single reference can render a patent claim obvious if any differences between that reference and the claims would have been obvious to a person of ordinary skill in the art. Alternatively, the teachings of two or more references may be combined in the same way as disclosed in the claims, if such a combination would have been obvious to one having ordinary skill in the art. In determining whether a combination based on either a single reference or multiple references would have been obvious, it is appropriate to consider, among other factors:

- whether the teachings of the prior art references disclose known concepts combined in familiar ways, and when combined, would yield predictable results;
- whether a person of ordinary skill in the art could implement a predictable variation, and would see the benefit of doing so;
- whether the claimed elements represent one of a limited number of known design choices, and would have a reasonable expectation of success by those skilled in the art;
- whether a person of ordinary skill would have recognized a reason to combine known elements in the manner described in the claim;
- whether there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; and
- whether the innovation applies a known technique that had been used to improve a similar device or method in a similar way.

19. Petitioner's counsel has informed me that one of ordinary skill in the art has ordinary creativity and is not an automaton. Petitioner's counsel has informed me that in considering obviousness, it is important not to determine obviousness using the benefit of hindsight derived from the patent being considered.

20. Petitioner's counsel has informed me that under specific circumstances whereby a secondary reference is not being used to teach a limitation but rather to

explain the teachings of a primary reference, a specific motivation to combine need not be identified; however, in the case of the combination of art discussed in this declaration, a specific motivation to combine is present and I have identified it.

21. I further understand that certain objective indicia can be important evidence regarding whether a patent is obvious or nonobvious, including the existence of a long-felt but unsolved need, unexpected results, commercial success, copying, and industry acceptance or praise. Evidence of such objective indicia must be considered when present.

IV. BACKGROUND

A. Technology Overview

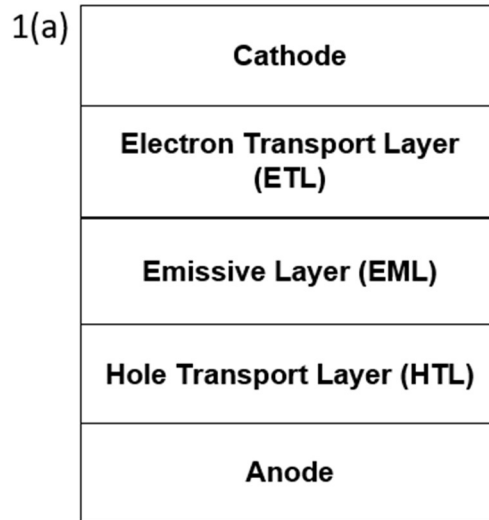
1. OLED Basics

22. Organic light-emitting devices (OLEDs) are an important component in mobile displays (*e.g.*, phones, watches, tablets) and also in televisions. There is also interest for application of OLEDs in virtual reality headsets and lighting applications with some products already available. Unlike their liquid crystal display (LCD) counterparts, OLEDs are electroluminescent, meaning they emit light in response to an electrical current. Conventional LCD displays require a backlight, a source of light that passes through an array of liquid crystal elements. The liquid crystal elements do not themselves emit light, but instead act as gates either blocking or passing light to the external viewer depending on the applied voltage. Displays

based on OLEDs are attractive for a variety of reasons including reduced power consumption, increased display contrast, and suitability for flexible display applications. Indeed, there are now several consumer products that incorporate mechanical flexible OLED displays, enabling an entirely new end-user experience.

23. An OLED display comprises a large assembly of individual microscopic OLED pixels that are each designed to produce light of a particular color. Each individual OLED pixel consists of a sequential stack of layers, where each layer is a collection of organic semiconductor molecules. The term “organic semiconductor” generally refers to carbon-containing molecules that exhibit some significant bond conjugation (i.e., alternating single and double bonds) to enable charge transport (i.e., the flow of electricity) across the molecule and through the layer.

24. A simplified layer structure of an example OLED is shown in Fig. 1(a) below.



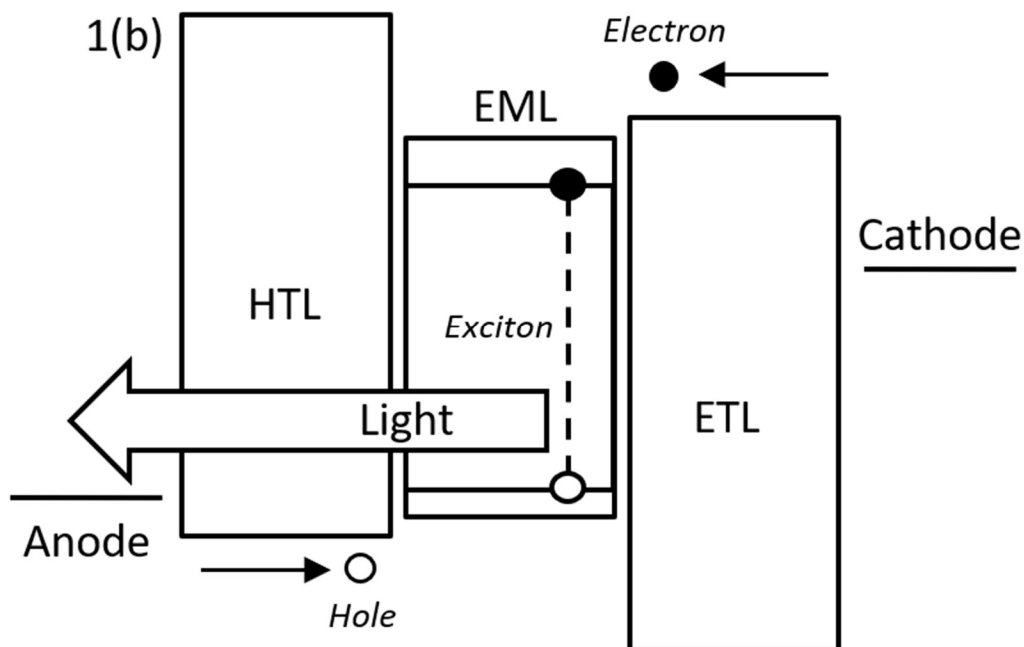
The function of light-emission is carried out by a particular layer within the OLED known as the emissive layer (EML) of the device. The EML can be thin, often tens of a billionth of a meter thick (i.e., tens of nanometers). In the above structure, the EML is placed between the electron transport layer (ETL) and the hole transport layer (HTL). In turn, these three layers (EML, ETL, and HTL) are placed between two conducting electrodes, the cathode and the anode, which permit the transport of electrical current through the device.¹ In an OLED, the anode is generally held at a more positive voltage than the cathode. At least one of the two electrodes is generally transparent or semi-transparent so as to enable the light generated in the emissive

¹ There may be more layers (*e.g.*, substrate) in a production OLED than the layers depicted in the example structure above for the purpose of illustrating basic OLED concepts.

layer to leave the device. The entire structure is supported by a substrate that could be for example glass or plastic.

25. This structure reflects the need for an OLED to efficiently transport electrons and holes into the EML. In the fields of solid-state and semiconductor physics, the “hole” is considered as an analog to the electron but with positive charge. In the structure of Fig. 1(a), an applied voltage leads to electrons traveling from the cathode through the electron transport layer (ETL) into the EML. Similarly, holes travel from the anode through the hole transport layer (HTL) into the EML. Once at the EML, electrons and holes meet to form a bound electron-hole pair known as an exciton on a now energetically excited molecule. The exciton eventually recombines, with the electron relaxing into the hole, and de-exciting the molecule. This process leads to light emission and electroluminescence from the OLED.

26. A schematic energy diagram for the structure in Fig. 1(a) is shown in Fig. 1(b) below. In Fig. 1(b) light is emerging through the anode however light may also emerge from the cathode depending on whether or not it is opaque or transparent.



In this diagram, energy levels are defined relative to vacuum (i.e., the case of a free electron outside of the material). The anode and cathode are characterized by a single energy level defined by the respective *work function* of each electrode. A material's "work function" is the energy required to remove an electron from the surface of that material to the vacuum level, essentially freeing the electron from the material. In an OLED, it is desirable that each electrode's work function be appropriately aligned with the energy levels of the adjacent layer, since the objective is for an electron (in the case of the cathode) or hole (in the case of the anode) to enter the layers of the OLED stack.

27. In energy level diagrams such as the one shown in Fig. 1(b), the energy levels of each organic material are typically represented by a rectangle or equivalently by a vertically separated pair of horizontal lines. In both cases, the

bottom of the rectangle (or bottom line) signifies the position of the highest occupied molecular orbital energy level (or HOMO level) relative to vacuum and the top of the rectangle (or top line) signifies the position of the lowest unoccupied molecular orbital energy level (or LUMO level) relative to vacuum. In the context of OLED operation, holes are transported along the HOMO while electrons are transported along the LUMO. On an energy diagram such as the one shown in Fig. 1(b), electrons tend to lower their energy by traveling “downhill” to LUMO levels that are lower. In contrast, due to their opposite charge, holes tend to lower their energy by traveling “uphill” to HOMO levels that are higher. Selecting OLED layer materials with appropriate HOMO and LUMO levels is critical for efficient transport to the EML.

28. HOMO and LUMO levels are routinely expressed as a negative energy in units of electron volts (eV), referencing the convention to define the vacuum energy as the zero of energy. The negative sign is often dropped as a matter of convenience when expressing the HOMO and the LUMO levels.

29. The separation between the HOMO and LUMO levels is often referred to as the *transport energy gap* of a material as it reflects the energy difference between a hole residing in the HOMO and an electron residing in the LUMO.

2. Mixed EML

30. The EML generally consists of at least two different types of molecules, referred to as host and guest, with the guest dispersed in the host and the guest emitter material ultimately responsible for light emission. The EML may also consist of additional materials with appropriate energy levels to encourage the desired transport of electrons and holes *within* the EML to the guest emitter material, facilitating light emission from the guest emitter material. In this approach, the EML contains both electron- and hole- transporting materials in addition to the luminescent guest emitter material. Holes are transported along the HOMO level of the hole-transporting material while electrons are transported along the LUMO level of the electron-transporting material, both of which reside in the EML. Practically, this requires that the HOMO and LUMO levels of the hole-transporting material be higher than the HOMO and LUMO levels of the electron-transporting material, respectively. This ensures that holes travel through the hole-transporting material and electrons travel through the electron-transporting material. To ensure that all charges ultimately travel to the guest emitter material to form excitons, the HOMO level of the guest emitter material is preferably higher than that of the hole-transporting material. Similarly, the LUMO of the guest emitter material is preferably lower than that of the electron-transporting material. This configuration allows holes traveling on the hole-transporting material to relax to the guest emitter

material's HOMO level, and electrons traveling on the electron-transporting material to relax to the guest emitter material's LUMO level. Thus, this architecture ensures that both holes and electrons reach the guest emitter material via the hole-transporting material and the electron-transporting material, respectively.

31. In the OLED literature, this architecture using an EML with multiple charge transporting materials and a luminescent guest is referred to as a "mixed EML." Devices of this type were known prior to the '164 patent. For example, Kim et al demonstrated phosphorescent OLEDs based on a variety of mixed EMLs, with the combination of TCTA as a hole-transport material, TPBi as an electron-transport material, and Ir(ppy)₃ as the guest emitter meeting the energetic specification noted previously. Ex 1015. The use of ultra-wide energy gap (UGH) hosts to act as matrix hosts that do not participate in charge transport was also well-established, especially in the context of phosphorescent blue OLEDs, where the first devices based on UGH hosts were first demonstrated by Holmes et al., as was the ability to tune charge transport in the EML by tuning the concentration of the guest in a UGH host. Ex 1016. The concepts of a mixed EML and a wide energy gap host were combined in several works that pre-date the '164 patent. For example, Yang and Neher demonstrated a single-layer polymer phosphorescent OLED combining hole- and electron- transporting materials of TPD and PBD with the phosphorescent emitter Ir(mppy)₃ in a common PVK host. Ex 1017. Choulis et al. also demonstrated a

similar mixed EML device. Ex 1018. Clearly the OLED community was actively considering the design of devices based on mixed EMLs containing a wide energy gap host combined with an emitter, hole-transporting material, and electron-transporting material, with the hole-transporting material and electron-transporting responsible for charge transport

B. Overview of the '164 Patent

32. The '164 patent is entitled “Electronic Device” and names Guenter Schmid, Ralf Krause, Stefan Seidel, Oliver Weiss, Christoph Gaerditz, Riikka Suhonen, Ulrich Neidermeier, and Fryderyk Kozlowski as inventors. The '164 patent is generally directed to “an electronic device with an improved charge carrier transport and an improved charge carrier balance in the organic layers,” and a method for preparing the same. '164 patent, 1:33–35.

33. The Abstract of the '164 patent states the following:

An electronic device comprising a substrate, a first electrode, at least one organic functional layer, and a second electrode is indicated. The organic functional layer comprises a first, a second, and a third matrix material, wherein the first matrix material has a larger band gap than the second and the third matrix materials.

'164 patent, Abstract.

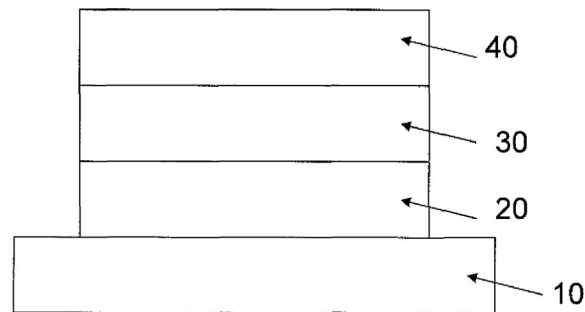
34. The “Background of the Invention” of the '164 patent explains that in the “emission layer” of an OLED device, “excitons are formed by a recombination

of electrons and ‘holes,’ which lead to light emission.” ’164 patent, 1:23-25. Consistent with my discussion above, the ’164 patent explains that a key consideration for OLED devices is “obtain[ing] a high efficiency” of light emission, where “the ratio between electrons and ‘holes’ which are transported in the emission layer is decisive.” ’164 patent, 1:25-28. “A nonbalanced ratio between hole and electron transport results in a low radiation efficiency of the device.” ’164 patent, 1:28-29.

35. The ’164 patent’s claims, which recite, among other things, an “electronic device” and a “method of production of an electronic device,” purportedly address the light emission efficiency issue by including materials in the organic layer of the OLED that meet certain Lowest Unoccupied Molecular Orbital (“LUMO”) and Highest Occupied Molecular Orbital (“HOMO”) criteria set forth in the claims. *See generally* ’164 patent, claims 1-16, 1:46–2:57. The ’164 patent states that an “object of the invention” is achieving “increased efficiency” of the OLED device with “an improved charge carrier transport and an improved charge carrier balance in the organic layers.” ’164 patent, 1:33-36.

36. The claimed structure is depicted in Figure 1 below. The electronic device has “a substrate 10, a first electrode 20, an emission layer 30, and a second electrode 40. The first electrode can, for example, be an anode and the second electrode, a cathode....The emission layer 30 can have a first, a second, and a third

matrix material and be doped with an emitter material.” ’164 patent, 6:6–16. The emission layer 30 is also referred to as an organic layer. ’164 patent, 1:38–59.



’164 patent, Fig. 1.

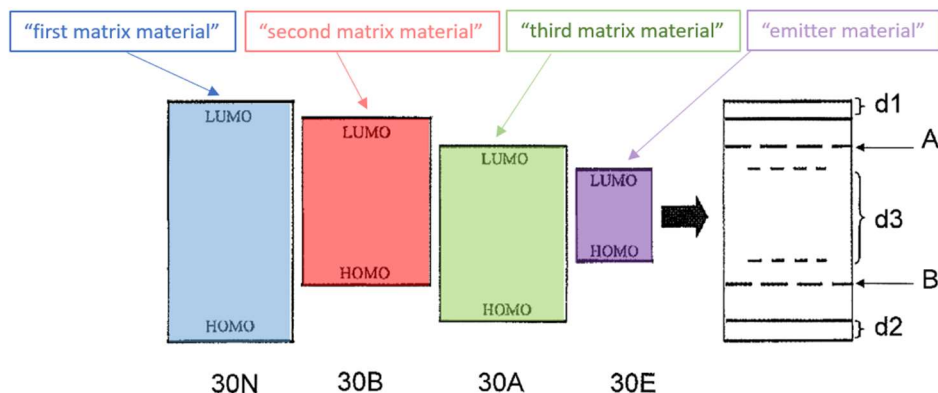
37. In the emission layer, the LUMO of the third matrix material is energetically lower than the LUMO of the first and the second matrix materials.’164 patent, 1:48–51. And the HOMO of the second matrix material is energetically higher than the HOMO of the first and the third matrix materials. ’164 patent, 1:51–55.

38. Additionally, the “first matrix material is selected thereby so that it has a large band gap that is, the difference between HOMO and LUMO, for example, so that its HOMO is energetically below the HOMO of the other two matrix materials, and its LUMO is energetically above the LUMO of the other two matrix materials.” ’164 patent, 2:4–9. Indeed, “the first matrix material can have the largest band gap between the HOMO and the LUMO, in comparison to the second and the third matrix material, and...can have a charge carrier mobility in the electronic device

which is less than the charge carrier mobility of the second and the third matrix material.” ’164 patent, 2:20–35. “Thus, it cannot have a share in the charge carrier transport.” ’164 patent, 2:35–36. On the other hand, “the second matrix material has a band gap which is shifted energetically to the band gap of the third matrix material. In this way, electrons can be transported on the LUMO of the third matrix material, and holes can be transported on the HOMO of the second matrix material.” ’164 patent, 2:22–27.

39. The ’164 patent also describes organic layers that contain one or more emitter materials, where “the LUMO of the emitter material can be energetically lower than the LUMO of the first, second, and third matrix material, and the HOMO of the emitter material can be energetically higher than the HOMO of the first, second, and third matrix material.” ’164 patent, 4:44–49. “Thus, the band gap between the HOMO and LUMO of the emitter material is smaller than the band gaps of the three matrix materials and, moreover, energetically is between all band gaps of all matrix materials.” ’164 patent, 4:49–52.

40. Figure 2 depicts the energy levels discussed above:



'164 patent, Fig. 2 (annotated).

41. The electronic device of the '164 patent can have additional organic layers compared to the single organic layer shown in Figure 1, including additional "emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers," where "these layers can also contain additional doping substances." '164 patent, 3:54–61, 6:50–56, Fig. 3.

42. The '164 patent has 16 claims. Claims 1, 15, and 16 are independent claims; claims 2–14 are dependent claims.

C. Priority Date of the '164 Patent

43. I have been asked to assume that the earliest possible priority date for the '164 patent is May 30, 2008, the earliest Foreign Application Priority Date listed on the face of the '164 patent. I have therefore analyzed the prior art as of that date or somewhat before that date.

D. Prosecution History of the '164 Patent

44. I have reviewed the prosecution history of the '164 patent (Ex. 1002).

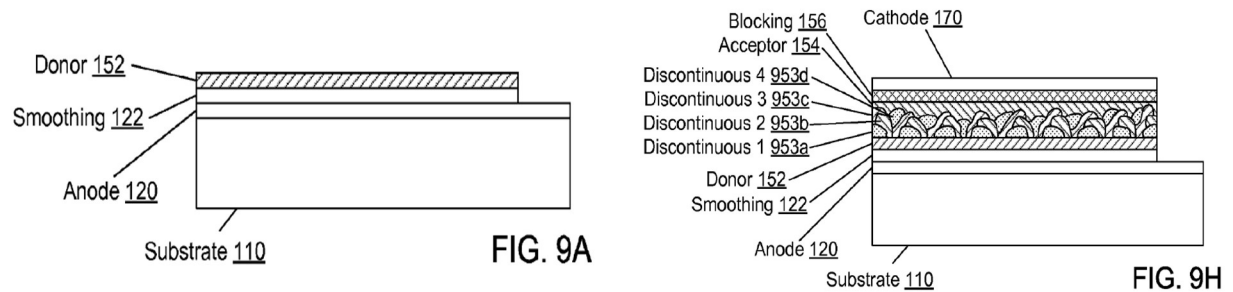
45. During prosecution of the '164 patent, prosecution claims 1, 3, 6, 7, 12, and 13 were rejected as anticipated by Forrest (US 2008/0116536) (Ex. 1013), while the remaining claims were objected to as being dependent upon the rejected claim 1. Ex. 1002 (File History) at 233, 236.

46. Forrest describes an invention which is directed towards a “photosensitive optoelectronic device having an improved hybrid planar bulk heterojunction” (Ex. 1013, Abstract). The Examiner found that Forrest disclosed all elements of prosecution claim 1 (among others):

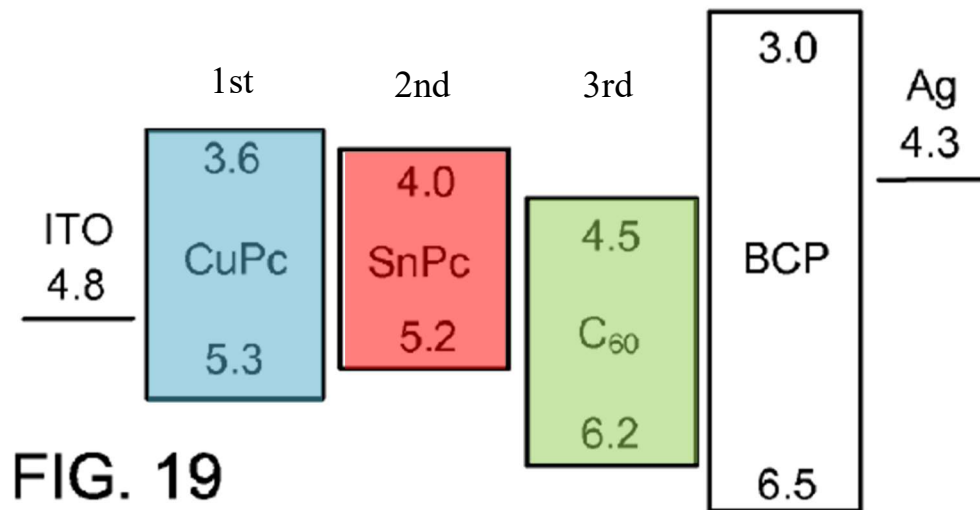
Forrest [] discloses an electronic device, comprising: a substrate (i.e. Figure 9a, reference sign 110), a first electrode (i.e. Figure 9a, reference sign 120), at least one organic, functional layer (i.e. paragraphs 0019, 0081-0083, Figure 9h, reference signs 953a-d), and a second electrode (i.e. Figure 9h, reference sign 170), wherein the at least one organic functional layer is located between the first electrode and the second electrode, and wherein the at least one organic functional layer has at least a first matrix material (i.e. paragraphs 0081, 0126, Figure 9h, reference sign 953a and Figure 19, “donor material CuPc”), a second matrix material (i.e. paragraphs 0081, 0126, Figure 9h, reference sign 953b and Figure 19, “sensitizer SnPc”), and a third matrix material (i.e. paragraphs 0081, 0126, Figure 9h, reference sign 953c and Figure 19, “acceptor material C50 [sic]”), and the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material (i.e. Figure 19).

Ex. 1002 at 233–34.

47. Figures 9a, 9h, and 19 of Forrest illustrate these anticipated claim elements.



Forrest, Figs. 9a, 9h.



Forrest, Fig. 19 (annotated).

48. Regarding dependent prosecution claim 3, which claims “the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material, and a HOMO which is energetically higher than the HOMO

of the third matrix material,” the Examiner determined that it was anticipated by Forrest in “paragraphs 0019-0021, 0081-0083, 0126, Figures 9a-9h, 19.” Ex. 1002 at 234. Regarding dependent prosecution claim 6, which added the limitation that “the third matrix material comprises an electron transport material,” the Examiner determined that it was anticipated by Forrest in “paragraphs 0019-0021, 0081-0083, 0126, Figures 9a-9h, 19.” Ex. 1002 at 234.

49. There were also a number of other dependent prosecution claims rejected by the Examiner. For these rejected dependent claims, which included claim 7 (“wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers”), claim 12 (“which is constructed as a radiation-emitting device”), and claim 13 (“which is constructed as a radiation-emitting device”), the Examiner determined that they “specifie[d] an intended use or field of use” and, as such, were “treated as nonlimiting.” Ex. 1002 at 234–35.

50. The applicant did not dispute the Examiner’s findings regarding Forrest anticipating the prosecution claims. Instead, the applicant submitted an amendment wherein “[a]llowable [prosecution] claim 8 (now canceled) has been incorporated into claim 1 from which it was directly dependent.” Ex. 1002 at 257. Applicant also added, as independent claims, prosecution claim 16 as “a combination of

[prosecution] claim 1 and allowable [prosecution] claim 2” as well as prosecution claim 17 as “a combination of [prosecution] claim 1 and allowable [prosecution] claim 4.” Ex. 1002 at 257. After the applicant submitted this amendment, the Examiner issued a notice of allowance allowing the claims.

51. As such, the claims of the '164 patent were only allowed after the independent claims were amended to overcome anticipation rejections by requiring that “wherein the organic functional layer is an emission layer and is doped with at least one emitter material” (allowed claim 1), '164 patent, 9:21–22, “wherein the first matrix material has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material” (allowed claim 15), '164 patent, 10:35–40, and “wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials” (allowed claim 16). '164 patent, 10:58–60.

E. Challenged Claims

52. I have been asked to consider the patentability of claims 1–16 of the '164 patent (“challenged claims”). Those claims are reproduced below for reference.

1. An electronic device, comprising: a substrate; a first electrode; at least one organic functional layer; and a second electrode, wherein the at least one organic functional layer is

located between the first electrode and the second electrode, and wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material, and the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material, wherein the organic functional layer is an emission layer and is doped with at least one emitter material.

2. The electronic device according to claim 1, wherein the first matrix material has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material.

3. The electronic device according to claim 1, wherein the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material, and a HOMO which is energetically higher than the HOMO of the third matrix material.

4. The electronic device according to claim 1, wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.

5. The electronic device according to claim 1, wherein the second matrix material comprises a hole transport material.

6. The electronic device according to claim 1 wherein the third matrix material comprises an electron transport material.

7. The electronic device according to claim 1, wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers.

8. The electronic device according to claim 1, wherein the emitter material in the emission layer has a concentration of ≤ 10 wt %.

9. The electronic device according claim 1, wherein the concentration of the emitter material in the emission layer has a gradient.

10. The electronic device according to claim 1, wherein the LUMO of the emitter material is energetically lower than the LUMO of the first, second, and third matrix materials, and the

HOMO of the emitter material is energetically higher than the HOMO of the first, second, and third matrix materials.

11. The electronic device according to claim 1, which is constructed as a radiation-emitting device.

12. The electronic device according to claim 1, wherein the device is selected from a group which comprises an organic light-emitting device, a solar cell, and a transistor.

13. A method for the production of an electronic device according to claim 1, comprising the steps of: A) preparation of a substrate; B) preparation of a first electrode and a second electrode; and C) placement of at least one organic functional layer between the first electrode and the second electrode, wherein in method step C), at least the first matrix material, the second matrix material, and the third matrix material are simultaneously applied.

14. A method according to claim 13, wherein in the method step C), the first matrix material, the second matrix material, and the third matrix material are applied by evaporation coating.

15. An electronic device, comprising: a substrate; a first electrode; at least one organic functional layer; and a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and; wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a

third matrix material, and the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material, and wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material, wherein the first matrix material [sic] has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material.

16. An electronic device, comprising: a substrate; a first electrode; at least one organic functional layer; and a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material, and the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO

of the third matrix material, wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.

V. PERSON OF ORDINARY SKILL IN THE ART

53. I have been informed by counsel that there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including the educational level of active workers in the field at the time of the alleged invention, the sophistication of the technology, the type of problems encountered in the art, and the prior art solutions to those problems.

54. Considering these factors, it is my opinion a person of ordinary skill in the art (POSITA) at the time of the alleged inventions would have had a Bachelor's degree in chemistry, physics, or a comparable field of study, and at least three years of research or industrial experience with organic optoelectronic light-emitting devices. An individual with additional education could have less research or industrial experience and vice versa.

VI. CLAIM CONSTRUCTION

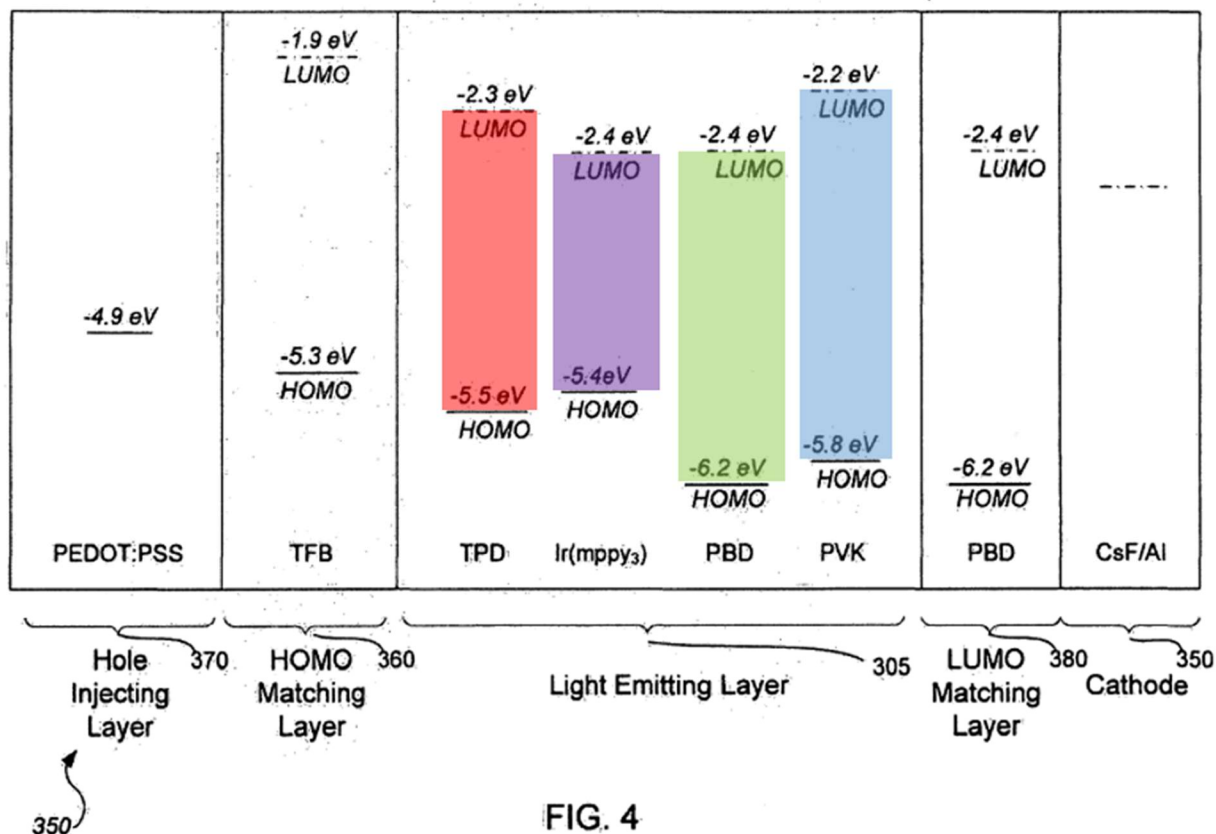
55. I understand that in IPR proceedings, claims are construed in accordance with their ordinary and customary meaning in light of the specification. For the purposes of my opinions, I have been asked to assume that the claim terms should be given their plain and ordinary meaning. I have therefore applied the terms' plain and ordinary meaning in my analysis.

VII. OVERVIEW OF THE PRIOR ART REFERENCES

A. Choulis (Ex. 1004)

56. Choulis is a U.S. patent application publication filed on September 28, 2005 and published on March 29, 2007. I am informed that Choulis is therefore prior art to the '164 patent.

57. Similar to the '164 patent, Choulis “is directed to improving the efficiency of an OLED by adding organic moieties to the light emitting layer.” Choulis, [0007]. Figure 4 of Choulis illustrates an embodiment of the invention where “[t]he light emitting layer 305 includes a host material 310, poly(9-vinylcarbazole) (PVK), a light emitting material 320, (Ir(mppy)₃), a first organic moiety 330, triphenyldiamine (TPD) and a second organic moiety 335, PBD.” Choulis, [0030]. Figure 4 is reproduced below with annotations showing the HOMO and LUMO energy levels of the materials in Choulis’s “light emitting layer 305.”



Choulis, Fig. 4 (annotated).

58. Choulis explains that “[t]he materials described in FIGS. 3 and 4 are only examples of possible materials for use in an OLED.” Choulis, [0031]. Indeed, “[o]ther possible materials are discussed herein. Additional suitable materials than those described for the host material 310, the light emitting material 320, the first organic moiety 335 and the second organic moiety 335, can also be selected according to the properties described herein.” Choulis, [0031].

59. For example, the “organic material that emits light” “may be organic or organo-metallic in nature” with the “[l]ight-emission in these materials...occur[ing] as a result of fluorescence or phosphorescence or both,” and “[e]xamples of

electroluminescent small molecule materials include chelates, such as tris(8-hydroxyquinolate) aluminum (Alq_3) and tris(2-phenylpyridine) iridium (Ir(ppy)_3), organic materials, such as anthracene, rubrene or triazine, or any metal-chelate compounds or derivatives of any of the organic materials or small molecule materials.” Choulis, [0041]–[0043].

60. Choulis also discloses that the light emitting layer can be formed either by the materials being “spun (spin-coated) onto the device, although other deposition methods...are possible too” such as being “deposited through evaporation, sublimation, or organic vapor phase deposition methods.” Choulis, [0042]–[0043].

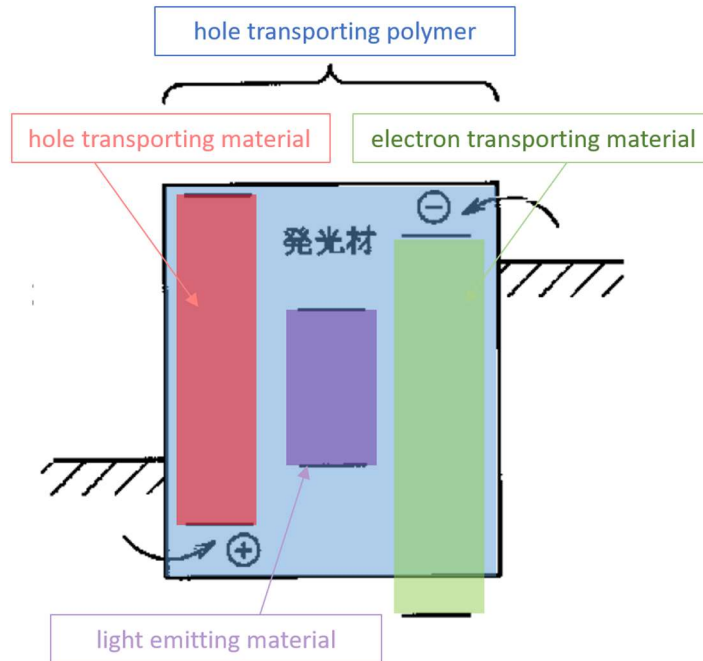
B. Sugiura (Ex. 1005/1006)

61. Sugiura is a Japanese published patent application that was published on April 20, 2001. I am informed that Sugiura is therefore prior art to the ’164 patent. Ex. 1006 is the certified English translation of the Japanese original version of Sugiura (Ex. 1005).

62. Similar to the ’164 patent, Sugiura “relates to an organic light-emitting device used in a flat light source or a flat display,” Sugiura, [0001], that “reali[zes] a high light-emitting efficiency and low driving voltage even in a polymer-dispersed organic light-emitting device.” Sugiura, [0014].

63. Figure 8 of Sugiura illustrates “energy diagram of an organic light-emitting device having the configuration: positive electrode / light-emitting layer

(hole transporting polymer + hole transporting material + electron transporting material + light-emitting material) / negative electrode.” Sugiura, [0049].



Sugiura, Fig. 8 (annotated).

64. Sugiura discloses an embodiment, where “[f]or the light-emitting layer...PVK was used for the polymer 3A, N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD) was used for the hole transporting material 3D, Alq3 was used for the electron transporting material 3E, and Nile Red was used for the light-emitting material 3C.” Sugiura, [0062]; *see also* Sugiura, Figs. 1, 4. Sugiura discloses manufacturing the light emitting layer in this embodiment by using “[t]he mixing ratio of each material [] PVK:Alq3:TPD:Nile red=100:60:80:0.2 (weight ratio),” with the layer “formed by dissolving 300 mg of PVK, 180 mg of

Alq3, 240 mg of TPD, and 0.6 mg of Nile Red in 50 mL of a 1:1 mixed solvent of toluene and chloroform, stirring the solution for one day, then spin-coating the solution onto the ITO-affixed glass substrate.” Sugiura, [0062].

C. Thompson (Ex. 1007)

65. Thompson is a U.S. patent application publication filed on March 13, 2002 and published on August 12, 2004. I am informed that Thompson is therefore prior art to the '164 patent.

66. Thompson “relates to highly efficient organic light emitting devices (OLEDs) that are, for example, capable of emitting blue light, and in particular to OLEDs that have an emitting layer comprising a phosphorescent dopant material and a charge carrying dopant material that are doped in an inert host material.” Thompson, [0001].

67. Thompson explains in one embodiment:

[T]he emissive layer comprises a wide gap host material doped with both a charge carrying dopant material and a phosphorescent dopant material. The charge carrying dopant material is capable of transporting a hole or an electron, and the phosphorescent dopant material is capable of transporting a charge opposite to the charge carried by the charge carrying dopant material. Each dopant material, thus, carries charge, though of opposite polarity. The charge carrying phosphorescent material also performs the function of emitting the phosphorescent radiation.

Thompson, [0008].

68. Thompson's Figure 4 illustrates the energy levels of the materials for one embodiment of the OLED disclosed in Thompson:

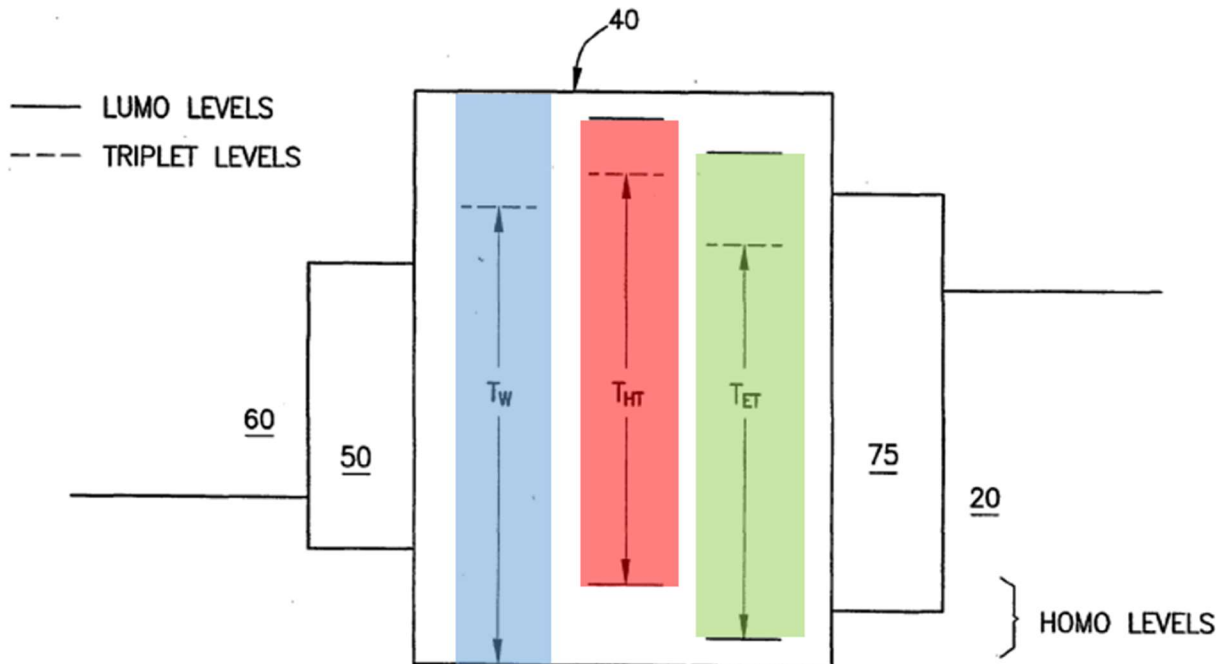


Fig. 4

Thompson, Fig. 4 (annotated). Thompson explains that “[p]referably, the HOMO level of the inert host material is lower than the HOMO level of any of the dopant materials....In addition, the LUMO level of the inert host material is [sic] higher than the LUMO level of any of the dopant materials.” Thompson, [0042].

D. Yong (Ex. 1008/1009)

69. Yong is a Chinese published patent application that was published on February 16, 2005. I am informed that Yong is therefore prior art to the '164 patent.

Ex. 1009 is the certified English translation of the Chinese original version of Yong (Ex. 1008).

70. Yong relates to “to a phosphorescent organic light emitting device and the preparation method thereof” where the emission layer “comprises a host material and a phosphorescent dye, and the doping concentration of the phosphorescent dye gradually increases or decreases along the direction from the anode layer to the cathode layer with the increase of the thickness of the organic light emitting layer, forming a construction with gradient doping.” Yong, Abstract.

71. Yong explains that gradient doping is a “solution...to make the distribution trend of phosphorescent dyes in the host material conform to the distribution trend of electrons in the host material,” such that “concentration distribution expands the luminescent region of the device, improves the utilization rate of phosphorescent dyes, and is also conducive to the combination of electrons and holes to form excitons.” Yong, Description at 3. This helps “improv[e] the luminescent efficiency and brightness of the device, improv[e] its stability, and overcom[e] the disadvantages of low luminescent efficiency and poor stability of the device under high current.” Yong, Description at 3.

VIII. SPECIFIC GROUNDS OF CHALLENGES

A. Ground I: Claims 1–8 and 10–16 Are Anticipated By Or At A Minimum Rendered Obvious By Choulis

1. Independent Claim 1

a. Preamble: An electronic device, comprising:

72. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 1 is limiting. However, if the preamble is limiting, Choulis discloses it.

73. Choulis discloses the preamble. Choulis states that its “invention relates to optoelectronic devices.” Choulis, [0014]. Choulis also describes “[t]echniques...forming an organic light emitting diode device with improved device efficiency,” Choulis, Abstract, where the OLEDs of the invention “have at least one organic layer between two electrodes.” Choulis, [0002].

74. Accordingly, a POSITA would have appreciated that Choulis discloses this preamble.

b. Element 1[a]: a substrate;

75. Choulis discloses this element. Choulis states that “[f]or example, referring to FIG. 1, OLED 100 includes a substrate 110, such as a transparent layer, for example, glass or plastic.” Choulis, [0003] (emphasis added). Choulis’s Figure 2 (reproduced below with annotations) likewise shows a substrate 110.

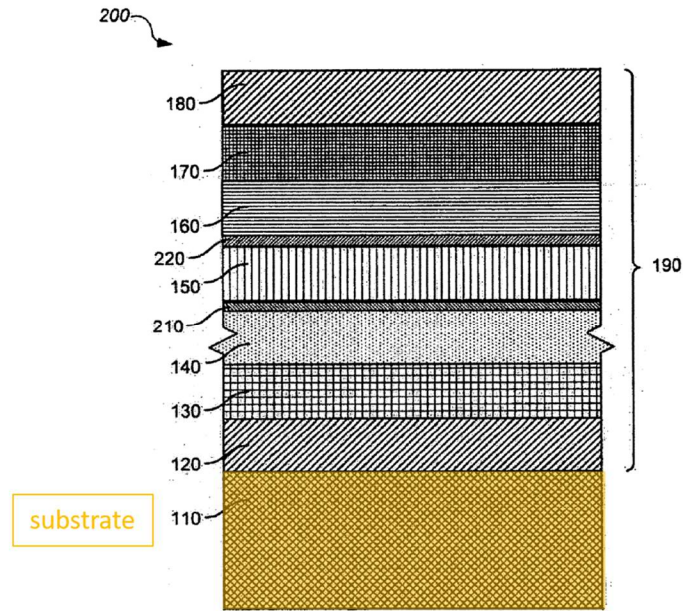


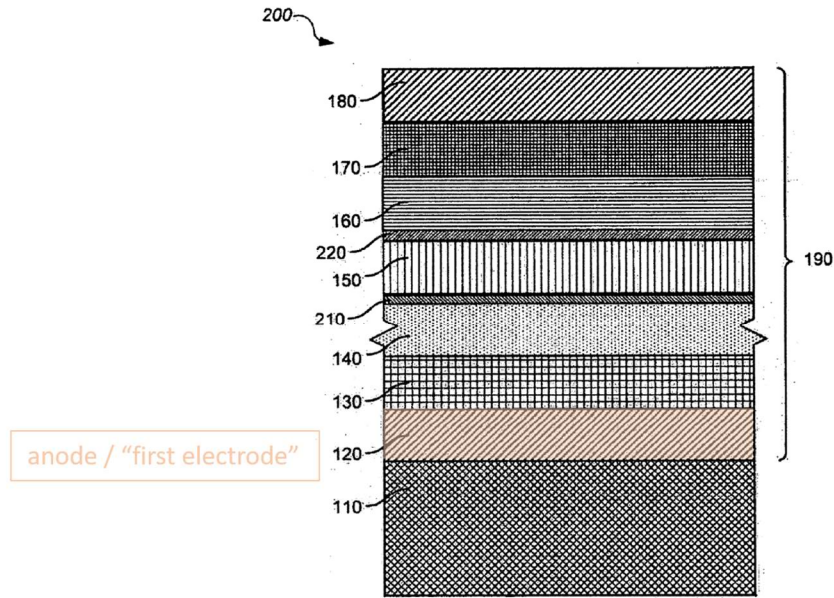
FIG. 2

Choulis, Fig. 2 (annotated).

76. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

c. Element 1[b]: a first electrode;

77. Choulis discloses this element. Choulis explains that, in its “optoelectronic devices[,]” a “light emitting diode has a first electrode, a light emitting layer coupled to the first electrode and second electrode coupled to the light emitting layer.” Choulis, [0014]; *see also* Choulis, [0024] (disclosing anode 120, i.e., “first electrode”).



Choulis, Fig. 2 (annotated).

78. Choulis also discloses a “lower electrode, such as an anode 120, [which] is supported by the substrate 110....An upper electrode, such as cathode 180, sandwiches the organic layers with the lower electrode.” Choulis, [0003].

79. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

d. Element 1[c]: at least one organic functional layer; and

80. Choulis discloses this element. Choulis discloses that a prior art OLED device includes “organic layers, such as...a light emitting layer.” Choulis, [0003]. Choulis further discloses that its OLED device has a “light emitting layer,” which includes “a phosphorescent organic material.” Choulis, [0014]; *see also* Choulis, [0024] (disclosing light emitting layer 150).

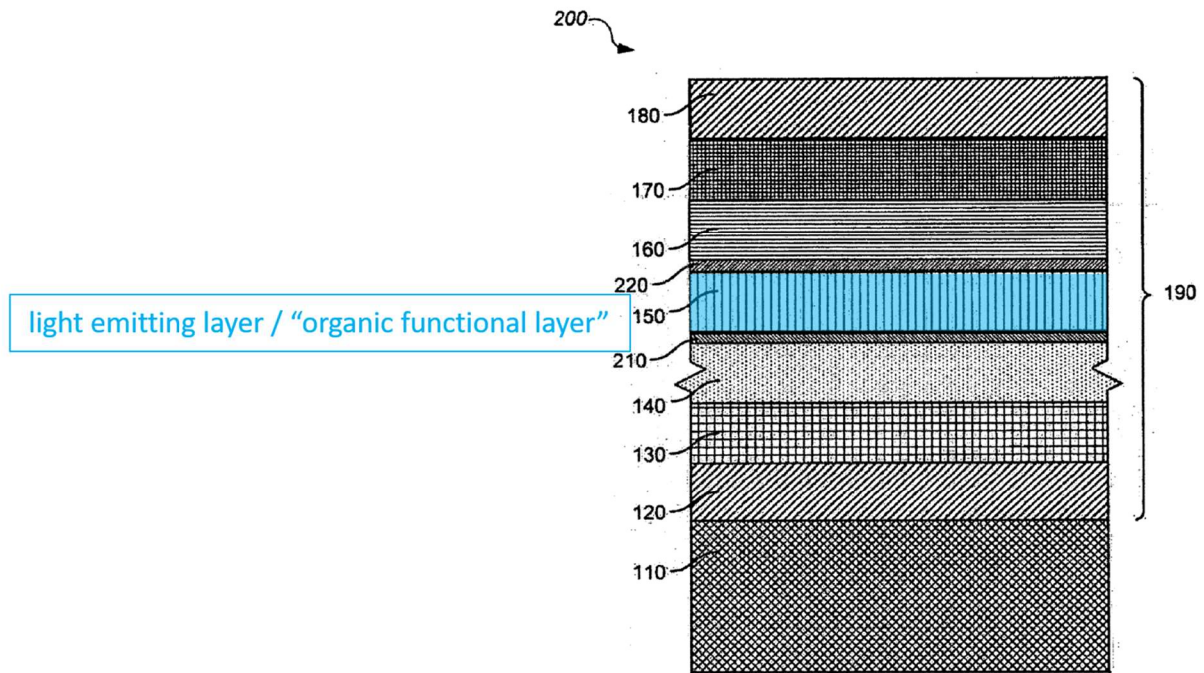


FIG. 2

Choulis, Fig. 2 (annotated).

81. A POSITA would understand that the light emitting layer of an OLED display is an organic layer which serves the function of light emission, and that it constitutes an organic functional layer. The '164 patent explains that "[t]he organic functional layer can be an emission layer and be doped with at least one emitter material." '164 patent at 3:61-63; *see also* '164 patent at 4:44-49.

82. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

- e. **Element 1[d]: a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and**

83. Choulis discloses this element. Choulis discloses a prior art OLED device, where an “upper electrode, such as cathode 180, sandwiches the organic layers with the lower electrode.” Choulis, [0003]. Similarly, as shown in annotated Figure 2 below, Choulis’s OLED device has a light emitting layer (i.e., “organic functional layer”) located between an anode (i.e., “first electrode”) and a cathode (i.e., “second electrode”). Choulis, [0024]; *see also* Choulis, [0014] (disclosing “a light emitting layer coupled to the first electrode and second electrode coupled to the light emitting layer”).

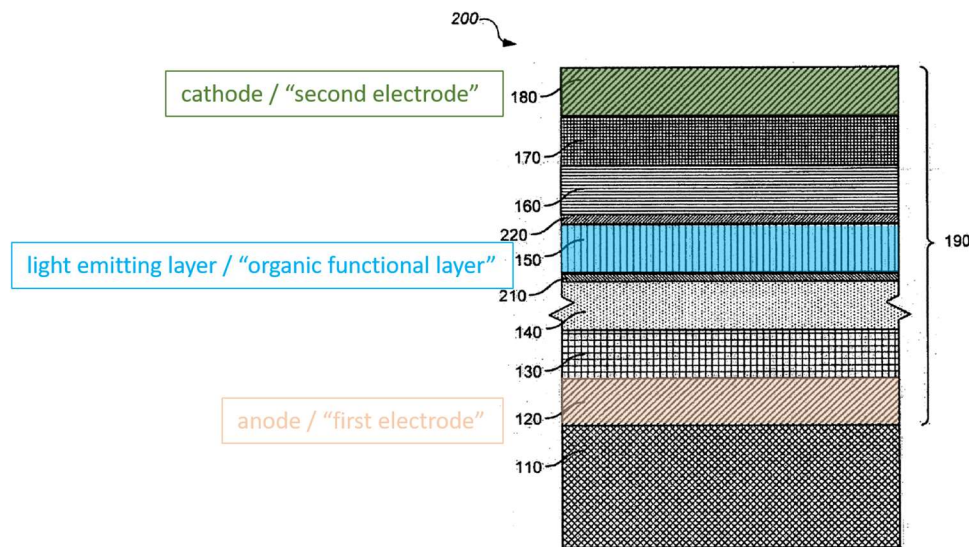


FIG. 2

Choulis, Fig. 2 (annotated).

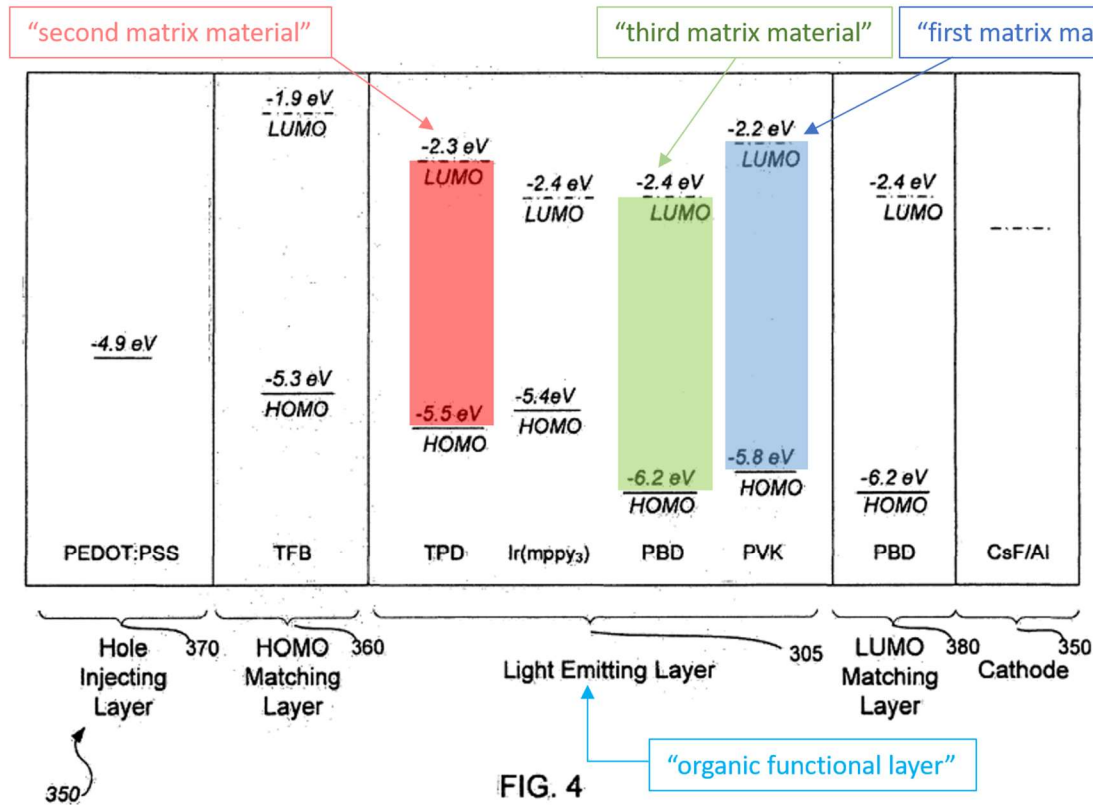
84. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

f. Element 1[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material and

85. Choulis discloses this element. Choulis discloses an organic functional layer, “the light emitting layer 305.” Choulis, [0030]. Choulis goes onto disclose that the “light emitting layer 305 includes a host material 310, poly(9-vinylcarbazole) (PVK), a light emitting material 320, Ir(mppy)_3 , a first organic moiety 330, triphenyldiamine (TPD) and a second organic moiety 335, PBD.” Choulis, [0030].

86. According to Choulis, “PVK has a large band gap and can confine the triplet excited state of the Ir(mppy)_3 phosphorescent molecule, preventing luminescence quenching.” Choulis, [0030]. A POSITA would have appreciated that, within the organic light emitting layer disclosed by Choulis, PVK is the “first matrix material,” that TPD is the “second matrix material,” and PBD is the “third matrix material.” Choulis, [0030]. Choulis further discloses that “[a]dditional suitable materials than those described for the host material 310, the light emitting material 320, the first organic moiety 335 and the second organic moiety 335, can also be selected according to the properties described herein.” Choulis, [0031].

87. Choulis shows its organic layer and the first, second, and third matrix material in Figure 4. Figure 4 is reproduced below with annotations to show the three matrix materials along with the emitter material.



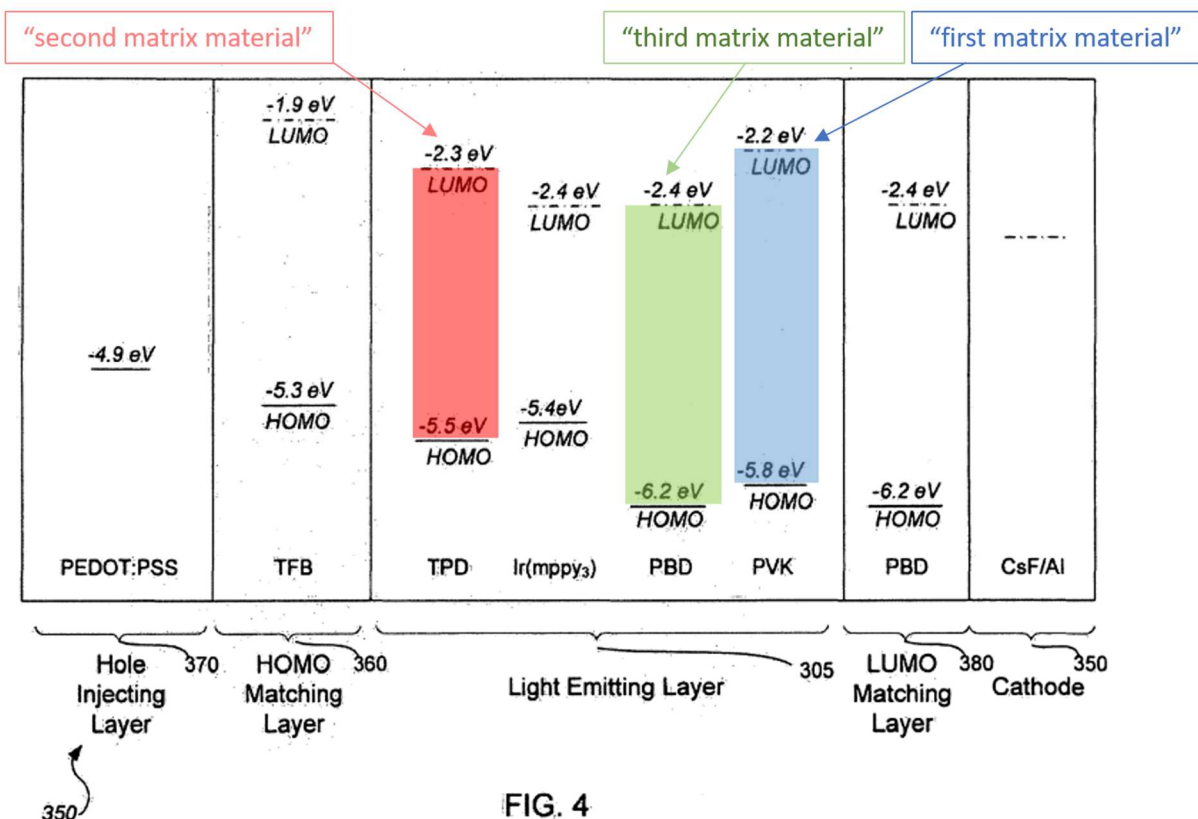
Choulis, Fig. 4 (annotated).

88. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

- g. **Element 1[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

89. Choulis discloses this element. Choulis discloses that its OLED contains a third matrix material that has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material

and the LUMO of the first matrix material. This is clearly shown in Choulis's Figure 4, which is reproduced below with annotations.



Choulis, Fig. 4 (annotated).

90. As I explained in §IV.A above, in energy diagrams such as annotated Figure 4 above, the vertically separated pair of horizontal lines represent the energy levels of each organic material, with the bottom line representing the position of the HOMO level and the top line representing the position of the LUMO level. As seen in annotated Figure 4, the top line for the third matrix material PBD (green), with a LUMO value of -2.4 eV, is located below both the top line for the second matrix material TPD (red) and the top line for the first matrix material PVK (blue), with

LUMO values of -2.3 eV and -2.2 eV, respectively. Thus, Choulis discloses that the third matrix material PBD has a LUMO value that is energetically lower than those of the second matrix material TPD and the first matrix material PVK.

91. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

- h. Element 1[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

92. Choulis discloses this element. Choulis discloses that its OLED includes a second matrix material that has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material. This is clearly shown in Choulis's Figure 4 which is reproduced below with annotations.

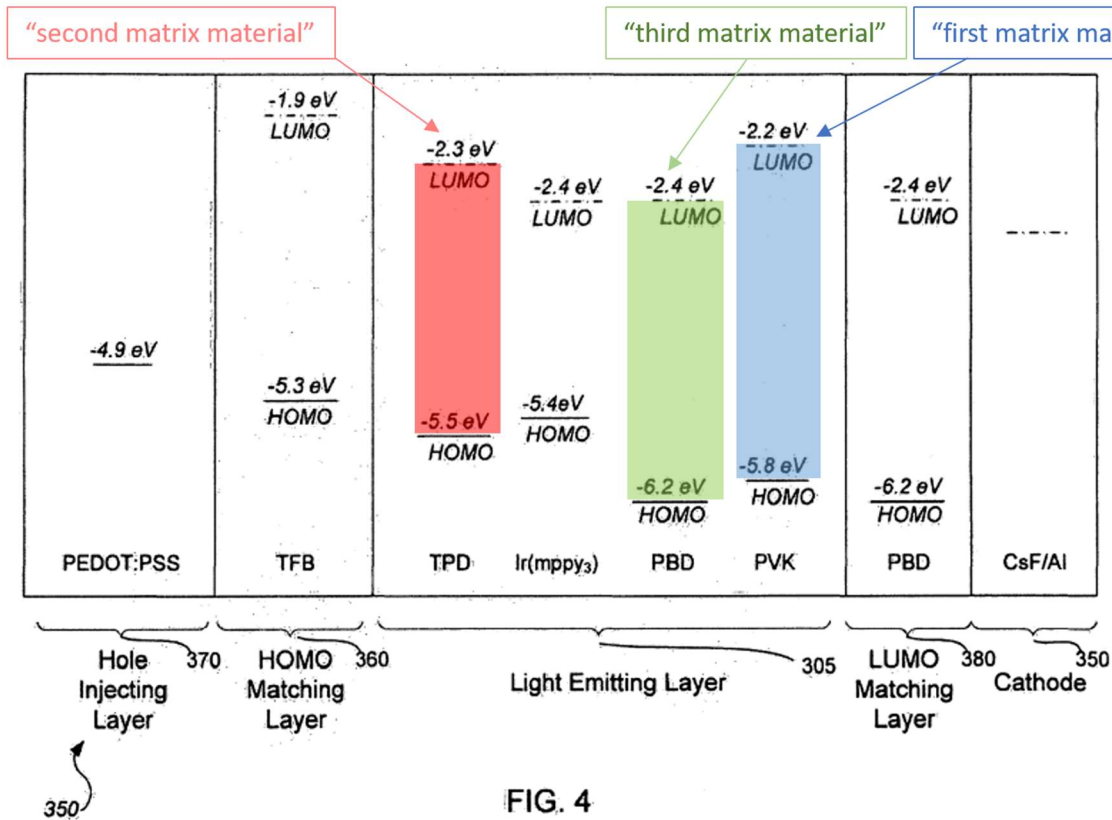


FIG. 4

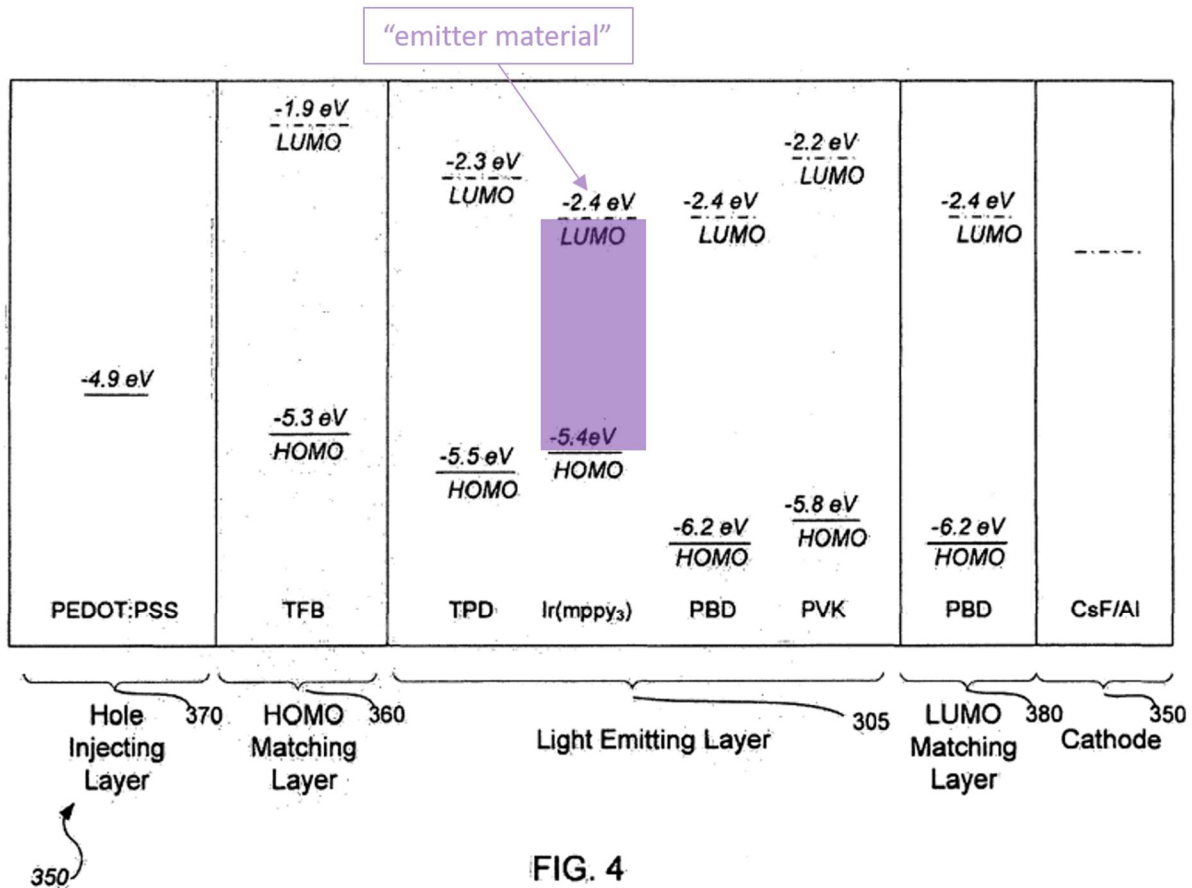
Choulis, Fig. 4 (annotated).

93. As seen in annotated Figure 4, the bottom line for the second matrix material TPD (red), with a HOMO value of -5.5 eV, is located above both the bottom line for the first matrix material PVK (blue) and the bottom line for the third matrix material PBD (green), with HOMO values of -5.8 eV and -6.2 eV, respectively. Thus, Choulis discloses that the second matrix material TPD has a HOMO value that is energetically higher than those of the first matrix material PVK and the third matrix material PBD.

94. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

i. Element 1[h]: wherein the organic functional layer is an emission layer and is doped with at least one emitter material.

95. Choulis discloses this element. As discussed in §VIII.A.1.d above regarding element 1[c], Choulis's light emitting layer is an organic functional layer. Choulis, [0014]. Choulis discloses that its device "can include an anode, one or more organic layers on the anode, at least one of the organic layers including a light emitting layer, wherein the light emitting layer includes an organo-metallic phosphorescent material and a cathode on the light emitting layer." Choulis, [0018]. Choulis further discloses that its light emitting layer is doped with an emitter material where it explains that "small organic molecules that emit by fluorescence or by phosphorescence can serve as a light emitting material residing in the light emitting layer." Choulis, [0043]. As shown in annotated Figure 4 below, Choulis discloses that, Choulis's "light emitting layer 305 includes...a light emitting material 320, (Ir(mppy)₃)." Choulis, [0030].



Choulis, Fig. 4 (annotated). Choulis also discloses forming the light emitting layer with other “electroluminescent small molecules,” such as rubrene. Choulis, [0043]. Therefore, Choulis discloses that its light emitting layer is doped with, *e.g.*, Ir(mppy)₃ or rubrene (i.e., “emitter material”).

96. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

- 2. Dependent Claim 2: The electronic device according to claim 1, wherein the first matrix material has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material.**

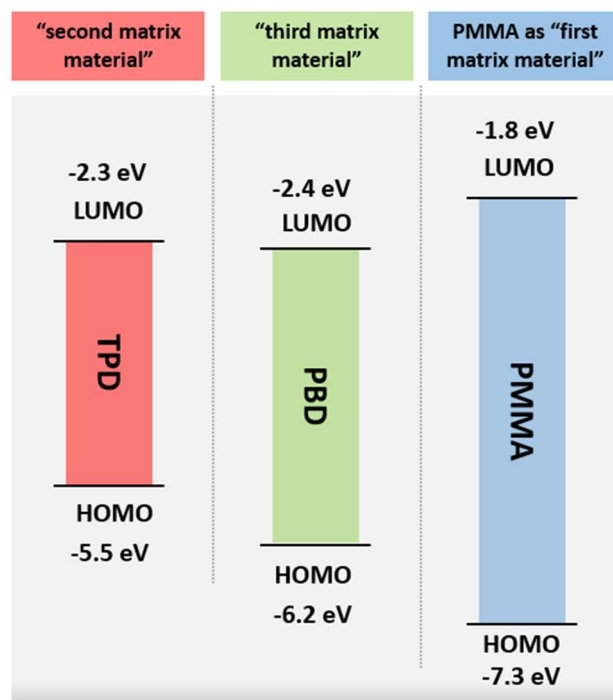
97. Choulis discloses this claim or at a minimum renders it obvious.

Choulis discloses that its “light emitting layer can include a host material” and that the host material “can have a high band gap (have a large difference between their HOMO and LUMO levels).” Choulis, [0044]. Choulis also discloses that “the light emitting layer [can] include[] materials that are insulated matrices, that is, the host does not have transport properties, such as... polymethyl methacrylate (PMMA)[.]” Choulis, [0044] (emphasis added). In other words, Choulis discloses that PMMA can be used as the “first matrix material,” i.e., the host material.

98. The HOMO and LUMO levels of PMMA have been characterized and reported as -7.3 eV and -1.8 eV, respectively. *See, e.g.*, Ex. 1011 (Li), Fig. 2; Ex. 1012 (Wu), Fig. 4. As such, when PMMA is used as the host material (as taught by Choulis, [0044]), the LUMO level of Choulis’s “first matrix material” (-1.8 eV) is “energetically higher” than the LUMO levels of Choulis’s second and third matrix materials (-2.3 eV and -2.4 eV, respectively) and the HOMO level of Choulis’s “first matrix material” (-7.3 eV) is “energetically lower” than the HOMO levels of

Choulis's second and third matrix materials (-5.5 eV and -6.2 eV, respectively).

Choulis, Fig. 4. This is illustrated below:



99. With PMMA as the "first matrix material," Choulis still discloses all of the limitations of claim 1 (from which claim 2 depends). As shown in the illustration above (which shows PMMA's HOMO/LUMO levels), Choulis's third matrix material (PBD) has a LUMO (-2.4 eV) which is energetically lower than the LUMO (-2.3 eV) of the second matrix material (TPD) and the LUMO (-1.8 eV) of the first matrix material (PMMA), as required by element 1[f]; and Choulis's second matrix material (TPD) has a HOMO (-5.5 eV) which is energetically higher than the HOMO (-7.3 eV) of the first matrix material (PMMA) and the HOMO (-6.2 eV) of the third matrix material (PBD), as required by element 1[g]. As for the remaining elements

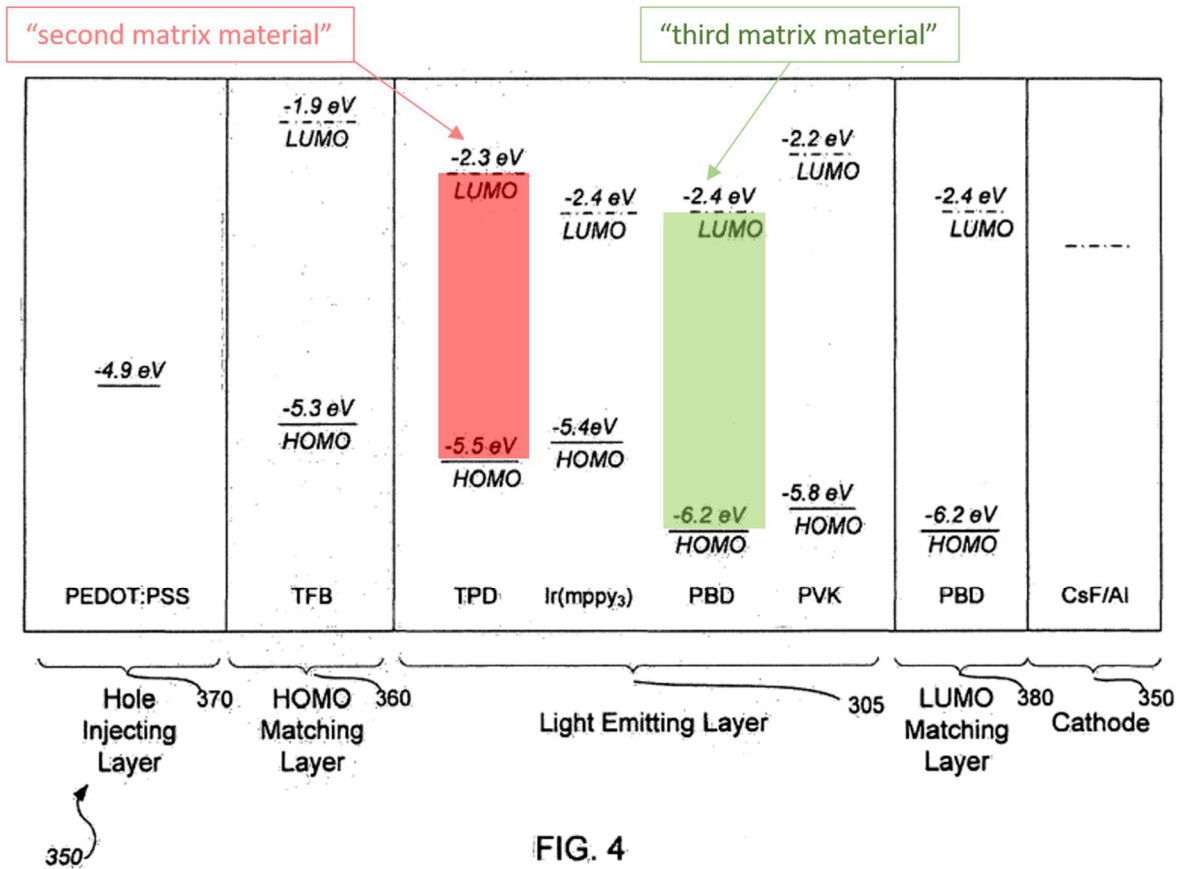
of claim 1—elements 1[a]-1[e] and 1[h]—Choulis discloses them for the reasons explained in §VIII.A.1.

100. To the extent Choulis does not expressly disclose this claim, it would have been obvious to a POSITA to use a material (such as PMMA) that has a LUMO level energetically higher than the LUMO levels of TPD (i.e., the “second matrix material”) and PBD (i.e., the “third matrix material”), and a HOMO level that is energetically lower than the HOMO levels of TPD and PBD, as the host material (i.e., the “first matrix material”) in Choulis’s OLED. As I explained in §IV.A.2 above, the host, which serves as a matrix in which the other three components are dispersed, preferably would have a wide energy gap so as not to interfere with the charge transport of the second and third matrix materials. A POSITA would have had a reasonable expectation of success in using such a material as the host material in an OLED such as the one disclosed by Choulis. Such use was well-known around 2008 and implementing it in Choulis’s OLED would have been a routine matter well within the ability of a POSITA. *See, e.g.*, Thompson, Abstract (“An OLED includes a wide gap inert host material doped with two dopants.”). As I explained in detail in §IV.A.2 above, the use of ultra-wide energy gap hosts (UGHs) to act as matrix hosts that do not interfere with charge transport was also well-established prior to the ’164 patent.

101. Accordingly, a POSITA would have appreciated that Choulis discloses this claim or at a minimum renders it obvious.

- 3. Dependent Claim 3: The electronic device according to claim 1, wherein the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material and a HOMO which is energetically higher than the HOMO of the third matrix material.**

102. Choulis discloses this claim. As illustrated in the annotated Figure 4 below, TPD as “the second matrix material” has a LUMO of -2.3 eV, “which is energetically higher than the LUMO of the third matrix material” PBD (-2.4 eV) and a HOMO of -5.5 eV, “which is energetically higher than the HOMO of the third matrix material,” PBD (-6.2 eV).



Choulis, Fig. 4 (annotated).

103. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

4. Dependent Claim 4: The electronic device according to claim 1, wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.

104. Choulis discloses this claim or at a minimum renders it obvious. Choulis discloses that the “light emitting layer” of its OLED device “can include a host material.” Choulis, [0044]. Choulis also discloses the use of “insulated matrices” as a “host [that] does not have transport properties.” Choulis, [0044].

Choulis explains that these materials include, for example, “polycarbonate (PC), polymethyl methacrylate (PMMA) or polystyrene sulphonate (PSS).” Choulis, [0044].

105. As discussed above in connection with dependent claim 2, Choulis, with PMMA as the “first matrix material,” discloses the limitations of claim 1 (from which claim 4 depends). *See* § VIII.A.2. Choulis discloses that “insulated matrices” such as PMMA “do[] not have transport properties.” Choulis, [0044]. The “transport properties” of a material refer to whether a particular type of charge carrier (electrons or holes) are able to traverse the layer under an applied voltage. This ability is generally quantified in terms of the “charge carrier mobility,” where a higher mobility reflects a greater ease of transport. Given that PMMA (i.e., “first matrix material”) does not have transport properties, the charge carrier mobility of this material is lower than that of the second and third matrix materials that do transport holes or electrons, as I discuss in § **Error! Reference source not found.** below regarding the second matrix material and in § **Error! Reference source not found.** regarding the third matrix material.

106. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

5. Dependent Claim 5: The electronic device according to claim 1, wherein the second matrix material comprises a hole transport material.

107. Choulis discloses this claim. As discussed above regarding claim 1, Choulis discloses the use of TPD as the “second matrix material.” In addition to explaining that its “light emitting layer can include a material capable of charge transport,” Choulis explains that TPD (the “second matrix material”) is a “hole transporting material.” Choulis, [0046] (explaining that “a hole transporting material” may include “TPD”).

108. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

6. Dependent Claim 6: The electronic device according to claim 1 wherein the third matrix material comprises an electron transport material.

109. Choulis discloses this claim. As discussed above regarding claim 1, Choulis discloses the use of PBD as the “third matrix material.” Choulis further discloses that its “light emitting layer can include a material capable of charge transport,” and describes PBD (the “third matrix material”) as a material that performs “electron...transport.” Choulis, [0047]. Choulis therefore discloses a third matrix material that comprises an electron transport material.

110. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

- 7. Dependent Claim 7: The electronic device according to claim 1, wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers.**

111. Choulis discloses this claim. As discussed in §VIII.A.1.d regarding element 1[c], Choulis discloses a light emitting layer (i.e., “emission layer”), which is an “organic functional layer.” Choulis, [0014], [0024].

112. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

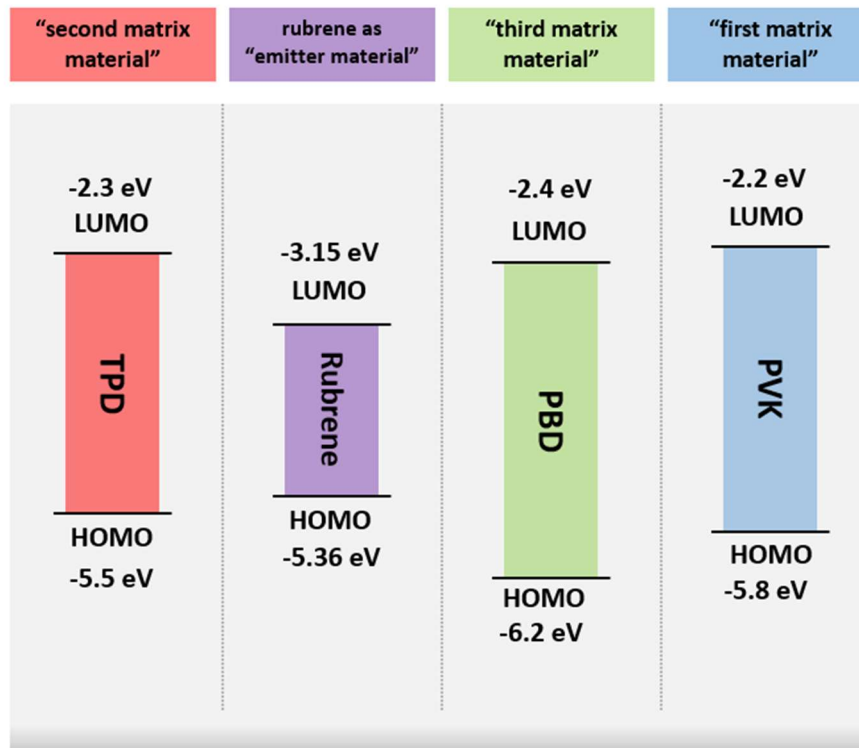
- 8. Dependent Claim 8: The electronic device according to claim 1, wherein the emitter material in the emission layer has a concentration of ≤ 10 wt %.**

113. Choulis discloses this claim. Choulis discloses an OLED device which, in one embodiment, contains a “light emitting layer [which] includes 61% PVK, 24% PBD, 9% TPD and 6% Ir(mppy)₃.” Choulis, [0054] (emphasis added). Choulis therefore discloses using an emitter material, Ir(mppy)₃, in the emission layer of the OLED at a concentration of 6%. Choulis, [0028]. Choulis discloses, and a POSITA would understand, that “Ir(mppy)₃” is a “light emitting material.” Choulis, [0028]. Choulis therefore discloses that the emitter material in the emission layer has a concentration of 6%, which is less than 10 wt%.

114. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

- 9. Dependent Claim 10: The electronic device according to claim 1, wherein the LUMO of the emitter material is energetically lower than the LUMO of the first, second, and third matrix materials, and the HOMO of the emitter material is energetically higher than the HOMO of the first, second, and third matrix materials.**

115. Choulis discloses this claim or at a minimum renders it obvious. As discussed in §VIII.A.1.i regarding element 1[h], Choulis discloses applying rubrene (i.e., “emitter material”) to form the light emitting layer. The HOMO and LUMO levels of rubrene are -5.36 eV and -3.15 eV, respectively. *See, e.g.,* Kang (Ex.1010), 756–57; Hamada (Ex.1024), Fig. 5. As illustrated below, the LUMO of rubrene (-3.15 eV) is energetically lower than the LUMOs of Choulis’s disclosed exemplary first, second, and third matrix materials (-2.2 eV, -2.3 eV, and -2.4 eV, respectively), and the HOMO of rubrene (-5.36 eV) is energetically higher than the HOMO of the Choulis’s disclosed exemplary first, second, and third matrix materials (-5.8 eV, -5.5 eV, and -6.2 eV, respectively). Choulis, Fig. 4.



To the extent Choulis does not expressly disclose this claim, it would have been obvious to a POSITA to use an emitter material with a LUMO level energetically lower than the LUMO levels of PVK (i.e., the “first matrix material”), TPD (i.e., the “second matrix material”) and PBD (i.e., the “third matrix material”), and a HOMO level energetically higher than the HOMO levels of PVK, TPD and PBD, as the emitter material in Choulis’s OLED. A POSITA would have known that examples of such emitter materials include PQIr and DCM2, with the HOMO/LUMO levels of -5.0 eV/-2.7 eV and -5.26 eV/-3.11 eV, respectively. *See, e.g.,* Kanno (Ex.1025), Fig. 2 caption; Hamada (Ex.1024), Fig. 5. As I explained in §IV.A.1, electrons tend to lower their energy by traveling “downhill” to LUMO levels that are lower, and

that, in contrast, holes tend to lower their energy by traveling “uphill” to HOMO levels that are higher. To ensure that all charges efficiently travel to the guest emitter material to form excitons, the LUMO level of the guest emitter material is preferably lower than those of other materials in the light emitting layer, and the HOMO level of the guest emitter material is preferably higher than those of other materials in the light emitting layer. A POSITA would have had a reasonable expectation of success in using such an emitter material; as I explained above, such use was well-known around 2008. *See* §IV.A.2. Implementing such an emitter material in Choulis’s OLED would have been a routine matter well within the ability of a POSITA. *See, e.g.,* Sugiura, Fig. 8.

116. Accordingly, a POSITA would have appreciated that Choulis discloses this claim or at a minimum renders it obvious.

10. Dependent Claim 11: The electronic device according to claim 1, which is constructed as a radiation-emitting device.

117. Choulis discloses this claim. As discussed above, Choulis discloses an OLED device. Choulis discloses that an OLED device “causes the anode to force holes toward the emitting layer 150 and the cathode to force electrons toward the emitting layer 150.” Choulis, [0003]. Choulis further discloses that this process produces light emission (which a POSITA would appreciate constitutes a form of radiation), explaining that “[w]hen the electrons and holes combine, excitons form, which emit light via radiative decay.” Choulis, [0003]. As discussed in §VIII.A.1.d

above regarding element 1[c], Choulis discloses that its OLED device has a light emitting layer. Choulis, [0024]. Choulis therefore discloses that its OLED device is constructed as a radiation-emitting device.

118. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

11. Dependent Claim 12: The electronic device according to claim 1 wherein the device is selected from a group which comprises an organic light-emitting device, a solar cell, and a transistor.

119. Choulis discloses this claim. As I explained above, Choulis discloses an organic light-emitting diode (OLED) device. For example, Choulis states that its invention is directed towards “[t]echniques...for forming an organic light emitting diode device with improved device efficiency.” Choulis, at Abstract (emphasis added).

120. Accordingly, a POSITA would have appreciated that Choulis discloses this claim.

12. Dependent Claim 13

a. Preamble: A method for the production of an electronic device according to claim 1, comprising the steps of:

121. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion

as to whether or not the preamble to claim 13 is limiting. However, if the preamble is limiting, Choulis discloses it.

122. As I discussed above, Choulis discloses an organic light emitting diode (OLED) device. Choulis also discloses a method of fabricating such a device, as it discloses “[a] method of fabricating a light emitting diode.” Choulis, [0019].

123. Accordingly, a POSITA would have appreciated that Choulis discloses this preamble.

b. Element 13[a]: A) preparation of a substrate;

124. Choulis discloses this element. As I explained above, Choulis discloses “[a] method of fabricating a light emitting diode.” Choulis, [0019]. Choulis discloses that this method of fabricating a light emitting diode includes a substrate, explaining that “[a] substrate with an electrode formed thereon is provided.” Choulis, [0019]; *see also* Choulis, [0003], Fig. 2.

125. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

c. Element 13[b]: B) preparation of a first electrode and a second electrode; and

126. Choulis discloses this element. Choulis discloses an OLED device with “the first electrode and second electrode.” Choulis, [0014]; *see also* Choulis, [0024], Fig. 2. As I explained above, Choulis discloses “[a] method of fabricating a light emitting diode.” Choulis, [0019]. With regards to this method of fabricating a light

emitting diode, Choulis discloses that “[a] substrate with an electrode formed thereon is provided.” Choulis, [0019].

127. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

d. Element 13[c]: C) placement of at least one organic functional layer between the first electrode and the second electrode,

128. Choulis discloses this element. Choulis discloses a prior art OLED device, where “[a]n upper electrode, such as cathode 180, sandwiches the organic layers with the lower electrode.” Choulis, [0003]. As discussed in §VIII.A.1.d regarding element 1[c], Choulis discloses a light emitting layer, which is the “organic functional layer.” Choulis, [0014], [0024]. Choulis discloses that the light emitting layer is “coupled to the first electrode and second electrode,” as depicted in annotated Figure 2 below. Choulis, [0014]; *see also* Choulis, [0024].

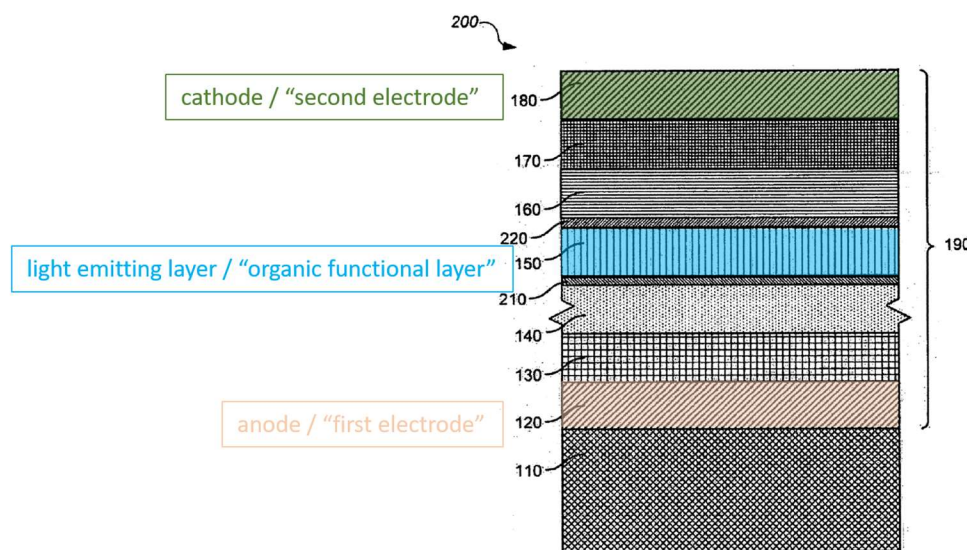


FIG. 2

Choulis, Fig. 2 (annotated).

129. Accordingly, a POSITA would have appreciated that Choulis discloses this element.

- e. **Element 13[d]: wherein in method step C), at least the first matrix material, the second matrix material, and the third matrix material are simultaneously applied.**

130. Choulis discloses this element or at a minimum renders it obvious. As I discussed in §VIII.A.1.f above regarding element 1[e], Choulis discloses a light emitting layer containing a first matrix material PVK, a second matrix material TPD, and a third matrix material PBD. Choulis, [0030], Fig. 4; *see also* Choulis, [0020] (“Forming the light emitting layer can include applying a layer including an organo-metallic phosphorescent compound and organic moieties”). PVK is a polymer while TPD and PBD are each small molecules. Choulis, [0044] (“PVK...is a non-conjugated polymer”); Ex. 1021, Fig. 1 (explaining that TPD is a material “commonly used in small molecule based OLEDs”); Ex. 1022, 203502-2 (noting “PBD” as a “small molecule”).

131. Choulis discloses creating OLED layers via spin-coating. Choulis, [0042] (“Polymers can be solvated in an organic solvent...and spun (spin-coated) onto the device”), ¶[0043] (“There are also small molecule materials that can be applied by solution methods too....For example, a PLED [polymer light emitting diode] may be...mixed with a small organic molecule to form the light emitting

layer.”). The process of spin-coating a mix of the first, second, and third matrix materials (polymer PVK and small molecules TPD and PBD) would involve dissolving PVK, TPD, and PBD in a solution, placing that solution on a substrate, and then spinning the substrate at high speed so that the solution spreads to form a thin layer. A POSITA would recognize that this process of spin-coating PVK, TPD, and PBD involves simultaneously applying the first, second, and third matrix materials to form a single emissive layer. A POSITA would also appreciate that spin-coating a mix of PVK, TPD, and PBD was well-known in the art before 2008. *See, e.g.,* Ex. 1017 (Neher), 2476 (“A blend of PVK, PBD, TPD and Ir(mppy)₃ in chlorobenzene solution was spin coated on top of indium tin oxide substrates....”).

132. Choulis also discloses depositing its materials using evaporation coating. Choulis, [0048] (discussing “deposit[ion] through evaporation”). Specifically, the evaporation process involves heating materials so that their molecules are released and subsequently travel through a vacuum chamber to be deposited on the target substrate simultaneously. Like the spin-coating method I explained above, evaporation coating similarly involves simultaneously applying the matrix materials to form an emissive layer.

133. Choulis discloses that “small organic molecules” such as TPD and PBD are “preferably deposited through evaporation.” Choulis, [0043]. As discussed above, Choulis also discloses PVK as the host material (i.e., the claimed “first matrix

material”). A POSITA would recognize that PVK, despite being a polymer rather than a small molecule, can be deposited via evaporation in manufacturing OLED devices. *See, e.g.,* Ex. 1023 (Djobo) at 1 (“PVK films...have been grown by evaporation process”).

134. It would have been obvious to a POSITA to apply the first matrix material (PVK) using evaporation coating, along with second matrix material (TPD) and third matrix material (PBD). A POSITA would have been motivated to apply the materials simultaneously via evaporation, as the approach would enable forming layers with increased control over film thickness and composition, and enable a broader variety of device architectures. These would allow higher yield and improved performance, when compared to other techniques such as spin-coating. A POSITA would have had a reasonable expectation of success in applying PVK, TPD, and PBD via evaporation coating, and doing so would be well within a POSITA’s ability. Indeed, Choulis explains that “the techniques described herein,” including evaporation coating, can be readily applied to OLED display manufacturing. Choulis, [0059].

135. In the alternative, A POSITA would have found it obvious to use a small molecule as the “host material” (instead of PVK) and simultaneously apply the small molecule first, second, and third matrix materials via evaporation coating. While, as discussed above, Choulis discloses using PVK as the host material,

Choulis also discloses that, alternatively, the “host material...can be...small molecules” Choulis, [0044]; *see also* Choulis, [0031] (“Additional suitable materials than those described for the host material...can also be selected according to the properties described herein.”). A POSITA would have found it obvious to simultaneously apply the substitute small molecule-based host material (i.e., the “first matrix material”), TPD (i.e., the “second matrix material”), and PBD (i.e., the “third matrix material”) via evaporation coating to achieve the manufacturing process benefits described above.

136. With a small molecule material as the “first matrix material,” Choulis still discloses all of the limitations of claim 1 (from which claim 13 depends) because Choulis discloses that any material that replaces the exemplary materials (including the host material PVK) is preferably “selected according to the properties described herein.” Choulis, [0031]. The aforementioned “properties” described in Choulis include, among other things, that the third matrix material should have a LUMO, which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material (element 1[f]), and that the second matrix material should have a HOMO, which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material (element 1[g]), as is the case for PVK relative to the second matrix material TPD and the third matrix material PBD, as I explained above. As for the remaining elements of claim 1—

elements 1[a]-1[e] and 1[h]—Choulis discloses them for the reasons I explained above in §VIII.A.1.

137. Accordingly, a POSITA would have appreciated that Choulis discloses this element or at a minimum renders it obvious.

13. Dependent Claim 14: A method according to claim 13, wherein in the method step C), the first matrix material, the second matrix material and the third matrix material are applied by evaporation coating.

138. Choulis discloses this claim or at a minimum renders it obvious. As I explained above in §VIII.A.12.e regarding element 13[d], Choulis discloses or at a minimum renders it obvious to a POSITA to apply the first, second, and third matrix materials (PVK, TPD, and PBD) via evaporation coating or, alternatively, replace PVK with a small molecule, and then apply the first, second, and third matrix materials via evaporation coating.

139. Accordingly, a POSITA would have appreciated that Choulis discloses this claim or at a minimum renders it obvious.

14. Independent Claim 15

a. Preamble: An electronic device, comprising:

140. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 15 is limiting. However, if the preamble is limiting, Choulis discloses it.

141. This element is the same as independent claim 1 preamble, and Choulis discloses it for the same reasons. *See* §VIII.A.1.a above.

b. Element 15[a]: a substrate;

142. Choulis discloses this element. This element is the same as independent claim 1[a], and Choulis discloses it for the same reasons. *See* §VIII.A.1.b above.

c. Element 15[b]: a first electrode;

143. Choulis discloses this element. This element is the same as independent claim 1[b], and Choulis discloses it for the same reasons. *See* §VIII.A.1.c above.

**d. Element 15[c]: at least one organic functional layer;
and**

144. Choulis discloses this element. This element is the same as independent claim 1[c], and Choulis discloses it for the same reasons. *See* §VIII.A.1.d above.

e. Element 15[d]: a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and

145. Choulis discloses this element. This element is the same as independent claim 1[d], and Choulis discloses it for the same reasons. *See* §VIII.A.1.e above.

**f. Element 15[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material
and**

146. Choulis discloses this element. This element is the same as independent claim 1[e], and Choulis discloses it for the same reasons. *See* §VIII.A.1.f above.

- g. Element 15[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

147. Choulis discloses this element. This element is the same as independent claim 1[f], and Choulis discloses it for the same reasons. *See* §VIII.A.1.g above.

- h. Element 15[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

148. Choulis discloses this element. This element is the same as independent claim 1[g], and Choulis discloses it for the same reasons. *See* §VIII.A.1.h above.

- i. Element 15[h]: wherein the first matrix material [sic] has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material.**

149. Choulis discloses this element. This element is the same as dependent claim 2, and Choulis discloses it for the same reasons. *See* §VIII.A.2 above.

15. Independent Claim 16

- a. Preamble: An electronic device, comprising:**

150. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion

as to whether or not the preamble to claim 16 is limiting. However, if the preamble is limiting, Choulis discloses it.

151. This element is the same as independent claim 1 preamble, and Choulis discloses it for the same reasons. *See* §VIII.A.1.a above.

b. Element 16[a]: a substrate;

152. Choulis discloses this element. This element is the same as independent claim 1[a], and Choulis discloses it for the same reasons. *See* §VIII.A.1.b above.

c. Element 16[b]: a first electrode;

153. Choulis discloses this element. This element is the same as independent claim 1[b], and Choulis discloses it for the same reasons. *See* §VIII.A.1.c above.

**d. Element 16[c]: at least one organic functional layer;
and**

154. Choulis discloses this element. This element is the same as independent claim 1[c], and Choulis discloses it for the same reasons. *See* §VIII.A.1.d above.

**e. Element 16[d]: a second electrode, wherein the at least
one organic functional layer is located between the first
electrode and the second electrode, and**

155. Choulis discloses this element. This element is the same as independent claim 1[d], and Choulis discloses it for the same reasons. *See* §VIII.A.1.e above.

- f. Element 16[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material and**

156. Choulis discloses this element. This element is the same as independent claim 1[e], and Choulis discloses it for the same reasons. *See* §VIII.A.1.f above.

- g. Element 16[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

157. Choulis discloses this element. This element is the same as independent claim 1[f], and Choulis discloses it for the same reasons. *See* §VIII.A.1.g above.

- h. Element 16[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

158. Choulis discloses this element. This element is the same as independent claim 1[g], and Choulis discloses it for the same reasons. *See* §VIII.A.1.h above.

- i. Element 16[h]: wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.**

159. Choulis discloses this element. This element is the same as dependent claim 4, and Choulis discloses it for the same reasons. *See* §VIII.A.4 above.

B. Ground II: Claim 9 Is Obvious Based on Choulis and Yong

1. Dependent Claim 9: The electronic device according [sic] claim 1, wherein the concentration of the emitter material in the emission layer has a gradient.

160. This claim would have been obvious to a POSITA based on Choulis in view of Yong. As I explained above in §§VIII.A.1.d & i above regarding elements 1[c] & 1[h], Choulis discloses an OLED device with a “light emitting layer,” which includes “a phosphorescent organic material,” such as Ir(mppy)₃. Choulis, [0014], [0030]. Choulis states that “[t]he recombination current in any of the layers...can be controlled...by adjusting dopant concentrations.” Choulis, [0002] (emphasis added). Choulis further discloses that this emitter material can be applied using various methods and techniques, including, *e.g.*, “evaporation, sublimation, or organic vapor phase deposition methods.” Choulis, [0043]. It would have been obvious to a POSITA to apply the emitter material in Choulis’s emission layer such that the concentration of the emitter material contains a gradient.

161. Such a gradient in emitter material concentration was generally well known in the art prior to the ’164 patent and would have been known to a POSITA at that time. The OLED disclosed in Yong, for example, has an organic light emitting layer in which “the doping concentration of the phosphorescent dye gradually increases or decreases along the direction from the anode layer to the cathode layer with the increase of the thickness of the organic light emitting layer, forming a

construction with gradient doping.” Yong, Abstract. Yong discloses forming this gradient in emitter material concentration through commonly known techniques, *e.g.*, evaporation. Yong, Description at 4.

162. A POSITA would understand that there are benefits to forming a gradient with the concentration of emitter material. Yong teaches one such benefit:

In the organic light emitting layer of the device, phosphorescent dyes are doped into the host material in a gradient doping manner, expanding the luminescent region of the device, improving the utilization rate of the phosphorescent dyes, and facilitating the combination of electrons and holes to form excitons, thereby improving the device’s luminescence efficiency and brightness, improving its stability, and overcoming the disadvantages of low luminescence efficiency and poor stability under high current.

Yong, Abstract.

163. Yong goes on to explain that the benefit of the “gradient distribution of the doping concentration of phosphorescent dyes in the organic light emitting layer in the host material” comes from the gradient “mak[ing] the distribution trend of phosphorescent dyes in the host material conform to the distribution trend of electrons in the host material,” and thus “such concentration distribution expands the luminescent region of the device, improves the utilization rate of phosphorescent dyes, and is also conducive to the combination of electrons and holes to form excitons.” Yong, Description at 3.

164. It would have been obvious to a POSITA to dope the emission layer in Choulis’s device such that “the concentration of the emitter material in the emission

layer has a gradient.” In light of the benefits of using such a gradient, which were well known in the art at the time, a POSITA would have been motivated to use a gradient for the emitter material concentration in the emission layer to achieve these benefits, including the benefit of improving the device’s luminescence efficiency and stability taught by Yong.

165. A POSITA would have reasonably expected success forming such a gradient in Choulis’s OLED display device. Gradient doping was a well-known technique at the time, and served as an alternative to the uniform doping of materials. A POSITA would certainly be familiar with the manufacturing techniques for producing a gradient composition. Moreover, such techniques are taught by Yong itself, as it describes methods for forming its gradient using *e.g.*, evaporation. Yong, Description at 4 (discussing “vapor depositing” in a “vacuum chamber” using “evaporation sources”). As discussed above, evaporation is a method also disclosed in Choulis. *See* §VIII.A.12.e regarding element 13[d]; Choulis, [0048]; Choulis, [0043]. Specifically, as I explained above in §VIII.A.12.e regarding element 13[d], Choulis discloses simultaneously applying a first, second, and third matrix material using evaporation. *See* Choulis, [0044], [0048].

166. In addition to disclosing the same methods of applying emitter material, the structure and emitter material of the OLED disclosed in Yong is quite similar to that disclosed in Choulis, including “a phosphorescent organic light emitting device”

comprising a “substrate, an anode layer, an organic functional layer, and a cathode layer,” with the organic functional layer formed from “an organic light emitting layer, selective of one or more layers of hole injection layer, hole transporting layer, electron transporting layer, and electron injection layer,” and “the organic light emitting layer comprises a host material and a phosphorescent dye” where the phosphorescent emitter is Ir(mppy)₃. Yong, Description at 3, 11. To a POSITA, forming a gradient of the emitter material in the emission layer would merely be replacing one well-known method of doping (uniform doping) with an alternative well-known doping method (gradient doping). Such an implementation of a predictable variation of the concentration structure of the emitter material using well-known methods (which are, moreover, also disclosed in Choulis) would have been a routine matter and would easily fall within the purview of a POSITA’s ability. Accordingly, a POSITA would have appreciated that the combination of Choulis and Yong renders this claim obvious.

C. Ground III: Claims 1, 3, 5–8, and 10–13 Are Anticipated By Or At A Minimum Rendered Obvious By Sugiura

1. Independent Claim 1

a. Preamble: An electronic device, comprising:

167. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion

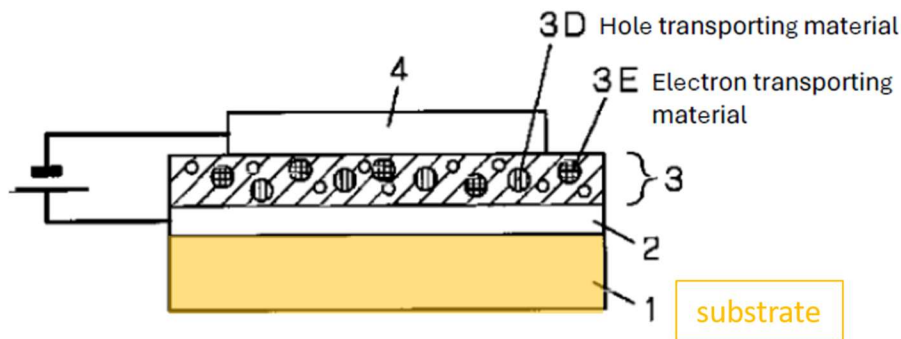
as to whether or not the preamble to claim 1 is limiting. However, if the preamble is limiting, Sugiura discloses it.

168. Sugiura states that its invention “relates to an organic light-emitting device used in a flat light source or a flat display,” Sugiura, [0001], where an “organic compound forms a light-emitting body, and...[has] features such as the ability to be driven at a lower voltage.” Sugiura, [0002].

169. Accordingly, a POSITA would have appreciated that Sugiura discloses this preamble.

b. Element 1[a]: a substrate;

170. Sugiura discloses this element. Sugiura discloses “[a]n organic light-emitting device having the configuration in FIG. 4” that has a “substrate 1, the positive electrode 2, and the negative electrode 4 the same configuration and thickness as in Example 1.” Sugiura, [0062] (emphasis added).

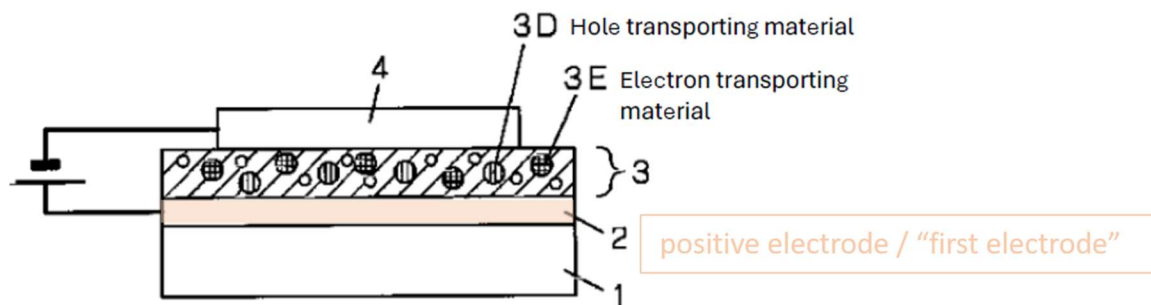


Sugiura, Fig. 4 (annotated).

171. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

c. Element 1[b]: a first electrode;

172. Sugiura discloses this element. In reference to its Figure 4, Sugiura discloses a “positive electrode 2.” Sugiura, [0062]. The positive electrode is the claimed “first electrode.”

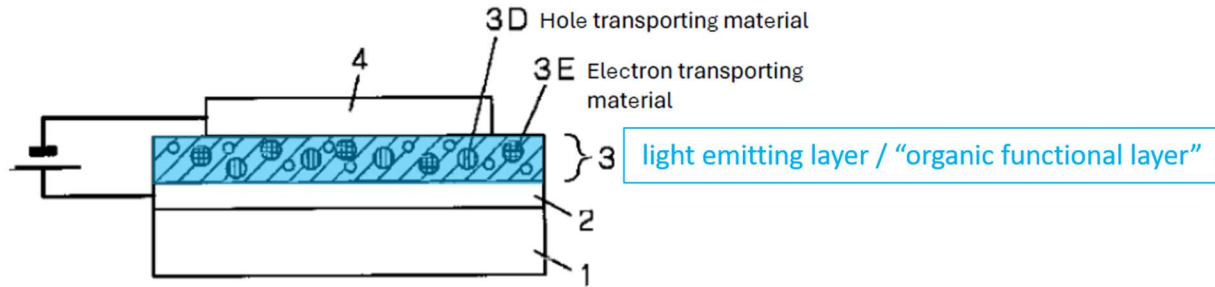


Sugiura, Fig. 4 (annotated).

173. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

d. Element 1[c]: at least one organic functional layer; and

174. Sugiura discloses this element. Sugiura discloses a “light-emitting layer 3” in connection with Figure 4. Sugiura, [0062].



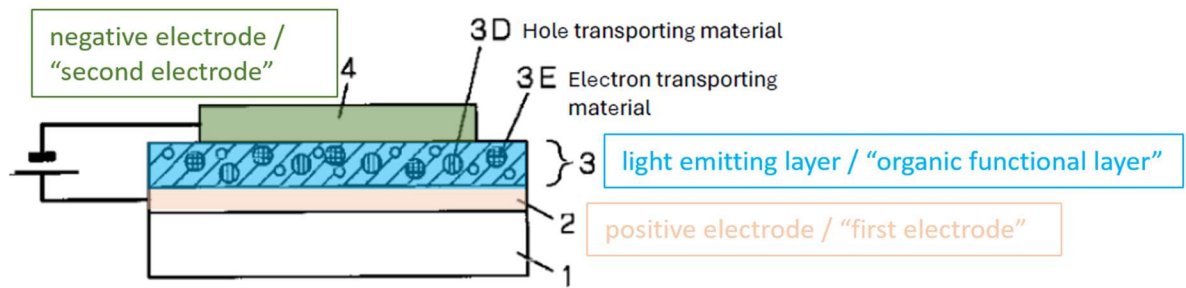
Sugiura, Fig. 4 (annotated).

175. A POSITA would understand that the light-emitting layer of an organic light emitting diode device is an organic layer which serves the function of light emission, and that it constitutes an organic functional layer. The '164 patent explains that "[t]he organic functional layer can be an emission layer and be doped with at least one emitter material." '164 patent at 3:61-63; *see also* '164 patent at 4:44-49.

176. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

- e. **Element 1[d]: a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and**

177. Sugiura discloses this element. Referring to Figure 4 below, Sugiura discloses "[t]he substrate 1, the positive electrode 2, and the negative electrode 4." Sugiura, [0062]. Sugiura discloses that the light emitting layer (i.e., "organic functional layer") is located between the positive electrode (i.e., "first electrode") and the negative electrode (i.e., "second electrode"). Accordingly, a POSITA would have appreciated that Sugiura discloses this element.



Sugiura, Fig. 4 (annotated).

- f. **Element 1[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material and**

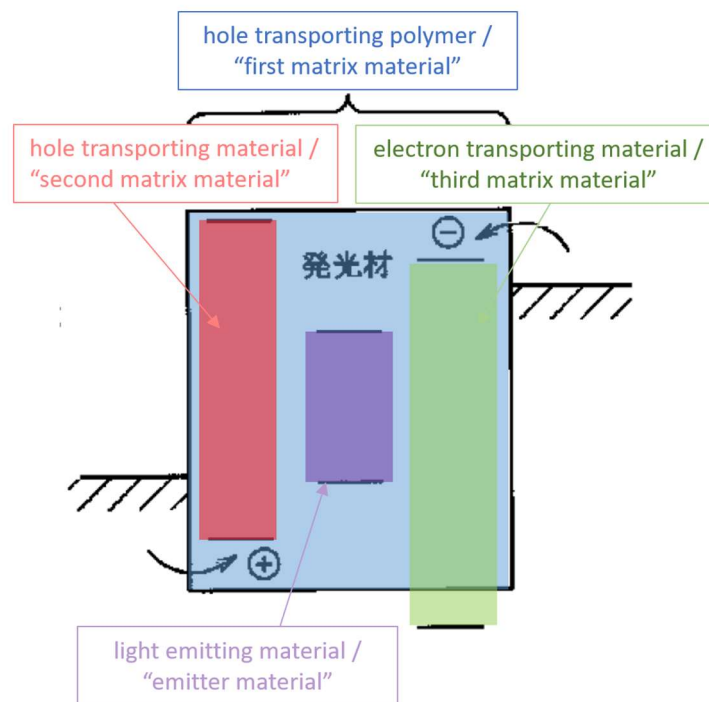
178. Sugiura discloses this element. As I discussed above, Sugiura discloses an OLED device. Specifically, Sugiura discloses that the OLED device depicted in Figure 4 has the following characteristics:

An organic light-emitting device having the configuration in FIG. 4 was fabricated and evaluated. The substrate 1, the positive electrode 2, and the negative electrode 4 had the same configuration and thickness as in Example 1. For the light-emitting layer 3, PVK was used for the polymer 3A, N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD) was used for the hole transporting material 3D, Alq3 was used for the electron transporting material 3E, and Nile Red was used for the light-emitting material 3C. The ionization potential of the TPD is 5.4 eV. The mixing ratio of each material was: PVK:Alq3:TPD:Nile Red = 100:60:80:0.2 (weight ratio).

Sugiura, [0062] (emphasis added) (referring to Figure 4 above).

179. A POSITA would understand that this OLED therefore has a "first matrix material," (polymer PVK), a "second matrix material" (hole transport material TPD), as well as a "third matrix material" (electron transport material Alq₃).

180. Figure 8 depicts the energy levels of the first, second, and third matrix materials, as well as the light emitting material. Sugiura discloses that “FIG. 8 is an energy diagram of an organic light-emitting device having the configuration: positive electrode / light-emitting layer (hole transporting polymer + hole transporting material + electron transporting material + light-emitting material) / negative electrode.” Sugiura, [0049] (emphasis added).



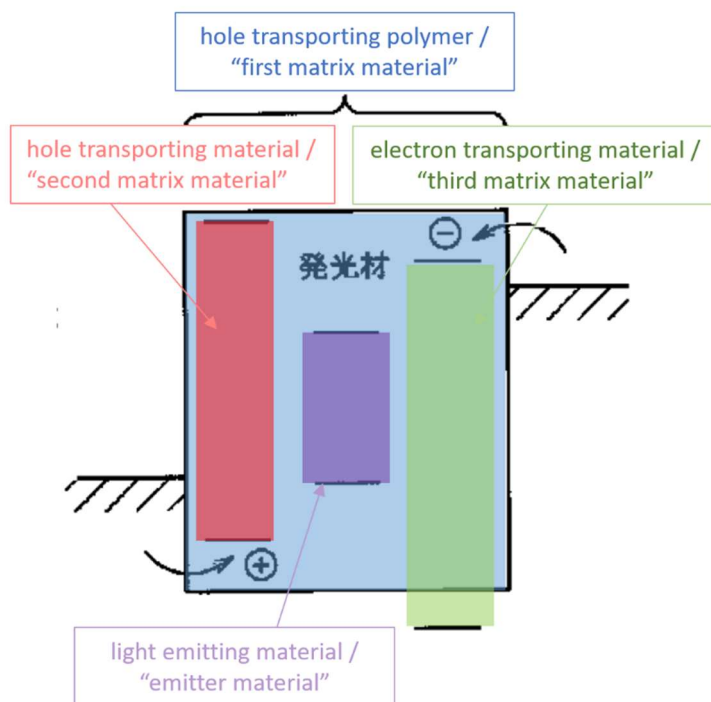
Sugiura, Fig. 8 (annotated).

181. The OLED illustrated in Figure 8 contains a light-emitting layer (i.e., “organic functional layer”) which has a hole transporting polymer (i.e., “first matrix material”), as well as a hole transporting material (i.e., “second matrix material”), and an electron transporting material (i.e., “third matrix material”). Sugiura, [0049].

182. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

- g. **Element 1[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

183. Sugiura discloses this element. As I discussed above, Sugiura's Figure 8 is "an energy diagram of an organic light-emitting device having the configuration: positive electrode / light-emitting layer (hole transporting polymer + hole transporting material + electron transporting material + light-emitting material) / negative electrode." Sugiura, [0049] (emphases added).



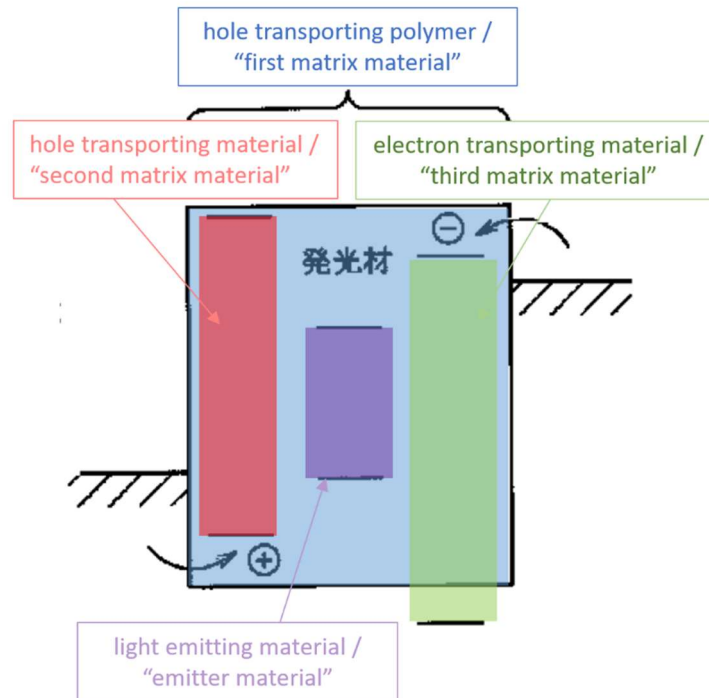
Sugiura, Fig. 8 (annotated).

184. As seen in annotated Figure 8, the top line for the third matrix material (green) is located below both the top line for the second matrix material (red) and the top of the rectangle for the first matrix material (blue). As such, the OLED device disclosed by Sugiura which is the subject of Figure 8 above contains an electron transport material (i.e., “third matrix material”) which has a LUMO which is energetically lower than the LUMO of its hole transporting material (i.e., “second matrix material”) as well as being energetically lower than the LUMO of the hole transporting polymer (i.e., “first matrix material”). *See also* §IV.A.

185. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

- h. Element 1[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

186. Sugiura discloses this element. As I explained above, Figure 8 displays an energy diagram of an embodiment of an OLED device taught by Sugiura.



Sugiura, Fig. 8 (annotated).

187. As seen in annotated Figure 8, the bottom line representing the HOMO for the second matrix material (red) is located above both the bottom of the rectangle for the first matrix material (blue) and the bottom line for the third matrix material (green). As such, the OLED device disclosed by Sugiura which is the subject of Figure 8 above includes a hole transporting material (i.e., “second matrix material”) which has a HOMO that is energetically higher than the HOMOs of its hole transporting polymer (i.e., “first matrix material”) and its electron transporting material (i.e., “third matrix material”).

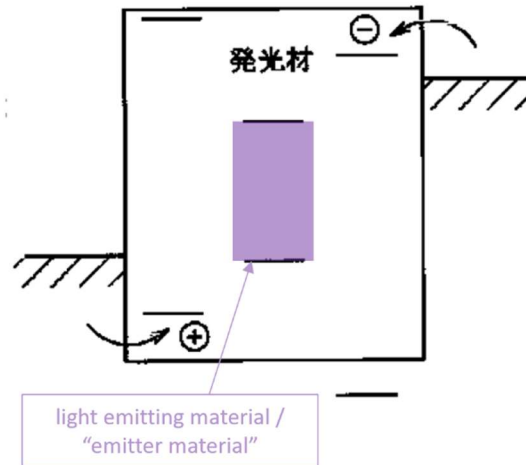
188. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

i. Element 1[h]: wherein the organic functional layer is an emission layer and is doped with at least one emitter material.

189. Sugiura discloses this element. As discussed in §VIII.C.1.d above regarding element 1[c], Sugiura's organic functional layer is an emission layer. Sugiura, [0002], [0038], [0062]. Sugiura further discloses an OLED device in which "the light-emitting layer includes...a light-emitting material." Sugiura, [0067] (emphasis added). For this light-emitting material, "a fluorescent substance or a phosphorescent substance that exhibits light emission in response to hole/electron recombination may be used, and as for a substance that exhibits particularly strong fluorescence or phosphorescence, a dye such as a cyanine dye, merocyanine dye, styryl dye, anthracene derivative, porphyrin derivative, phthalocyanine derivative, coumarin, DCM, and Nile Red, and a laser dye may be used." Sugiura, [0041]; *see also* Sugiura, [0002] (teaching an "organic EL device, in which an organic compound forms a light-emitting body").

190. Sugiura discloses doping the light-emitting layer with light-emitting material Nile Red. Sugiura, [0062] ("The light-emitting layer was formed by dissolving 300 mg of PVK, 180 mg of Alq3, 240 mg of TPD, and 0.6 mg of Nile Red in 50 mL of a 1:1 mixed solvent of toluene and chloroform, stirring the solution for one day.") (emphasis added). Figure 8 shows an energy diagram of an OLED device which includes "positive electrode / light-emitting layer (hole transporting

polymer + hole transporting material + electron transporting material + light-emitting material) / negative electrode.” Sugiura, [0049] (emphasis added). Thus, Sugiura discloses an OLED in which the light-emitting layer is doped with at least one light-emitting material.



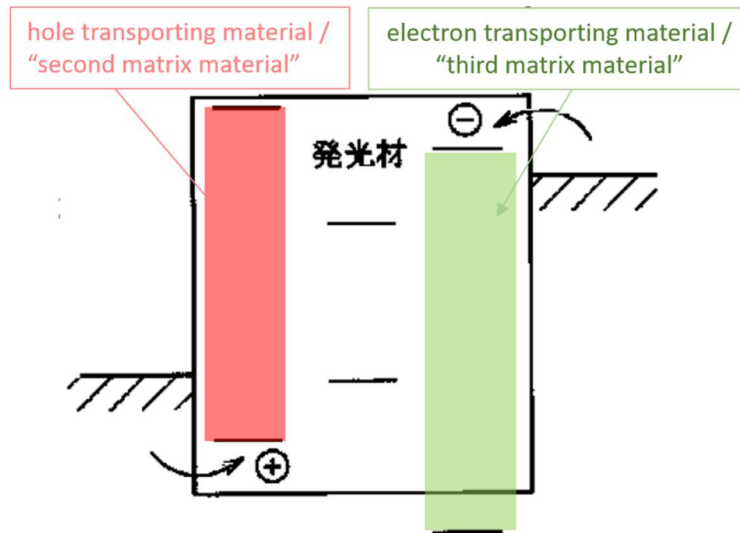
Sugiura, Fig. 8 (annotated).

191. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

2. **Dependent Claim 3: The electronic device according to claim 1, wherein the second matrix material has a LUMO which is energetically higher than the LUMO of the third matrix material and a HOMO which is energetically higher than the HOMO of the third matrix material.**

192. Sugiura discloses this claim. As seen in annotated Figure 8 below, the top line representing the LUMO for the second matrix material (red) is located above the top line for the third matrix material (green), and the bottom line representing the HOMO for the second matrix material (red) is also located above the bottom line

for the third matrix material (green). As such, the OLED device disclosed by Sugiura which is the subject of Figure 8 above includes a hole transporting material (i.e., “second matrix material”) which has a LUMO and a HOMO that are energetically higher than those of its electron transporting material (i.e., “third matrix material”).



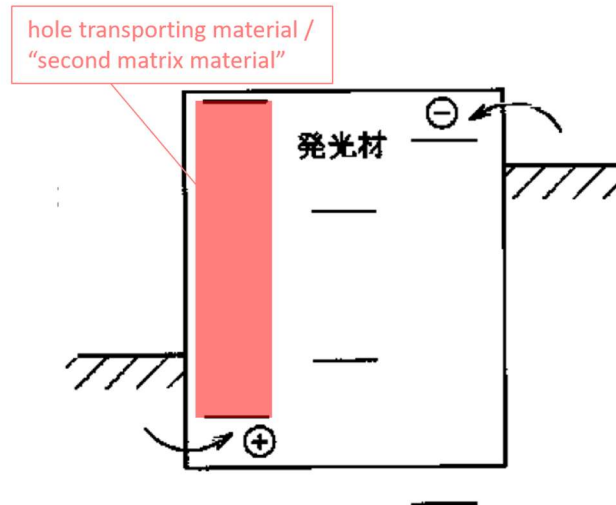
Sugiura, Fig. 8 (annotated).

193. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

3. Dependent Claim 5: The electronic device according to claim 1, wherein the second matrix material comprises a hole transport material.

194. Sugiura discloses this claim. As discussed in §VIII.C.1.f above, Sugiura discloses a hole transporting material, which is the “second matrix material.” Sugiura, [0049] (“FIG. 8[,] [which] is an energy diagram of an organic light-emitting device having...[a] light-emitting layer (hole transporting polymer + hole

transporting material + electron transporting material + light-emitting material)”) (emphasis added).



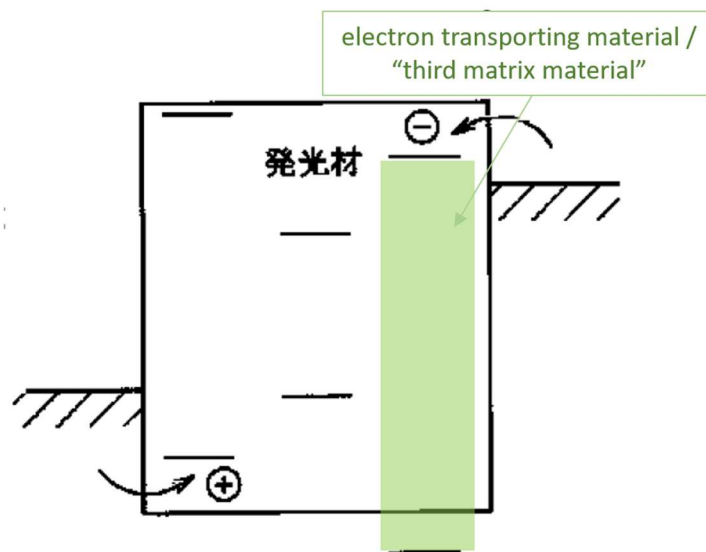
Sugiura, Fig. 8 (annotated). The plus sign represents a hole and the arrow next to it represents transport. In an embodiment, “N,N’-diphenyl-N,N’-bis(3-methylphenyl)-1,1’-biphenyl-4,4’-diamine (TPD) was used for the hole transporting material 3D.” Sugiura, [0062].

195. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

4. Dependent Claim 6: The electronic device according to claim 1 wherein the third matrix material comprises an electron transport material.

196. Sugiura discloses this claim. As explained in §VIII.C.1.f above, Sugiura discloses an electron transporting material, which is the “third matrix material.” Sugiura, [0049] (“FIG. 8[,] [which] is an energy diagram of an organic

light-emitting device having...[a] light-emitting layer (hole transporting polymer + hole transporting material + electron transporting material + light-emitting material)” (emphasis added).



Sugiura, Fig. 8 (annotated). The minus sign represents an electron and the arrow next to it represents transport. In an embodiment, “Alq3 was used for the electron transporting material 3E.” Sugiura, [0062].

197. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

- 5. Dependent Claim 7: The electronic device according to claim 1, wherein the organic functional layer is selected from a group which comprises emission layers, electron transport layers, hole transport layers, electron blocking layers, hole blocking layers, hole injection layers, electron injection layers, and intermediate layers.**

198. Sugiura discloses this claim. As discussed in §VIII.C.1.d regarding element 1[c], Sugiura discloses a light emitting layer, which is the “organic functional layer.” Sugiura, [0062]. Sugiura therefore discloses an “organic functional layer” which can be chosen from a group comprising various types of layers, including emission layers (which Sugiura refers to as a “light-emitting layer”).

199. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

- 6. Dependent Claim 8: The electronic device according to claim 1, wherein the emitter material in the emission layer has a concentration of ≤ 10 wt %.**

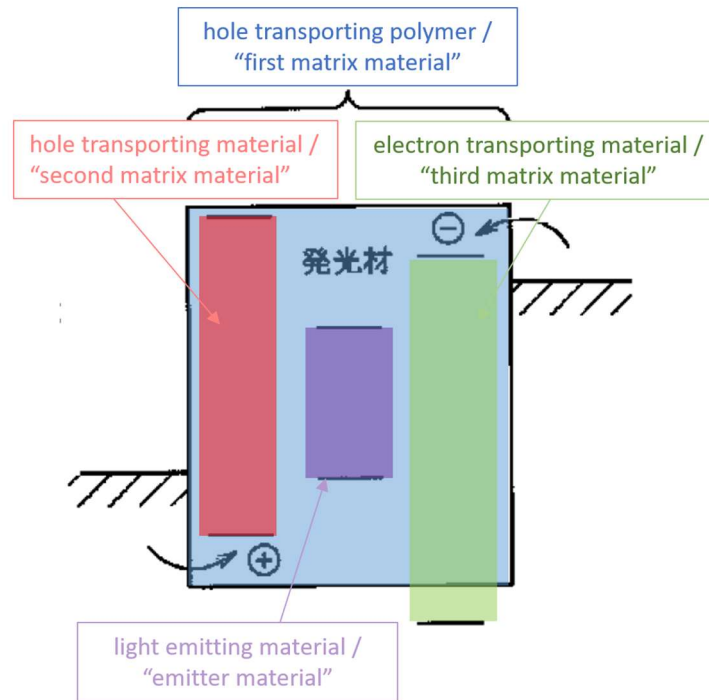
200. Sugiura discloses this claim. Sugiura discloses an OLED in which its emission layer (“light-emitting layer”) can include “PVK...[as] the polymer 3A, N,N'-diphenyl-N,N'-bis(3-methylphenyl)-1,1'-biphenyl-4,4'-diamine (TPD)...[as] the hole transporting material 3D, Alq3...[as] the electron transporting material 3E, and Nile Red...[as] the light-emitting material 3C.” Sugiura, [0062]. Sugiura discloses using an emitter material, Nile Red, in the emission layer, wherein “[t]he mixing ratio of each material was: PVK:Alq3:TPD:Nile Red = 100:60:80:0.2

(weight ratio).” Sugiura, [0062] (emphasis added). Sugiura thus discloses that the emitter material (Nile Red) concentration in the emission layer is $0.2/(100+60+80+0.2)*100$, which is 0.08 wt% and less than 10 wt%.

201. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

7. **Dependent Claim 10: The electronic device according to claim 1, wherein the LUMO of the emitter material is energetically lower than the LUMO of the first, second, and third matrix materials, and the HOMO of the emitter material is energetically higher than the HOMO of the first, second, and third matrix materials.**

202. Sugiura discloses this claim. As seen in annotated Figure 8 below, the top line representing the LUMO for the emitter material (purple) is located below the top of the rectangle for the first matrix material (blue) and below the top lines for the second and third matrix materials (red and green). In addition, the bottom line representing the HOMO for the emitter material (purple) is located above the bottom of the rectangle for the first matrix material (blue) and above the bottom lines for the second and third matrix materials (red and green, respectively). *See §IV.A.*



Sugiura, Fig. 8 (annotated).

203. As such, Sugiura discloses an emitter material with a LUMO that is energetically lower than the LUMO of its hole transporting polymer (i.e., “first matrix material”), its hole transporting material (i.e., “second matrix material”), and its electron transporting material (i.e., “third matrix material”). Sugiura further discloses that the emitter material has a HOMO that is energetically higher than that of its hole transporting polymer (i.e., “first matrix material”), its hole transporting material (i.e., “second matrix material”), and its electron transporting material (i.e., “third matrix material”).

204. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

8. Dependent Claim 11: The electronic device according to claim 1, which is constructed as a radiation-emitting device.

205. Sugiura discloses this claim. As discussed above, Sugiura discloses an OLED which emits light. Specifically, Sugiura discloses that “[t]he light emitting mechanism of the organic light emitting device of the present invention” involves a process wherein “[h]oles and electrons are recombined in the light emitting layer, and in response to this, fluorescence or phosphorescence is emitted from the light emitting material in the light emitting layer.” Sugiura, [0042]. Because light is a form of radiation, the OLED device disclosed in Sugiura is “a radiation-emitting device.”

206. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

9. Dependent Claim 12: The electronic device according to claim 1 wherein the device is selected from a group which comprises an organic light-emitting device, a solar cell, and a transistor.

207. Sugiura discloses this claim. As I explained above, Sugiura discloses an organic light emitting diode (OLED) device. Indeed, Sugiura states that its “present invention relates to an organic light-emitting device used in a flat light source or a flat display.” Sugiura, [0001] (emphasis added).

208. Accordingly, a POSITA would have appreciated that Sugiura discloses this claim.

10. Dependent Claim 13

a. Preamble: A method for the production of an electronic device according to claim 1, comprising the steps of:

209. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 13 is limiting. However, if the preamble is limiting, Sugiura discloses it.

210. As discussed above, Sugiura discloses an OLED device. Sugiura further discloses the method whereby such an OLED device is “fabricated and evaluated.” Sugiura, [0062].

211. Accordingly, a POSITA would have appreciated that Sugiura discloses this preamble.

b. Element 13[a]: A) preparation of a substrate;

212. Sugiura discloses this element. Sugiura discloses an OLED device, seen in Figure 4 below, and further discloses how the “organic light-emitting device having the configuration in FIG. 4 was fabricated and evaluated.” Sugiura, [0062]. Specifically, Sugiura discloses that “substrate 1, the positive electrode 2, and the negative electrode 4 had the same configuration and thickness as in Example 1.” Sugiura, [0062] (emphasis added). Sugiura further specifies that the “substrate 1 may be any substrate capable of carrying the organic light-emitting device of the present

invention, and may be a transparent substrate such as glass or a resin film such as polycarbonate, polymethyl methacrylate, or polyethylene terephthalate, or a non-transparent substrate such as silicon.” Sugiura, [0039].

213. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

c. Element 13[b]: B) preparation of a first electrode and a second electrode; and

214. Sugiura discloses this element. Sugiura discloses that the OLED device shown in Figure 4 was “fabricated and evaluated” such that “substrate 1, the positive electrode 2, and the negative electrode 4 had the same configuration and thickness as in Example 1.” Sugiura, [0062] (emphasis added). Sugiura discloses additional details about fabricating the OLED device including the following:

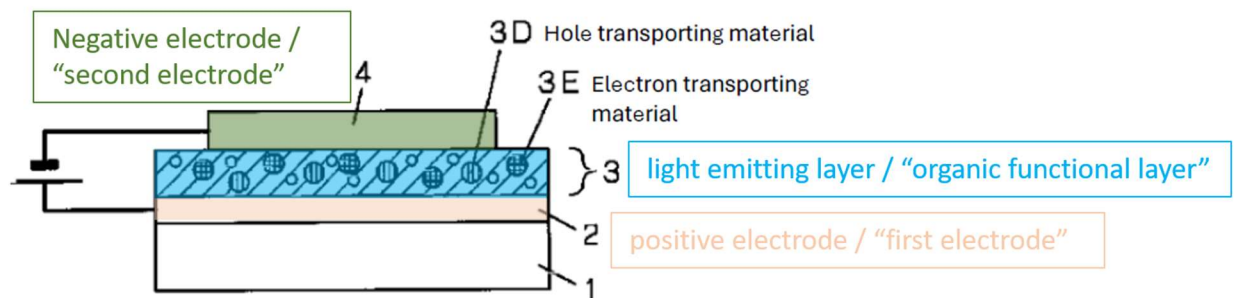
At least one of the positive electrode 2 and the negative electrode 4 must be transparent or semi-transparent, and light emitted from the light-emitting layer is ejected to the outside through one or both of these electrodes. The positive electrode 2 typically is a transparent electrode such as indium tin oxide (ITO) or tin oxide, however, a metal electrode such as Ni, Au, Pt, or Pd may be used. For the purpose of improving transparency or reducing resistivity of the ITO film, a film forming method such as sputtering, electron beam deposition, or ion plating is used....The negative electrode 4 can be a metal such as Al, Ag, or Au, an alloy of a metal having a low work function and a metal having a relatively large and stable work function, such as an MgAg alloy or an AlLi alloy, or a laminated electrode of a metal having a low work function and a metal having a high work function, such as Li/Al or LiF/Al. Vapor deposition methods and sputtering methods are preferable for forming these negative electrodes.

Sugiura, [0040].

215. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

d. Element 13[c]: C) placement of at least one organic functional layer between the first electrode and the second electrode,

216. Sugiura discloses this element. As discussed in §VIII.C.1.d regarding element 1[c], Sugiura discloses a light emitting layer, which is the “organic functional layer.” Sugiura, [0062]. As shown in annotated Figure 4 below, Sugiura discloses that the light emitting layer (i.e., “organic functional layer”) is located between the positive electrode (i.e., “first electrode”) and the negative electrode (i.e., “second electrode”).



Sugiura, Fig. 4 (annotated); *see also* Sugiura, [0062].

217. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

- e. **Element 13[d]: wherein in method step C), at least the first matrix material, the second matrix material, and the third matrix material are simultaneously applied.**

218. Sugiura discloses this element. Sugiura discloses an OLED device wherein the light-emitting layer is “formed by dissolving 300 mg of PVK, 180 mg of Alq3, 240 mg of TPD, and 0.6 mg of Nile Red in 50 mL of a 1:1 mixed solvent of toluene and chloroform, stirring the solution for one day, then spin-coating the solution onto the ITO-affixed glass substrate” Sugiura, [0062]. Sugiura thus discloses that the matrix materials in the light-emitting layer are “formed by dissolving” the materials in “a mixed solvent” which is applied via “spin-coating.” Sugiura, [0062]. A POSITA would understand that applying the matrix materials in the light-emitting layer of an OLED device via spin coating would constitute applying the different matrix materials simultaneously. The solution resulting from dissolving the matrix materials contains all three matrix materials, and spin-coating using the solution deposits the three materials simultaneously.

219. Accordingly, a POSITA would have appreciated that Sugiura discloses this element.

D. Ground IV: Claims 15–16 Are Anticipated By Or At A Minimum Rendered Obvious By Thompson

1. Independent Claim 15

a. Preamble: An electronic device, comprising:

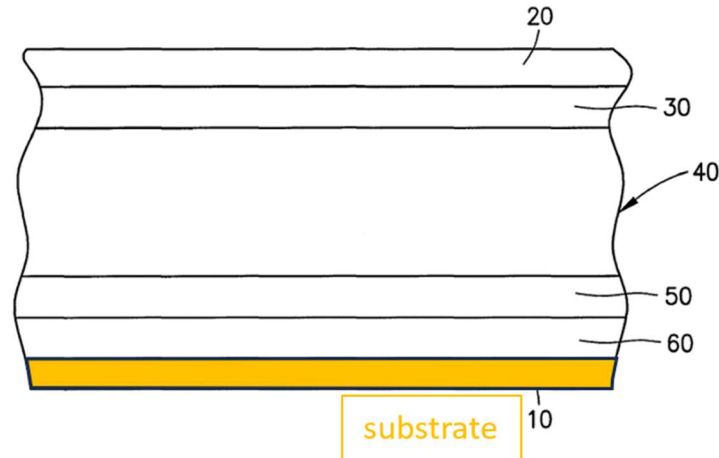
220. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 15 is limiting. However, if the preamble is limiting, Thompson discloses it.

221. Thompson discloses electronic devices, including “[o]rganic light emitting devices (OLEDs), which make use of thin film materials that emit light when excited by electric current.” Thompson, [0002].

222. Accordingly, a POSITA would have appreciated that Thompson discloses this preamble.

b. Element 15[a]: a substrate;

223. Thompson discloses this element. Thompson discloses an OLED device containing a substrate. Specifically, Thompson explains that “An embodiment of an OLED structure according to the invention is described with reference to Fig. 1” and discloses that this OLED device “can be manufactured, for example, by forming the various layers on a substrate 10...” Thompson, [0033] (emphasis added).

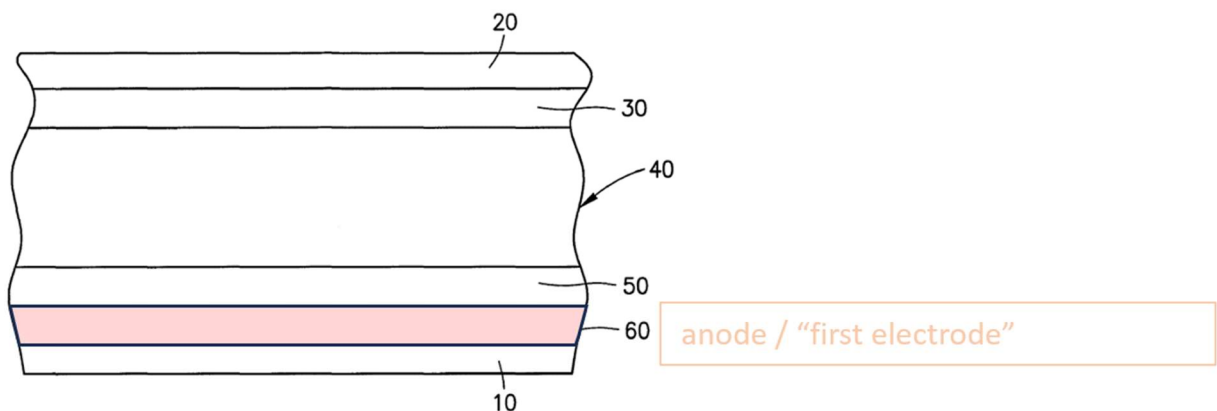


Thompson, Fig. 1 (annotated).

224. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

c. Element 15[b]: a first electrode;

225. Thompson discloses this element. Thompson discloses that, for this OLED, “[a] substrate 10 is first formed, on which an anode layer 60 [i.e., a “first electrode”] connected to a positive power supply is formed,” Thompson, [0034] (emphasis added) (referring to Figure 1 below).



Thompson, Fig. 1 (annotated).

226. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

**d. Element 15[c]: at least one organic functional layer;
and**

227. Thompson discloses this element. Thompson states that the preferred embodiments of its invention are “directed toward OLEDs containing a single, emissive, organic layer.” Thompson, [0032] (emphasis added). In one such embodiment, seen in Figure 1:

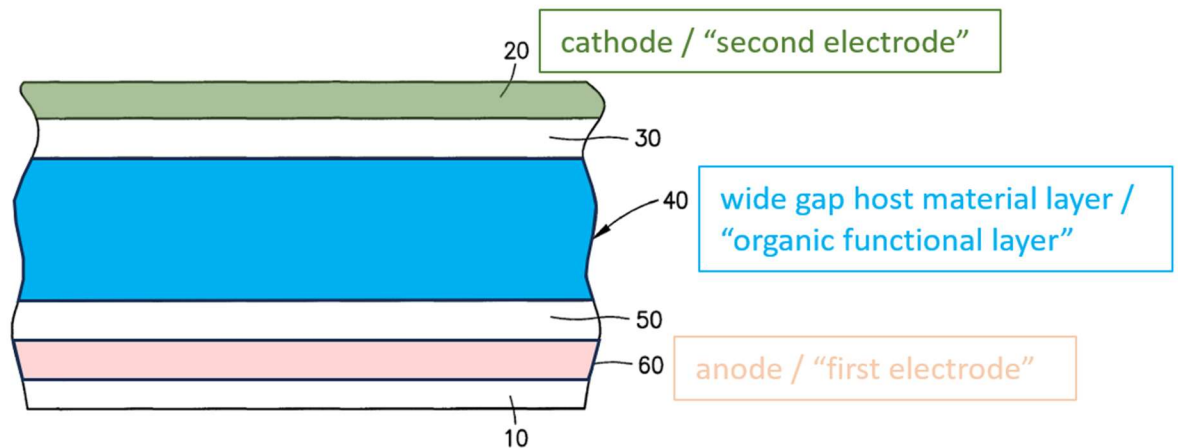
A substrate 10 is first formed, on which an anode layer 60 connected to a positive power supply is formed....A wide gap host material layer 40 is formed above the optional hole injecting layer 50, using conventional manufacturing methods. The wide gap host material layer 40 thus defines the emissive region of the OLED, which comprises a doped layer containing the charge carrying dopant material and the phosphorescent dopant material...and is followed by a conventional cathode layer 20 connected to a negative power supply.

Thompson, [0034] (emphasis added) (referring to Figure 1 above). A POSITA would understand that the emissive layer of an organic light emitting diode device is an organic layer which serves the function of light emission, and that it constitutes an organic functional layer. The '164 patent explains that “[t]he organic functional layer can be an emission layer and be doped with at least one emitter material.” '164 patent at 3:61-63; *see also* '164 patent at 4:44-49.

228. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

e. Element 15[d]: a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and

229. Thompson discloses this element. As discussed above, Thompson discloses an OLED device. In one embodiment disclosed by Thompson, it discloses that the “OLEDs contain[] a single, emissive, organic layer comprising only the host material doped with the charge carrying dopant material and the charge carrying phosphorescent dopant material, with one interface in direct contact with an anode and the opposite interface in direct contact with a cathode.” Thompson, [0032] (emphasis added). This is further illustrated by the OLED displayed in Figure 1, below, in which Thompson discloses, “A substrate 10 is first formed, on which an anode layer 60 [i.e., “first electrode”] connected to a positive power supply is formed....A wide gap host material layer 40 [i.e., “organic functional layer”] is formed...[which] defines the emissive region of the OLED...followed by a conventional cathode layer 20 [i.e., “second electrode”] connected to a negative power supply.” Thompson, [0034].



Thompson, Fig. 1 (annotated).

230. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

- f. **Element 15[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material and**

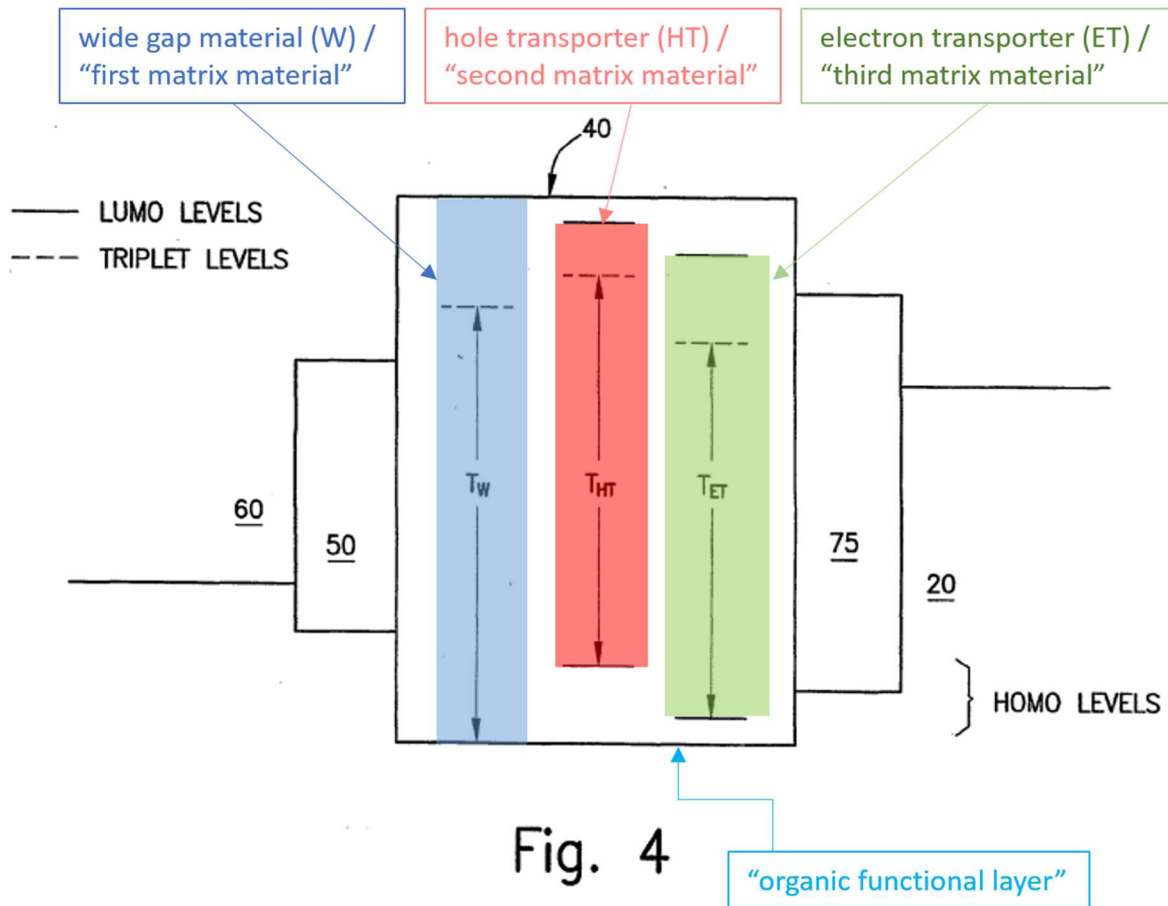
231. Thompson discloses this element. Thompson states that its invention is directed to:

[A]n OLED, and to methods of preparing the same, in which the emissive layer comprises a wide gap host material doped with both a charge carrying dopant material and a phosphorescent dopant material. The charge carrying dopant material is capable of transporting a hole or an electron, and the phosphorescent dopant material is capable of transporting a charge opposite to the charge carried by the charge carrying dopant material. Each dopant material, thus, carries charge, though of opposite polarity. The charge carrying phosphorescent material also performs the function of emitting the phosphorescent radiation.

Thompson, [0008] (emphasis added).

232. The “wide gap host material” in Thompson’s OLED device serves as a “first matrix material.” Thompson further discloses that the OLED device has a “second matrix material” and a “third matrix material.” Thompson discloses that the OLED contains a “charge carrying dopant material [that] is capable of transporting a hole or an electron” and a “phosphorescent dopant material [that] is capable of transporting a charge opposite to the charge carried by the charge carrying dopant material.” A POSITA would appreciate that each of these could serve either as the claimed “second matrix material” or the claimed “third matrix material.”

233. Thompson further discloses the energy levels of the aforementioned first, second, and third matrix materials. For example, Figure 4, below, illustrates the energy levels of these matrix materials, wherein “T indicates triplet energy, and the subscripts indicate the wide gap material (W) the electron transporter (ET) and hole transporter (HT).” Thompson, [0040]. Thompson further discloses that “HOMO-LUMO energy gap of the inert host material layer 40 (i.e., the wide gap material (W))...is greater than the energy gap of both the hole and electron transporters.” Thompson, [0042]. I have provided an annotated version of Figure 4 below where I have added annotations identifying the first matrix material (wide gap host material “W”), the second matrix material (hole transporter “HT”), and the third matrix material (electron transporter “ET”) taught by Thompson.



Thompson, Fig. 4 (annotated).

234. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

- g. **Element 15[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

235. Thompson discloses this element. Thompson's Figure 4, discussed above, "shows the energy levels of the materials forming an OLED device according

to the invention.” Thompson, [0039]. An annotated version of Figure 4 can be seen below:

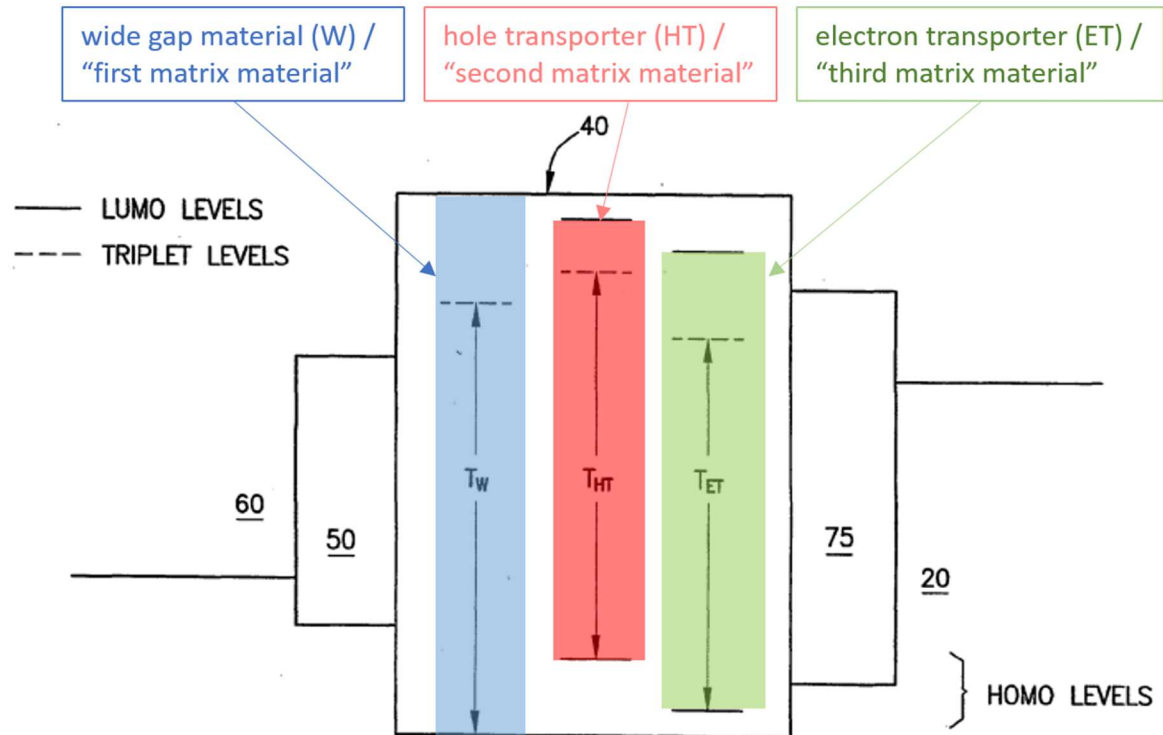


Fig. 4

Thompson, Fig. 4 (annotated).

236. As seen in annotated Figure 4, the top line for the third matrix material (green) is located below both the top line for the second matrix material (red) and the top of the rectangle for the first matrix material (blue). As such, as seen in this annotated Figure 4, Thompson discloses that in its OLED device the third matrix material (electron transporter material “ET”) has a LUMO which is energetically lower than that of the LUMO of the second matrix material (hole transporter “HT”).

Thompson further discloses that the third matrix material (electron transporter “ET”) has a LUMO which is energetically lower than that of the LUMO of the first matrix material (wide gap host material “W”). *See* §IV.A.

237. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

- h. Element 15[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

238. Thompson discloses this element. As discussed above, Thompson’s Figure 4 “shows the energy levels of the materials forming an OLED device according to the invention.” Thompson, [0039]. An annotated version of Figure 4 can be seen below:

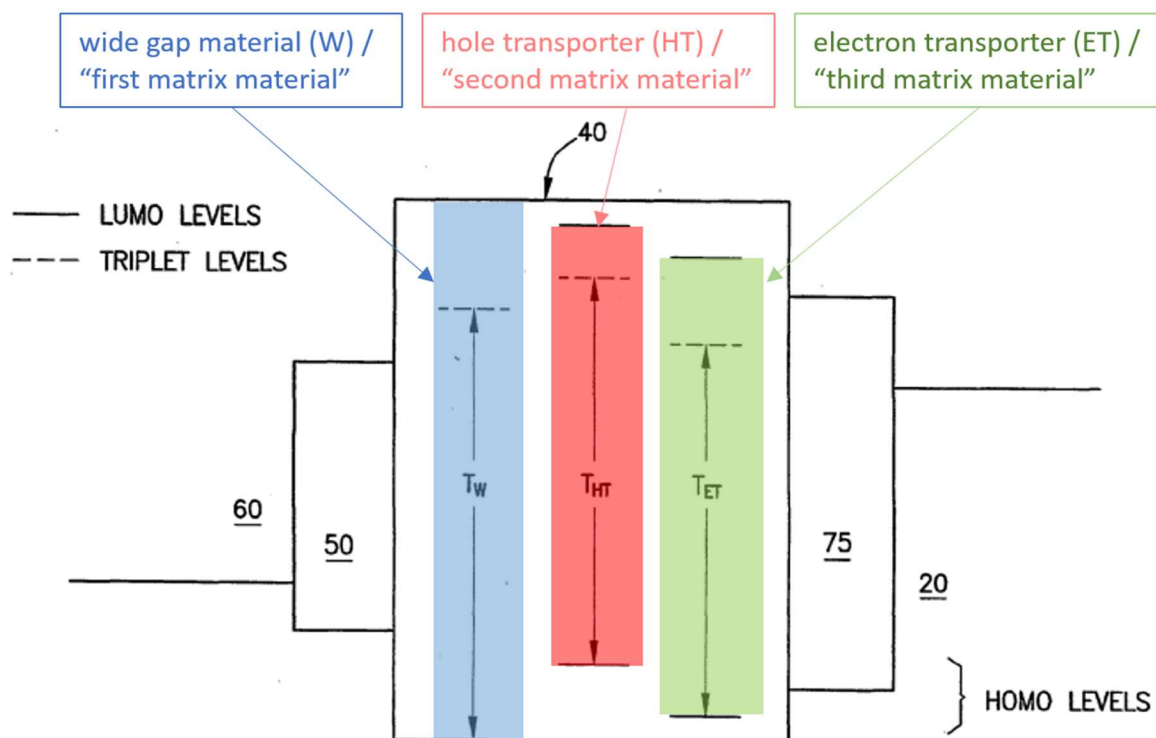


Fig. 4

Thompson, Fig. 4 (annotated).

239. As seen in annotated Figure 4, the bottom line representing the HOMO for the second matrix material (red) is located above both the bottom of the rectangle for the first matrix material (blue) and the bottom line for the third matrix material (green). As such, Thompson discloses an OLED wherein the second matrix material (hole transporting "HT") has a HOMO that is energetically higher than that of the HOMO of the first matrix material (wide gap host material "W"). Thompson further discloses that the second matrix material (hole transporting "HT") has a HOMO that

is also energetically higher than that of the third matrix material (electron transporting “ET”).

240. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

- i. **Element 15[h]: wherein the first matrix material [sic] has a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material.**

241. Thompson discloses this element. As discussed above, Thompson’s Figure 4 “shows the energy levels of the materials forming an OLED device according to the invention.” Thompson, [0039]. An annotated version of Figure 4 can be seen below:

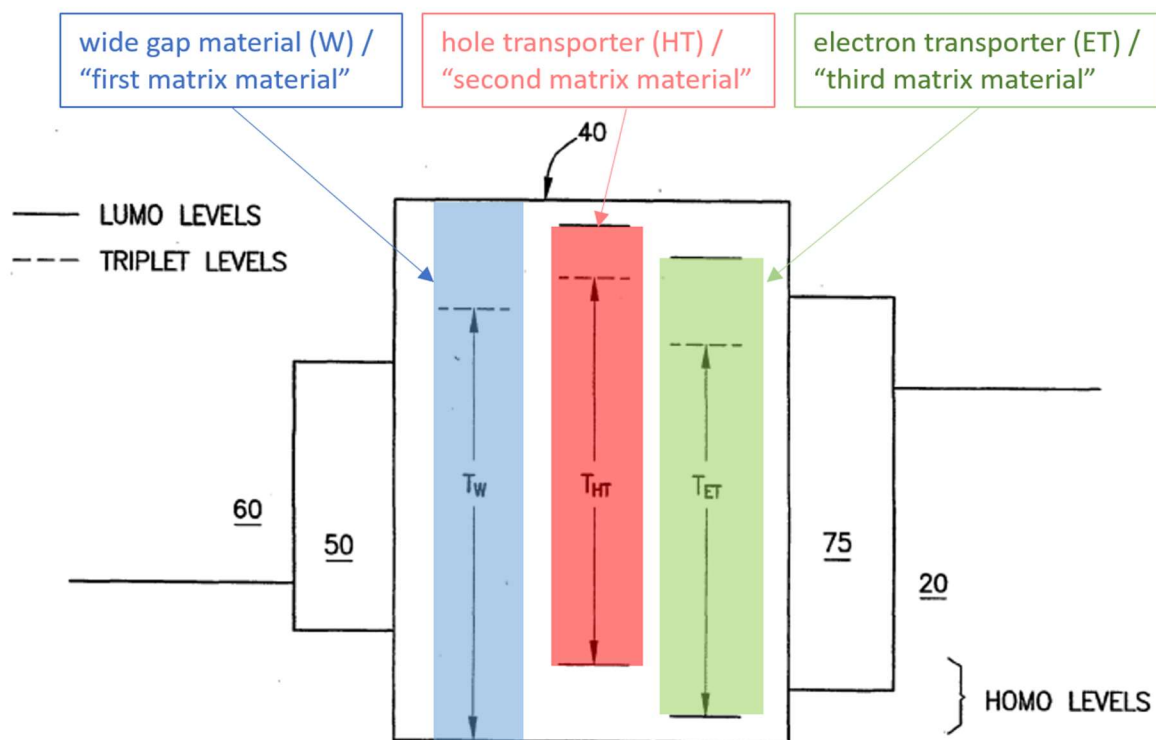


Fig. 4

Thompson, Fig. 4 (annotated).

242. As seen in annotated Figure 4, the top of the rectangle representing the LUMO for the first matrix material (blue) is located above the top lines for the second and third matrix materials (red and green, respectively), and the bottom of the rectangle representing the HOMO for the first matrix material (blue) is located below the bottom lines for the second and third matrix materials (red and green, respectively).

243. Thompson further explains the following:

Preferably, the HOMO level of the inert host material is lower than the HOMO level of any of the dopant materials as well as any adjacent

layers that are in direct physical contact with the inert host material. In addition, the LUMO level of the inert host material is higher than the LUMO level of any of the dopant materials as well as any adjacent layers that are in direct physical contact with the inert host material.

Thompson, [0042] (emphasis added).

244. Lastly, Thompson discloses that “the constraints on the HOMO and LUMO levels of the inert host material layer 40 relative to the levels of the electron and hole transporter dopants typically result in an inert host material layer having a wide energy gap between the HOMO and the LUMO energy levels.” Thompson, [0043].

245. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

2. Independent Claim 16

a. Preamble: An electronic device, comprising:

246. I have been informed by counsel that the preamble to a patent claim may, in some instances, limit the scope of the claims. I do not express any opinion as to whether or not the preamble to claim 16 is limiting. However, if the preamble is limiting, Thompson discloses it.

247. This element is the same as independent claim 15 preamble, and Thompson discloses it for the same reasons. *See* §VIII.D.1.a above.

b. Element 16[a]: a substrate;

248. Thompson discloses this element. This element is the same as independent claim 15[a], and Thompson discloses it for the same reasons. *See* §VIII.D.1.b above.

c. Element 16[b]: a first electrode;

249. Thompson discloses this element. This element is the same as independent claim 15[b], and Thompson discloses it for the same reasons. *See* §VIII.D.1.c above.

**d. Element 16[c]: at least one organic functional layer;
and**

250. Thompson discloses this element. This element is the same as independent claim 15[c], and Thompson discloses it for the same reasons. *See* §VIII.D.1.d above.

e. Element 16[d]: a second electrode, wherein the at least one organic functional layer is located between the first electrode and the second electrode, and

251. Thompson discloses this element. This element is the same as independent claim 15[d], and Thompson discloses it for the same reasons. *See* §VIII.D.1.e above.

- f. Element 16[e]: wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and a third matrix material and**

252. Thompson discloses this element. This element is the same as independent claim 15[e], and Thompson discloses it for the same reasons. *See* §VIII.D.1.f above.

- g. Element 16[f]: the third matrix material has a Lowest Unoccupied Molecular Orbital (LUMO), which is energetically lower than the LUMO of the second matrix material and the LUMO of the first matrix material, and**

253. Thompson discloses this element. This element is the same as independent claim 15[f], and Thompson discloses it for the same reasons. *See* §VIII.D.1.g above.

- h. Element 16[g]: wherein the second matrix material has a Highest Occupied Molecular Orbital (HOMO), which is energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material,**

254. Thompson discloses this element. This element is the same as independent claim 15[g], and Thompson discloses it for the same reasons. *See* §VIII.D.1.h above.

- i. **Element 16[h]: wherein the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.**

255. Thompson discloses this element. Thompson discloses that its emissive layer contains a host material that is “inert” and has “a large energy gap between the HOMO and LUMO levels of the material [such] that the inert host matrix does not participate in hole or electron transport.” Thompson, [0028] (emphasis added). Thompson also discloses that its “inert host material layer” has “a wide energy gap between the HOMO and the LUMO energy levels.” Thompson, [0043]. Thompson further discloses that the “[w]ide gap host material layer 40 is preferably inert” meaning that “it preferably does not carry a charge within the structure of the OLED.” Thompson, [0035]. Accordingly, Thompson explains, “charge is preferably carried only by the dopants, and not by the wide gap host material layer 40.” Thompson, [0035].

256. As I explained above in my discussion of claim 15, the inert host material acts as “the first matrix material,” while the hole transporting dopant and electron transporting dopant act as second and third matrix materials, respectively. *See* §VIII.D.1.f above. As such, the first matrix material, which is “inert,” “does not participate in hole or electron transport,” and “does not function as a charge carrying material,” would therefore have a lower charge carrier mobility than that of the

second matrix material, which acts as a hole transporter, and that of the third matrix material, which acts as an electron transporter.

257. Accordingly, a POSITA would have appreciated that Thompson discloses this element.

IX. SECONDARY CONSIDERATIONS OF NON-OBVIOUSNESS

258. I understand that no secondary considerations evidence has been identified for the '164 patent at this time. I am not aware of any such evidence that would apply to the challenged claims.

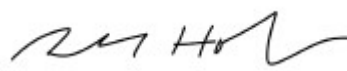
X. CONCLUSION

259. For the reasons discussed above, claims 1–16 of the '164 patent would have been anticipated and/or obvious to a POSITA.

* * *

I 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.

Executed on: June 28, 2024



Russell J. Holmes, Ph.D.