

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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SAMSUNG DISPLAY CO., LTD.,  
Petitioner,

v.

PICTIVA DISPLAYS INTERNATIONAL LTD.,  
Patent Owner.

Case No. IPR2026-00129  
Patent No. 12,158,250

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**DECLARATION OF RUSSELL J. HOLMES, PH.D.  
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF  
U.S. PATENT NO. 12,158,250**

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## **I. INTRODUCTION**

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 certain claims of U.S. Patent No. 12,158,250 (“the ’250 patent”). For the reasons discussed below, it is my opinion that claims 1–16 of the ’250 patent would have been anticipated by the prior art or obvious to a person of ordinary skill in the art.

2. I am being compensated at my standard hourly consulting rate for my time. My compensation is in no way contingent on the content of my testimony or the outcome of these or any other proceedings relating to the ’250 patent.

## **II. BACKGROUND AND QUALIFICATIONS**

3. 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 provided as Exhibit 1004. 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. *See* Ex. 1004.

4. 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.

5. 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.

6. 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, which are listed in my *curriculum vitae*.

7. 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.

8. 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 also serve as Department Executive Officer for Materials Science. Also notable is my past service as Chair of the Department Head

Search Committee (2023-2024) and prior appointment as Director of Graduate Studies for Materials Science (2013-2020). Finally, from 2017-2024 I served as an Editor for the Elsevier journal Synthetic Metals, and since 2024 I have served as Editor-in-Chief. Broadly speaking, Synthetic Metals publishes papers on the physics, chemistry, and applications of organic and carbon electronic materials and their application in a variety of electronic devices including OLEDs.

9. 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 21 completed Ph.D. graduate advisees (and an additional 6 current graduate advisees), 5 completed master's degree advisees, and more than 30 undergraduate advisees. Of my graduated Ph.D. students, many now work and hold leadership positions in the display and electronics industries.

10. Over the past 24 years, I have been an author on over 125 peer-reviewed publications, and given over 130 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, the study of singlet and triplet exciton phenomena, and

the impact of molecular orientation on organic semiconductor thin film properties and OLEDs. A complete list of my publications and presentations can be found in my *curriculum vitae*.

11. My research career has led to the filing of several patent applications, which are reflected in my *curriculum vitae*. The listed patents and patent applications pertain to organic semiconductor materials and devices.

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

13. In summary, I have extensive familiarity with organic light-emitting devices. At the time around 2008, 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 in 2008.

### **III. MATERIALS CONSIDERED**

14. In forming my opinions, I have reviewed the '250 patent, as well as the prosecution history of the '250 patent and its related U.S. applications and prosecution histories. I have also reviewed a number of prior art and background references from the time of the alleged invention of the '250 patent. Specifically, I have reviewed the materials cited throughout my declaration and each of 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. 12,158,250                                                                                                                                                             |
| 1002        | File History for U.S. Patent No. 12,158,250                                                                                                                                            |
| 1003        | INTENTIONALLY LEFT BLANK                                                                                                                                                               |
| 1004        | INTENTIONALLY LEFT BLANK                                                                                                                                                               |
| 1005        | INTENTIONALLY LEFT BLANK                                                                                                                                                               |
| 1006        | INTENTIONALLY LEFT BLANK                                                                                                                                                               |
| 1007        | Certified Translation of Japanese Patent Application Publication No. JP 2007-277631 A (“Suzuki”)                                                                                       |
| 1008        | Japanese Patent Application Publication No. JP 2007-277631 A (“Suzuki”)                                                                                                                |
| 1009        | Certified Translation of International Patent Application Publication No. WO 2008/040323 A2 (“Diekmann”)                                                                               |
| 1010        | International Patent Application Publication No. WO 2008/040323 A2 (“Diekmann”)                                                                                                        |
| 1011        | J.W. Ma et al., <i>Organic light-emitting diodes based on new n-doped electron transport layer</i> , Synthetic Metals 158 (2008) (“Ma”)                                                |
| 1012        | U.S. Patent Application Publication No. 2005/0146267 (“Lee”)                                                                                                                           |
| 1013        | U.S. Patent No. 11,828,425 (“’425 patent”)                                                                                                                                             |
| 1014        | File History for U.S. Patent No. 11,828,425                                                                                                                                            |
| 1015        | File History for U.S. Patent Application No. 16/790,198                                                                                                                                |
| 1016        | File History for U.S. Patent Application No. 15/651,508                                                                                                                                |
| 1017        | File History for U.S. Patent Application No. 13/139,514                                                                                                                                |
| 1018        | Gufeng He et al., <i>Very high-efficiency and low voltage phosphorescent organic light-emitting diodes based on a p-i-n junction</i> , 95 J. Appl. Phys., 5773-5777 (2004)             |
| 1019        | Gufeng He et al., <i>High-efficiency and low-voltage p-i-n electrophosphorescent organic light-emitting diodes with double-emission layers</i> , 85 Appl. Phys. Lett. 3911-3913 (2004) |
| 1020        | Martin Pfeiffer et al., <i>Electrophosphorescent p-i-n organic light-emitting devices for very-high-efficiency flat-panel displays</i> , 22 Adv. Mater. 14 (2002)                      |
| 1021        | Harald Gross et al., <i>High Power Efficiencies at Record Lifetimes: NOVALED’S PIN-OLEDs</i> , FPD Yokohama 2005                                                                       |
| 1022        | INTENTIONALLY LEFT BLANK                                                                                                                                                               |

| Exhibit No. | Description                                                                                                                                                                                                           |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1023        | V. Bulovic et al., <i>Transparent light-emitting devices</i> , 29 Nature 380 (1996)                                                                                                                                   |
| 1024        | K. Walzer et al., <i>Highly Efficient Organic Devices Based on Electrically Doped Transport Layers</i> , 107 Chem. Rev. 1233-1271 (2007)                                                                              |
| 1025        | L. Moro et al, <i>Process and design of a multilayer thin film encapsulation of passive matrix OLED displays</i> , Proceedings of SPIE Vol. 5214 (2004)                                                               |
| 1026        | Anna B. Chwang et al., <i>Thin film encapsulated flexible organic electroluminescent displays</i> , 83 Appl. Phys. Lett. 413-415 (2003)                                                                               |
| 1027        | U.S. Patent Application Publication No. 2011/0260201 ("Klein")                                                                                                                                                        |
| 1028        | Zugang Liu et al., <i>Improved electron injection in organic LED with lithium quinolate/aluminium cathode</i> , 128 Synthetic Metals 211-214 (2002)                                                                   |
| 1029        | Lumtec, Liq, <a href="https://www.lumtec.com.tw/products-view.php?ID=327">https://www.lumtec.com.tw/products-view.php?ID=327</a>                                                                                      |
| 1030        | Lumtec, LiF, <a href="https://www.lumtec.com.tw/products-view.php?ID=371">https://www.lumtec.com.tw/products-view.php?ID=371</a>                                                                                      |
| 1031        | Commission on Isotopic Abundances and Atomic Weights, Barium, <a href="https://www.ciaaw.org/barium.htm">https://www.ciaaw.org/barium.htm</a>                                                                         |
| 1032        | Commission on Isotopic Abundances and Atomic Weights, Cesium, <a href="https://www.ciaaw.org/caesium.htm">https://www.ciaaw.org/caesium.htm</a>                                                                       |
| 1033        | Adachi et al., <i>Confinement of charge carriers and molecular excitons within 5-nm-thick emitter layer in organic electroluminescent devices with a double heterostructure</i> , 57 Appl. Phys. Lett. 531–533 (1990) |
| 1034        | Jun Endo et al., <i>Organic Electroluminescent Devices Having Metal Complexes as Cathode Interface Layer</i> , Jpn. J. Appl. Phys. Vol. 41 (2002)                                                                     |
| 1035        | Gregor Schwartz et al., <i>Reduced efficiency roll-off in high-efficiency hybrid white organic light-emitting diodes</i> , Appl. Phys. Lett. 92, 053311 (2008)                                                        |
| 1036        | Gregor Schwartz et al., <i>High efficiency white organic light emitting diodes combining fluorescent and phosphorescent emitter systems</i> , Proc. of SPIE Vol. 6192, 61920Q (2006)                                  |

| Exhibit No. | Description                                                                                                                                                                          |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1037        | Baldo et al., <i>Highly efficient phosphorescent emission from organic electroluminescent devices</i> , 395 Nature 151 (1998)                                                        |
| 1038        | Baldo et al., <i>Very high-efficiency green organic light-emitting devices based on electrophosphorescence</i> , 75 Appl. Phys. Lett. 4–6 (1999)                                     |
| 1039        | Xinyou Zheng et al., <i>Efficiency improvement of organic light-emitting diodes using 8-hydroxy-quinolinato lithium as an electron injection layer</i> , Thin Solid Films 478 (2005) |
| 1040        | Sung Hoon Choi et al., <i>Improved Efficiency and Lifetime of Organic Light-Emitting Diode with Lithium-Quinolate-Doped Electron Transport Layer</i> , Jpn. J. Appl. Phys. 48 (2009) |
| 1041        | Kaushik Roy Choudhury et al., <i>LiF as an n-Dopant in Tris(8-hydroxyquinoline) Aluminum Thin Films</i> , Adv. Mater. 2008, 20, 1456–1461                                            |
| 1042        | Christoph Schmitz et al., <i>Lithium-Quinolate Complexes as Emitter and Interface Materials in Organic Light-Emitting Diodes</i> , Chem. Mater. 2000, 12, 3012–3019                  |
| 1043        | INTENTIONALLY LEFT BLANK                                                                                                                                                             |
| 1044        | INTENTIONALLY LEFT BLANK                                                                                                                                                             |
| 1045        | Claim Construction Order, <i>Pictiva Displays International Ltd. v. Samsung Electronics Co., Ltd., et al.</i> , Case No. 2:23-cv-00495, Dkt. 397 (E.D. Tex. June 27, 2025)           |
| 1046        | INTENTIONALLY LEFT BLANK                                                                                                                                                             |
| 1047        | INTENTIONALLY LEFT BLANK                                                                                                                                                             |
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#### IV. RELEVANT LEGAL STANDARDS

15. 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:

16. 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.

17. 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 of the invention. 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 of the invention.

18. 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.

19. 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.

20. 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.

21. 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.

22. 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.

23. Petitioner's counsel has informed me that unpatentability of a patent claim can be demonstrated by a preponderance of the evidence. I understand that a preponderance of the evidence means more likely than not in this context.

## **V. TECHNOLOGY BACKGROUND**

### **A. Technology Overview**

#### **1. Organic Light Emitting Diodes (OLEDs)**

24. Organic light-emitting diodes (OLEDs) are an important component in mobile displays (phones, watches, tablets) and also in televisions, virtual reality headsets, and lighting applications. 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, essentially 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 contrast, and suitability for flexible display applications. There are now several consumer products that incorporate mechanically flexible OLED displays, enabling an entirely new end-user experience.

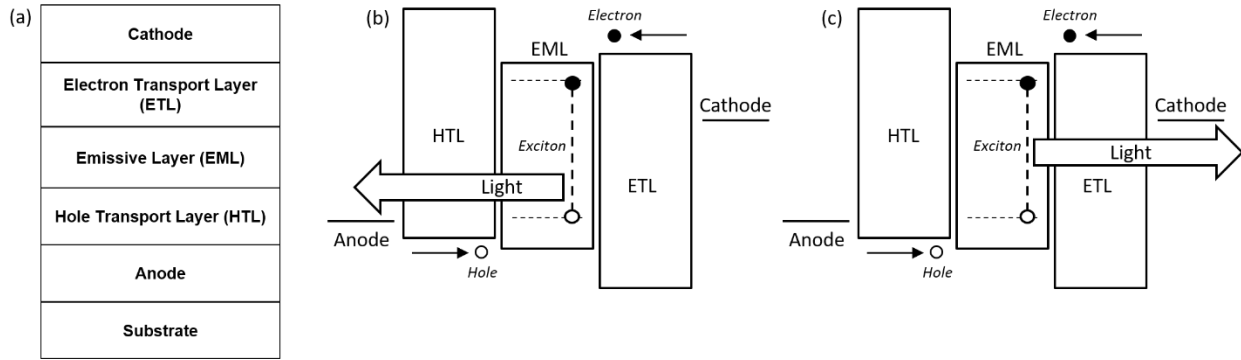
25. An OLED display comprises a large assembly of individual microscopic OLED pixels. Each individual OLED consists of a sequential stack of layers, where each layer is a collection of organic semiconductor molecules. The function of light-emission is carried out by a particular layer known as the emissive layer (EML) of the device. The organic layers are placed between two conducting

electrodes, a positive electrode (anode) and a negative electrode (cathode), which permit the injection of electrical current through the device. Using at least one transparent or semi-transparent electrode allows light generated in the emissive layer to leave the device. In practice, this can be achieved by making the electrodes thin enough to be transparent or semi-transparent to the light generated in the organic layer stack.

26. In order to make a transparent or semi-transparent electrode, a thin metal layer can be utilized to ensure light can pass through. For example, the first fully transparent OLEDs utilized a cathode of thickness 5-40 nm consisting of a silver-magnesium (Ag-Mg) alloy, a metal combination which is commonly used as a cathode in OLEDs. *See* Ex. 1023 (Bulovic), 29. It was found that the transmission of light through the cathode was sharply reduced as the thickness of the cathode increased: with a cathode comprising a 7.5 nm thick layer of silver-magnesium alloy, the transmission of light was 81% and sharply fell to 10% at a thickness of 20 nm and fell all the way to 1% at a cathode thickness of 40 nm. *See* Ex. 1023 (Bulovic), 29. As such, it has long been understood that for metals, a thin film needs to be used for the cathode of the OLED to realize an appreciable level of light transmission. *See* Ex. 1023 (Bulovic), 29.

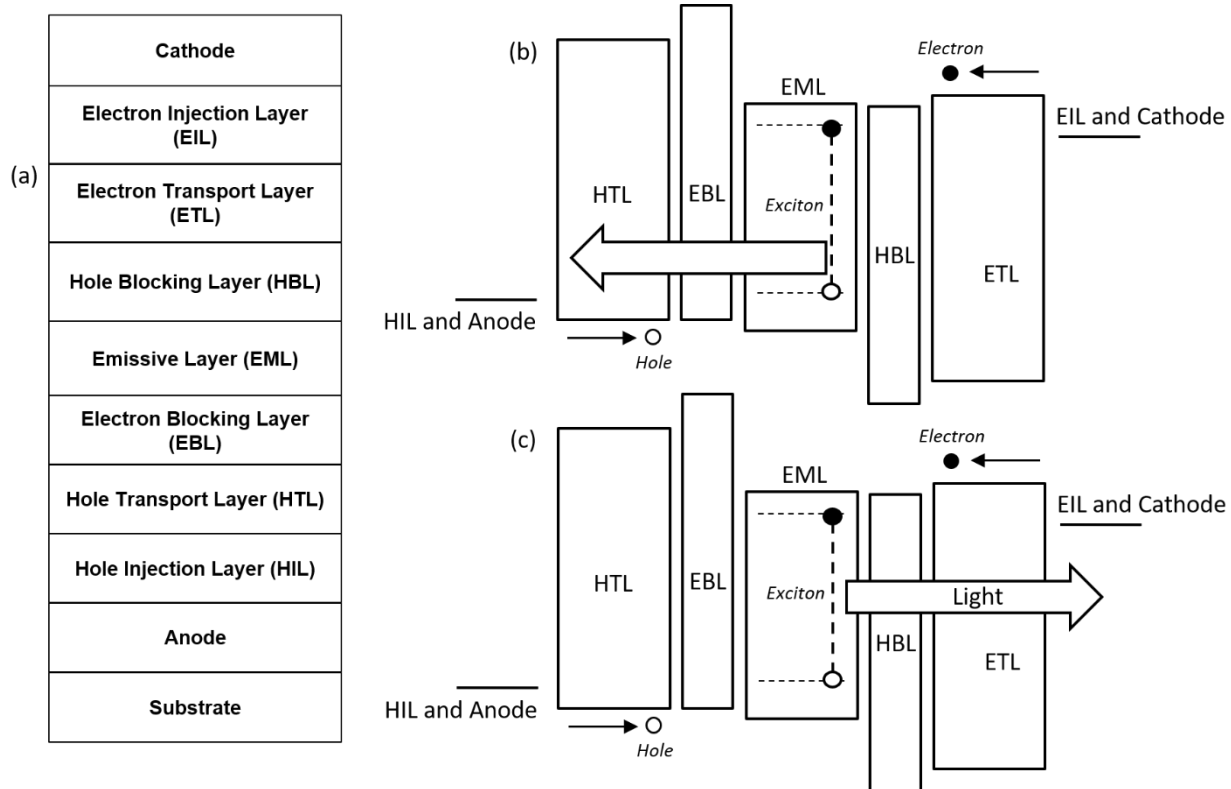
## **2. OLED Layer Structure**

27. OLEDs are often classified based on whether they emit light through the anode (bottom-emitting), the cathode (top-emitting), or both electrodes (transparent or semi-transparent). An exemplary layer structure for an OLED is shown in Figure 1(a). Here, while the electrode on the substrate is labeled as the anode and the electrode at the top of the device is the cathode, other electrode configurations are also possible. This structure reflects the need for an OLED to efficiently convert injected electrons and holes into light. 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 being injected into the OLED from the cathode while holes are injected into the OLED from the anode. This process is shown in Fig. 1(b) for an example bottom-emitting OLED with the emitted light emerging through the transparent electrode on the substrate (here the anode). Fig. 1(c) shows the same process for an example top-emitting OLED where the anode may be reflective and the top electrode (here the cathode) is instead transmissive, allowing light to escape from the top of the OLED.



**Figs. 1(a), 1(b), and 1(c).**

28. Electrons travel from the cathode through a specifically designed sequence of layers permitting efficient arrival into the emissive layer (EML) of the device. There are a variety of layer architectures applied in OLEDs, here emphasis has been placed on the typical elements. For electrons, this sequence typically includes an electron transport layer (ETL) before reaching the EML. In some OLEDs, an electron injection layer (EIL) may also be used between the ETL and cathode. In some OLEDs, a hole blocking layer (HBL) between the ETL and EML may be used. Similarly, holes travel from the anode through a specifically designed sequence of layers permitting efficient arrival into the EML of the device. For holes, this sequence typically includes a hole transport layer (HTL) before reaching the EML. In some OLEDs, a hole injection layer (HIL) may also be used between the anode and the HTL. In some OLEDs, an electron blocking layer (EBL) between the HTL and EML may be used. An OLED which contains electron and hole injection layers as well as electron and hole blocking layers is illustrated below in Figure 2.



**Figs. 2(a), 2(b), and 2(c).**

29. In the EML, electrons and holes meet to form a bound electron-hole pair known as an exciton, an energetically excited molecule. Balanced injection of electrons and holes into the EML can result in efficient formation of excitons. In an OLED, the goal is for excitons to energetically relax (or “recombine”) by emitting light, a process known as electroluminescence. The EML usually consists of at least two different types of molecules, referred to as host and emitter (or guest), with the host encompassing roughly 90% of the film, but with the emitter ultimately responsible for light emission.

### **3. Emission Layer (EML)**

30. The selection of the materials that are included in the EML of the OLED strongly determines the light-emitting efficiency of the device. The efficiency of an OLED can be defined using several metrics. Most fundamental is the external quantum efficiency (or EQE), which is a measure of the rate of photon (i.e. light) emission from the device divided by the rate of electron injection. More relevant for display applications are efficiency units that account for the photopic response of the human eye, accounting for example for the increased sensitivity of the human eye to green light versus blue or red light. These include the current efficiency, in units of candelas per Ampere (cd/A) and the power efficiency, in units of lumens per electrical Watt (lm/W). To maximize the light emitted by an OLED, it is important to utilize a light-emitting material in the EML capable of efficiently converting injected electrons and holes into excitons which decay radiatively to emit light.

31. By 2008, two different classes of light-emitting (or emitter) material had been applied in the construction of OLEDs. Molecules in these classes are denoted as either fluorescent or phosphorescent depending on their light-emitting mechanism. While fluorescent emitter materials were applied in initial demonstrations of thin film OLEDs, they were limited in the efficiency they could realize. When excitons are formed in the EML of an OLED, they are either “triplet” or “singlet” excitons; these are formed at a ratio of 3:1 (meaning for every three

triplet excitons, there will be one singlet exciton). Although singlet excitons are capable of undergoing rapid recombination to emit light (termed fluorescence), triplet excitons, in contrast, are usually unable to relax radiatively in a fluorescent material, and tend to decay non-radiatively. Since under electrical excitation the triplet to singlet ratio is 3:1, electroluminescence from simple fluorescent materials can be at best 25% efficient. This limitation presented a significant obstacle to the commercialization of OLEDs until the advent of electroluminescence from phosphorescent emitter molecules.

32. A phosphorescent emitter differs from a fluorescent emitter in that light emission originates from the recombination of the excitons in the triplet state rather than those in the singlet state. Additionally, any electrically generated singlet excitons can be rapidly converted into triplet excitons, increasing the maximum possible efficiency of the OLED to 100%. The conversion from singlets to triplets, as well as efficient light emission via phosphorescence from the triplet state is made possible through the heavy atom effect which increases the coupling between singlet and triplet exciton states. By 2008, phosphorescent emitters were being widely utilized to demonstrate OLEDs with high efficiency, with the requisite heavy atom effect enabled by including an element like platinum (Pt) or iridium (Ir) in the molecular structure. Initial demonstrations of electroluminescence from OLEDs relying on phosphorescence were by Baldo et al. using a platinum-containing

phosphor, Ex. 1037 (Baldo 1998), and Baldo et al. using an iridium-based phosphor. Ex. 1038 (Baldo 1999). These early demonstrations built off aspects of OLED architecture previously demonstrated for fluorescent emitters. For example, the use of the host-guest EML concept had already been widely applied for fluorescent emitters. The use of a double-heterostructure device architecture has also already been developed for fluorescent OLEDs as noted in the following section dealing with transport layers. Likewise, many molecular systems previously used for functions including host and transport layer in fluorescent OLEDs were transferred and successfully applied in phosphorescent OLEDs, further reflecting the sharing of knowledge and active materials between both approaches for OLED electroluminescence. By 2008, significant commercialization efforts were already underway for the use of phosphorescent OLEDs in displays by Universal Display Corporation. As such, the OLED community as a whole was well-aware of iridium-phosphors as a means to maximize OLED efficiency, and there was vigorous effort to further develop these materials toward commercial applications in the early 2000s.

#### **4. Transport and Injection Layers**

33. Transport layers are a core unit of OLED architecture and are ubiquitous for their presence across devices found in the literature. Many of the most prominent papers in OLEDs utilize this terminology (i.e., “electron transport layer” and “hole transport layer”) in describing a layer responsible for charge transport

from the electrode. In 1990, Adachi et al. introduced the advantage of sandwiching a purpose-designed EML between hole- and electron-transport layers. Ex. 1033 (Adachi). The relevant device structure comprised, in order: an anode of ITO, followed by a hole-transport layer of TAD, an EML, an electron-transport layer of PBD, and a cathode. In this work, the transport layers are noted for their role in moving electrons and holes from the electrodes to the EML, and also to prevent quenching of excitons in (and fluorescence from) the EML by the electrodes.

34. Another prominent example is the aforementioned first demonstration of efficient electroluminescence from an Ir-containing phosphorescent guest by Baldo et al. who constructed a device comprising an anode, followed by a hole-transport layer of  $\alpha$ -NPD, an emissive layer consisting of CBP and Ir(ppy)<sub>3</sub>, a blocking layer of BCP, an electron transport layer of Alq3, and finally a cathode consisting of magnesium and silver. Ex. 1038 (Baldo 1999). Notably, even with the inclusion of a blocking layer of BCP, Alq3 is designated as the electron transport layer, sitting between the blocking layer and the cathode. It is also notable that even though Adachi utilized a fluorescent emitter and Baldo a phosphorescent emitter, the same general double heterostructure type architecture was applied, with similar architectures continuing to be applied today across OLEDs utilizing fluorescent, phosphorescent, or even combinations of both emitters.

35. A relevant issue being considered by those in the art at the time was the potentially low conductivity of the electron- and hole- transport layers which, as explained above, serve to bring charge carriers from the OLED electrodes to the EML to generate light. By 2008, it was well-understood that the conductivity of transport layers could be improved through doping the transport layer. For example, it was understood at the time that one way to increase the conductivity of the hole transport layer was to dope the hole transport layer with a p-type dopant (this practice being referred to as “p-doping”). A p-type dopant is an atomic or molecular species that when added to the HTL increases the conductivity for holes in the layer. Similarly, it was well known that one way to increase the conductivity of the electron transport layer in an OLED was to dope the electron transport layer with an n-type dopant (also known as “n-doping”). An n-type dopant is an atomic or molecular species that when added to the ETL increases the conductivity for electrons in the layer.

36. A notable example of this conductivity doping approach applied to OLEDs based on iridium-containing phosphorescent emitters is described in an article published by Pfeiffer et al. in 2002. Ex. 1020 (Pfeiffer). In the Pfeiffer paper, a hole transport layer of MTDATA is doped with the p-dopant F<sub>4</sub>-TCNQ and an electron transport layer is doped with the n-dopant lithium. The OLED disclosed in the Pfeiffer paper also utilizes electron- and hole-blocking layers of Ir(ppz)<sub>3</sub> and

BPhen, respectively and has an EML consisting of a CBP host doped with the iridium-containing compound Ir(ppy)<sub>3</sub>. Pfeiffer et al. found that the inclusion of conductivity doping in the transport layers, and specifically n-doping the electron transport layer and p-doping the hole transport layer, increased its power efficiency under display-relevant brightness conditions. This OLED configuration (with an n-doped electron transport layer and a p-doped hole transport layer) is often referred to as a “*p-i-n*” OLED. Pfeiffer et al.’s work was also notable in that it demonstrated how an OLED with an n-doped electron transport layer does not require a separate electron injection layer. Pfeiffer et al.’s work is an early demonstration of the dual impact of electron transport layer doping on conductivity and injection. Thus, while an OLED need contain hole- and electron-transport layers, it need not necessarily contain injection layers. Pfeiffer et al.’s work led to further investigation into n- and p- doping of transport layers to realize improved performance in phosphorescent devices, and also led to commercialization efforts by Novaled.

37. Other OLEDs with doped electron and hole transport layers had also been successfully demonstrated by 2008. For example, in a 2004 paper He et al. demonstrated high performance phosphorescent OLEDs based on an iridium-containing emitter molecule achieved by using a p-i-n OLED including a p-doped hole transport layer (doped with p-dopant F<sub>4</sub>-TCNQ) and an n-doped electron transport layer (doped with n-dopant cesium). Ex. 1018 (He). He et al. notes that the

larger size of the cesium dopant compared to the lithium doping employed in Pfeiffer et al. “reduces the probability of Cs diffusing into the emission layer to quench excitons.” Ex. 1018 (He), 5775. He et al. further notes that this is reflected by the ability to use a thinner blocking layer of BPhen for devices with an ETL doped with cesium compared to lithium, concluding that “Cs hardly penetrates into the nominally undoped region.” Ex. 1018 (He), 5775. He’s work demonstrates how the use of a less diffuse dopant relaxes the constraints on the blocking layer. It is important to note that the devices of He and Pfeiffer both show excellent performance with appropriate blocking layers, demonstrating that lithium-doped phosphorescent OLEDs based on iridium-containing emitter molecules could be optimized for high performance by using blocking layers that help prevent quenching. Finally, like the devices of Pfeiffer et al., those of He et al. did not require a separate electron injection layer when using a doped electron transport layer of BPhen, as the n-doped electron transport layer can itself serve to improve electron injection into the device.

38. By the time of the ’250 patent, phosphorescent OLEDs with p- and n-doped transport layers were a well-established technology. As noted by Walzer et al., the “p-i-n architecture has been extended to phosphorescent OLEDs.” Ex. 1024 (Walzer), 1254–1255. The work referenced by Walzer is the work of Pfeiffer et al. from 2002. Ex. 1020 (Pfeiffer), 1633. By the time of the ’250 patent years later,

many others had successfully created phosphorescent OLEDs with p- and n-doped transport layers, including for both monochromatic OLEDs, Ex. 1024 (Walzer), 1256–1257; Ex. 1018 (He), 5773–5774, Fig. 1; Ex. 1021 (Gross), 7, 9–19; Ex. 1019 (He), 3911–3912, Fig. 1, and white OLEDs with multiple emissive layers, Ex. 1024 (Walzer), 1257; Ex. 1035 (Schwartz), 053311-1–053311-2, Fig. 1; Ex. 1036 (Schwartz), 61920Q-1–61920Q-2, Fig. 1.

39. Prior to the '250 patent, it was understood that improving the ability to inject charges from the cathode into the adjacent organic stack was important for reducing the voltage needed to realize a particular brightness from the OLED. Reducing the OLED driving voltage in turn also reduces the power consumed by the OLED. When considering electrons, this can in practice be accomplished by inserting an electron injection layer or, alternatively, an electron transport layer that has been doped to increase conductivity (as I explained above) between the cathode and the organic layer stack.

40. By the late 1990s, the inclusion of lithium-containing compounds in the organic layer stack had been shown to be an effective means to realize a reduced injection barrier for electrons, and a practical means to reduce the driving voltage of the OLED. For example, in a 2002 paper Liu et al. studied the use of Liq as an electron injection layer paired with, and directly below, an aluminum cathode. Ex. 1028 (Liu). Devices containing a thin layer of Liq as the electron injection layer

showed improved current and luminance output compared to devices using a layer of calcium. The performance of devices containing Liq was found to be similar to devices using LiF in a similar capacity. As such, by this time it was well known in the OLED community that the inclusion of an electron injection layer of LiF or Liq could favorably improve device performance by reducing the barriers for electron injection into the organic stack.

41. By the time of the '250 patent, it was understood that many of the materials used in p- and n- doped transport layers could serve different functions in an OLED depending on how they were implemented. For example, BPhen could be utilized as a hole-blocking layer or a doped ETL. Ex. 1018 (He), Ex. 1020 (Pfeiffer). Alkali metals such as Li can be used as n-dopants in an ETL or as EILs when used as neat films between the cathode and the ETL. Ex. 1020 (Pfeiffer), Ex. 1039 (Zheng). Similarly, LiF was and still is frequently used as an EIL, but can also be used as a dopant in an ETL. Ex. 1041 (Choudhury), 1456, 1460, Figs. 1, 4 (LiF as EIL and LiF as ETL dopant); Ex. 1028 (Liu), Abstract, 211, 212–213 (LiF as EIL); Ex. 1034 (Endo), L800, L802, Fig. 1 (LiF as ETL dopant). Liq had previously been demonstrated as both an ETL and EIL in OLEDs, as well as an effective n-dopant for several ETL materials. Ex. 1042 (Schmitz), 3012, 3016–3019 (Liq as ETL or EIL); Ex. 1028 (Liu), Abstract, 212–213 (Liq as EIL); Ex. 1034 (Endo), L800, L802, Fig. 1 (Liq as ETL dopant). In a 2008 paper, Ma et al. combined a p-doped hole

transport layer (doped with p-dopant F<sub>4</sub>-TCNQ) and an n-doped electron transport layer (doped with n-dopant Liq) in a single device to improve OLED performance. Ex. 1011 (Ma). The community understood the multifaceted utility of Liq, and with Ma's work, the usefulness of Liq as a molecular n-dopant to increase the conductivity of electron transporting layers in OLEDs.

## **5. Blocking Layers**

42. OLEDs may also contain one or more blocking layers adjacent to the EML. In most cases, these layers are selected to prevent the leakage of electrons and holes out of the EML. This is desirable since charges that leak past the emissive layer do not form excitons in the EML and are hence lost, potentially reducing device efficiency and in some cases impacting stability. These layers can also serve to confine excitons formed within the EML, preventing quenching with other layers in the stack or the electrodes (as noted above in prior work by Adachi (Ex. 1033)). In order to realize these functions, the blocking layers are normally chosen to have larger exciton energies than the materials comprising the EML. The hole-blocking layer can be selected to have a deeper HOMO energy level than the material in the EML responsible for hole transport, enabling hole confinement to the EML. The electron-blocking layer can have a shallower LUMO than the material in the EML responsible for electron transport, enabling electron confinement to the EML. In addition, it is usually desirable for the hole-blocking layer to be conductive to

electrons, and the electron-blocking layer to be conductive to holes. This minimizes the impact of the blocking layers on the injection of electrons and holes into the EML to form excitons.

43. By the time of the '250 patent, blocking layers were routinely used to allow the doped transport layers to be spaced from the emissive layer, addressing concerns about dopant diffusion and exciton quenching. *See, e.g.*, Ex. 1020 (Pfeiffer), 1633–1634, Fig. 1 (blocking layers with Li-doped ETL); Ex. 1018 (He), 5773–5774, Fig. 1 (blocking layers with Cs-doped ETL); Ex. 1019 (He), 3911–3912, Fig. 1 (blocking layers with Cs-doped ETL). In fact, in Pfeiffer, blocking layers provided “nearly complete isolation of the EML from the conductive dopants,” even where the n-dopant was pure elemental lithium Ex. 1020 (Pfeiffer), 1635. This said, a less diffusive dopant relaxes the constraints on the blocking layer, as noted earlier.

## **6. Encapsulation**

44. At the same time that those in the art were working to improve device performance via the use of iridium-containing emission layers and n- and p- doped transport layers, there was simultaneously a significant effort directed at developing the means to encapsulate OLEDs from the ambient environment and specifically to protect the constituent organic and metallic layers from oxygen and water vapor to increase the device operational lifetime.

45. One approach at the time was to utilize a multilayer coating consisting of alternating layers, where one layer is designed to serve as the barrier and the other can serve to help decouple defect formation between layers or planarize the barrier layer. An example application of this general idea is the use of a multilayer barrier coating consisting of alternating organic and inorganic layers as described, for example, in a 2004 publication by Moro et al. Ex. 1025 (Moro). Specifically, Moro et al. fabricated an OLED in which an organic layer was deposited onto the OLED followed by polymerization with ultraviolet light to form an insulating layer comprising an insulating acrylic polymer film. Ex. 1025 (Moro). The polymer layer is then followed by the deposition of an inorganic metal oxide layer. In this structure, the inorganic layer serves as the moisture/oxygen permeation barrier while the polymer layer serves to planarize the layer and enable the smooth deposition of the inorganic layer, minimizing the presence of defects. This structure serves to decouple the propagation of defects between these layers, removing continuous channels for moisture and oxygen diffusion. Multi-layer encapsulations such as this create a tortured path for diffusion, improving the encapsulation ability of the structure and in doing so, better protecting the OLED and extending its life. This encapsulation approach was successfully applied to phosphorescent OLED displays by Chwang et al. in order to realize flexible devices on plastic substrates. Ex. 1026 (Chwang). At the time of the '250 patent, this approach was already being developed

commercially by Vitex Systems, reflecting the understanding in the art at the time that stacks of dissimilarly structured materials can serve as effective encapsulation layers for phosphorescent OLEDs.

## 7. Lithium Quinolate (Liq)

46. Liq, also known as lithium quinolate, or 8-Hydroxyquinolinolato-lithium, was a well-studied material by the time of the '250 patent. The art recognized that Liq (which is a molecule) could be used as an n-dopant for the electron transport layer and as an electron injection layer, and Liq was further known to be effective in facilitating both electron transport and electron injection from as early as 2000 and through the time of the '250 patent. For example:

- Ex. 1011 (Ma), 813: Liq-doped ETL resulted in “high electron mobility of n-doping ETL”
- Ex. 1034 (Endo), L800: Doping ETL with Liq “was also effective in facilitating the electron injection from the cathode to the organic layer”
- Ex. 1040 (Choi), 062101-1–062101-2: Liq-doped ETL improves electron injection
- Ex. 1042 (Schmitz), 3019: Liq has “good electron injection and electron transport properties”
- Ex. 1028 (Liu), 212–214: “Liq is an electron transporting material”; Liq “improves electron injection”

47. Liq has been used both as a dopant (e.g., in the electron transport layer) and as a neat interface layer (e.g., as the electron injection layer) in the prior art, and the mechanisms by which Liq improves OLED performance in each case can vary accordingly. For example:

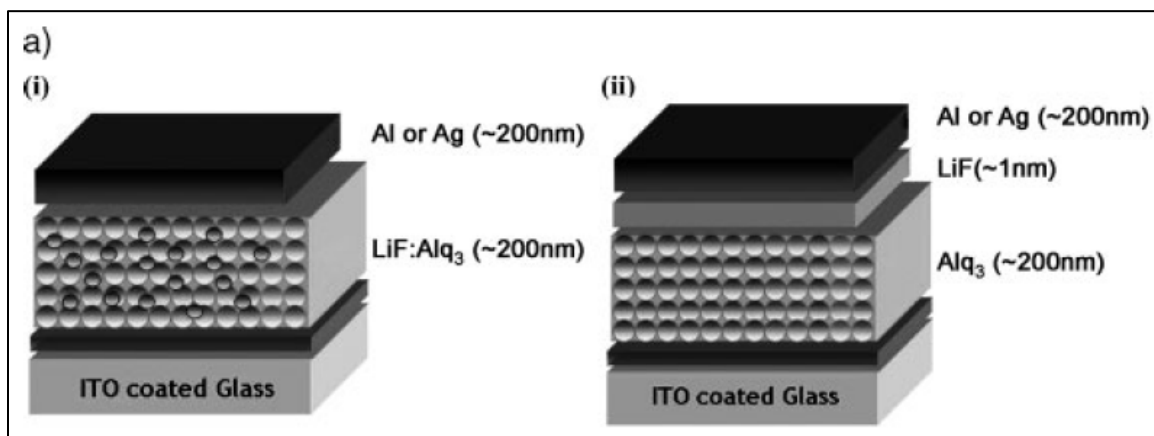
- Ex. 1011 (Ma), 813 (Liq as ETL dopant showing improved electron transport)
- Ex. 1034 (Endo), L800 (Liq as ETL dopant showing improved electron injection)
- Ex. 1028 (Liu), 211, 213 (Liq as neat EIL showing improved electron injection)
- Ex. 1042 (Schmitz), 3012, 3018–3019 (Liq as neat EIL showing improved electron injection)

48. The Kido group at Yamagata University worked on doping Liq into an ETL. A 2002 paper by this group showed Liq-doped ETLs led to better electron injection and reduced driving voltage, Ex. 1034 (Endo), L800, L802, consistent with Ma's results, Ex. 1011 (Ma), 810, 813. Other prior art also shows Liq's effective electron-injection properties, further noting Liq's doping effect. Ex. 1042 (Schmitz), 3012, 3018–3019; Ex. 1028 (Liu), 211, 213–214.

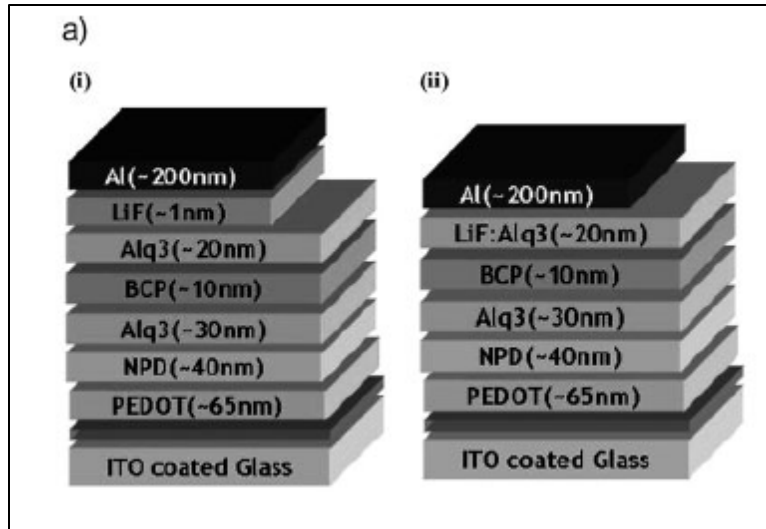
49. By the time of the '250 patent, a POSITA would have understood that Liq and other n-dopants are used in analogous contexts for the same reasons, thus supporting their interchangeability.

50. For example, as discussed above, Liq has been used as both a dopant in the electron transport layer and as a neat interface layer. Likewise, Diekmann shows that barium and lithium fluoride (LiF) can be used as both n-dopants for the electron transport layer and neat electron injection layers. Ex. 1009 (Diekmann), 5 (listing “LiF,” “Ba” as exemplary materials for “the electron injecting layer”), 10 (“Preferred n-dopants are cesium, barium and lithium fluoride” for increasing the conductivity of the doped organic layer adjacent to the cathode.).

51. For another example, Choudhury et al. shows comparative structures with both LiF as EIL and LiF as ETL dopant. Ex. 1041 (Choudhury), 1456, 1460, Fig. 1 (single-carrier devices), Fig. 4 (OLED).



Ex. 1041 (Choudhury), Fig. 1(a).



Ex. 1041 (Choudhury), Fig. 4(a). Choudhury also confirms that the mechanism for LiF doping is *in situ* doping activated by deposition of the cathode—the same as the mechanism for Liq doping shown in Endo. Ex. 1041 (Choudhury), 1459; Ex. 1034 (Endo), Abstract, L801–L802; *see also* Ex. 1028 (Liu), Abstract, 212–214. Choudhury further notes that LiF doping resulted in “higher carrier mobility in the doped samples compared to the undoped samples,” and concludes that “doping leads to a gradual filling of intrinsic charge traps in the material, resulting in higher low-field carrier mobility compared to undoped samples.” Ex. 1041 (Choudhury), 1457, 1460. These findings of increased mobility in the electron transport layer due to LiF-doping are further consistent with Ma’s hypothesis of increased conductivity due to increased mobility in the electron transport layer due to Liq-doping. Ex. 1011 (Ma), 812–813.

52. That Liq and these other known n-dopants are used for the same purposes in the same types of layers in the prior art literature shows that a POSITA would have considered them to be interchangeable analogues that work through similar mechanisms. It is well within the skill of a POSITA to swap out one n-dopant in the ETL for another n-dopant.

## **VI. OVERVIEW OF U.S. PATENT NO. 11,828,250**

### **A. Summary**

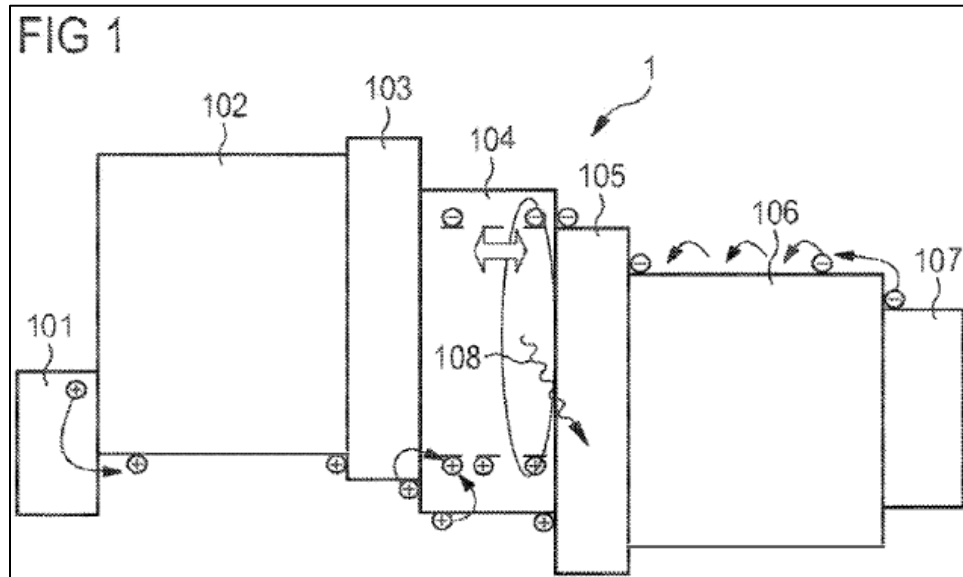
53. The '250 patent is entitled "Organic-Light Emitting Diode." The '250 patent is generally directed "to an organic light-emitting diode comprising an organic layer sequence, a radiation exit area and an encapsulation." '250 patent, 1:35–37.

54. A stated object of the patent is providing "an organic light-emitting diode comprising an organic layer sequence, a radiation exit area and an encapsulation." '250 patent, 1:35–37. The patent describes the organic layer sequence to include "at least one radiation-emitting region which generates electromagnetic radiation in the spectral range from infrared radiation to UV radiation during operation." '250 patent, 1:34–42.

55. The '250 patent illustrates an example OLED in Figure 1. Specifically, this figure depicts an "organic light-emitting diode 1" that has "first electrode 101" (as the anode) and a "hole transport layer 102" that "transports the positive charge

carriers toward the radiation-emitting region 104 of the organic light-emitting diode

1.” ’250 patent, 24:42–49.



’250 patent, Fig. 1.

56. Figure 1 depicts the radiation-emitting region 104 which generates electromagnetic radiation during operation. ’250 patent, 24:55–57. The ’250 patent describes that the electron transport layer 106 “transports negative charge carriers—electrons—from the second electrode 107, embodied as a cathode, to the radiation-emitting region 104.” ’250 patent, 25:1–4. The ’250 patent further describes that the electron transport layer 106 includes for “for example, a matrix material” that is n-doped. ’250 patent, 25:5–9.

57. For the electron transport layer 106, the ’250 patent describes that various materials could be used. ’250 patent, 26:44–47. As an example, the ’250 patent lists “8-hydroxyquinolinolato-lithium,” which is also known as Liq,

among others. '250 patent, 26:44–47. The '250 patent does not provide any explanation that Liq was the inventive idea for its OLED device.

58. The '250 patent includes five independent claims (claims 1, 6, 10, 11, and 16) and eighteen dependent claims (claims 2–5, 7–9, and 12–15).

**B. Priority Date of the '250 Patent**

59. I have been asked to assume that the earliest possible priority date for the '250 patent is December 11, 2008, the earliest Foreign Application Priority Date listed on the face of the '250 patent. I have therefore analyzed the prior art as of that date or somewhat before that date.

**C. Prosecution History**

60. I have reviewed the prosecution history of the '250 patent (Ex. 1002).

61. I understand that the '250 patent issued from Application No. 18/492,397 (“’397 Application”), which is a continuation of Application No. 18/098,326 that issued as U.S. Patent No. 11,828,425 (“’425 patent”). Application No. 18/098,326 is a continuation of Application No. 16/790,198 (“’198 Application”), which is a continuation of Application No. 15/651,508 (“’508 Application”), which is a continuation of Application No. 13/139,514 (“’514 Application”), which was filed as PCT Application No. PCT/DE2009/001741 on December 9, 2009.

62. The '397 Application (which issued as the '250 patent) was filed on October 23, 2023. The Applicant canceled original claims 1–21 and amended the claims to add new claims 22–37. Ex. 1002, 245–252.

63. The Examiner issued an Office Action, rejecting then pending claims 22–37 as being unpatentable over the '425 patent. *See* Ex. 1002, 295–304. In response, the Applicant filed a terminal disclaimer. Ex. 1002, 309–312, 315–323.

64. On July 19, 2024, the Examiner issued a notice of allowance. Ex. 1002, 353–362. On September 13, 2024, the Applicant submitted an information disclosure statement (IDS), which listed Suzuki (Ex. 1007) and Diekmann (Ex. 1009) among over 30 references. Ex. 1002, 364–369. The Examiner marked the IDS form sheet but did not discuss the substance of the references. Ex. 1002, 491–497, 503.

65. On October 17, 2024, the Examiner issued a subsequent notice of allowance. This notice stated that the reasons for allowance were “provided in the previous office action mailed on July 19, 2024.” Ex. 1002, 503. The “previous office action” (which is the notice of allowance issued July 19, 2024) did not discuss the new references in the September 13, 2024 IDS. Ex. 1002, 498–505. As a result, the Suzuki and Diekmann references were not discussed by the Examiner during prosecution of the '250 patent.

**D. The Claims at Issue**

66. I have been asked to consider the patentability of claims 1–16 of the '250 patent ("Challenged Claims"). Those claims are reproduced below for reference:

**Claim 1**

[1Pre] A device comprising:

[1A] an organic light-emitting diode comprising:

[1B] an organic layer sequence,

[1C] a radiation exit area, and

[1D] an encapsulation wherein the encapsulation forms a seal of the organic layer sequence against environmental influences,

[1E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,

[1F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,

[1G] wherein the organic layer sequence comprises an electron transport layer that is n-doped; and

[1H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound; and

[1I] wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.

**Claim 2**

[2A] The device of claim 1, wherein at least one part of the encapsulation is formed by an insulation layer, and

[2B] wherein the insulation layer comprises at least one of: resin, silicon oxide, or silicon nitride.

**Claim 3**

[3A] The device of claim 1, wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,

[3B] the first and the second encapsulation layer each having a respective volume structure,

[3C] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, and

[3D] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.

**Claim 4**

The device according to claim 1, wherein the organic light-emitting diode comprises a hole transport layer that is p-doped.

**Claim 5**

[5A] The device according to claim 1, wherein a color filter is arranged between the emission layer and the radiation exit area, and

[5B] wherein the color filter is configured to be highly transmissive for a first spectral subrange of the generated electromagnetic radiation and highly absorbent for a second spectral subrange of the generated electromagnetic radiation.

**Claim 6**

[6Pre] A device comprising:

[6A] an organic light-emitting diode comprising:

[6B] an organic layer sequence,

[6C] a radiation exit area, and

[6D] an encapsulation,

[6E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,

[6F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,

[6G] wherein the organic layer sequence comprises an electron transport layer that is n-doped,

[6H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound; and

[6J]<sup>1</sup> wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm.

**Claim 7**

The device according to claim 6, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.

**Claim 8**

The device according to claim 6, wherein the cathode is in direct contact with a Lithium containing layer.

**Claim 9**

The device according to claim 6, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.

**Claim 10**

[10Pre] A device comprising:

[10A] an organic light-emitting diode comprising:

[10B] an organic layer sequence,

[10C] a radiation exit area, and

[10D] an encapsulation,

---

<sup>1</sup> For simplicity, this element is labeled as [6J] (instead of [6I]) so that it has the same alphabetical identifier as [10J] in claim 10.

[10E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,

[10F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,

[10G] wherein the organic layer sequence comprises an electron transport layer that is n-doped;

[10I]<sup>2</sup> wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium; and

[10H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound;

[10J] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm;

[10K] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and

[10L] wherein the cathode is in direct contact with a Lithium containing layer.

### **Claim 11**

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<sup>2</sup> This element is labeled as [10I] (instead of [10H]) so that it has the same alphabetical identifier as element [1I] in claim 1.

**[11Pre]** A device comprising:

**[11A]** an organic light-emitting diode comprising:

**[11B]** an organic layer sequence,

**[11C]** a radiation exit area, and

**[11D]** an encapsulation,

**[11E]** wherein the organic layer sequence and the encapsulation are disposed on a carrier,

**[11F]** wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,

**[11G]** wherein the organic layer sequence comprises an electron transport layer that is n-doped;

**[11H]** wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound;

**[11J]<sup>3</sup>** wherein at least one part of the encapsulation is formed by an insulation layer, the insulation layer comprising at least one of: resin, silicon oxide, silicon nitride; and

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<sup>3</sup> This element is labeled as [11J] (instead of [11I]) so that it has the same alphabetical identifier as element [16J] in claim 16.

[11K] wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,

[11L] the first and the second encapsulation layer each having a respective volume structure,

[11M] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, and

[11N] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.

**Claim 12**

The device of claim 11, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.

**Claim 13**

The device of claim 11, wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm.

**Claim 14**

The device of claim 13, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.

**Claim 15**

The device of claim 13, wherein the cathode is in direct contact with a Lithium containing layer.

**Claim 16**

[16Pre] A device comprising:

[16A] an organic light-emitting diode comprising:

[16B] an organic layer sequence,

[16C] a radiation exit area, and

[16D] an encapsulation,

[16E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,

[16F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,

[16G] wherein the organic layer sequence comprises an electron transport layer that is n-doped,

[16I]<sup>4</sup> wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium;

[16H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound;

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<sup>4</sup> This element is labeled as [16I] (instead of [16H]) so that it has the same alphabetical identifier as element [1I] in claim 1.

[16J] wherein at least one part of the encapsulation is formed by an insulation layer, the insulation layer comprising at least one of: resin, silicon oxide, silicon nitride;

[16K] wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,

[16L] the first and the second encapsulation layer each having a respective volume structure,

[16M] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer,

[16N] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.

[16O] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm;

[16P] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and

[16Q] wherein the cathode is in direct contact with a Lithium containing layer.

## **VII. LEVEL OF ORDINARY SKILL IN THE ART**

67. 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.

68. 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.

69. In the OLED field, when an interesting new material or device architecture emerges, there is interest from POSITAs to integrate it into their own work. This was true at the time of the '250 patent. POSITAs would routinely apply and/or modify materials and architectures whose mechanisms were not fully understood but demonstrated promising device performance. It was by first building OLEDs with varying parameters and running experiments on those devices that POSITAs would discover the underlying mechanisms governing the behavior of OLED materials and architectures. This approach is reflected in much of the literature cited in this proceeding, which are discussed later in this declaration. To illustrate with some examples:

- Ex. 1011 (Ma), 811, Figs. 2–3 (studying effect of Liq-doped ETL by forming test OLEDs at various doping concentrations and comparing against an undoped OLED as a control).
- Ex. 1020 (Pfeiffer), 1634–1636, Figs. 1, 3–4 (studying effect of doping charge-transport layers on phosphorescent OLED performance by forming OLEDs with Li-doped ETLs and an OLED with LiF EIL, and comparing against undoped PHOLED as control).
- Ex. 1028 (Liu, 2002), 211–212, Figs. 1, 2 and 4 (studying mechanisms of Liq by forming test OLEDs with Liq EIL and comparing against OLEDs with Ca EIL or LiF EIL as controls; also studying effect of different cathodes by forming test OLEDs with Liq EIL and varying metals used as cathode).
- Ex. 1018 (He, 2004), 5773–5774, Figs. 1, 3–4, Table 1 (studying the effect of an n-doped ETL in *p-i-n* OLEDs by comparing test OLEDs with BPhen doped with cesium as ETL against *p-i-i* OLEDs with undoped BPhen and an EIL of LiF as a control; also studying effect of emission layer thickness on quantum efficiency, power efficiency, and operating voltage of *p-i-n* OLEDs by forming *p-i-n* OLEDs with varying emission layers).

Consistent with the practices reflected in the OLED literature, a POSITA would not have needed to fully understand the mechanism of a material in order to be motivated to use that material or reasonably expect success in constructing an OLED with that material.

70. Further, many of the most important innovations in OLEDs at the time were coming from academic laboratories staffed with graduate students, and not exclusively from large teams of scientists. Notable examples were the discovery of phosphorescent OLEDs at Princeton University (the same research group where I received my training as a graduate student) and the demonstration of polymer OLEDs by the University of Cambridge. Research in academic groups often led to related or spin-out companies working in OLEDs. For the aforementioned groups, the companies Universal Display Corporation and Cambridge Display Technologies are notable related and/or spin-out companies.

71. At the time of the '250 patent, I would have qualified as at least a POSITA. As discussed above, I was actively working in the field at that time. I had extensive experience in the research of organic electronic materials and devices, and more broadly in the areas of semiconductor physics and materials science. I have personally trained students who developed into POSITAs around the time of the '250 patent. My opinions herein are informed by my own knowledge and personal

experience, as well as my observations of others of various skill levels working in the field.

### **VIII. CLAIM CONSTRUCTION**

72. 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.

73. I have also been informed by counsel that one term (“electromagnetic radiation . . .”) recited in the parent ’425 patent was construed in a district court litigation and have been asked to consider the construction and related discussion that I discuss below.

74. I have also considered the claims, specification, and the file history of the ’250 patent. Ex. 1001 (’250 patent); Ex. 1002 (’250 patent File History). I have also reviewed the file histories of the ’425 patent, U.S. patent application no. 16/790,198; U.S. patent application no. 15/651,508, and U.S. patent application no. 13/139,514 (“’514 Application”) (Ex. 1014–Ex. 1017). In particular, I have considered the Applicant’s explanation concerning “volume structure” as I discuss below.

**A. “Electromagnetic radiation in a spectral range from infrared radiation to UV radiation”**

75. I have been informed by counsel that Patent Owner has sued defendants Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. in district court and has argued that they infringe the ’425 patent (which the ’250 patent claims priority and shares the same specification).

76. In district court, Patent Owner argued that the term “electromagnetic radiation in a spectral range from infrared radiation to UV radiation” means “electromagnetic radiation having a spectrum of wavelengths that fall anywhere within the spectral range from a wavelength in the infrared radiation range to a wavelength in the UV radiation.” Ex. 1045, 47–48. The district court issued a claim construction order construing this term to mean “electromagnetic radiation with one or more wavelengths in a spectral range anywhere between the lowest frequency of the UV spectrum and the highest frequency of the IR spectrum.” Ex. 1045, 48. The defendants in district court proposed this term’s meaning as “electromagnetic radiation in a spectral range that includes the full spectrum from infrared radiation to UV radiation.” Ex. 1045, 47. I also understand that, in IPR2024-01095, Petitioner argues that this term encompasses the prior art’s “white light” emission.

77. As I provide my opinions below for element [1F/6F/10F], the prior art (e.g., Suzuki and Diekmann) teaches “white light” encompassed by this term under any construction discussed above.

78. I first note that the prior art's "white light" covers the entire spectrum from infrared-to-UV and corresponds to the claimed "radiation in a spectral range from infrared radiation to UV radiation." Suzuki, [0319] (disclosing "any desired light emission color," including "[w]hite light"); Diekmann, 76, 91; *see also* Diekmann, 40–41, 44, 66, 70, 122, 157. In fact, during prosecution of the '514 Application, to which the '250 patent claims priority, the Examiner determined that Diekmann discloses "a plurality of functional layers . . . which comprise at least one radiation-emitting region in which electromagnetic radiation is generated during the operation of the organic light-emitting diode . . . wherein the organic light-emitting diode *generates electromagnetic radiation in the spectral range from infrared radiation to UV radiation during operation.*" Ex. 1017, 1407 (emphasis added).

79. I also note that the OLEDs in the prior art (e.g., Suzuki and Diekmann) generate "white light" that includes visible wavelengths that "fall anywhere within the spectral range from a wavelength in the infrared radiation range to a wavelength in the UV radiation" and "in a spectral range anywhere between the lowest frequency of the UV spectrum and the highest frequency of the IR spectrum" under Patent Owner's and the district court's constructions in the district court litigation (Ex. 1045, 47–48).

80. As I explain below, the prior art (e.g., Suzuki and Diekmann) teaches this term which encompasses “white light” covering the full infrared-to-UV spectrum, or at least a wavelength falling anywhere between the lowest frequency of the UV spectrum and the highest frequency of the IR spectrum.

**B. “Volume Structure”**

81. As I mentioned above, the '250 patent claims priority to the '514 Application. During prosecution of the '514 Application, in order to overcome the numerous rejections issued by the Examiner, the Applicant repeatedly sought to explain the meaning of the term “volume structure.” The same term is recited in claims 3, 11, and 16 of the '250 patent. Specifically, the Applicant argued that “volume structure” is “a term of art to a person of ordinary skill in the pertinent art,” and that it is distinct from “surface structure”:

Thus, in solids there is a well-ordered molecular, atomic or ionic arrangement. Part of the atoms or molecules of the solid are ordered at the surface of the solid and is called surface structure. Part of the atoms or molecules of the solid are ordered inside the solid, wherein every atom or molecule has neighbors. This part is called a “volume structure.”

Ex. 1017, 1386–1387; *see also* Ex. 1017, 1240–1242, 1313–1314.

82. Regarding this term, the Applicant also argued that “[i]n the present application, the term ‘volume structure’ was chosen to comprise any structure

ranging from polycrystalline to polyamorphous.” Ex. 1017, 1241; *see also* Ex. 1017, 1313–1314, 1386–1387. The Applicant further stated that “examples of volume structures” include “crystalline, partly crystalline and/or polycrystalline or completely amorphous.” Ex. 1017, 1241; *see also* Ex. 1017, 1313–1314, 1386–1387. The Applicant further explained that a crystal structure has “long range order and symmetry,” whereas in an amorphous structure, “atoms or molecules do not have a long range order, but a short range order.” Ex. 1017, 1314.

83. Accordingly, the Applicant described that the term “volume structure” covers the part of the atoms or molecules inside a solid, and examples of “volume structure” include crystalline to completely amorphous structures. As I explain below for claim 3, the prior art (e.g., Lee) discloses the structure described by the Applicant.

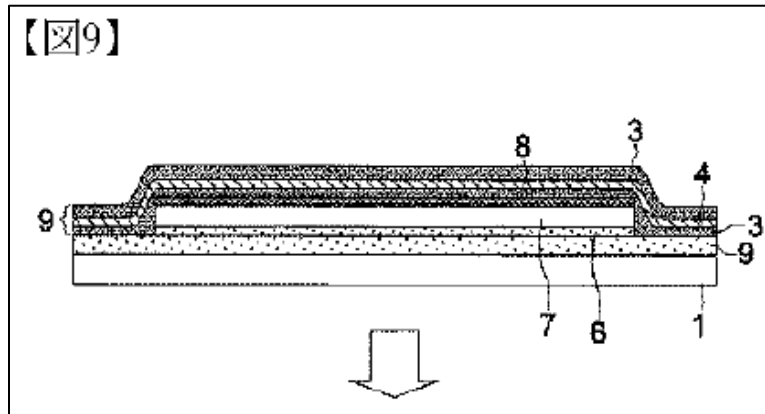
## **IX. OVERVIEW OF THE PRIOR ART REFERENCES**

### **A. Suzuki (Ex. 1007)**

84. Suzuki is a Japanese patent application publication published on October 25, 2007. Suzuki, 1. I am informed that Suzuki is therefore prior art to the ’250 patent.

85. Similar to the ’250 patent, Suzuki relates to “an organic electroluminescent device” using a “gas barrier resin substrate material”

encapsulation. Suzuki, [0001]. Figure 9 of Suzuki, seen below, illustrates an embodiment of the OLED disclosed by Suzuki:



Suzuki, Fig. 9.

86. For example, Suzuki discloses OLED devices with a resin substrate material 1, a gas barrier thin film laminate 9, an anode 6, an organic layer 7 (including a hole transport layer, a light emission layer, an electron transport layer), a cathode 8, and a gas barrier thin film laminate 9, which includes a buffer film 3, barrier film 4, another buffer film 3, and silicon oxide film used for encapsulation. Suzuki, [0274].

87. Suzuki explains that the “electron transport layer” in the OLED devices is of “high n nature doped.” Suzuki, [0333]. Suzuki’s devices include the hole blocking layer between the “light emission layer” and the n-doped “electron transport layer.” Suzuki, [0283], [0287], [0296]–[0297], [0322].

88. In addition, Suzuki’s emission layers include iridium compounds. Suzuki discloses that its OLED devices generate “white light” from the emission

### B. Diekmann (Ex. 1009)

90. Similar to the '250 patent, Diekmann relates to “an organic lighting device and lighting equipment with such a lighting device” Diekmann, 1. Figure 2A of Diekmann, seen below, illustrates an embodiment of the OLED disclosed by Diekmann:

91. Diekmann explains that the OLED seen above in Figure 2A comprises a “substrate 1 having a first main surface 101, to which the first electrode 2 is applied within an active region 5 of the substrate 1.” Diekmann, 91. In addition, “[a]n

organic layer stack 4 with at least one layer 401 suitable for generating light is arranged on the first electrode 2, to which the second electrode 3 is applied.”

Diekmann, 91. Diekmann also explains that “the first electrode 2 on the substrate 1 is the anode and the second electrode 3 on the organic layer stack 4 is the cathode.”

Diekmann, 91. Diekmann further explains that “[o]n its outer side facing the cathode, the organic layer stack 4 has a doped layer 402 with a dopant 410” which “advantageously increases the injection of electrons from the cathode into the organic layer stack.” Diekmann, 91. Diekmann similarly explains that the advantage of doping this layer is that it “advantageously increases the conductivity of the doped organic layer and, in the case of an n-doped layer adjacent to the cathode, leads to better injection of electrons from the cathode into the organic layer stack or, in the case of a p-doped layer adjacent to the anode, to better hole injection from the anode into the organic layer stack.” Diekmann, 10. Additionally, there is a thin-film encapsulation 6 that is “applied directly to the second electrode.” Diekmann, 92.

92. Diekmann explains that its OLED is “designed to be transparent to visible light, in particular to light generated by the organic layer stack.” Diekmann, 92. To achieve this, Diekmann explains that the substrate, the first electrode, the organic material in the organic layer stack, the second electrode, and the thin-film encapsulation, are all designed to be “transparent to visible light.” Diekmann, 92, 94.

**C. Ma (Ex. 1011)**

93. Ma is a research publication published on August 29, 2008. Ma, 810. I am informed that Ma is therefore prior art to the '250 patent.

94. Ma was published in the journal Synthetic Metals by the publisher Elsevier. Since before the time of the '250 patent, Elsevier was a well-established publisher of academic literature. At the time of the '250 patent and even earlier, I routinely reviewed papers found in journals published by Elsevier in my own work relating to OLEDs. I regularly searched for and found literature relating to OLEDs using ScienceDirect, a searchable database of scientific publications from Elsevier, as well as Web of Science and Google Scholar. By August of 2008 and earlier than that, I was retrieving journal articles online routinely. Whenever articles became available online was when I and other researchers were reading them (rather than in paper copy). I also read Synthetic Metals at the time. Articles published in Synthetic Metals were relevant to the subject matter of the '250 patent.

95. For Ma and other articles in Synthetic Metals, the face of the article shows dates for when an article was “received,” “accepted,” and “available online.” Based on my experience, the “received” date reflects the date that the author(s) made the initial submission to the publisher. After an article is “accepted” by the editors, the substantive content of the article cannot be changed. The “available online” date

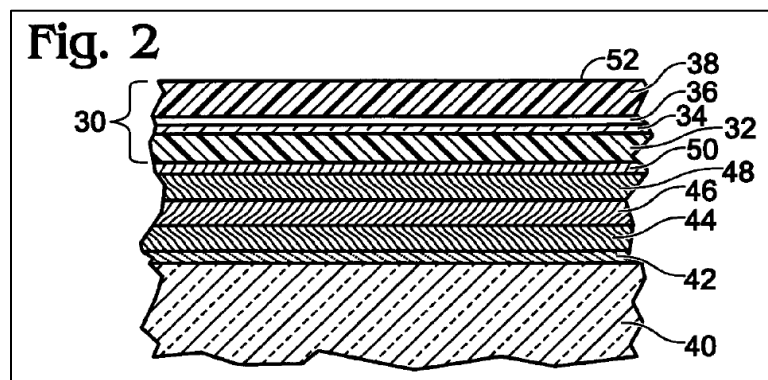
indicates the date the article was published and made accessible online, for example on the journal website.

96. Ma is a study of “[o]rganic light-emitting diodes with 8-hydroxy-quinolinato lithium doped 4’7-diphenyl-1,10-phenanthroline as electron transport layer” and describes the benefits of doping “8-hydroxy-quinolinato lithium (Liq)” into an electron transport layer so as to improve the OLED efficiency and performance. Ma, Abstract. Ma conducted research and testing concerning the “conductivity of carrier transport layers with different doping concentration” and concludes that a “doping concentration of the Liq” (short for 8-hydroxy-quinolinato lithium) in the electron transport layer results in increased current density. Ma, Abstract, 813. Ma also explains that a certain doping ratio of Liq to Bphen (electron transport layer material) can “improve the electron transport ability of the co-deposited layer.” Ma, 813. Specifically, Ma attributes the improved current and power efficiency to “the improved conductivity of the transport layers and the efficient charge balance in the emission zone.” Ma, Abstract. Ma further notes that improved charge balance would be expected to improve OLED stability. In a device where “the holes and electrons have a good balance . . . we can predict that the complete [device] should have a good lifetime.” Ma, 814.

**D. Lee (Ex. 1012)**

97. Lee is a U.S. patent application publication filed on December 8, 2004, and published on July 7, 2005. Lee, 1. I am informed that Lee is therefore prior art to the '250 patent.

98. Lee relates to “an organic light emitting device having a barrier for protection against environmental degradation.” Lee [0002]. Figure 2 of Lee, below, illustrates an embodiment of such an organic light emitting device. Lee explains that the OLED is formed on a substrate 40 and includes “a transparent anode 42, an organic hole transport layer 44, an organic light emitting layer 46, an organic electron transport layer 48, and a cathode 50,” for example, as shown in Figure 2. Lee, [0022]. Lee specifies that this is merely an exemplary configuration and “any other suitable architecture may be used.” Lee, [0022].



Lee, Fig. 2.

99. Lee discloses an OLED with a multi-layered encapsulation, including parylene-based polymer layers 32 and 38 sandwiching an inorganic barrier layer 34,

that improves OLED lifetime. Lee, [0022]. Layer 32 is formed by depositing a “semi-crystalline parylene-based polymer,” and layer 38 is formed by depositing a semi-crystalline parylene-based polymer and then annealing it to form a “highly crystalline parylene-based polymer” with different amorphicity. Lee, [0021]. This annealing process increases the crystallinity of the polymer film. Lee, [0024]. Thus, the layers 32 and 38 in Lee’s OLED have different levels of crystallinity: “the first semi-crystalline and second highly crystalline parylene-based polymer layers respectively have at least 10% and up to 70% of crystallinity.” Lee, [0023]. Lee provides that its encapsulation layers “prevent the propagation of defects between inorganic layers” and “help block water vapor and oxygen permeation into the OLED.” Lee, [0020].

## **X. SPECIFIC GROUNDS FOR CHALLENGE**

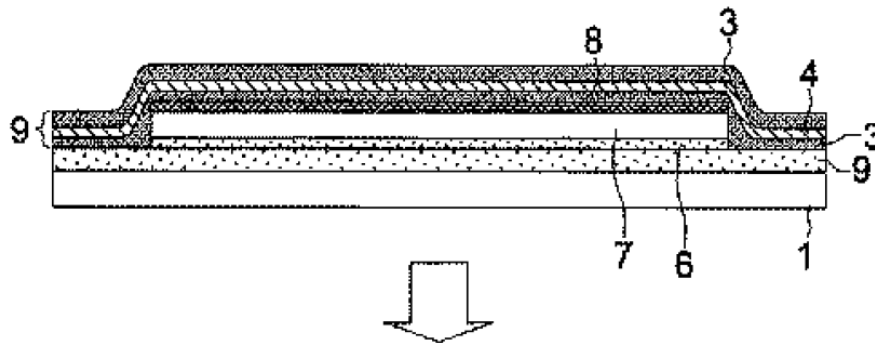
### **A. Grounds 1-2: Suzuki and Ma Render Obvious Claims 1-2, 4-5, and 8-10 (Ground 1); Suzuki Anticipates or Renders Obvious Claims 6-8 (Ground 2)**

#### **1. Independent Claims 1, 6, and 10**

##### **i. [1Pre/6Pre/10Pre] A device comprising:**

100. Suzuki discloses a device. Specifically, Suzuki discloses OLEDs, and devices that incorporate OLEDs. *See, e.g.*, Suzuki, [0001], [0274]–[0279]. For example, Figures 9 and 10 in Suzuki depict an “organic electroluminescent [(EL)] device”:

【図9】



Suzuki, Fig. 9, Fig. 10, [0274]–[0279], [0286].

101. Suzuki discloses that the devices using “the organic EL element . . . can be used as a display device, a display, and various light-emitting light sources.” Suzuki, [0343]–[0345]. Suzuki also explains that the “[d]isplay devices and displays include TVs, PCs, mobile devices” and “[i]llumination devices.” Suzuki, [0343]–[0345].

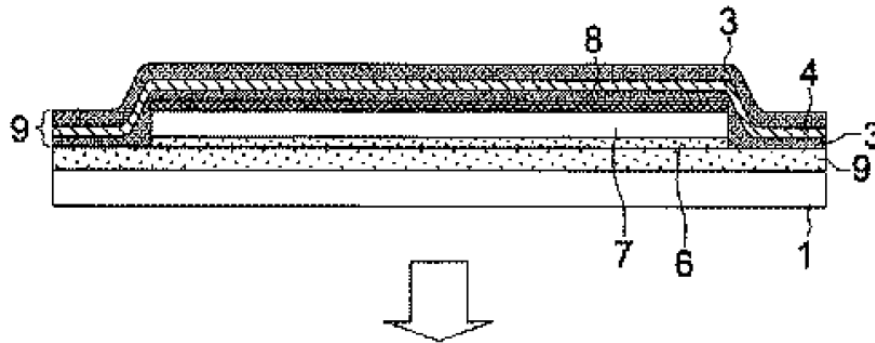
102. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**ii. [1A/6A/10A] an organic light-emitting diode comprising:**

103. Suzuki discloses an organic light-emitting diode. As discussed above, Suzuki discloses OLEDs or “organic EL device[s].” Suzuki, [0274]–[0279], [0287]. A POSITA would have understood that an “organic EL device” is another name for an organic light emitting diode (OLED).

104. Suzuki discloses an “organic EL device” as shown in Figure 9:

【図9】



Suzuki, Fig. 9, Fig. 10, [0274]–[0279], [0286].

105. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

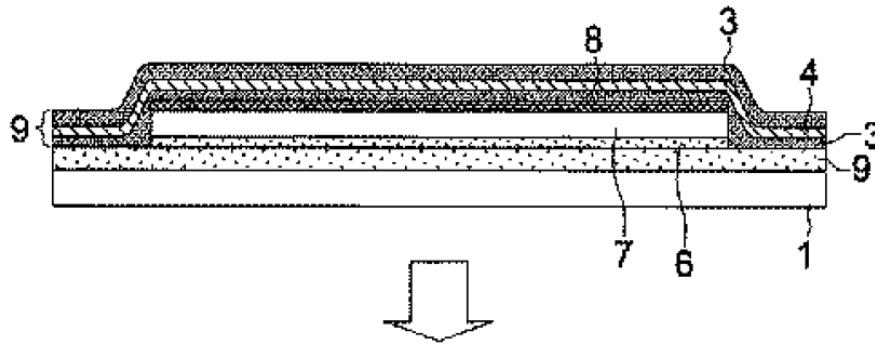
**iii. [1B/6B/10B] an organic layer sequence,**

106. Suzuki discloses this element. As discussed above, Suzuki discloses OLEDs. Suzuki also explains that its OLEDs include “an organic EL element comprising an anode, a light emission layer[,] an organic layer, and a cathode.” Suzuki, [0274].

107. Suzuki discloses that the “organic EL element” includes an anode 6, “an organic layer (comprising a hole transport layer, a light emission layer, an electron transport layer, and the like),” and a cathode 8. Suzuki, [0274]–[0279], [0287]. For instance, Suzuki shows an organic layer sequence including the anode, an “organic layer” (including several organic layers), and the cathode as illustrated

in its Figure 9 example below:

【図9】

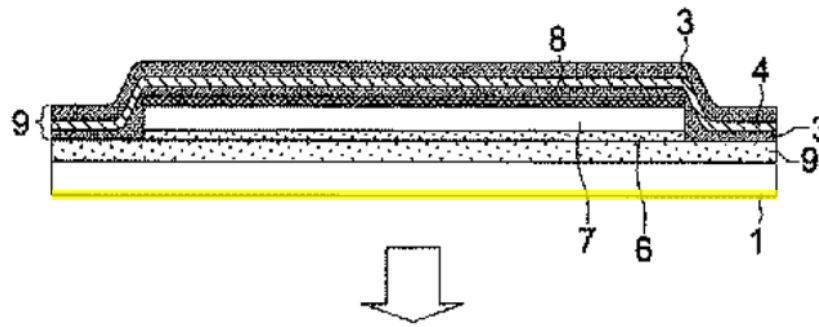


Suzuki, Fig. 9, Fig. 10.

**iv. [1C/6C/10C] a radiation exit area, and**

108. Suzuki discloses this element. For instance, Suzuki discloses that the OLEDs generate light that may exit from the bottom after passing through the resin substrate material 1. Suzuki, [0274]. A POSITA would recognize this area where light exits the OLED to be a radiation exit area. A radiation exit area is highlighted yellow below in Figure 9 as an example, where the arrow indicates the direction of light. Suzuki, [0274].

【図9】



Suzuki, Fig. 9, Fig. 10, [0274]–[0279]. Moreover, a POSITA would have understood that a radiation exit area is present at a surface of any component of the OLED below the substrate where the light exits.

109. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

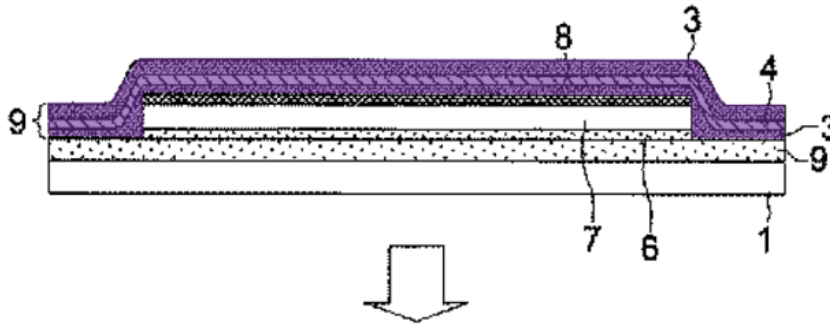
**v. [1D/6D/10D] an encapsulation [wherein the encapsulation forms a seal of the organic layer sequence against environmental influences],<sup>5</sup>**

110. Suzuki discloses this element. Suzuki teaches that its OLEDs include an encapsulation, “gas barrier thin film laminate 9” (purple below). Suzuki, [0274]. Suzuki explains that “gas barrier thin film laminate 9” includes a “buffer film 3,” “barrier film 4,” another “buffer film 3,” and silicon oxide film. Suzuki, [0275]–[0279], Figs. 9–10. Figure 9 below illustrates an example.

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<sup>5</sup> This bracket is recited only in [1D].

【図9】



Suzuki, Fig. 9, Fig. 10.

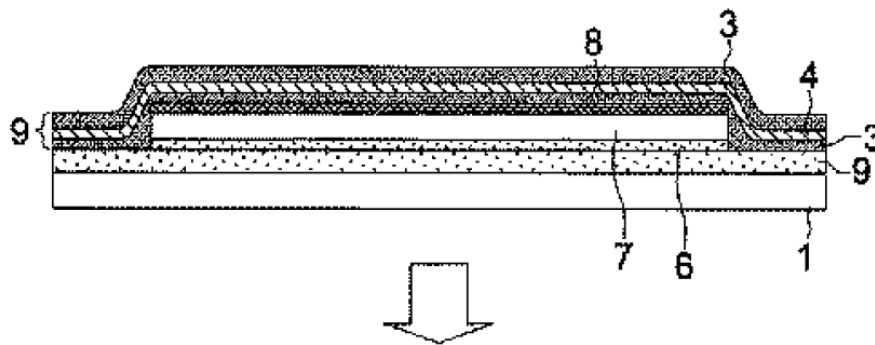
111. For instance, the encapsulation is “formed on the cathode and sealed,” creating “the sealed organic electroluminescent device.” Suzuki, [0273]–[0274]. A POSITA would have understood that the “gas barrier thin film laminate 9” is an encapsulation that seals the organic EL element. Suzuki also discloses that the combination of films discussed above, including the buffer films and barrier films, forms a seal and protects the organic layer from environmental influences as the “barrier film” has “low gas and moisture vapor permeability” and laminating films provide good “gas barrier performance.” Suzuki, [0067], [0416]. Thus, a POSITA would have recognized that the “gas barrier thin film laminate 9 protects the sealed from environmental influences, including moisture.

112. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**vi. [1E/6E/10E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,**

113. Suzuki discloses this element. As discussed above, Suzuki teaches that its OLED comprises an organic layer sequence sealed by an encapsulation. For example, Suzuki discloses organic EL element with the anode 6, organic layer 7, and cathode 8 as well as the gas barrier thin film laminate 9 are disposed on a carrier, a resin substrate material 1:

【図9】



Suzuki, Fig. 9, Fig. 10, [0121], [0274], [0275]–[0279].

114. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

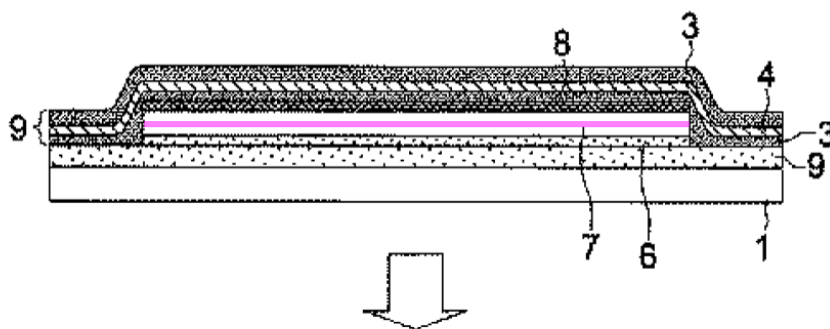
**vii. [1F/6F/10F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,**

115. Suzuki discloses this element. Suzuki discloses that the organic layer 7

of the organic EL element (including the anode 6, organic layer 7, and cathode 8) has “a light emission layer.” Suzuki further describes that this light emission layer includes a radiation-emitting region for emitting light. Suzuki, [0274]–[0279].

116. The radiation-emitting region is indicated in pink highlighting below as an example:

【図9】



Suzuki, Fig. 9, Fig. 10.

117. Suzuki explains that the light emission layer of organic layer 7 generates light through electron-hole recombination. Suzuki, [0299]. Suzuki also explains that the radiation-emitting region provides white light in a spectral range from infrared to ultraviolet radiation.

118. For example, Suzuki describes the generation of “white light” from the radiation-emitting region to cover such a full spectral range from infrared radiation to UV radiation, including visible light. *See, e.g.*, Suzuki, [0369]. For instance, Suzuki states that “by using a plurality of dopant compounds, it is possible to mix

different light emissions, thereby obtaining any desired light emission color.” *See, e.g.,* Suzuki, [0316]–[0319], [0369]–[0370].

119. Suzuki further discloses that the OLEDs generate the full spectral range from infrared to ultraviolet radiation, including visible light, by explaining that “[w]hite light emission” is achieved “by adjusting the type and doping amount of phosphorescent compounds, and can be applied to illumination and backlighting.” Suzuki, [0316]–[0319], [0348], [0369]–[0370]. Using the emitted full spectral range, Suzuki implements the OLEDs for backlights, full-color displays, and providing white light to filter and output desired colors using filters. Suzuki, [0336], [0348], [0373]–[0374].

120. In addition, Suzuki explains that the films within the OLED have “a uniform light absorption, and a light absorption rate of 0.1% or less” for the “380-800 nm” range, which covers some infrared and UV radiation. Suzuki, [0096], [0118], [0264] (describing visible light in “the range of 400-700 nm”). In fact, Suzuki describes near-infrared and near-UV radiation in the wavelength around 400 and 700 nm, respectively, by describing visible light in “the range of 400-700 nm.” Suzuki, [0264]. Suzuki teaches having minimum or no absorption in the “380-800 nm” range for the films within the OLED devices to increase transmission of generation radiation with wavelengths in the 380–800 nm range. Accordingly, a POSITA would have appreciated that Suzuki’s white light includes radiation from

infrared to UV wavelengths.

121. As I explain above in §VIII.A, prior art describes white light as providing “a spectrum with wavelengths in an ultraviolet to infrared spectral range.” Diekmann, 40–41, 44, 66, 70, 76, 91, 122, 157.

122. Based on the above, and also for the reasons explained in §VIII.A (Claim Construction), Suzuki teaches OLEDs generating “white light” that is encompassed by “electromagnetic radiation in a spectral range from infrared radiation to UV radiation.” Specifically, Suzuki teaches “white light” covering the full infrared-to-UV spectrum, or at a minimum, wavelengths falling “anywhere between the lowest frequency of the UV spectrum and the highest frequency of the IR spectrum” because the emitted white light includes visible wavelengths.

123. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**viii. [1G/6G/10G] wherein the organic layer sequence comprises an electron transport layer that is n-doped[; and]**

124. Suzuki discloses or renders obvious this element alone or in view of Ma. As I explained above, Suzuki discloses that the organic EL element with organic layer 7 has “an electron transport layer.” Suzuki, [0274]. Suzuki discloses that the “electron transport layer comprises a material having the function of transporting electrons” and that the “electron transport layer can be a single layer or a plurality

of layers.” Suzuki, [0274], [0283], [0286]–[0287], [0329]–[0333]. Suzuki specifies using “an electron transport layer with a high n nature doped with impurities” and lists examples of this ETL. Suzuki, [0333]. A POSITA would have understood that “an electron transport layer with a high n nature doped with impurities” refers to an electron transport layer which has been n-doped. Moreover, Suzuki cites an article by Gufeng He et al., the same article I discussed above in §V.A.4 as an “[e]xample” of such “an electron transport layer with a high n nature doped with impurities” as taught by Suzuki. *See* Suzuki, [0333] (citing “J. Appl. Phys., 95, 5773(2004)”; Ex. 1018 (He). He teaches an OLED with a “hole injection and transport layer (HTL)” which is “*p*-doped” and an “*n*-doped electron transport layer.” Ex. 1018 (He), Abstract. The article further teaches that OLEDs with this “*p-i-n*” configuration (i.e., a configuration which has a *p*-doped HTL and *n*-doped ETL) feature “efficient carrier injection from both contacts into the doped transport layers and low ohmic losses in these highly conductive layers.” Ex. 1018 (He), Abstract, 5774–5775, Fig. 3. As such, a POSITA would have understood that Suzuki’s reference to “an electron transport layer with a high n nature doped with impurities” is describing an electron transport layer which has been n-doped.

125. Even had Suzuki not disclosed that its doped electron transport layer was specifically n-doped, it would have been obvious to a POSITA to use an n-doped ETL in the OLEDs as taught by Suzuki and Ma.

126. A POSITA would have been motivated to include an n-doped ETL in Suzuki's OLEDs to improve electron injection from the cathode and enhance electron transport to the light-emitting region. Ma, 812–814. As explained above in §V.A.4, by 2008, using n-doped electron transport layers in both fluorescent and phosphorescent OLEDs, and the advantages for doing so, were well known in the art. Ex. 1024 (Walzer), 1254–1255; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross); Diekmann, 10, 91, 119. A POSITA would have appreciated the desire for improved device characteristics, such as lower driving voltage and better power efficiency, and that use of an n-doped ETL would achieve that objective. Ma, 810; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross). And Suzuki already discloses using “a high n nature doped” ETL and cites references using n-doped electron transport layers due to their benefits. Suzuki, [0333]; Ex. 1018 (He).

127. A POSITA would have had a reasonable expectation of success at least because n-doped ETLs were widely used due to their contribution to increases in OLED performance as discussed above. Using n-doped ETLs in Suzuki's OLEDs would have been a straightforward, routine modification to Suzuki, particularly as Suzuki refers to numerous “[e]xamples” for such a component. Suzuki, [0333]. The prior art also has numerous examples. Ma, 812–814; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross); Diekmann, 10, 91, 119; *see also* §X.A.1.x.

**ix. [1H/6H/10H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound; and**

128. Suzuki discloses this element. As I discussed above, Suzuki discloses the organic EL element with organic layer 7 comprising a “light emission layer.” Suzuki, [0274]–[0279], [0287], [0299].

129. Suzuki further teaches that, to achieve “even higher light emission efficiency,” this light emission layer “preferably contains a host compound and a dopant compound.” Suzuki, [0300]. And Suzuki discloses that its OLEDs use “iridium compounds” for its phosphorescent dopants. Suzuki, [0302]–[0301], [0303]. Suzuki further provides examples of such iridium compounds well known in the art. Suzuki, [0303]–[0304], [0307]–[0308]. In addition, Suzuki provides an example of fabricating emissive layers with iridium compounds. Suzuki, [0409].

130. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**x. [1I/10I] wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

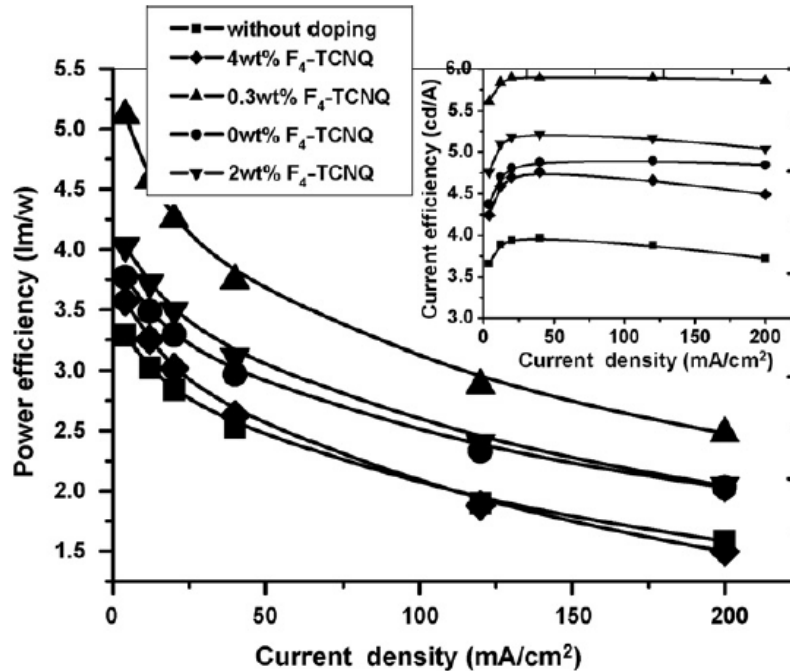
131. This element would have been obvious to a POSITA based on Suzuki in view of Ma. As I explained above, Suzuki discloses, and at a minimum, renders obvious using an n-doped electron transport layer, alone or in view of Ma. *See* §X.A.1.viii. It would have been obvious to a POSITA to use 8-hydroxyquinolinolato-lithium as the dopant in Suzuki’s n-doped electron transport layer, as

taught by Ma. Ma teaches an OLED with an electron transport layer n-doped with 8-hydroxy-quinolinatolithium (“Liq”) and its benefits. Ma, Abstract, 810–814.

132. A POSITA would have been motivated to use an Liq-doped ETL as taught by Ma in Suzuki’s OLEDs to obtain the known benefits of Liq-doped ETLs to their performance. The use of Liq-doped electron transport layers in OLEDs was a known practice with known benefits. *See* §V.A.7; Ex. 1034 (Endo), L800, L802; Ma, 810, 811; Ex. 1040 (Choi), 062101-1. At the time, it was highly desirable to create OLEDs with a low operating voltage and high efficiency, and it was known that Liq-doping the electron transport layer was one way of realizing these benefits. This understanding is reflected, for example, in Ma, which explains that “[s]ince the discovery of organic light-emitting devices (OLEDs), there has been a considerable interest in developing OLEDs with high efficiency.” Ma, 810. Ma further explains “it is critical to enhance the carrier injection from the electrode to the transporting layer and to increase the transport conductivity” to improve power efficiency. Ma, 810. *See also* §V.A.7; Ex. 1034 (Endo), L800, L802; Ma, 810, 813.

133. Ma discloses an OLED with an Liq-doped electron transport layer. Ma tests the power efficiency of four different OLEDs, one with an undoped ETL and HTL, and four others with a fixed n-doping of Liq in the ETL and a varying amount of p-doping in the HTL. As shown in Ma’s Figure 3 below, Ma finds that “the current and power efficiencies” are improved between the control device with no doping

(squares) and the optimized device that has both n-type and p-type doping (up triangles).



Ma, Fig. 3.

134. Ma concludes based on this testing that “[t]his significant enhancement in the device performance is attributed to the improved transport conductivity of both p-doped HTL and n-doped ETL at a particular doping concentration of F<sub>4</sub>-TCNQ into m-MTDATA and Liq into Bphen” and, “[a]s a result, the high carrier balance is reached in the emission zone, which leads to the enhanced current and power efficiency at low driving voltage.” Ma at 812. Therefore, Ma explicitly teaches that the current and power efficiency of an OLED can be increased at a low driving voltage by utilizing an ETL which is doped with Liq.

135. Accordingly, Ma discloses that a “doping concentration of the Liq” in the electron transport layer leads to an increase in current density. Ma, 811–814. In fact, as I explained above in §V.A.4, it was understood in the art at the time, as explained in Ma, that to “enhance power efficiency, it is critical to enhance the carrier injection from the electrode to the transporting layer and to increase the transport conductivity.” Ma, 810. For example, Ma teaches that doping “Liq to Bphen can improve the electron transport ability of the co-deposited layer.” Ma, 813. Ma further notes that improved charge balance would be expected to improve OLED stability. In a device where “the holes and electrons have a good balance . . . we can predict that the complete [device] should have a good lifetime.” Ma, 814. A POSITA would have been motivated to use an Liq-doped electron transport layer in Suzuki’s OLEDs to achieve these benefits.

136. Indeed, Suzuki already contemplates an n-doped electron transport layer for “efficient carrier injection” and “highly conductive” ETLs, so using an Liq-doped electron transport layer merely involves using a different dopant. *See* Ex. 1018 (He), Abstract (cited in Suzuki, [0333]). As I explained above, Liq was known in the art at the time to have good electron injection and transport properties. *See* §V.A.7 A POSITA thus would have recognized that Liq would be an advantageous dopant for Suzuki’s doped electron transport layer.

137. Moreover, a POSITA would have been motivated to use Liq as the n-

dopant as it was understood that doping with large molecules such as Liq provides benefits. *See* §V.A.7; Ex. 1018 (He), 5775 (noting that a larger size dopant “reduces the probability” of the dopant “diffusing into the emission layer to quench excitons”). For example, Diekmann explains that “doping advantageously increases the conductivity of the doped organic layer” and that the “dopant preferably has a low diffusion constant . . . as is usually the case with large atoms or molecules.” Diekmann, 10.

138. Liq has a larger molecular weight than Diekmann’s preferred n-dopants, and n-dopants contemplated by Suzuki. The molecular weight for Liq, LiF, Barium, and Cesium are as follows:

- Liq: 151.09 g/mole. *See* Ex. 1029 (Lumtec, Liq, <https://www.lumtec.com.tw/products-view.php?ID=327>);
- LiF: 25.94 g/mole. *See* Ex. 1030 (Lumtec, LiF, <https://www.lumtec.com.tw/products-view.php?ID=371>);
- Barium: 137.327(7) g/mole. *See* Ex. 1031 (CIAAW, Barium, <https://www.ciaaw.org/barium.htm>);
- Cesium: 132.90545196(6) g/mole. *See* Ex. 1032 (CIAAW, Cesium, <https://www.ciaaw.org/caesium.htm>).

Ex. 1029–Ex. 1032. A POSITA thus would have recognized Liq would be advantageous in reducing dopant diffusion.

139. Suzuki discloses an n-doped layer, and Diekmann explains that large dopant size is one factor for selecting preferred dopants. Diekmann, 10. Liq is one such dopant. Suzuki and Diekmann are not limited to any preferred dopants, and does not teach away from other n-dopants. *See* Diekmann, 91 (“dopant 410 can be *for example* cesium, barium or lithium fluoride”); Suzuki, [0333].

140. A POSITA would further have recognized that Liq could have additional benefits over n-dopants like those contemplated by Suzuki, and would not view existing dopant materials contemplated by Suzuki as the final, optimized solution. For example, Zheng et al. noted that “[t]o achieve a balanced injection of carriers, it is common to use low-work-function metals such as Li, Ca, Mg, etc., to enhance electron injection into organic materials. However, such metals are not stable in air and need to be protected in the device processing, and sometimes may react with and diffuse into organic material and deteriorate the device.” Ex. 1039 (Zheng), 252. Thus, a POSITA would have expected Liq to be more stable than low-work-function metals, such as cesium and barium, when used to n-dope an ETL. Zheng et al. further noted that insulating materials like LiF “need quite high temperature for evaporation and accurate control of thickness.” Ex. 1039 (Zheng), 253. Liu et al. also taught that Liq can be made thicker than LiF without significantly compromising EL characteristics such as power efficiency, because Liq has electron transporting properties while LiF is insulating and can block electron injection at

greater thicknesses. Ex. 1028 (Liu), 212–213. Thus, a POSITA would have expected that Liq would be easier to process and have better EL characteristics than LiF when used to n-dope an ETL. Ex. 1034 (Endo), L802, Figs. 4, 5 (showing better luminance and current density characteristics for Liq-doped ETL than LiF-doped ETL).

141. Accordingly, a POSITA would have recognized that Liq increases ETL conductivity, has good electron injection and transport properties, and has a larger molecular weight suitable for use as an n-dopant, consistent with the well-known conceptions of n-doping in Suzuki and the art, and would have been motivated to use Liq as the dopant in Suzuki's electron transport layer with a high probability of success, particularly considering Suzuki already contemplates an analogous n-doped layer for electron transport. Suzuki, [0333]; Ma, 813–814; *see also* Ex. 1028 (Liu), 211, 212–214; Diekmann, 10, 91, 119; *compare* Ex. 1029 *with* Ex. 1030–Ex. 1032.

142. A POSITA could readily have implemented an Liq-doped electron transport layer in Suzuki's device. Such a configuration would have amounted to implementing a known technique (Liq-doping the ETL) of Ma to improve similar OLEDs (e.g., OLEDs using an n-doped ETL) taught by Suzuki in the same way. By the time of the '250 patent, conductive doping of transport layers was a mature technology. *See* §V.A.4. Indeed, Suzuki acknowledges the benefits of using n-doped electron transport layers as in Ma. Suzuki, [0333] (citing Ex. 1018 (He)); Ma, 810–814. For example, He uses an n-doped ETL in an OLED having an iridium-

containing compound (Ir(ppy)<sub>3</sub>) in the emissive layer, based on the same type of electron transport layer and emissive layer taught by Ma and Suzuki, respectively.

143. Further, LiF is a known n-dopant. *See* Diekmann, 10. It is well-established that the mechanism by which LiF improves electron injection is analogous to the mechanism by which Liq improves electron injection. Ex. 1028 (Liu), 213 (lithium released from LiF/Liq dopes organic layer); Ex. 1039 (Zheng), 254 (electron injection enhancement with Liq “very similar” to LiF). Thus, a POSITA would have understood Liq is a suitable n-dopant to use in place of n-dopants like LiF, and further would have reasonably expected success in creating OLEDs with Liq-doped ETL, just as others have succeeded in creating OLEDs with an LiF-doped ETL. It is well within the skill of a POSITA to swap out one n-dopant in the ETL for another.

144. A POSITA would also have reasonably expected success in using Liq as the n-dopant in Suzuki’s ETL because Suzuki already includes blocking layers between the doped ETL and emissive layer. Suzuki at [0287], [0296]–[0298]. Blocking layers have long been known to be effective in reducing dopant diffusion and mitigating exciton quenching, including for n-dopants like lithium and cesium. *See* §V.A.5. Because Liq is a larger molecule with a higher molecular weight, *see* Diekmann, 10 (“the dopant preferably has a low diffusion constant within the organic layer stack, as is usually the case with large atoms or molecules, for

example”), a POSITA would understand it would be less mobile than these elemental n-dopants. Thus, that blocking layers were sufficient to alleviate quenching concerns for n-dopants like lithium and cesium supports a POSITA’s expectation that Liq would be a suitable n-dopant, while also relaxing the constraints on the blocking layer, as noted earlier. *See* §V.A.4.

145. Thus, a POSITA would have understood the benefits of using Liq to n-dope an ETL and such use constituted incorporating a well-known technique to Suzuki’s OLEDs. And a POSITA would have reasonably expected success to achieve improved performance of OLEDs by n-doping the ETL. Liq was a known n-dopant facilitating electron transport and injection for the ETL. *See* §V.A.7; Ma, 813; Ex. 1034 (Endo), L800; Ex. 1040 (Choi), 062101-1–062101-2; *see also* Ex. 1042 (Schmitz), 3019; Ex. 1028 (Liu), 212–214.

146. A POSITA would have reasonably expected success in using an Liq-doped ETL for Suzuki’s OLEDs. First of all, Suzuki itself contemplates an n-doped ETL. Suzuki, [0333]. And incorporating an Liq-doped ETL simply involves using a different dopant whose application would have been a routine matter for a POSITA, particularly given that n-doped ETLs was a well-established technology. *See* §V.A.4. A POSITA would have understood that elements in Ma’s devices were applicable to Suzuki’s OLEDs. For example, He discloses an example of n-doping an ETL (such as BPhen like Ma) for OLEDs with an iridium-containing emissive layer such as

with Ir(ppy)<sub>3</sub>, the same type of emissive layer disclosed by Suzuki. Accordingly, a POSITA would have reasonably expected to succeed in using Liq as the n-dopant for the ETLs in Ir-based OLEDs as taught by prior art (Suzuki, Diekmann, He, and Ma). As I explained above, phosphorescent OLEDs with p- and n-doped transport layers were well-known devices, *see* §V.A.4, and Liq was also a well-studied material. *See, e.g.*, §V.A.7.

147. Moreover, it would have been obvious for a POSITA to apply the same dopant to different ETL materials (and vice versa) in different OLEDs, and a POSITA would have been readily able to do so with a reasonable expectation of success. For instance, applying Liq as a dopant to ETL materials such as BPhen (Ma's ETL) and Alq<sub>3</sub> (identified as ETL in Suzuki) was a known technique to improve OLED performance. Ma, 810–814; Suzuki, [0329]–[0333]; *see also* Ex. 1034 (Endo), L800–L802. As another example of the same dopant used in different ETLs, the n-dopant Li has been used in BPhen (Ex. 1020 (Pfeiffer), 1633), BCP (Ex. 1024 (Walzer), 1245), and Alq<sub>3</sub> (Ex. 1034 (Endo), L802). As examples of different dopants used in the same ETLs used in different OLEDs: Li was the n-dopant for a BPhen ETL used for a phosphorescent OLED (Ex. 1020 (Pfeiffer), 1633), as well as for a BPhen ETL used for a fluorescent OLED (Ex. 1024 (Walzer), Fig. 29); Cs was the n-dopant for a BPhen ETL used for a phosphorescent OLED (Ex. 1018 (He), Fig. 1); and Liq has been used as the n-dopant for a BPhen ETL (Ma,

810–811; Ex. 1034 (Endo), L802, Fig. 1).

148. Given an emissive layer, identifying an ETL material that is appropriate for the emitter materials and that meets the required energy levels for injection and transport is within the skill of a POSITA. POSITAs in the OLED field routinely design OLED stacks based on energy level alignment and known material compatibilities. White OLEDs like those in Suzuki do not require a different analysis. Indeed, the prior art includes many examples of white OLED stacks with appropriate choices of ETL, dopant type, and concentration capable of being determined experimentally. *See, e.g.*, Ex. 1053 (Schwartz, 2008), 053311-1, Fig. 1; Ex. 1054 (Schwartz, 2006), 61920Q-1–61920Q-2, Fig. 1.

149. Further, identifying the appropriate doping concentration of Liq for good charge balance in a given OLED is a matter of routine optimization well within the skill of a POSITA. There are many examples in the literature showing how researchers could readily create OLEDs at various different doping concentrations, measure their electrical characteristics, and determine which doping concentrations result in the highest current density and lowest driving voltage. For example:

- Ex. 1040 (Choi), 062101-2–062101-3 (measuring different Liq doping ratios)
- Ex. 1024 (Walzer), Fig. 6 (varying concentration of F4-TCNQ in ZnPc to change conductivity), Fig. 18 (varying concentration of pyronin in

NTCDA to vary conductivity), Fig. 27 (showing impact of doping concentration on current flow through an OLED)

Ma itself also demonstrates that the Liq doping concentration for optimum charge balance can be experimentally determined, Ma, 813. These papers further illustrate that operating OLEDs do not require optimum charge balance, because they show that functioning devices were formed at various different doping concentrations.

150. I also note that a POSITA would have applied teachings concerning electron and hole transport layers from fluorescent OLEDs to phosphorescent OLEDs. For example, the 2007 Walzer paper explains how the “p-i-n architecture” was first developed for fluorescent OLEDs, and then “extended to phosphorescent OLEDs.” Ex. 1024 (Walzer), 1254–1255. The fluorescent OLED structure (Fig. 29) is nearly identical to the phosphorescent OLED structure (Fig. 30) except the phosphorescent emitter replaces the fluorescent emitter and a different blocking layer is used. Ex. 1024 (Walzer), 1254–1255; Ex. 1016 (Pfeiffer), 1633–1634. Notably, the n-doped ETL Li:Bphen is used for both fluorescent and phosphorescent OLEDs. Ex. 1024 (Walzer), 1254–1255; Ex. 1020 (Pfeiffer), 1633–1634. This demonstrates the modular approach to OLED stack design, even across different emitter types, and shows that it was not a big leap for a POSITA to apply ETL n-dopants studied in the context of fluorescent OLEDs, such as Ma’s Liq, as the n-dopant for phosphorescent OLEDs with n-doped ETLs.

151. Thus, n-doping the electron transport layer was a well-known technique for both fluorescent and phosphorescent devices by the time of the '250 patent, and the use of the same n-dopants for both fluorescent and phosphorescent OLEDs was known. Ex. 1024 (Walzer), 1254–1255. Even further, the use of both fluorescent and phosphorescent emitters in the same stack sharing the same layers for OLEDs was also known. Ex. 1035 (Schwartz, 2008), 053311-1, Fig. 1; Ex. 1036 (Schwartz, 2006), 61920Q-1–61920Q-2, Fig. 1. Therefore, a POSITA would naturally have applied n-dopants with good performance in fluorescent OLEDs (as in Ma) to n-doped phosphorescent OLEDs (as in Suzuki), and would have reasonably expected success of such an application.

**xi. [6J/10J] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm;**

152. Suzuki discloses or suggests this element. Suzuki's OLEDs include a "cathode 8," Suzuki, [0274], which "can be fabricated by forming a thin film of this electrode material with a method such as deposition or sputtering." Suzuki, [0288]. As I explained above in §V.A.1, it was well known in the art at the time that making a cathode thin enough to be transparent or semi-transparent facilitates transmission of generated light.

153. In particular, the organic light-emitting layer sequence in Suzuki's OLEDs includes a "cathode." Suzuki, [0274]–[0290]. Suzuki explains that "the

cathode of the organic EL element is transparent or semi-transparent for improved luminance of the emitted light.” Suzuki, [0288]. Suzuki further discloses that “a transparent or semi-transparent cathode can be fabricated by fabricating a film . . . to 1-20 nm thick for the cathode.” Suzuki, [0289].

154. Suzuki thus discloses a cathode of a thickness of the claimed range. It would be clear to a POSITA that the upper bound of 21 nm to 50 nm in the claimed range is not critical to the claimed invention; as explained above, the reason for using a thickness in this range is to render the cathode transparent or semi-transparent to improve light transmission. Indeed, the '250 patent also makes this clear, as it merely describes the 1–50 nm range as an example thickness for a transparent metal layer. *See, e.g.*, '250 patent, 3:8–11. Moreover, while Suzuki mentions, in general, the cathode thickness can be in the range of 10 nm to 5  $\mu\text{m}$ , Suzuki specifically discloses a 1–20 nm thick cathode that is transparent or semi-transparent. Suzuki, [0288]. Accordingly, a POSITA would have appreciated that Suzuki discloses this element by specifically teaching cathode thicknesses within and overlapping with the claimed range.

155. Even had Suzuki not disclosed this element, it would have been obvious to a POSITA to select a cathode of a thickness between 1–50 nm range for use in Suzuki's OLEDs. Suzuki discloses advantages of using a transparent electrode, specifically a transparent or semi-transparent cathode from using a “1-20 nm thick”

cathode to improve luminance. Suzuki, [0288]–[0290]. As I explained above in §V.A.1, it was quite common to use thin cathodes at the time; indeed, using a 1–50 nm thick cathode to light transmission was well known. *See, e.g.*, Suzuki, [0289]; Ex. 1023 (Bulovic), 29; Diekmann, 92 (using 30 nm thick silver cathode). The reason for this is that it was well-known by those in the art that the cathode in an OLED would preferably be sufficiently thin to be transparent or semi-transparent and thus enable the light generated by the OLED to exit the device.

156. Accordingly, a POSITA would have been motivated to incorporate a 1–50 nm thick cathode into Suzuki’s OLEDs to improve light output performance of the OLED devices. A POSITA would have reasonably expected success in using such a thin cathode because it would have been a routine modification known in the art as I explained above, and the use of a 1–50 nm thick cathode (e.g., made of magnesium and/or silver) was well-known technique used for improving light output efficiency of OLEDs. *See* Suzuki, [0288]–[0290]; Diekmann, 92; Ex. 1023, 29.

**xii. [10K] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and**

157. Suzuki discloses this element. Suzuki’s OLED devices contain a “cathode 8.” Suzuki, [0274]. Suzuki discloses that its OLEDs use “magnesium” or “magnesium/silver mixtures” (i.e., a magnesium and silver alloy) as conductive materials with “small work functions (4 eV or lower)” for the cathode. Suzuki,

[0288]-[0290]. Suzuki thus discloses a cathode comprising magnesium or an alloy comprised of silver and magnesium.

158. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**xiii. [10L] wherein the cathode is in direct contact with a Lithium containing layer.**

159. Suzuki modified by Ma satisfies this element. Suzuki discloses exemplary OLEDs where the cathode is directly in contact with the ETL in the following order: “anode / hole transport layer / light emission layer / hole blocking layer / electron transport layer cathode.” Suzuki, [0287]; *id.*, [0274]. The ETL immediately follows the cathode; therefore, the ETL is in direct contact with the cathode. Suzuki, [0287], [0292].

160. As explained in §X.A.x, it would have been obvious to use an Liq-doped ETL in Suzuki’s OLEDs. Thus, in this combined Suzuki/Ma system, the cathode is in direct contact with a Li containing layer (i.e., the Liq-doped ETL), because Suzuki discloses that the cathode directly contacts the doped-ETL in the exemplary OLEDs discussed above. *See* Suzuki, [0287].

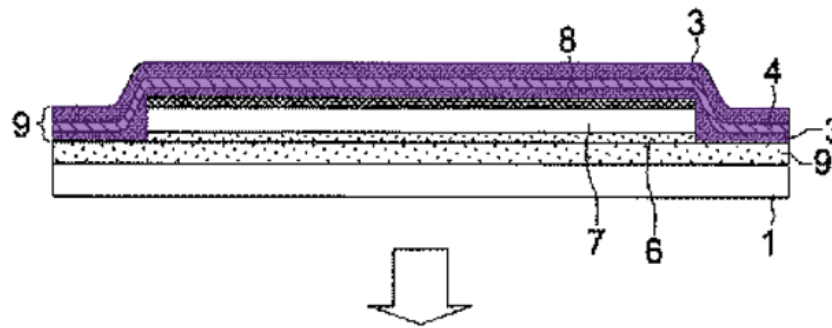
**2. Claim 2**

**i. [2A] The device of claim 1, wherein at least one part of the encapsulation is formed by an insulation layer, and**

161. Suzuki discloses this element. Suzuki’s OLEDs are sealed by an

encapsulation, “gas barrier thin film laminate 9,” which is comprised of multiple layers: “buffer film 3,” “barrier film 4,” another “buffer film 3,” and “silicon oxide” film, for example, as Suzuki explains for Figure 9 below. *See, e.g.*, Suzuki, [0274] – [0279].

【図9】



Suzuki, Fig. 9.

162. Suzuki describes the barrier film as “a dense film . . . comprising a ceramic composition with low or no carbon content and having at least Si and O atoms” and describes the buffer film as “a flexible film with . . . a lower density than the barrier film consisting of a film with a high content of carbon atoms with Si, O, and C atoms.” Suzuki, [0117]; *see also* Suzuki, [0068]–[0069].

163. A POSITA would have understood that Suzuki’s encapsulation has insulation layers including buffer films, barrier film, and silicon oxide film. For example, a POSITA would have recognized that Suzuki’s film layers for the encapsulation electrically insulate the cathode and anode from one another as shown

in Figure 9 above. If that were not the case, a POSITA would have understood that the described OLED would not function due to the short-circuit between the cathode and anode. Moreover, it was known that silicon oxide and ceramic materials including silicon and oxygen are electrical insulators. Suzuki, [0222] (identifying ceramic to provide electrical insulation), [0398] (showing SiO<sub>2</sub> barrier film, a known electrical insulator).

164. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

**ii. [2B] wherein the insulation layer comprises at least one of: resin, silicon oxide, or silicon nitride.**

165. Suzuki discloses or at a minimum renders obvious this element. Suzuki discloses an insulation layer that includes silicon oxide or silicon nitride. As I explained above for element [2A], Suzuki's encapsulation has insulation layers with the buffer films, barrier film, and silicon oxide film. Suzuki, [0222], [0274]–[0279], [0398]. Suzuki further teaches that the barrier and buffer films being made from “at least one of *silicon oxide*, silicon oxide nitride, and *silicon nitride*.” Suzuki, [0068]–[0069].

166. Moreover, it would have been obvious to a POSITA to use resin, silicon oxide, or silicon nitride in the insulation layer as such use was well-known in the art. Suzuki, [0068]–[0069]; Diekmann, 15. A POSITA would have been motivated to use these materials in Suzuki's encapsulation for insulation, as they were well known

insulating materials and Suzuki already discloses the use of silicon oxide and silicon nitride. Suzuki, [0068]–[0069]. A POSITA would have known that it would have been beneficial to include resin, silicon oxide, or silicon nitride, well-known insulating materials, in the insulation layer. A POSITA would have had a reasonable expectation of success for such use because it would have been a routine modification to Suzuki’s encapsulation by applying commonly used materials.

**3. Claim 4: The device according to claim 1, wherein the organic light-emitting diode comprises a hole transport layer that is p-doped.**

167. Suzuki discloses or at a minimum renders obvious this element alone or in combination with Ma. As I explained above, Suzuki teaches that its OLEDs include an “hole transport layer” (HTL). *See, e.g.*, Suzuki, [0274], [0283], [0287], [0322]–[0328]. Suzuki explains that “[a] single or a plurality of hole transport layers” may be included in the organic layer 7 of the OLEDs. Suzuki, [0322]–[0323]. Suzuki further teaches doping this hole transport layer, and specifically discloses that “a hole transport layer with a high p nature doped with impurities can also be used,” and lists examples of this HTL. Suzuki, [0328]. Suzuki cites an article by Gufeng He et al. as an “[e]xample” of a “hole transport layer with a high p nature doped with impurities” as taught by Suzuki. *See* Ex. 1018 (He). He et al.’s work teaches an OLED with a “hole injection and transport layer (HTL)” which is “p-doped” and an “n-doped electron transport layer.” Ex. 1018 (He), 5773. The article

further teaches that OLEDs with this “*p-i-n*” configuration (i.e., a configuration which has a p-doped HTL and n-doped ETL) feature “efficient carrier injection from both contacts into the doped transport layers and low ohmic losses in these highly conductive layers.” Ex. 1018 (He), Abstract. Accordingly, a POSITA would have understood that Suzuki’s reference to “a hole transport layer with a high p nature doped with impurities” is describing a hole transport layer that is p-doped. *See, e.g.*, Suzuki, [0328] (citing He).

168. Even had Suzuki not disclosed the specific use of a p-doped hole transport layer, it would have been obvious to a POSITA to p-dope the hole transport layer in Suzuki’s OLEDs. A POSITA would have been motivated to use a p-doped HTL in Suzuki’s OLEDs to improve their performance. As I explained above in §V.A.4, p-doped hole transport layers were well known for OLEDs at the time. In particular, it was well known that using a p-doped hole transport layer could reduce the voltage and improve current and power efficiencies of the OLED. *See* Ex. 1018 (He) (cited by Suzuki), 5773 (“*p-i-n*” OLED (i.e., an OLED with an n-doped ETL and p-doped HTL) “features efficient carrier injection from both contacts into the doped transport layers and low ohmic losses in these highly conductive layers” and “low operating voltages are obtained compared to conventional undoped OLEDs”); Ex. 1019 (He), 3911 (“high conductive *p*- and *n*-doped layers enhance the charge injection from the contacts and reduce the ohmic losses in these layers resulting in

“reduced . . . operating voltage for both fluorescent and phosphorescent devices.”); Ma, 810 (“[r]ecently, the p-doping of HTL has drawn a lot of attentions because of its ability to enhance hole injection”); Ma, 812–814 (finding that “the current and power efficiencies” of devices with an ETL n-doped with Liq and an HTL which is p-doped “are considerably improved as compared to” devices with no doping).

169. Indeed, Ma explains using “p-doping of HTL” to “enhance hole injection.” Ma, 810. That p-doping hole transport layer leads to “better hole injection from the anode into the organic layer stack” was well-known. Diekmann, 10. And numerous materials such as 4,4',4''-tris(3-methylphenylphenylamono) triphenylamine (m-MTDATA) were well-known compounds to be p-doped for improved hole transport from the anode to the EML. Ma, 810–814; Diekmann, 4–5; *see also* Ex. 1018 (He); Ex. 1020 (Pfeiffer).

170. A POSITA would have further recognized the benefits of combining a p-doped hole transport layer with an n-doped electron transport layer which, as I explained above in §X.A.1.viii, Suzuki also teaches. For example, as explained by Ma, “current efficiency not only relies on the carrier injection, but also on the carrier balance.” Ma, 813. A POSITA would recognize that a “*p-i-n*” OLED (i.e., an OLED that has both a p-doped hole transport layer and an n-doped electron transport layer) would offer substantial flexibility to tune electron and hole currents in the OLED to optimize charge balance, which benefits both efficiency and device stability. Ma,

810–814; Ex. 1018 (He), Abstract; Ex. 1019 (He), 3911–3912; Ex. 1020 (Pfeiffer), 1633; Ex. 1021 (Gross), 5–14. Indeed, the “*p-i-n*” configuration which Suzuki and Ma teach was well known. *See, e.g.*, Ma, 810–814; Ex. 1018 (He); Ex. 1019 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross). In light of these well-known benefits, a POSITA would have been motivated to combine an p- and n- doping in the hole- and electron- transport layers of Suzuki’s OLEDs. Moreover, adding an p-dopant to a hole transport layer would be a routine matter well within a POSITA’s ability.

171. A POSITA would have reasonably expected success in using a p-doped hole transport layer in Suzuki’s OLEDs, in conjunction with the n-doped electron transport layer also taught by Suzuki (as explained above in §X.A.1.viii). As discussed above, Suzuki already contemplates both an n-doped electron transport layer and a p-doped hole transport layer. Further, *p-i-n* OLEDs using both n-doped and p-doped transport layers were well known in the art. *See* §V.A.4 above; Ma, 810–814; Ex. 1018 (He); Ex. 1019 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross). Moreover, adding a p-dopant to a hole transport layer would be a routine matter well within a POSITA’s ability.

172. Accordingly, a POSITA would have appreciated that Suzuki discloses or at a minimum renders obvious this claim alone or in view of Ma.

**4. Claim 5**

- i. [5A] The device according to claim 1, wherein a color filter is arranged between the emission layer and the radiation exit area, and**

173. Suzuki discloses or at a minimum suggests this element. Suzuki teaches using a “color filter” in its OLEDs to convert the color of light from the emission layer. Suzuki, [0336]. Suzuki explains that a “color filter[] . . . or the like may also be used, and a color conversion filter that converts the color emitted from the organic EL element to multicolor using phosphors may also be used.” Suzuki, [0336]. Suzuki further teaches that “one emission color, e.g., white emission light, can be made into BGR using a color filter to create a full-color display” and that “it is possible to convert the organic EL light emission color to other colors using color conversion filters to achieve full color.” Suzuki, [0348], [0373]. A POSITA would appreciate that the color filter taught by Suzuki necessarily must be placed between the emission layer and the radiation exit area as, in order for the device to produce this kind of colored light, light must be generated (which occurs in the emission layer), then pass through the color filter, and then, after being converted into colored light, exit the OLED (which occurs at the radiation exit area). Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

174. Even had Suzuki not disclosed a color filter arranged between the emission layer and the radiation exit area, it would have been obvious to use such a

color filter in view Suzuki. A POSITA would have been motivated to use this color filter arrangement because Suzuki discloses converting light generated by the emission layer using color filters to the desired color provided by the OLED. *See, e.g.,* Suzuki, [0336], [0348], [0373]. In fact, the technique of placing color filters between the emission layer and the radiation exit area so that the filters function to convert color of light was well known in the art. Diekmann, 37–38, 40, 128–133, Figs. 35–37.

175. In addition, a POSITA would have had a reasonable expectation of success for using this color filter in Suzuki because such use would have been amounted to a conventional and routine modification to Suzuki's OLEDs and a resulted in an operable structure known in the art. *See* Suzuki, [0336], [0348], [0373]; Diekmann, 37–38, 40, 128–133, Figs. 35–37.

- ii. **[5B] wherein the color filter is configured to be highly transmissive for a first spectral subrange of the generated electromagnetic radiation and highly absorbent for a second spectral subrange of the generated electromagnetic radiation.**

176. Suzuki discloses or at a minimum suggests this element.

177. As explained above, Suzuki discloses a color filter that is arranged between the emission layer and the radiation exit area and that, by doing so, Suzuki's OLEDs produce different colors and achieve a "full color display." Suzuki further teaches that these color filters correspond to (i.e. are highly transmissive to) a

particular wavelength range and, conversely, are relatively absorbing to wavelengths falling outside of that wavelength range. For example, Suzuki discloses that “any combination of the platinum complexes according to the present invention and other known light emitting materials can be selected, combined and whitened to *match the wavelength range corresponding to the color filter (CF) characteristics*.” Suzuki, [0373] (emphasis added). The use of color filters in lighting devices was well known at the time and POSITA would know that, as explained by Diekmann, each “color filter is suitable for filtering light of a specific wavelength range” meaning that “light of this wavelength range is at least partially absorbed by the color filter.” Diekmann, 40. For example, “a first color component can be filtered out of white light” while at the same time “a second color component can pass through the color filter essentially unhindered.” Diekmann, 40. Suzuki therefore discloses color filters which are highly transmissive to one spectral subrange of generated electromagnetic radiation while also being highly absorbing to another spectral subrange. Accordingly, a POSITA would have appreciated that Suzuki discloses this element.

178. Even had Suzuki not disclosed using a color filter configured to be highly transmissive for a first spectral subrange of the generated radiation and highly absorbent for a second spectral subrange, it would have been obvious use this color filter in view Suzuki. A POSITA would have been motivated to use such a color filter as Suzuki discloses the benefits of converting colors using color filters. *See*,

*e.g.*, Suzuki, [0336], [0348], [0373]. Moreover, implementing color filters that are highly transmissive in one spectral range and highly absorbent in another spectral range was well-known at the time. Diekmann, 40 (color filters transmitting one color unhindered while absorbing another color), 41, 129–130.

179. In addition, a POSITA would have had a reasonable expectation of success to use such color filters in Suzuki’s OLEDs because such use would have been a conventional and routine modification to Suzuki’s OLEDs and applying the known technique of effective color filters would have improved OLED functionality. *See* Suzuki, [0336], [0348], [0373]; Diekmann, 40–41, 129–130.

**5. Claim 7: The device according to claim 6, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.**

180. Suzuki discloses this element for the same reasons provided in §X.A.1.xii [10K].

**6. Claim 8: The device according to claim 6, wherein the cathode is in direct contact with a Lithium containing layer.**

181. Suzuki discloses this element, or at a minimum, renders obvious this element in combination with Ma.

182. First, Suzuki discloses this element. Suzuki’s OLEDs include a “cathode 8.” Suzuki, [0274]. As an example, Suzuki discloses that the layers are stacked in the following order, with the cathode being stacked directly on top of the cathode buffer layer: “anode / anode buffer layer / hole transport layer / light

emission layer / hole blocking layer / electron transport layer / *cathode buffer layer* / *cathode*.” Suzuki, [0287], [0292]– [0293], [0295].

183. Suzuki makes clear that this optional electron injection layer serves as a “cathode buffer layer,” and when present is the layer immediately following the cathode, and thus is in direct contact with it. Suzuki, [0287], [0292]. As such, Suzuki discloses that the cathode is in direct contact with the electron injection layer.

184. Suzuki also teaches that this cathode buffer layer, in direct contact with the cathode, contains lithium. Suzuki discloses using an “alkali metal compound buffer layer[] typified by *lithium fluoride*” as an electron injection layer. Suzuki, [0295]. A POSITA would recognize that lithium fluoride is a compound which contains lithium. A POSITA thus would have appreciated that Suzuki discloses this element.

185. Second, it would have been obvious to combine Suzuki and Ma, and the combined Suzuki/Ma OLED satisfies this element for the same reasons provided in §X.A.1.xiii [1L/10L].

**7. Claim 9: The device according to claim 6, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

186. It would have been obvious to combine Suzuki and Ma, and the combined Suzuki/Ma OLED satisfies this element for the same reasons provided in §X.A.1.x [1I/10I].

**B. Grounds 3-4: Suzuki, Ma, and Lee Render Obvious Claims 3, 11-12, and 15-16 (Ground 3); Suzuki and Lee Render Obvious Claims 11 and 13-15 (Ground 4)**

**1. Claim 3**

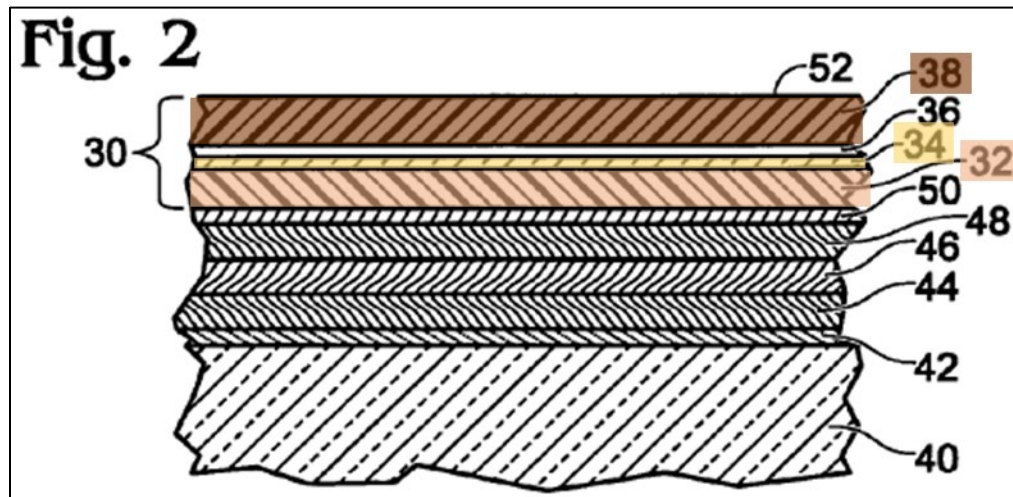
**i. [3A] The device of claim 1, wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,**

187. This element would have been obvious to a POSITA based on Suzuki (alone or in combination with Ma) as modified in view of Lee's teachings.

188. As I explained above in §X.A.2, Suzuki discloses that its OLEDs are encapsulated in a "gas barrier thin film laminate 9," which comprises multiple encapsulation layers, a "buffer film 3," "a barrier film 4," another "buffer film 3," and a "silicon oxide film." Suzuki, [0274]–[0279]. Suzuki also teaches that the encapsulation may include multiple barrier films and buffer films. Suzuki, [0274].

189. Like Suzuki, Lee similarly teaches an encapsulation for an OLED comprising multiple encapsulation layers, a first encapsulation layer ("second semi-crystalline parylene-based polymer layer 38") and a second encapsulation layer ("first semi-crystalline parylene-based polymer layer 32"). Lee, [0022] ("The first semi-crystalline parylene-based polymer layer is shown in FIG. 2 at 32, the inorganic barrier layer is shown at 34, . . . and the second semi-crystalline parylene-based polymer layer is shown at 38"); Lee, [0021] ("annealing . . . the second semi-crystalline parylene-based polymer layer [forms] a highly crystalline parylene-based

polymer layer”). Lee thus discloses that the two encapsulation layers have independent volume structures and different levels of crystallinity. These are illustrated in Lee’s annotated Figure 2 below:



Lee, Fig. 2 (annotated), [0021]–[0022].

190. It would have been obvious to apply Lee’s technique to Suzuki’s OLEDs to improve the encapsulation. For example, it would have been obvious to replace Suzuki’s encapsulation with Lee’s multi-layered encapsulation. A POSITA would have been motivated to use Lee’s multi-layered encapsulation with Suzuki’s OLEDs to improve the encapsulation. As I explained above in §V.A.6 and §IX.D, the use of encapsulation in OLEDs was well known at the time, specifically to protect the OLED from the ambient environment and extend its lifetime. *See, e.g.*, Ex. 1025 (Moro); Ex. 1026 (Chwang). Indeed, Lee itself teaches the benefits of using an encapsulation in an OLED; for example, Lee explains that “the low work function metals typically used as cathodes in OLEDs are environmentally sensitive,

and may be easily oxidized by moisture or oxygen from air. Therefore, it is important to protect these materials from air both during processing and during use.” Lee, [0005].

191. Lee discloses using an encapsulation including semi-crystalline and highly-crystalline polymer barrier layers. Lee explains that semi- and highly-crystalline parylene-based polymer films “have low-enough WVTR [(water vapor transport rate)] and OTR [(oxygen transport rate)]<sup>6</sup> values that they not only ‘decouple’ adjacent inorganic layers to prevent the propagation of defects between inorganic layers, but also themselves help block water vapor and oxygen permeation into the OLED.” Lee, [0020]; *see also* Lee, [0010], [0021], [0042]–[0043].

192. Specifically, Lee teaches that its encapsulation has “low-enough WVTR and OTR values that they not only “decouple” adjacent inorganic layers to prevent propagation of defects between inorganic layers, but also themselves help block water vapor and oxygen permeation into the OLED” and themselves act as barrier layers. Lee further notes that “Therefore an OLED having [a] barrier constructed with the semi-crystalline and highly crystalline parylene-based polymer barrier layers . . . may have significantly improved lifetime compared to OLEDs

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<sup>6</sup> WVTR means “water vapor transport rate” and OTR means “oxygen transport rate.” Lee, [0007]–[0008].

having polyacrylate or amorphous parylene barrier layers.” Lee explains that the prior polymer polyacrylate barrier stack was “found to have a [WVTR] of approximately  $10^{-5}$ - $10^{-6}$  g/m<sup>2</sup>/day/atm,” (Lee, [0007]), and teaches that its encapsulation has improved (i.e., smaller) WVTR (and OTR) values compared to the prior art stack (Lee, [0020], [0027]). On the other hand, Suzuki reports a WVTR of about  $10^{-3}$  g/m<sup>2</sup>/day for its encapsulation (Suzuki, Table 1; *see also* Suzuki, [0020], [0061], [0078], claim 6), which performance is worse than the prior art stack in Lee. Thus, a POSITA would have appreciated that Lee teaches that its multi-layered encapsulation improves over conventional OLED encapsulations (such as the one reported by Suzuki), and provides lower WVTR and OTR values, which are beneficial for OLEDs. *See, e.g.*, Lee, [0007]–[0008], [0020], [0031], [0034].

193. A POSITA would have been motivated to apply Lee’s multi-layer encapsulation into Suzuki’s OLEDs for improved protection. Applying Lee’s multi-layered encapsulation to Suzuki’s OLEDs would have been a mere application of a known technique to protect the OLED from outside materials and improve device lifetimes. *See, e.g.*, Lee, [0020]; Suzuki, [0067]. Lee explains that the techniques of using encapsulations to protect OLEDs from moisture and the ambient environment were well known. Lee, [0002], [0036]. Such techniques were also known in the broader art. Diekmann, 130; Ex. 1025; Ex. 1026. Lee also teaches specific benefits of its multi-layer encapsulation. *See, e.g.*, Lee, [0020] (its semi-crystalline and

highly-crystalline polymer barrier layers “prevent the propagation of defects between inorganic layers” and prevent water vapor and oxygen permeation to “significantly improve[] lifetime”), [0029] (providing “thermally stable” films). Specifically, Lee describes that “the low work function metals typically used as cathodes in OLEDs are environmentally sensitive, and may be easily oxidized by moisture or oxygen from air. Therefore, it is important to protect these materials from air both during processing and during use.” Lee, [0005].

194. A POSITA would have had a reasonable expectation of success in applying Lee’s multi-layered encapsulation to Suzuki’s OLEDs. Suzuki contemplates a multi-layered encapsulation with alternating layers of multiple “buffer films,” multiple “barrier films,” and silicon oxide film. Applying Lee’s multi-layer encapsulation merely replaces one set of alternating layers with another, to obtain the benefits taught in Lee. Moreover, using a multilayer OLED encapsulation including alternating organic and inorganic layers was known in the art. Lee, [0020]–[0024], Fig. 2; Suzuki, [0274]; Diekmann, 94, Figs. 13 and 17A; Ex. 1025; Ex. 1026. Implementing Lee’s encapsulation which would have been well within the ability of a POSITA in view of Lee’s teaching, and a POSITA would have reasonably expected the benefits. *See* Lee, [0007]–[0008], [0020]–[0021], [0029], [0031], [0034], [0036]–[0038], [0042]–[0043].

195. Moreover, Lee is specifically directed to encapsulation for OLEDs, and

teaches methods to apply its multi-layered encapsulation technique, including methods to “avoid[] delivering unwanted energy to the organic layers.” Lee, [0033]–[0035]. A POSITA thus would have expected reasonable success in applying Lee’s encapsulation technique to OLEDs such as Suzuki’s, alone or as modified by Ma, with a reasonable expectation of success.

196. Accordingly, a POSITA would have appreciated that Suzuki (alone or in combination with Ma) in view of Lee discloses this element.

**ii. [3B] the first and the second encapsulation layer each having a respective volume structure,**

197. This element would have been obvious to a POSITA based on Suzuki (alone or in combination with Ma) as modified in view of Lee’s teachings. As explained above in §X.B.1.i, the encapsulation taught by Lee includes a first and second encapsulation layer which each have distinct volume structures.

198. First of all, as I explained in §VIII.B, during prosecution of the ’514 Application (which the ’250 patent claims priority to), the Applicant offered explanations for the meaning of “volume structure.” Specifically, the Applicant distinguished between the atomic and molecular arrangement inside of a solid (“volume structure”) and that at the solid’s surface (“surface structure”). Ex. 1017, 1386. The Applicant also explained that “volume structure” “comprise[s] any structure ranging from polycrystalline to polyamorphous,” including “crystalline, partly crystalline and/or polycrystalline or completely amorphous.” Ex. 1017, 1241.

199. Consistent with the explanations, Lee discloses multiple encapsulation layers that have respective, independent volume structures. Lee discloses that its encapsulation has a first “*highly crystalline*” encapsulation layer with “up to 70% of crystallinity” and a second “*semi-crystalline*” “parylene-based polymer layer” with “at least 10%” of crystallinity.” Lee, [0023], [0027]; *see also* Lee, [0020]–[0021]. A POSITA would have appreciated that two solids necessarily have different internal molecular and atomic arrangements if they have different levels of crystallinity. Lee thus discloses a first and second encapsulation layer each having respective, independent volume structures, regardless of how the term “volume structure” is defined.

200. Accordingly, a POSITA would have appreciated that Suzuki (alone or in combination with Ma) in view of Lee discloses this element.

**iii. [3C] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, and**

201. This element would have been obvious to a POSITA based on Suzuki (alone or in combination with Ma) as modified in view of Lee’s teachings. *See* §X.B.1.i-ii. As explained above in §X.B.1.i-ii, Lee teaches a multi-layer comprising encapsulation layers with volume structures which are distinct and independent from one another: the first (highly-crystalline) encapsulation layer has “up to 70% of crystallinity” and the second (semi-crystalline) encapsulation layer has “at least

10%” of crystallinity. Lee, [0023], [0027]; *see also* Lee, [0020]–[0021]. Lee also explains that its polymer layers have low-enough WVTR and OTR values that they “‘decouple’ adjacent inorganic layers to prevent the propagation of defects between inorganic layers.” Lee, [0020].

202. Accordingly, a POSITA would have appreciated that Suzuki (alone or in combination with Ma) in view of Lee discloses this element.

**iv. [3D] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.**

203. This element would have been obvious to a POSITA based on Suzuki (alone or in combination with Ma) as modified in view of Lee’s teachings. *See* §X.B.1.i-iii. As explained in §X.B.1.i-ii, Lee discloses a multi-layer encapsulation wherein the first (highly-crystalline) encapsulation layer (e.g., highly-crystalline parylene-based polymer layer 38) has “up to 70% of crystallinity” and the second (semi-crystalline) encapsulation layer (e.g., semi-crystalline parylene-based polymer layer 32) has “at least 10%” of crystallinity. Lee, [0020]–[0027]. Lee explains that the semi-crystalline polymer layer may be about 10% crystallinity as deposited, while the highly-crystalline polymer layer, formed by depositing a semi-crystalline polymer film and annealing to increase its crystallinity, may be about 70% crystallinity. Lee, [0021], [0023]–[0027]. Amorphicity and crystallinity both describe the volume structure of solids, and have an inverse relationship; crystalline

solids have a long-range order, meaning the atoms or molecules are arranged in a periodic pattern, while amorphous solids have no long-range order, meaning the atoms or molecules are arranged without a periodic pattern. *See* Ex. 1017, 1313–1314, 1386–1387. In practical terms, this means that the higher a material's crystallinity, the lower its amorphicity; if material A has higher crystallinity than material B, then material A necessarily has a lower amorphicity than material B. Therefore, a POSITA would recognize that because Lee's second (semi-crystalline) encapsulation layer has lower crystallinity than the first (highly-crystalline) encapsulation layer, the second encapsulation layer must also have a higher amorphicity than the first encapsulation layer.

204. Accordingly, a POSITA would have appreciated that Suzuki (alone or in combination with Ma) in view of Lee discloses this element.

## **2. Independent Claims 11 and 16**

### **i. [11Pre/16Pre] A device comprising:**

205. Suzuki discloses this element for the same reasons provided in §X.A.1.i [1Pre/6Pre/10Pre].

### **ii. [11A/16A] an organic light-emitting diode comprising:**

206. Suzuki discloses this element for the same reasons provided in §X.A.1.ii [1A/6A/10A].

### **iii. [11B/16B] an organic layer sequence,**

207. Suzuki discloses this element for the same reasons provided in §X.A.1.iii [1B/6B/10B].

**iv. [11C/16C] a radiation exit area, and**

208. Suzuki discloses this element for the same reasons provided in §X.A.1.iv [1C/6C/10C].

**v. [11D/16D] an encapsulation,**

209. Suzuki (alone or in combination with Ma) as modified in view of Lee's teachings satisfies this element for the same reasons provided in §X.B.1 [Claim 3].

**vi. [11E/16E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,**

210. Suzuki (alone or in combination with Ma) as modified in view of Lee's teachings satisfies this element because the modified encapsulation is located on Suzuki's substrate for the same reasons provided in §X.A.1.vi [1E/6E/10E].

**vii. [11F/16F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,**

211. Suzuki discloses this element for the same reasons provided in §X.A.1.vii [1F/6F/10F].

**viii. [11G/16G] wherein the organic layer sequence comprises an electron transport layer that is n-doped,**

212. The combined Suzuki/Lee OLED by itself or further in combination with Ma satisfies this element for the same reasons provided in §X.A.1.viii [1G/6G/10G].

**ix. [11H/16H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound;**

213. Suzuki discloses this element for the same reasons provided in §X.A.1.ix [1H/6H/10H].

**x. [16I] wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium;**

214. It would have been obvious to a POSITA to modify the combined Suzuki/Lee OLED in view of Ma's teaching, and the modified OLED satisfies this element, for the reasons provided in §X.A.1.x [1I/10I].

**xi. [11J/16J] wherein at least one part of the encapsulation is formed by an insulation layer, the insulation layer comprising at least one of: resin, silicon oxide, silicon nitride; [and]**

215. Suzuki discloses or at a minimum renders obvious this element for the same reasons provided in §X.A.2 [Claim 2]. Thus, Suzuki (alone or as modified by Ma) in view of Lee satisfies this element because the encapsulation of the combined OLED includes silicon oxide or silicon nitride. *See* §X.B.1.

216. Moreover, Lee discloses its encapsulation includes inorganic barrier

layer 34 formed by insulating materials  $\text{SiO}_x$  or  $\text{Si}_x\text{N}_y$ . Lee, [0022], [0031]–[0032].

Thus, Suzuki (alone or as modified by Ma) in view of Lee satisfies this element because the encapsulation of the combined OLED includes silicon oxide or silicon nitride. *See* §X.B.1.

**xii. [11K/16K] wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,**

217. Suzuki (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.B.1.i [3A].

**xiii. [11L/16L] the first and the second encapsulation layer each having a respective volume structure,**

218. Suzuki (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.B.1.ii [3B].

**xiv. [11M/16M] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, and**

219. Suzuki (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.B.1.iii [3C].

**xv. [11N/16N] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.**

220. Suzuki (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.B.1.iv [3D].

**xvi. [16O] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at**

**least 1 nm and at most 50 nm;**

221. Suzuki discloses or renders obvious this element for the same reasons provided in §X.A.1.xi [6J/10J].

**xvii. [16P] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and**

222. Suzuki discloses this element for the same reasons provided in §X.A.1.xii [10K].

**xviii. [16Q] wherein the cathode is in direct contact with a Lithium containing layer.**

223. The Suzuki/Lee OLED as modified by Ma satisfies this element for the same reasons provided in §X.A.1.xiii [10L].

**3. Claim 12: The device of claim 11, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

224. I first note that the Suzuki/Lee combination satisfies claim 11 for the reasons discussed in §X.B.2.

225. The Suzuki/Lee combination in view of Ma satisfies this element for the same reasons provided in §X.A.1.x [1I/10I] and §X.B.2.x [16I].

**4. Claim 13: The device of claim 11, wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm.**

226. Suzuki discloses or renders obvious this element for the same reasons provided in §X.A.1.xi [6J/10J].

- 5. Claim 14: The device of claim 13, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.**

227. Suzuki discloses this element for the same reasons provided in §X.A.1.xii [10K].

- 6. Claim 15: The device of claim 13, wherein the cathode is in direct contact with a Lithium containing layer.**

228. I first note that the Suzuki/Lee combination satisfies claim 13 as discussed above. Suzuki discloses this element, or at a minimum, renders obvious this element in view of Ma, for the same reasons provided in §X.A.6 [Claim 8] and §X.A.1.xiii [10L].

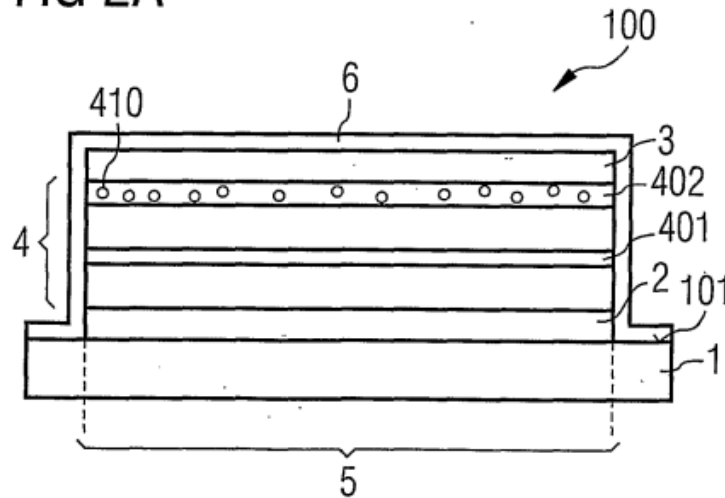
**C. Grounds 5-6: Diekmann and Ma Render Obvious Claims 1-2, 4-5, and 8-10 (Ground 5); Diekmann Anticipates or Renders Obvious Claims 6-8 (Ground 6)**

**1. Independent Claims 1, 6, and 10**

**i. [1Pre/6Pre/10Pre] A device comprising:**

229. Diekmann discloses a device. Specifically, Diekmann discloses OLEDs, and devices that incorporate OLEDs. For example, Diekmann discloses a “lighting device.”

FIG 2A

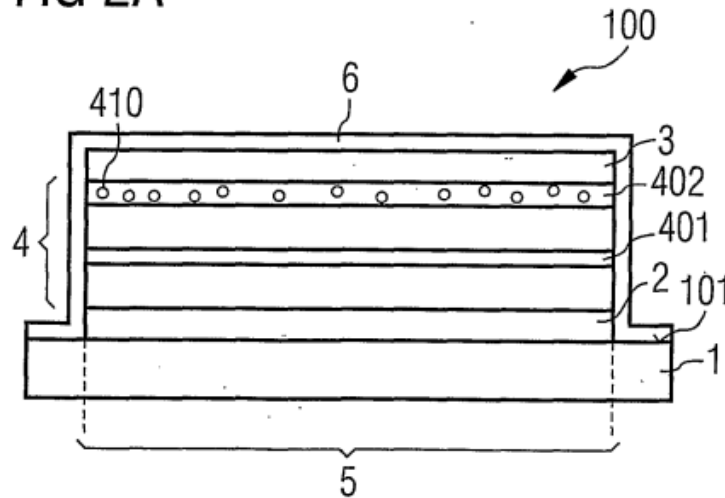


Diekmann, 87, 91, Fig. 2A. Diekmann further discloses display devices and lighting equipment incorporating this lighting device. Diekmann, Abstract, 1, 134, Fig 40A. Accordingly, a POSITA would have appreciated that Diekmann discloses the preamble.

**ii. [1A/6A/10A] an organic light-emitting diode comprising:**

230. Diekmann discloses this element. As I explained above, Diekmann discloses a lighting device. Diekmann further discloses that this lighting device includes an organic light-emitting diode (OLED) comprising a “first electrode 2 [which] is the anode,” a “second electrode 3 [which] is the cathode,” and an “organic layer stack 4 with at least one layer 401 suitable for generating light,” for example, as shown below. Diekmann, 91.

FIG 2A



Diekmann, 91, Fig. 2A.

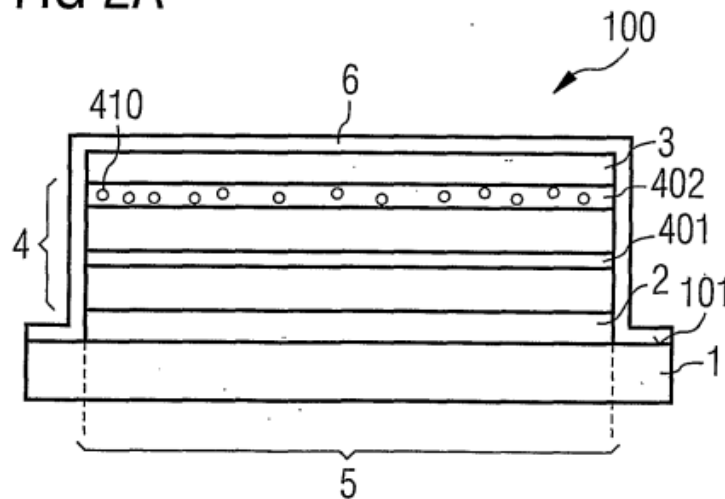
231. Within this OLED, Diekmann teaches that the anode “injects holes into the organic layer stack,” and the cathode “injects electrons into the organic layer stack.” Diekmann, 3. As I explained in §V.A.1–§V.A.3 above, this process of recombination of holes and electrons in the organic layer stack is what generates light in an OLED. Thus, Diekmann describes an organic light-emitting diode. *See* ’250 patent, Fig. 1, 24:39–25:4. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**iii. [1B/6B/10B] an organic layer sequence,**

232. Diekmann discloses this element. Diekmann discloses that the OLED, discussed above, includes an organic radiation-emitting component including a first electrode, an “organic layer or a layer sequence with at least one organic layer with an active area that can emit electromagnetic radiation during operation,” and a

second electrode. Diekmann, 73. As an example, Diekmann discloses that the first electrode 2 serves as an anode, the second electrode 3 serves as the cathode, and further explains that the organic radiation-emitting component includes organic layer stack 4 with multiple organic layers with at least one organic layer 401 as shown below. Diekmann explains that organic layer stack 4 includes multiple layers applied in sequence to the first electrode 2. Diekmann, 91. Thus, Diekmann describes an organic layer sequence including the anode, an “organic layer stack” comprising multiple organic layers, and the cathode.

FIG 2A



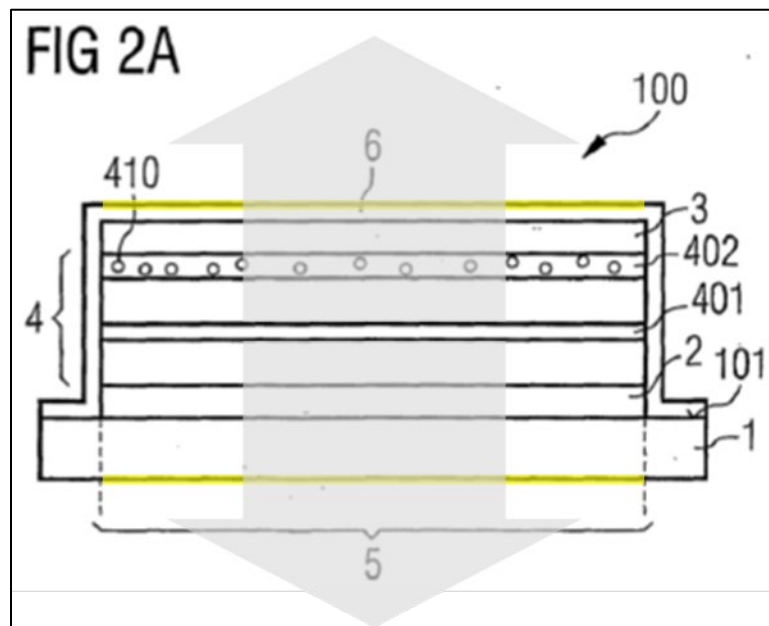
Diekmann, 73–74, 91–92, Fig. 2A.

233. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**iv. [1C/6C/10C] a radiation exit area, and**

234. Diekmann discloses this element. Diekmann discloses that the OLED,

discussed above, further includes a radiation exit area. For example, Diekmann explains that “[t]he lighting device according to Figure 2A is designed to be transparent to visible light, in particular to light generated by the organic layer stack 4.” Diekmann, 92. Diekmann accomplishes this by teaching that each of substrate 1, first electrode 2, organic layer stack 4, second electrode 3, and thin-film encapsulation 6 are each designed to be “transparent to visible light” that is “generated by the organic layer stack.” Diekmann, 92, 94. The OLED disclosed by Diekmann includes radiation exit areas at the top and bottom of the OLED, as illustrated in Figure 2A below:

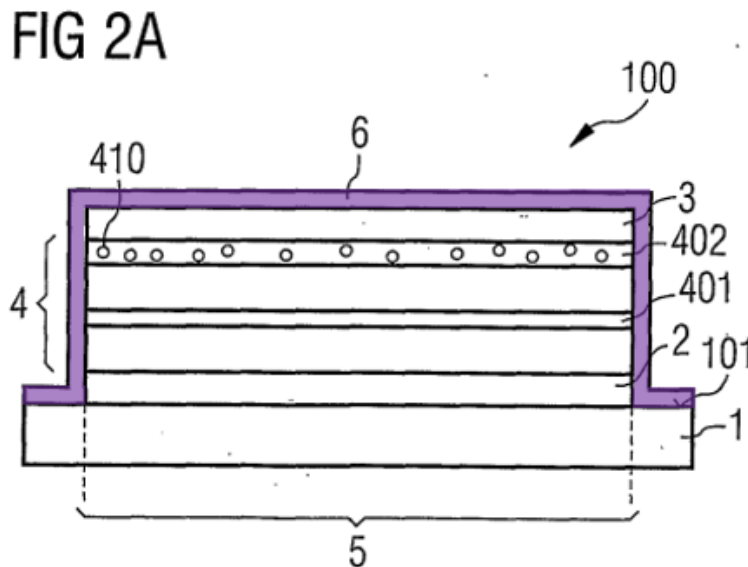


Diekmann, Fig. 2A (annotated); Diekmann, 5. Moreover, a POSITA would have understood that a radiation exit area is present at a surface of any component of the OLED below the substrate or above the encapsulation where the light exits.

235. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

- v. **[1D/6D/10D] an encapsulation [wherein the encapsulation forms a seal of the organic layer sequence against environmental influences],<sup>7</sup>**

236. Diekmann discloses this element. Diekmann discloses that the OLED, discussed above, includes an encapsulation. Specifically, the encapsulation is a “thin-film encapsulation 6.” Diekmann, 92. The encapsulated OLED can be seen in annotated Figure 2A below:



Diekmann, Fig. 2A; Diekmann, 92.

237. Diekmann discloses that its encapsulation forms a seal for the organic radiation-emitting component in order to protect the component against

<sup>7</sup> This bracket is recited only in [1D].

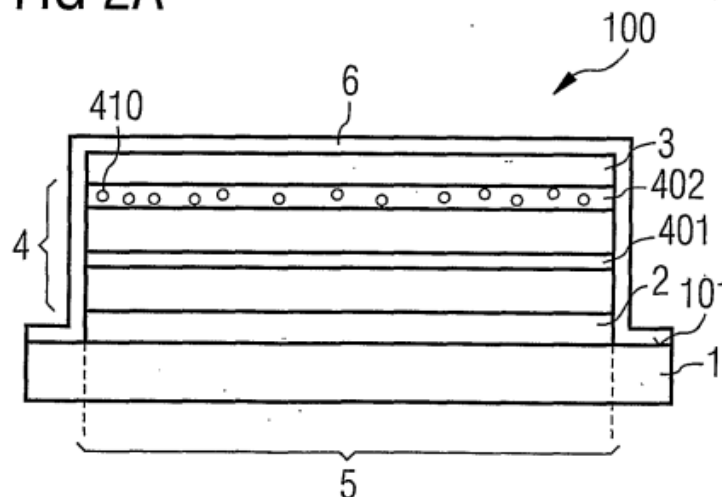
environmental influences such as “oxygen and moisture as well as other atmospheric gases.” Diekmann, 11, 13-14, 46, 75, 92. Diekmann explains that “the organic layer stack” and “the electrodes” in particular must be protected and “well sealed against oxygen and moisture as well as other atmospheric gases.” Diekmann, 11; *see also* Diekmann, 13, 75.

238. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**vi. [1E/6E/10E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,**

239. Diekmann discloses this element. Diekmann discloses that its OLED includes a carrier, “substrate 1.” Diekmann discloses that its organic radiation-emitting component with the first electrode 2, organic layer stack 4, second electrode 3 as well as thin-film encapsulation 6, discussed above, is mounted on this carrier, for example, as shown in Figure 2A below. Diekmann, 91.

**FIG 2A**



Diekmann, Fig. 2A.

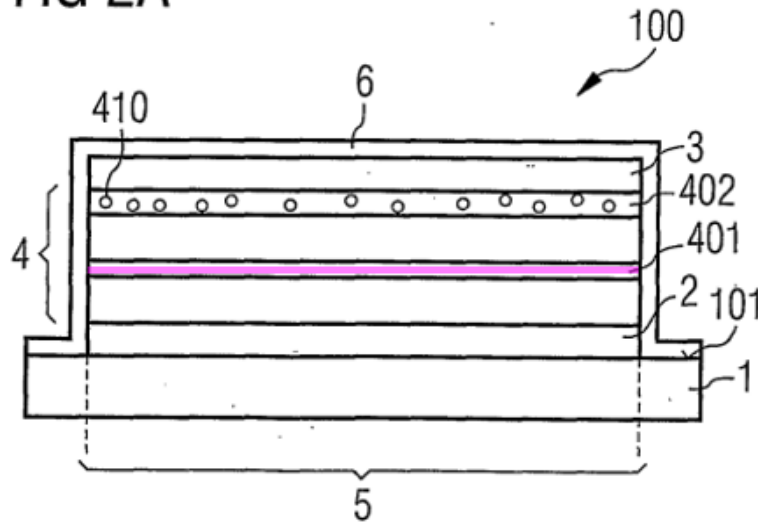
240. Diekmann further teaches that the “organic layer stack 4 . . . is arranged on the first electrode 2,” which is applied to the substrate 1, and that the “thin-film encapsulation 6 is applied directly to the second electrode 3,” which is applied to the “organic layer stack 4.” Diekmann, 91–92. Diekmann thus discloses the organic layer sequence and the encapsulation being disposed on substrate 1. *See, e.g.*, Diekmann, Fig. 2A.

241. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

- vii. [1F/6F/10F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,**

242. Diekmann discloses this element. Diekmann’s organic layer stack 4 of the organic radiation-emitting component with the first electrode 2, organic layer stack 4, and second electrode 3 comprises “at least one layer 401 suitable for generating light.” *See, e.g.*, Diekmann, 91, Fig. 2A (annotated). Diekmann explains that the active area of the radiation-emitting component generates light by electron-hole recombination thus containing a radiation-emitting region (e.g., indicated in pink highlighting below) emitting light. Diekmann, 73, 91, 95.

FIG 2A



Diekmann, Fig. 2A (annotated).

243. Moreover, Diekmann discloses that “[t]he electromagnetic radiation generated by the active area of the radiation-emitting component may in particular have a spectrum with wavelengths *in an ultraviolet to infrared spectral range.*”

Diekmann, 76 (emphasis added); *see also* Ex. 1017, 1407.

244. Diekmann explains that the light emission layer of organic layer stack 4 generates light through electron-hole recombination. Diekmann, 49, 141–142. Diekmann also explains that the radiation-emitting region provides white light in a spectral range from infrared to ultraviolet radiation.

245. For example, Diekmann explains that the radiation-emitting region of organic layer stack 4 generates “white light” (e.g., “similar to daylight”) in a spectral range from infrared to UV, including visible light. *See, e.g.*, Diekmann, 91, 122; *see also* Diekmann, 41, 66. Diekmann teaches that the OLEDs provide “white light”

covering such a full spectral range using a “broadband emitter” and a combination of emitters. *See, e.g.*, Diekmann, 41. Thus, using full spectral range of emission, Diekmann teaches OLEDs utilized for backlights, multi-colored devices, or providing white light to obtain desired colors. Diekmann, 41, 65–66, 70.

246. Diekmann further explains “[t]he organic layer stack 4 can, for example, comprise the layers of the organic layer stack of Figure 1” Diekmann, 92, which includes as radiation-emitting regions “a SEB-010:SEB020 layer . . . a TMM-004:Ir(ppy)3(15%) layer . . . and a TMM-04:TER012 layer,” Diekmann, 91. Diekmann discloses that “[t]his organic layer stack is suitable for emitting white light.” Diekmann, 91. Thus, a POSITA would recognize that these emissive layers are configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation.

247. In particular, SEB-010:SEB-020 is a blue light-emitting layer, TMM-004:Ir(ppy)3(15%) is a green light-emitting layer, and TMM-004:TER-012 is a red light-emitting layer. *See, e.g.*, Ex. 1027 (Klein), [0064]. These blue, green, and red light-emitting layers will generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

248. As I explain above in §VIII.A, prior art describes white light as corresponding to the spectral range from infrared radiation to UV radiation. *See also*

Suzuki, [0096], [0118], [0264], [0274]-[0279], [0299], [0316]-[0319], [0369]-[0370].

249. Based on the above, and also for the reasons explained in §VIII.A (Claim Construction), Diekmann teaches OLEDs generating “white light” that is encompassed by “electromagnetic radiation in a spectral range from infrared radiation to UV radiation.” Specifically, Diekmann teaches “white light” covering the full infrared-to-UV spectrum, or at a minimum, wavelengths falling “anywhere between the lowest frequency of the UV spectrum and the highest frequency of the IR spectrum” because the emitted white light includes visible wavelengths.

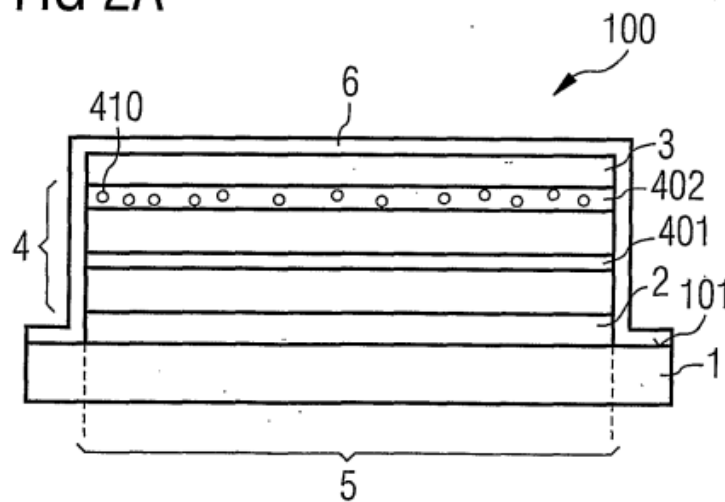
250. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**viii. [1G/6G/10G] wherein the organic layer sequence comprises an electron transport layer that is n-doped[; and]**

251. Diekmann discloses or at a minimum suggests this element. As I explained above, Diekmann discloses that its organic radiation-emitting component includes an organic functional layer with an “electron transport layer[.]” *See, e.g.*, Diekmann, 73. Diekmann discloses that the organic radiation-emitting component with organic layer stack 4 “has a doped layer 402 with a dopant 410 . . . . The dopant 410 can be for example cesium, barium or lithium fluoride.” Diekmann, 91. As shown in the Figure 2A example below, the doped layer 402 is located between

cathode 3 and radiation-emitting region of layer 401. Diekmann explains that the doped layer could be “arranged so that it faces the cathode or is adjacent to the cathode,” Diekmann, 10, consistent with where ETLs are positioned in OLEDs. Diekmann also explains that the doped layer arranged to face the cathode is “an n-doped layer.” Diekmann, 10. In addition, Diekmann discloses the doped layer 402 is doped to “*increase[] the conductivity* of the doped organic layer and, in the case of an n-doped layer adjacent to the cathode, leads to better injection of electrons from the cathode into the organic layer stack.” Diekmann, 10, 91. A POSITA thus would have recognized doped layer 402 as an “electron transport layer” which serves the function of “transport[ing] negative charge carriers—electrons—from the . . . cathode, to the radiation-emitting region” as described in the ’250 patent. ’250 patent, 25:1-4; Diekmann, 10, 73.

FIG 2A



Diekmann, 87, 91, Fig. 2A; *see also* Diekmann, 115–116, 118–119, Fig. 2A.

252. In fact, Diekmann teaches the use of exemplary materials for its electron-conducting layer, including Alq<sub>3</sub>, BAlq, and TPBi, that were well-known materials for ETLs (*see, e.g.*, Ex. 1038 (Baldo, 1999)). Diekmann, 5. Indeed BAlq and TPBi are exemplary electron transport layer materials as listed by the '250 patent. '250 patent, 26:44-55.

253. Moreover, Diekmann discloses that its electron transport layer, doped layer 402, “is generally an n-doped layer,” and explains that “[p]referred n-dopants are cesium, barium and lithium fluoride.” Diekmann, 10; *see also* Diekmann, 91, 119. A POSITA would have understood that Diekmann’s doped layer 402 is an electron transport layer that is n-doped.

254. Even had Diekmann not disclosed that its doped layer is an n-doped electron transport layer, it would have been obvious to a POSITA to use an n-doped ETL in the OLEDs as taught by Diekmann.

255. A POSITA would have been motivated to use an n-doped ETL to improve conductivity of Diekmann’s ETL and improve electron transport from the cathode to the light-emitting region and facilitate injection of electrons from the cathode. Diekmann, 10. As explained above in §V.A.4, by 2008, using n-doped electron transport layers in both fluorescent and phosphorescent OLEDs, and the advantages for doing so, were well known in the art. §X.A.1.viii; Ex. 1024 (Walzer), 1254–1255; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross); Diekmann, 10,

91, 119. A POSITA would have appreciated the desire for improved device characteristics, such as lower driving voltage and better power efficiency, and that use of an n-doped ETL would achieve that objective. Ma, 810; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross).

256. A POSITA would have had a reasonable expectation of success in using n-doped ETLs at least because they were widely used due to their contribution to increases in OLED performance as discussed above. Implementing n-doped ETLs would have been a straightforward and routine modification to Diekmann's OLEDs, particularly as Diekmann recognizes the benefits of an "n-doped layer." Diekmann, 10. The prior art also has numerous examples for such n-doped ETLs, as explained above. §X.A.1.viii; Ma, 812–814; Ex. 1018 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross); Suzuki, [0333]; *see also* §X.C.1.x.

**ix. [1H/6H/10H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound; and**

257. Diekmann discloses this element. Diekmann teaches that its radiation-emitting component with organic layer stack 4 comprises a layer containing Ir(ppy)<sub>3</sub>, which is an iridium-containing compound. For example, Diekmann teaches that "[t]he organic layer stack 4 can, for example, comprise the layers of the organic layer stack of Figure 1," Diekmann, 92, which includes "a TMM-004:Ir(ppy)<sub>3</sub>(15%) layer (Irppy = fac-tris(2-phenyl-pyridyl)iridium complex)." Diekmann, 91. The TMM-

004:Ir(ppy)<sub>3</sub>(15%) layer contains Ir(ppy)<sub>3</sub>, which is an iridium-containing compound which functions as a green light-emitting phosphorescent dopant. Ex. 1038 (Baldo, 1999), 4.

258. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**x. [11/10I] wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

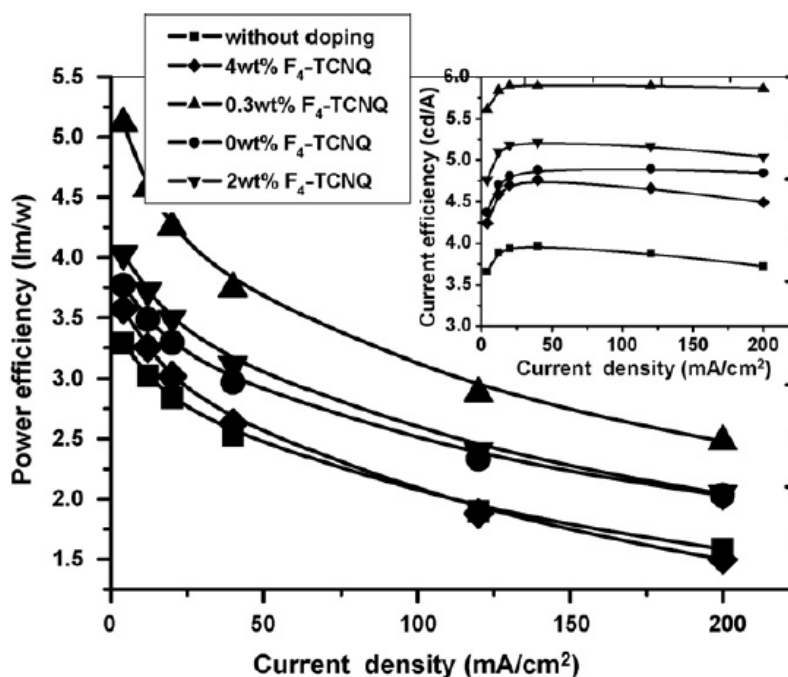
259. This element would have been obvious to a POSITA based on Diekmann in view of Ma. As I explained above, Diekmann discloses, and at minimum, renders obvious using an n-doped electron transport layer. *See* §X.C.1.viii. It would have been obvious to a POSITA to use 8-hydroxyquinolinolato-lithium as the dopant in Diekmann's n-doped electron transport layer, as taught by Ma. Ma teaches an OLED with an electron transport layer n-doped with 8-hydroxy-quinolinatolithium ("Liq") and its benefits, as explained above. §X.A.1.x; Ma, Abstract, 810–814.

260. A POSITA would have been motivated to use an Liq-doped ETL as taught by Ma in Diekmann's OLEDs to obtain the known benefits of Liq-doped ETLs to their performance. The use of Liq-doped electron transport layers in OLEDs was a known practice with known benefits. *See* §V.A.7; Ex. 1034 (Endo), L800, L802; Ma, 810, 811; Ex. 1040 (Choi), 062101-1. At the time, it was highly desirable to create OLEDs with a low operating voltage and high efficiency, and it was known

that Liq-doping the electron transport layer was one way of realizing these benefits.

This understanding is reflected, for example, in Ma, which explains that “[s]ince the discovery of organic light-emitting devices (OLEDs), there has been a considerable interest in developing OLEDs with high efficiency.” Ma, 810. Ma further explains “it is critical to enhance the carrier injection from the electrode to the transporting layer and to increase the transport conductivity” to improve power efficiency. Ma, 810. *See also* §V.A.7; Ex. 1034 (Endo), L800, L802; Ma, 810, 813.

261. Ma discloses an OLED with an Liq-doped electron transport layer. Ma tests the power efficiency of four different OLEDs, one with an undoped ETL and HTL, and four others with a fixed n-doping of Liq in the ETL and a varying amount of p-doping in the HTL. As shown in Ma’s Figure 3 below, Ma finds that “the current and power efficiencies” are improved between the control device with no doping (squares) and the optimized device that has both n-type and p-type doping (up triangles).



Ma, Fig. 3.

262. Ma concludes based on this testing that “[t]his significant enhancement in the device performance is attributed to the improved transport conductivity of both p-doped HTL and n-doped ETL at a particular doping concentration of F<sub>4</sub>-TCNQ into m-MTDATA and Liq into Bphen” and, “[a]s a result, the high carrier balance is reached in the emission zone, which leads to the enhanced current and power efficiency at low driving voltage.” Ma at 812. Therefore, Ma explicitly teaches that the current and power efficiency of an OLED can be increased at a low driving voltage by utilizing an ETL which is doped with Liq.

263. Accordingly, Ma discloses that a “doping concentration of the Liq” in the electron transport layer leads to increased current density. Ma, 811–814. In fact,

as I explained above in §V.A.4, it was understood in the art at the time, as explained in Ma, that to “enhance power efficiency, it is critical to enhance the carrier injection from the electrode to the transporting layer and to increase the transport conductivity.” Ma, 810. For example, Ma teaches that doping “Liq to Bphen can improve the electron transport ability of the co-deposited layer.” Ma, 813. Ma further notes that improved charge balance would be expected to improve OLED stability. In a device where “the holes and electrons have a good balance . . . we can predict that the complete [device] should have a good lifetime.” Ma, 814. A POSITA would have been motivated to use an Liq-doped electron transport layer in Diekmann’s OLEDs to achieve these benefits.

264. Indeed, Diekmann already contemplates an n-doped electron transport layer that “advantageously increases the conductivity” of the ETL and “leads to better injection of electrons,” so using an Liq-doped electron transport layer merely involves using a different dopant. *See* Diekmann, 10. As I explained above, Liq was known in the art at the time to have good electron injection and transport properties. *See* §V.A.7 A POSITA thus would have recognized that Liq would be an advantageous dopant for Diekmann’s doped electron transport layer.

265. Moreover, a POSITA would have been motivated to use Liq as the n-dopant as it was understood that doping with large molecules such as Liq provides benefits. *See* §V.A.7; Ex. 1018 (He), 5775 (noting that a larger size dopant “reduces

the probability” of the dopant “diffusing into the emission layer to quench excitons”).

For example, Diekmann explains that “doping advantageously increases the conductivity of the doped organic layer” and that the “dopant preferably has a low diffusion constant . . . as is usually the case with large atoms or molecules.”

Diekmann, 10.

266. Liq has a larger molecular weight than Diekmann’s preferred n-dopants. The molecular weight for Liq, LiF, Barium, and Cesium are as follows:

- Liq: 151.09 g/mole. *See* Ex. 1029 (Lumtec, Liq, <https://www.lumtec.com.tw/products-view.php?ID=327>);
- LiF: 25.94 g/mole. *See* Ex. 1030 (Lumtec, LiF, <https://www.lumtec.com.tw/products-view.php?ID=371>);
- Barium: 137.327(7) g/mole. *See* Ex. 1031 (CIAAW, Barium, <https://www.ciaaw.org/barium.htm>);
- Cesium: 132.90545196(6) g/mole. *See* Ex. 1032 (CIAAW, Cesium, <https://www.ciaaw.org/caesium.htm>).

Ex. 1029–Ex. 1032. A POSITA thus would have recognized Liq would be advantageous in reducing dopant diffusion.

267. Diekmann discloses an n-doped layer and explains that large dopant size is one factor for selecting preferred dopants. Diekmann, 10. Liq is one such dopant. Suzuki and Diekmann are not limited to any preferred dopants, and does not

teach away from other n-dopants. *See* Diekmann, 91 (“dopant 410 can be *for example* cesium, barium or lithium fluoride”); Suzuki, [0333].

268. A POSITA would further have recognized that Liq could have additional benefits over n-dopants like Diekmann’s preferred n-dopants, and would not view existing dopant materials contemplated by Diekmann as the final, optimized solution. For example, Zheng et al. noted that “[t]o achieve a balanced injection of carriers, it is common to use low-work-function metals such as Li, Ca, Mg, etc., to enhance electron injection into organic materials. However, such metals are not stable in air and need to be protected in the device processing, and sometimes may react with and diffuse into organic material and deteriorate the device.” Ex. 1039 (Zheng), 252. Thus, POSITAs would have expected Liq to be more stable than low-work-function metals, such as cesium and barium, when used to n-dope an ETL. Zheng et al. further noted that insulating materials like LiF “need quite high temperature for evaporation and accurate control of thickness.” Ex. 1039 (Zheng), 253. Liu et al. also taught that Liq can be made thicker than LiF without significantly compromising EL characteristics such as power efficiency, because Liq has electron transporting properties while LiF is insulating and can blocks electron injection at greater thicknesses. Ex. 1018 (Liu), 212–213. Thus, a POSITA would have expected that Liq would be easier to process and have better EL characteristics than LiF when used to n-dope an ETL. Ex. 1034 (Endo), L802, Figs. 4, 5 (showing better luminance

and current density characteristics for Liq-doped ETL than LiF-doped ETL).

269. Accordingly, a POSITA would have recognized that Liq increases ETL conductivity, has good electron injection and transport properties, and has a larger molecular weight suitable for use as an n-dopant, consistent with the well-known conceptions of n-doping in Diekmann and the art, and would have been motivated to use Liq as the dopant in Diekmann's electron transport layer with a high probability of success, particularly considering Diekmann already contemplates an analogous n-doped layer for electron transport. Diekmann, 10, 91, 119; Ma, 813–814; *see also* Ex. 1028 (Liu), 211, 212–214; Suzuki, [0333]; *compare* Ex. 1029 with Ex. 1030–Ex. 1032.

270. A POSITA could readily have implemented an Liq-doped electron transport layer in Diekmann's device. Such a configuration would have amounted to applying a known technique (Liq-doping the ETL) of Ma to improve similar OLEDs (e.g., OLEDs using an n-doped ETL) taught by Diekmann in the same way. By the time of the '250 patent, conductive doping of transport layers was a mature technology. *See* §V.A.4. Indeed, Diekmann acknowledges the benefits of using n-doped electron transport layers as in Ma. Diekmann, 10, 91, 119; Ma, 810–814. For example, He uses an n-doped ETL in an OLED having an iridium-containing compound ( $\text{Ir(ppy)}_3$ ) in the emissive layer, based on the same type of electron transport layer and emissive layer taught by Ma and Diekmann, respectively.

271. Further, LiF is a preferred n-dopant for Diekmann. *See* Diekmann, 10.

It is well-established that the mechanism by which LiF improves electron injection is analogous to the mechanism by which Liq improves electron injection. Ex. 1028 (Liu), 213 (lithium released from LiF/Liq dopes organic layer); Ex. 1039 (Zheng), 254 (electron injection enhancement with Liq “very similar” to LiF). Thus, a POSITA would have understood Liq is a suitable n-dopant to use in place of n-dopants like LiF, and further would have reasonably expected success in creating OLEDs with Liq-doped ETL, just as others have succeeded in creating OLEDs with an LiF-doped ETL. It is well within the skill of a POSITA to swap out one n-dopant in the ETL for another.

272. A POSITA would also have reasonably expected success in using Liq as the n-dopant in Diekmann’s ETL because Diekmann already includes blocking layers between the doped ETL and emissive layer. Diekmann, Fig. 2A. Blocking layers have long been known to be effective in reducing dopant diffusion and mitigating exciton quenching, including for n-dopants like lithium and cesium. *See* §V.A.5. Because Liq is a larger molecule with a higher molecular weight, *see* Diekmann, 10 (“the dopant preferably has a low diffusion constant within the organic layer stack, as is usually the case with large atoms or molecules, for example”), a POSITA would understand it would be less mobile than these elemental n-dopants. Thus, that blocking layers were sufficient to alleviate

quenching concerns for n-dopants like lithium and cesium supports a POSITA's expectation that Liq would be a suitable n-dopant, while also relaxing the constraints on the blocking layer, as noted earlier. *See* §V.A.4.

273. Thus, a POSITA would have understood the benefits of using Liq to n-dope an ETL and such use constituted incorporating a well-known technique to Diekmann's OLEDs. And a POSITA would have reasonably expected success to achieve improved performance of OLEDs by n-doping the ETL. Liq was a known n-dopant facilitating electron transport and injection for the ETL. *See* §V.A.7; Ma, 813; Ex. 1034 (Endo), L800; Ex. 1040 (Choi), 062101-1–062101-2; *see also* Ex. 1042 (Schmitz), 3019; Ex. 1028 (Liu), 212–214.

274. A POSITA would have reasonably expected success in using an Liq-doped ETL for Diekmann's OLEDs. First of all, Diekmann already contemplates an n-doped ETL. Diekmann, 10. And incorporating an Liq-doped ETL simply involves using a different dopant whose application would have been a routine matter for a POSITA, particularly given that n-doped ETLs was a well-established technology. *See* §V.A.4. A POSITA would have understood that elements in Ma's devices were applicable to Diekmann's OLEDs. For example, He discloses an example of n-doping an ETL (such as BPhen like Ma) for OLEDs with an iridium-containing emissive layer such as with Ir(ppy)<sub>3</sub>, the same type of emissive layer disclosed by Diekmann. Accordingly, a POSITA would have reasonably expected to succeed in

using Liq as the n-dopant for the ETLs in Ir-based OLEDs as taught by prior art (Diekmann, Suzuki, He, and Ma). As I explained above, phosphorescent OLEDs with p- and n-doped transport layers were well-known devices, *see* §V.A.4, and Liq was also a well-studied material. *See, e.g.*, §V.A.7.

275. Moreover, it would have been obvious for a POSITA to apply the same dopant to different ETL materials (and vice versa) in different OLEDs, and a POSITA would have been readily able to do so with a reasonable expectation of success. For instance, applying Liq as a dopant to ETL materials such as BPhen (Ma's ETL) and Alq<sub>3</sub> (identified as ETL in Diekmann) was a known technique to improve OLED performance. Ma, 810–814; Diekmann, 5; *see also* Ex. 1034 (Endo), L800–L802. As another example of the same dopant used in different ETLs, the n-dopant Li has been used in BPhen (Ex. 1020 (Pfeiffer), 1633), BCP (Ex. 1024 (Walzer), 1245), and Alq<sub>3</sub> (Ex. 1034 (Endo), L802). As examples of different dopants used in the same ETLs used in different OLEDs: Li was the n-dopant for a BPhen ETL used for a phosphorescent OLED (Ex. 1020 (Pfeiffer), 1633), as well as for a BPhen ETL used for a fluorescent OLED (Ex. 1024 (Walzer), Fig. 29); Cs was the n-dopant for a BPhen ETL used for a phosphorescent OLED (Ex. 1018 (He), Fig. 1); and Liq has been used as the n-dopant for a BPhen ETL (Ma, 810–811; Ex. 1034 (Endo), L802, Fig. 1).

276. Given an emissive layer, identifying an ETL material that is appropriate

for the emitter materials and that meets the required energy levels for injection and transport is within the skill of a POSITA. POSITAs in the OLED field routinely design OLED stacks based on energy level alignment and known material compatibilities. White OLEDs like those in Diekmann do not require a different analysis. Indeed, the prior art includes many examples of white OLED stacks with appropriate choices of ETL, dopant type, and concentration capable of being determined experimentally. *See, e.g.*, Ex. 1053 (Schwartz, 2008), 053311-1, Fig. 1; Ex. 1054 (Schwartz, 2006), 61920Q-1–61920Q-2, Fig. 1.

277. Further, identifying the appropriate doping concentration of Liq for good charge balance in a given OLED is a matter of routine optimization well within the skill of a POSITA. There are many examples in the literature showing how researchers could readily create OLEDs at various different doping concentrations, measure their electrical characteristics, and determine which doping concentrations result in the highest current density and lowest driving voltage. For example:

- Ex. 1040 (Choi, 2009), 062101-2–062101-3 (measuring different Liq doping ratios)
- Ex. 1024 (Walzer, 2007), Fig. 6 (varying concentration of F4-TCNQ in ZnPc to change conductivity), Fig. 18 (varying concentration of pyronin in NTCDA to vary conductivity), Fig. 27 (showing impact of doping concentration on current flow through an OLED)

Ma itself also demonstrates that the Liq doping concentration for optimum charge balance can be experimentally determined, Ma, 813. These papers further illustrate that operating OLEDs do not require optimum charge balance, because they show that functioning devices were formed at various different doping concentrations.

278. As I explained above in §X.A.1.x, a POSITA would have also applied teachings regarding electron and hole transport layers from fluorescent OLEDs to phosphorescent OLEDs. For example, the 2007 Walzer paper explains how the “p-i-n architecture” was first developed for fluorescent OLEDs, and then “extended to phosphorescent OLEDs.” Ex. 1024 (Walzer), 1254–1255. The fluorescent OLED structure (Fig. 29) is nearly identical to the phosphorescent OLED structure (Fig. 30) except the phosphorescent emitter replaces the fluorescent emitter and a different blocking layer is used. Ex. 1024 (Walzer), 1254–1255; Ex. 1016 (Pfeiffer), 1633–1634. Notably, the n-doped ETL Li:Bphen is used for both fluorescent and phosphorescent OLEDs. Ex. 1024 (Walzer), 1254–1255; Ex. 1020 (Pfeiffer), 1633–1634. This demonstrates the modular approach to OLED stack design, even across different emitter types, and shows that it was not a big leap for a POSITA to apply ETL n-dopants studied in the context of fluorescent OLEDs, such as Ma’s Liq, as the n-dopant for phosphorescent OLEDs with n-doped ETLs.

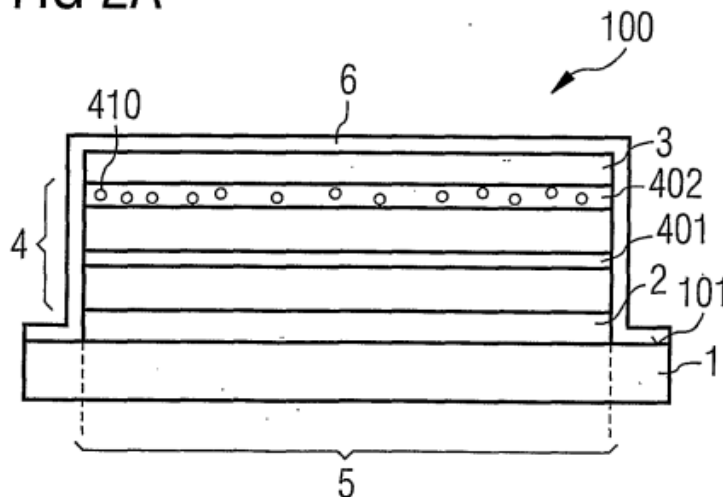
279. Thus, n-doping the electron transport layer was a well-known technique for both fluorescent and phosphorescent devices by the time of the ’250 patent, and

the use of the same n-dopants for both fluorescent and phosphorescent OLEDs was known. Ex. 1024 (Walzer), 1254–1255. Even further, the use of both fluorescent and phosphorescent emitters in the same stack sharing the same layers for OLEDs was also known. Ex. 1035 (Schwartz, 2008), 053311-1, Fig. 1; Ex. 1036 (Schwartz, 2006), 61920Q-1–61920Q-2, Fig. 1. Therefore, a POSITA would naturally have applied n-dopants with good performance in fluorescent OLEDs (as in Ma) to n-doped phosphorescent OLEDs (as in Diekmann), and would have reasonably expected success of such an application.

- xi. [6J/10J] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm;**

280. Diekmann discloses or suggests this element. Diekmann discloses that it includes an organic light-emitting layer sequence that includes a “second electrode 3” serving as the cathode, as illustrated in the example below:

**FIG 2A**



Diekmann, 91, Fig. 2A.

281. Diekmann discloses that the cathode is a “metallic layer that contains . . . silver and has a *thickness of approximately 30 nm*.” Diekmann, 92 (emphasis added). Diekmann thus discloses a cathode having a thickness of at least 1 nm and at most 50 nm.

282. Diekmann further teaches that this cathode is transparent so as to enable light to be transmitted through it: “[t]he second electrode 3 is also transparent to visible light, in particular to light generated by the organic layer stack 4.” Diekmann, 92. It was well-known in the art at the time that in order for light to be transmitted through an electrode, the electrode must be made sufficiently thin to be rendered transparent or semi-transparent. *See* §V.A.1 above; *see also, e.g.*, Ex. 1023 (Bulovic). Diekmann teaches this as well, explaining that “to be permeable to the light emitted by the organic layer stack, the metallic layer must be sufficiently thin.” Diekmann, 8. Thus, Diekmann teaches an OLED with a cathode thickness of approximately 30 nm, and further teaches a range of cathode thicknesses to provide transparency such that the cathode will be made permeable to the light generated in the organic light-emitting layer. Diekmann thus teaches a range of cathode thickness that overlaps with the range of thicknesses claimed.

283. It would have been clear to a POSITA that the upper bound of 50 nm in the claimed range is not critical to the claimed invention; as explained above, the

reason for using a thickness in this range is to render the cathode transparent or semi-transparent. Indeed, the '250 patent also makes this clear, as the specification merely describes the 1–50 nm range as an example thickness for a transparent metal layer. '250 patent, 3:8–11. Thus, while Diekmann describes that the cathode thickness can generally be between 1 nm and 100 nm, Diekmann specifically discloses using a cathode thickness of about 30 nm which is transparent or semi-transparent. Diekmann, 92. Accordingly, a POSITA would have appreciated that Diekmann discloses this element by specifically teaching cathode thicknesses within and overlapping with the claimed range.

284. Moreover, even had Diekmann not disclosed this element, it would have been obvious to a POSITA to use a cathode thickness in the 1–50 nm range in Diekmann's OLEDs. Diekmann specifically explains that there are advantages in using transparent electrodes to improve luminance, and particularly teaches a transparent or semi-transparent cathode with about 30 nm thickness. Diekmann, 8, 92. And as I explain above, the technique of using a cathode thickness in the 1–50 nm range to achieve improved transmission by implementing transparent or semi-transparent electrodes was well known in the art. §X.A.1.xi; *see also* Diekmann, 92; Suzuki, [0289]; Ex. 1023, 29. Accordingly, a POSITA would have been motivated to use a cathode with a thickness between 1–50 nm in Diekmann to achieve improved light output. Moreover, a POSITA would have reasonably expected

success in incorporating a 1–50 nm thick cathode because such a cathode (e.g., made of magnesium, silver, or Mg/Ag alloy) was already used and known to improve luminescence in prior OLEDs. *See* Diekmann, 92; Suzuki, [0288]-[0290]; Ex. 1023, 29.

**xii. [10K] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and**

285. Diekmann discloses this element. Diekmann discloses that its cathode is “metallic layer that contains . . . silver.” Diekmann, 92; Diekmann, 3–4. Diekmann explains that the “second electrode 3 serves as the cathode. It consists of aluminum or silver.” Diekmann, 91.

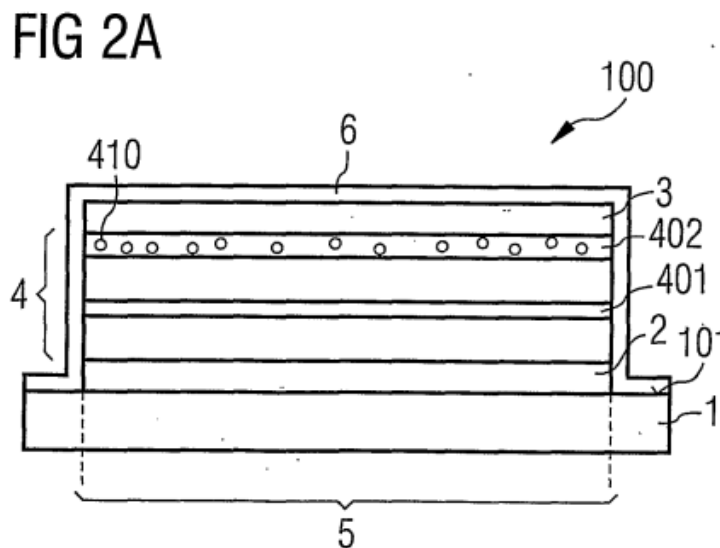
286. Diekmann further explains that “compounds, combinations and alloys” of silver and magnesium “can prove to be advantageous as cathode material,” allowing the cathode to be transparent for a “top emitter” OLED. Diekmann, 75. Diekmann also teaches that the cathode “preferably has a material that has a low work function for electrons.” Diekmann, 3–4. As I explained above in §V.A.1, silver-magnesium alloys were well-known in the art as a suitable cathode material for OLEDs because they have a low work function and can be made sufficiently transparent for top-emission OLEDs. *See, e.g.*, Ex. 1023 (Bulovic), 29.

287. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

**xiii. [10L] wherein the cathode is in direct contact with a Lithium containing layer.**

288. Diekmann in combination with Ma renders obvious this element.

289. The combined Diekmann/Ma system satisfies this element. I explain above that it would have been obvious to use Liq in Diekmann's n-doped electron transport layer (organic layer 402) as taught by Ma. *See* §X.C.x. Diekmann describes that the cathode is in direct contact with organic layer 402 containing dopant 410, for example, as shown below:



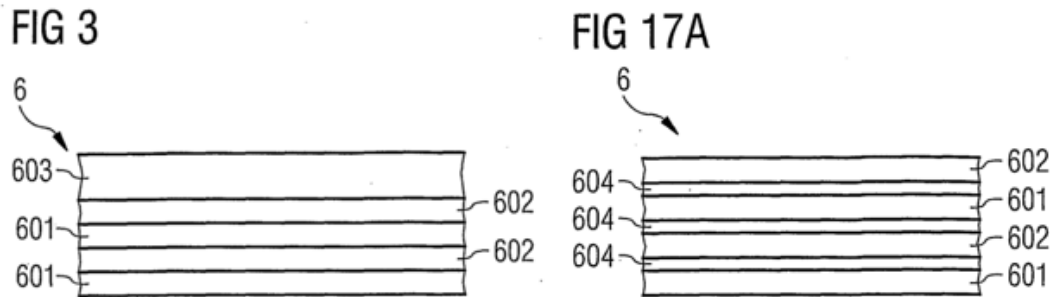
Diekmann, Fig. 2A; *id.*, 10, 91. Accordingly, in the combined Diekmann/Ma system, the cathode is in direct contact with a Li containing layer because Liq-doped ETL (organic layer 402 containing Liq) is in direct contact with the cathode as illustrated in the Figure 2A example.

**2. Claim 2**

**i. [2A] The device of claim 1, wherein at least one part of**

**the encapsulation is formed by an insulation layer, and**

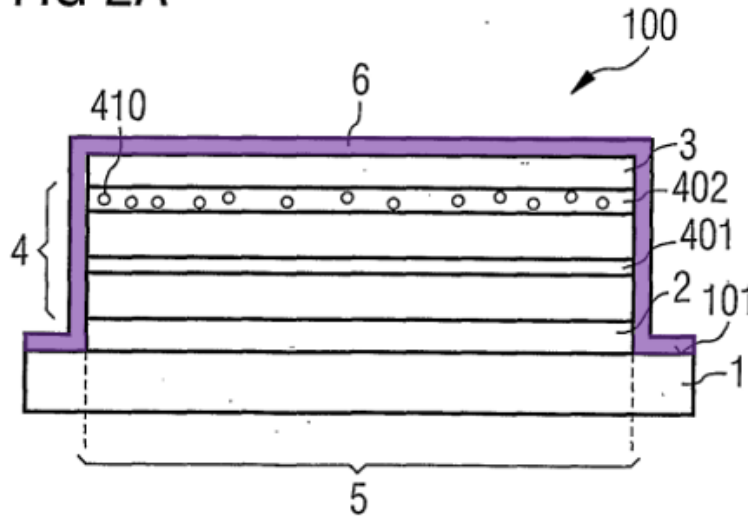
290. Diekmann discloses this element. As I explain in §X.C.1.v, Diekmann discloses a thin-film encapsulation (labeled 6), as illustrated below.



Diekmann, 94, 109, Figs. 3, 17A.

291. Diekmann describes that “the thin-film encapsulation 6 comprises two first barrier layers 601, which comprise silicon oxide or consist of silicon oxide, and two second barrier layers 602, which comprise silicon nitride or consist of silicon nitride.” Diekmann, 94. A POSITA would recognize that both silicon oxide and silicon nitride are insulating materials. A POSITA would also have understood that Diekmann’s encapsulation layers electrically insulate the cathode and anode in the organic radiation-emitting component from each other as shown below, to avoid short-circuiting on the sides of the electrodes. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

FIG 2A



Diekmann, Fig. 2A.

- ii. **[2B] wherein the insulation layer comprises at least one of: resin, silicon oxide, or silicon nitride.**

292. Diekmann discloses this element. As I explained above, Diekmann's encapsulation includes insulation layers comprised of the insulating materials silicon oxide and silicon nitride. Diekmann, 94 ("the thin-film encapsulation comprises two first barrier layers 601, which comprise *silicon oxide* or consist of silicon oxide, and two second barrier layers 602, which comprise *silicon nitride* or consist of silicon nitride.") (emphases added)).

293. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

3. **Claim 4: The device according to claim 1, wherein the organic light-emitting diode comprises a hole transport layer that is p-doped.**

294. Diekmann discloses or at a minimum renders obvious this element alone or in combination with Ma. Diekmann discloses that its organic layer sequence comprises a hole transport layer that is p-doped. Diekmann explains that “[t]he organic layer stack 4 can, for example, comprise the layers of the organic layer stack of Figure 1.” Diekmann, 92. Diekmann teaches that the organic layer stack of Figure 1 includes “a 1-TNATA layer” and “a sp-TAD layer.” Diekmann, 4–5. Diekmann further teaches that these materials are used in “hole-conducting” layers. Diekmann, 4–5. A POSITA would have understood that Diekmann’s “hole-conducting layer” is a hole transport layer. Indeed, the materials taught by Diekmann as examples of a hole-conducting layer such as sp-TAD were well-known materials for facilitating the transport of holes from the anode to the emissive layer. *See* §V.A.4; Ex. 1018 (He); Ex. 1020 (Pfeiffer).

295. Diekmann further teaches that this hole transport layer is p-doped. Diekmann discloses that “the organic layer stack comprises a *doped organic layer* with a dopant.” Diekmann, 10 (emphasis added). Diekmann explains that the p-doped layer is “arranged so that it faces the anode or is adjacent to it.” Diekmann, 10. Diekmann further explains that this doped organic layer may be the “outermost layer of the organic layer stack” that “forms a common interface with the respective electrode facing it.” Diekmann, 10. In such a case, p-doping the hole transport layer would result in “better hole injection from the anode into the organic layer stack.”

Diekmann, 10. Thus, Diekmann discloses including a p-doped hole transport layer within its organic layer stack.

296. Even had Diekmann not explicitly disclosed the specific use of a p-doped hole transport layer, it would have been obvious to a POSITA to p-dope Diekmann's hole transport layer adjacent to the anode as taught by Diekmann and Ma. A POSITA would have been motivated to use a p-doped HTL in Diekmann's OLEDs to improve their performance. As I explained in §V.A.4 above, p-doped hole transport layers were well-known for OLEDs at the time. In particular, it was well-known that using a p-doped hole transport layer could reduce the voltage and improve current and power efficiencies of the OLED. *See* Ex. 1018 (He), 5773 ("p-i-n" OLED (i.e., an OLED with an n-doped ETL and p-doped HTL) "features efficient carrier injection from both contacts into the doped transport layers and low ohmic losses in these highly conductive layers" and "low operating voltages are obtained compared to conventional undoped OLEDs"); Ex. 1019 (He), 3911 ("high conductive *p*- and *n*-doped layers enhance the charge injection from the contacts and reduce the ohmic losses in these layers resulting in "reduced . . . operating voltage for both fluorescent and phosphorescent devices."); Ma, 810 ("[r]ecently, the p-doping of HTL has drawn a lot of attentions because of its ability to enhance hole injection and lower driving voltages in OLEDs."); Ma, 812–814 (finding that "the current and power efficiencies" of devices with an ETL n-doped with Liq and an

HTL which is p-doped “are considerably improved as compared to” devices with no doping).

297. Indeed, Ma explains using “p-doping of HTL” to “enhance hole injection.” Ma, 810. That p-doping hole transport layer leads to “better hole injection from the anode into the organic layer stack” was well-known. Diekmann, 10. And numerous materials such as 4,4',4''-tris(3-methylphenylphenylamono) triphenylamine (m-MTDATA) were well-known compounds to be p-doped for improved hole transport from the anode to the EML. Ma, 810–814; Diekmann, 4–5; *see also* Ex. 1018 (He); Ex. 1020 (Pfeiffer).

298. A POSITA would have further recognized the benefits of combining a p-doped hole transport layer with an n-doped electron transport layer which, as I explained above in §X.C.1.viii, Diekmann also teaches. For example, as explained by Ma, “current efficiency not only relies on the carrier injection, but also on the carrier balance.” Ma, 813. A POSITA would recognize that a “*p-i-n*” OLED (i.e., an OLED that has both a p-doped hole transport layer and an n-doped electron transport layer) would offer substantial flexibility to tune electron and hole currents in the OLED to optimize charge balance, which benefits both efficiency and device stability. Ma, 810–814; Ex. 1018 (He), Abstract; Ex. 1019 (He), 3911–3912; Ex. 1020 (Pfeiffer), 1633; Ex. 1021 (Gross), 5–14. Indeed, the “*p-i-n*” configuration which Suzuki and Ma teach was well known. *See, e.g.*, Ma, 810–814; Ex. 1018 (He);

Ex. 1019 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross). In light of these well-known benefits, a POSITA would have been motivated to combine an p- and n- doping in the hole- and electron- transport layers of Diekmann's OLEDs. Moreover, adding an p-dopant to a hole transport layer would be a routine matter well within a POSITA's ability.

299. A POSITA would have reasonably expected success in using a p-doped hole transport layer in Diekmann's OLEDs, in conjunction with the n-doped electron transport layer also taught by Diekmann (as explained above in §X.C.1.viii). As discussed above, Diekmann already contemplates both an n-doped electron transport layer and a p-doped hole transport layer. Further, *p-i-n* OLEDs using both n-doped and a p-doped transport layers were well known in the art. *See* §V.A.4 above; Ma, 810–814; Ex. 1018 (He); Ex. 1019 (He); Ex. 1020 (Pfeiffer); Ex. 1021 (Gross). Moreover, adding a p-dopant to a hole transport layer would be a routine matter well within a POSITA's ability.

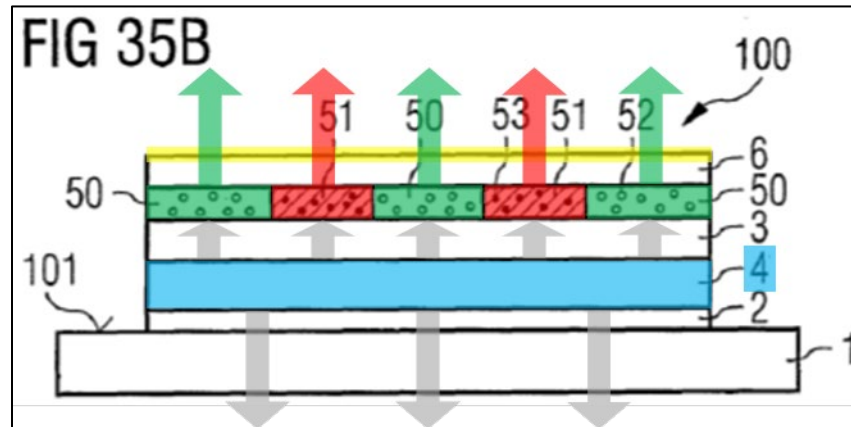
300. Accordingly, a POSITA would have appreciated that Diekmann discloses or at a minimum renders obvious this claim alone or in view of Ma.

#### 4. Claim 5

- i. **[5A] The device according to claim 1, wherein a color filter is arranged between the emission layer and the radiation exit area, and**

301. Diekmann discloses this element. Diekmann describes that the OLEDs

comprise a color filter layer forming different colored subregions and generating a “multicolored” output. *See, e.g.*, Diekmann, 36–38, 40–41, 128–130. As shown in the example below, Figure 35B shows the color filters arranged between the emission layer (within organic layer stack 4), and the radiation exit area:



Diekmann, Fig. 35B (annotated).

302. Diekmann also teaches that “at least a majority of the electromagnetic radiation generated in the organic layer stack 4 during operation passes through this [color filter] layer.” Diekmann, 130; *see also* Diekmann, 40, 129.

303. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

- ii. **[5B] wherein the color filter is configured to be highly transmissive for a first spectral subrange of the generated electromagnetic radiation and highly absorbent for a second spectral subrange of the generated electromagnetic radiation.**

304. Diekmann discloses this element. As explained above, Diekmann discloses that the OLED may include a color filter layer to form differently colored

subregions and a “multicolored” output. Diekmann further discloses that a “first color sub-region emits light of a first color” and a “second color sub-region emits light of a second color,” with the first color being different from the second color. Diekmann, 41; *see* Diekmann, 129–130. Diekmann teaches that each such “color filter is suitable for filtering light of a specific wavelength range.” Diekmann, 40. As such, light of these specific wavelength ranges is “at least partially absorbed by the color filter.” Diekmann, 40. Thus, “a first color component can be filtered out of white light” while at the same time “a second color component can pass through the color filter essentially unhindered.” Diekmann, 40. As a result, “[t]he color sub-area with the color filter then essentially emits light of the second color component.” Diekmann, 40. Accordingly, a POSITA would have appreciated that light wavelength matching color of Diekmann’s color filters is highly transmissive while wavelength outside the color property of the filter is highly absorbent to achieve the purpose of color filtering. Diekmann, 40. Accordingly, a POSITA would have appreciated that Diekmann discloses this element.

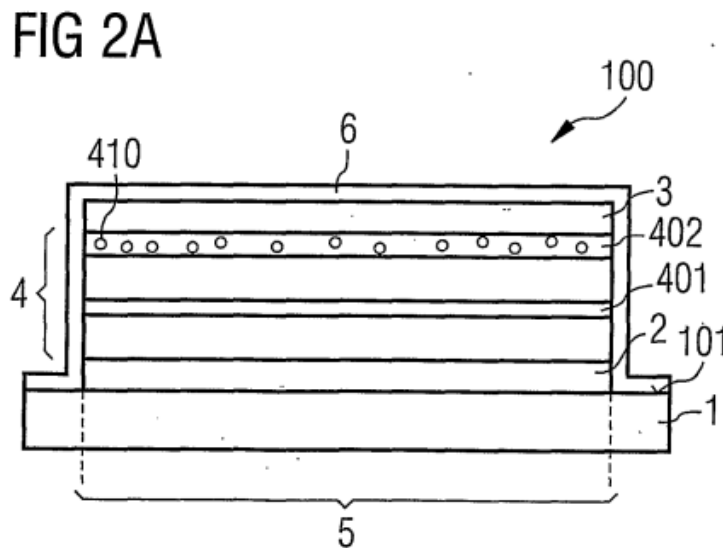
- 5. Claim 7: The device according to claim 6, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.**

305. Diekmann discloses this element for the same reasons provided in §X.C.1.xii [10K].

- 6. Claim 8: The device according to claim 6, wherein the cathode is in direct contact with a Lithium containing layer.**

306. Diekmann discloses this element, or at a minimum, renders obvious this element in combination with Ma.

307. First, Diekmann discloses this element. Diekmann discloses that the cathode is in direct contact with a Li containing layer. For example, as illustrated in Figure 2A, the cathode is in direct contact with organic layer 402 containing dopant 410:



Diekmann, 91, Fig. 2A. Diekmann specifically discloses that the “doped layer 402 with a dopant 410” is on the “outer side” of the organic layer stack “facing the cathode” and that “[t]he dopant 410” is “lithium fluoride.” Diekmann, 91. Diekmann also explains the doped organic layer to form “a common interface with the respective electrode facing it.” Diekmann, 10.

308. Second, it would have been obvious to combine Diekmann and Ma, and the combined Suzuki/Ma OLED satisfies this element for the same reasons provided

in §X.C.1.xiii [1L/10L].

- 7. Claim 9: The device according to claim 6, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

309. It would have been obvious to combine Diekmann and Ma, and the combined Diekmann/Ma OLED satisfies this element for the same reasons provided in §X.C.1.x [1I/10I].

**D. Grounds 7-8: Diekmann, Ma, and Lee Render Obvious Claims 3, 12, and 15-16 (Ground 7); Diekmann and Lee Render Obvious Claims 11 and 13-15 (Ground 8)**

**1. Claim 3**

- i. [3A] The device of claim 1, wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,**

310. This element would have been obvious to a POSITA based on Diekmann (alone or in combination with Ma) as modified in view of Lee's teachings.

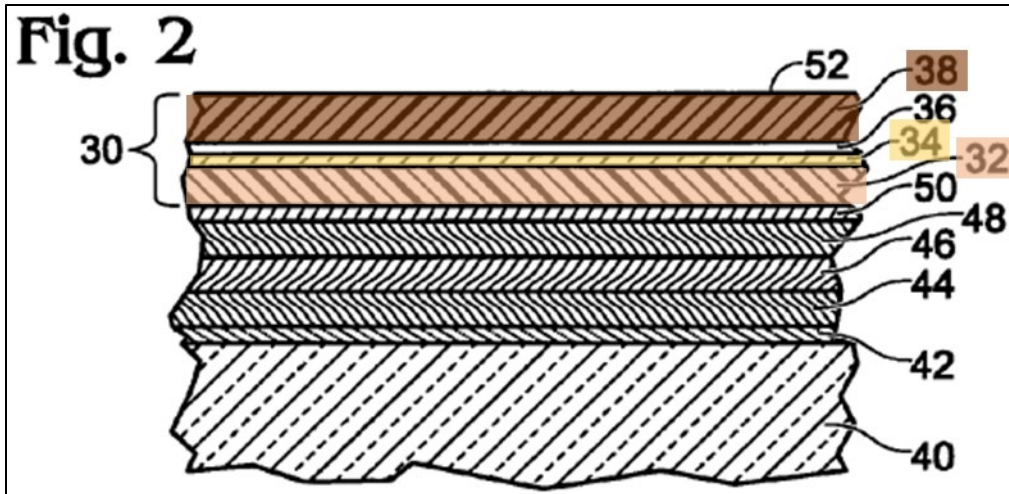
311. As I explained above in §X.C.2, Diekmann discloses a "thin-film encapsulation 6." For example, Diekmann discloses that the "thin-film encapsulation 6" includes barrier layers separated by intermediate polymer layers 604 (highlighted as orange) as shown below:

FIG 17A



Diekmann, 94, 109, Fig. 17A (annotated).

312. As I explain in §X.B.1.i, Lee teaches an encapsulation for an OLED comprising multiple encapsulation layers, a first encapsulation layer (“second semi-crystalline parylene-based polymer layer 38”) and a second encapsulation layer (“first semi-crystalline parylene-based polymer layer 32”). Lee, [0022] (“The first semi-crystalline parylene-based polymer layer is shown in FIG. 2 at 32, the inorganic barrier layer is shown at 34, . . . and the second semi-crystalline parylene-based polymer layer is shown at 38”); Lee, [0021] (“annealing . . . the second semi-crystalline parylene-based polymer layer [forms] a highly crystalline parylene-based polymer layer”). Lee thus discloses that the two encapsulation layers have independent volume structures and different levels of crystallinity. These are illustrated in Lee’s annotated Figure 2 below:



Lee, Fig. 2 (annotated), [0021]–[0022].

313. It would have been obvious to apply Lee’s technique to Diekmann’s OLEDs because Lee teaches that its multi-layered encapsulation improves the sealing performance over the structures analogous to that taught by Diekmann. *See* Lee, [0007]–[0008], [0020], [0031], [0034]). For example, it would have been obvious to replace Diekmann’s encapsulation with Lee’s multi-layered encapsulation. As another example,, it would have been obvious to use Lee’s “first semi-crystalline parylene-based polymer layer” and “second semi-crystalline parylene-based polymer layer” for Diekmann’s intermediate polymer layers 604.

314. A POSITA would have been motivated to use Lee's multi-layered encapsulation with Diekmann's OLEDs to improve the encapsulation for the reasons explained in §X.B.1.i. As I explained above in §V.A.6 and §IX.D, using of encapsulations to protect OLEDs from the ambient environment was well known at the time. *See e.g.*, Ex. 1025 (Moro); Ex. 1026 (Chwang). Indeed, Lee itself teaches the benefits of using an encapsulation in an OLED; for example, Lee explains, "the low work function metals typically used as cathodes in OLEDs are environmentally sensitive, and may be easily oxidized by moisture or oxygen from air. Therefore, it is important to protect these materials from air both during processing and during use." Lee, [0005].

315. Lee also explains specific benefits of the type of multi-layer encapsulation that it teaches. Lee discloses using an encapsulation including semi-crystalline and highly-crystalline polymer barrier layers. Lee explains that semi- and highly-crystalline parylene-based polymer films "have low-enough WVTR [(water vapor transport rate)] and OTR [(oxygen transport rate)] values that they not only 'decouple' adjacent inorganic layers to prevent the propagation of defects between inorganic layers, but also themselves help block water vapor and oxygen permeation into the OLED." Lee, [0020]; *see also* Lee, [0010], [0021], [0042]–[0043]. Thus, Lee notes that its multi-layered encapsulation provides "a significantly improved lifetime compared to prior OLEDs having polyacrylate or amorphous parylene

barrier layers.” Lee, [0020]. Diekmann explains that its intermediate polymer layers are “vapor-deposited as monomers and . . . cross-linked using UV radiation,” Diekmann, 15. This is the prior art structure that Lee’s encapsulation is intended to improve upon. Lee, [0008]. Accordingly, a POSITA would have been motivated to apply Lee to Diekmann’s OLEDs because Lee teaches its technique to provide have “low-enough WVTR and OTR values,” which are beneficial for OLEDs. *See* §X.B.1.i.

316. A POSITA would have reasonably expected success in applying Lee’s multi-layered encapsulation to Diekmann’s OLEDs. Diekmann contemplates the use of a multi-layered encapsulation with alternating layers of inorganic barrier layers and polymer interlayers. Applying Lee’s encapsulation merely replaces one set of alternating layers of inorganic barriers and polymers with another, to obtain the benefits taught by Lee. Moreover, using such a multilayer OLED encapsulation consisting of alternating organic and inorganic layers was already known in the art. Diekmann, 94, Fig. 17A; Lee, [0020]-[0024], Fig. 2; Suzuki, [0274]; *see also, e.g.*, Ex. 1025; Ex. 1026. Implementing Lee’s encapsulation which would have been well within the ability of a POSITA in view of Lee’s teaching, and a POSITA would have reasonably expected the benefits. *See* Lee, [0007]–[0008], [0020]–[0021], [0029], [0031], [0034], [0036]–[0038], [0042]–[0043].

317. Moreover, Lee is specifically directed to encapsulation for OLEDs, and teaches methods to apply its multi-layered encapsulation technique, including methods to “avoid[] delivering unwanted energy to the organic layers.” Lee, [0033]–[0035]. A POSITA thus would have expected reasonable success in applying Lee’s encapsulation technique to OLEDs such as Diekmann’s, alone or as modified by Ma, with a reasonable expectation of success.

318. Accordingly, a POSITA would have appreciated that Diekmann (alone or in combination with Ma) in view of Lee discloses this element.

**ii. [3B] the first and the second encapsulation layer each having a respective volume structure,**

319. This element would have been obvious to a POSITA based on Diekmann (alone or in combination with Ma) as modified in view of Lee’s teachings. *See* §X.D.1.i. As I explained above in §VIII.B and §X.B.1.ii, Lee teaches encapsulation layers having respective, independent volume structures.

320. First of all, as I explained in §VIII.B, during prosecution of the '514 Application (which the '250 patent claims priority to), the Applicant offered explanations for the meaning of “volume structure.” Specifically, the Applicant distinguished between the atomic and molecular arrangement inside of a solid (“volume structure”) and that at the solid’s surface (“surface structure”). Ex. 1017, 1386. The Applicant also explained that “volume structure” “comprise[s] any structure ranging from polycrystalline to polyamorphous,” including “crystalline, partly crystalline and/or polycrystalline or completely amorphous.” Ex. 1017, 1241.

321. Consistent with the explanations, Lee discloses multiple encapsulation layers that have respective, independent volume structures. Lee discloses that its encapsulation has a first “*highly crystalline*” encapsulation layer with “up to 70% of crystallinity” and a second “*semi-crystalline*” “parylene-based polymer layer” with “at least 10%” of crystallinity.” Lee, [0023], [0027]; *see also* Lee, [0020]–[0021]. A POSITA would have appreciated that two solids necessarily have different internal molecular and atomic arrangements if they have different levels of crystallinity. Lee thus discloses a first and second encapsulation layer each having respective, independent volume structures, regardless of how the term “volume structure” is defined, as explained in §X.B.1.ii.

322. Accordingly, a POSITA would have appreciated that Diekmann (alone or in combination with Ma) in view of Lee discloses this element.

**iii. [3C] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, and**

323. This element would have been obvious to a POSITA based on Diekmann (alone or in combination with Ma) as modified in view of Lee's teachings. *See* §X.D.1.i-ii. As explained in §X.D.1.i-ii and §X.B.1.iii, Lee teaches a multi-layer comprising encapsulation layers with volume structures which are distinct and independent from one another: the first (highly-crystalline) encapsulation layer has "up to 70% of crystallinity" and the second (semi-crystalline) encapsulation layer has "at least 10%" of crystallinity. Lee, [0023], [0027]; *see also* Lee, [0020]–[0021]. Lee also explains that its polymer layers have low-enough WVTR and OTR values that they "'decouple' adjacent inorganic layers to prevent the propagation of defects between inorganic layers." Lee, [0020].

324. Accordingly, a POSITA would have appreciated that Diekmann (alone or in combination with Ma) in view of Lee discloses this element.

**iv. [3D] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.**

325. This element would have been obvious to a POSITA based on Diekmann (alone or in combination with Ma) as modified in view of Lee's teachings. *See* §X.D.1.i-iii. As I explain in §X.D.1.i-ii and §X.B.1.iv, Lee discloses a second encapsulation layer that has a higher amorphicity than the first encapsulation layer. Specifically, Lee discloses a multi-layer encapsulation wherein the first (highly-crystalline) encapsulation layer (e.g., highly-crystalline parylene-based polymer layer 38) has "up to 70% of crystallinity" and the second (semi-crystalline) encapsulation layer (e.g., semi-crystalline parylene-based polymer layer 32) has "at least 10%" of crystallinity. Lee, [0020]–[0027]. Lee explains that the semi-crystalline polymer layer may be about 10% crystallinity as deposited, while the highly-crystalline polymer layer, formed by depositing a semi-crystalline polymer film and annealing to increase its crystallinity, may be about 70% crystallinity. Lee, [0021], [0023]–[0027]. Amorphicity and crystallinity both describe the volume structure of solids, and have an inverse relationship; crystalline solids have a long-range order, meaning the atoms or molecules are arranged in a periodic pattern, while amorphous solids have no long-range order, meaning the atoms or molecules are arranged without a periodic pattern. *See* Ex. 1017, 1313–1314, 1386–1387. In practical terms, this means that the higher a material's crystallinity, the lower its amorphicity; if material A has higher crystallinity than material B, then material A necessarily has a lower amorphicity than material B. Therefore, a POSITA would

recognize that because Lee's second (semi-crystalline) encapsulation layer has lower crystallinity than the first (highly-crystalline) encapsulation layer, the second encapsulation layer must also have a higher amorphicity than the first encapsulation layer.

326. Accordingly, a POSITA would have appreciated that Diekmann (alone or in combination with Ma) in view of Lee discloses this element.

**2. Independent Claims 11 and 16**

**i. [11Pre/16Pre] A device comprising:**

327. Diekmann discloses this element for the same reasons provided in §X.C.1.i [1Pre/6Pre/10Pre].

**ii. [11A/16A] an organic light-emitting diode comprising:**

328. Diekmann discloses this element for the same reasons provided in §X.C.1.ii [1A/6A/10A].

**iii. [11B/16B] an organic layer sequence,**

329. Diekmann discloses this element for the same reasons provided in §X.C.1.iii [1B/6B/10B].

**iv. [11C/16C] a radiation exit area, and**

330. Diekmann discloses this element for the same reasons provided in §X.C.1.iv [1C/6C/10C].

**v. [11D/16D] an encapsulation,**

331. Diekmann (alone or in combination with Ma) as modified in view of Lee's teachings satisfies this element for the same reasons provided in §X.D.1 [Claim 3].

**vi. [11E/16E] wherein the organic layer sequence and the encapsulation are disposed on a carrier,**

332. Diekmann (alone or in combination with Ma) as modified in view of Lee's teachings satisfies this element because the modified encapsulation is located on Diekmann's substrate for the same reasons provided in §X.C.1.vi [1E/6E/10E].

**vii. [11F/16F] wherein the organic layer sequence comprises at least one radiation-emitting region configured to generate electromagnetic radiation in a spectral range from infrared radiation to UV radiation during operation,**

333. Diekmann discloses this element for the same reasons provided in §X.C.1.vii [1F/6F/10F].

**viii. [11G/16G] wherein the organic layer sequence comprises an electron transport layer that is n-doped;**

334. The combined Diekmann/Lee OLED satisfies this element for the same reasons provided in §X.C.1.viii [1G/6G/10G].

**ix. [11H/16H] wherein the organic layer sequence comprises an emission layer comprising an iridium-containing compound;**

335. Diekmann discloses this element for the same reasons provided in §X.C.1.ix [1H/6H/10H].

- x. **[16I] wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium;**

336. It would have been obvious to a POSITA to modify the combined Diekmann/Lee OLED in view of Ma's teaching, and the modified OLED satisfies this element, for the reasons provided in §X.C.1.x [1I/10I].

- xi. **[11J/16J] wherein at least one part of the encapsulation is formed by an insulation layer, the insulation layer comprising at least one of: resin, silicon oxide, silicon nitride; [and]**

337. Diekmann discloses this element for the same reasons provided in §X.C.2 [Claim 2]. Thus, Diekmann (alone or as modified by Ma) in view of Lee satisfies this element because the encapsulation of the combined OLED includes silicon oxide or silicon nitride. *See* §X.D.1.

338. Moreover, Lee discloses its encapsulation includes inorganic barrier layer 34 formed by insulating materials  $\text{SiO}_x$  or  $\text{Si}_x\text{N}_y$ . Lee, [0022], [0031]–[0032]. Thus, Diekmann (alone or as modified by Ma) in view of Lee satisfies this element because the encapsulation of the combined OLED includes silicon oxide or silicon nitride. *See* §X.D.1.

- xii. **[11K/16K] wherein the encapsulation comprises a first encapsulation layer and a second encapsulation layer,**

339. Diekmann (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.D.1.i [3A].

- xiii. [11L/16L] the first and the second encapsulation layer each having a respective volume structure,**

340. Diekmann (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.D.1.ii [3B].

- xiv. [11M/16M] wherein the volume structure of the second encapsulation layer is independent of the volume structure of the first encapsulation layer, [and]**

341. Diekmann (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.D.1.iii [3C].

- xv. [11N/16N] the volume structure of the second encapsulation layer has a higher amorphicity than the volume structure of the first encapsulation layer.**

342. Diekmann (alone or as modified by Ma) in combination with Lee satisfies this element for the same reasons provided in §X.D.1.iv [3D].

- xvi. [16O] wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm;**

343. Diekmann discloses or renders obvious this element for the same reasons provided in §X.C.1.xi [6J/10J].

- xvii. [16P] wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium; and**

344. Diekmann discloses this element for the same reasons provided in §X.C.1.xii [10K].

- xviii. [16Q] wherein the cathode is in direct contact with a**

**Lithium containing layer.**

345. Diekmann/Lee OLED as modified by Ma satisfies this element for the same reasons provided in §X.C.1.xiii [10L].

**3. Claim 12: The device of claim 11, wherein the electron transport layer comprises 8-hydroxyquinolinolato-lithium.**

346. I first note that the Diekmann/Lee combination satisfies claim 11 for the reasons discussed in §X.D.2. The Diekmann/Lee combination in view of Ma satisfies this element for the same reasons provided in §X.C.1.x [1I/10I] and §X.D.2.x [16I].

**4. Claim 13: The device of claim 11, wherein the organic light-emitting layer sequence comprises a cathode having a thickness of at least 1 nm and at most 50 nm.**

347. Diekmann discloses or renders obvious this element for the same reasons provided in §X.C.1.xi [6J/10J].

**5. Claim 14: The device of claim 13, wherein the cathode comprises one of: Silver, Magnesium, or an alloy comprising Silver and Magnesium.**

348. Diekmann discloses this element for the same reasons provided in §X.C.1.xii [10K].

**6. Claim 15: The device of claim 13, wherein the cathode is in direct contact with a Lithium containing layer.**

349. I first note that the Diekmann/Lee combination satisfies claim 13 as discussed above. Diekmann discloses this element, or at a minimum, renders obvious

this element in view of Ma, for the same reasons provided in §X.C.6 [Claim 8] and §X.C.1.xiii [10L].

## **XI. SECONDARY CONSIDERATIONS OF NON-OBVIOUSNESS**

350. I understand that no secondary considerations evidence has been identified for the '250 patent at this time. I am not aware of any such evidence that would apply to the challenged claims.

## **XII. CONCLUSION**

351. For the reasons discussed above, claims 1–16 of the '250 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 November 17, 2025, at Minneapolis, MN.



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Russell J. Holmes, Ph.D.