

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG DISPLAY CO., LTD.
Petitioner,

v.

PICTIVA DISPLAYS INTERNATIONAL LTD.,
Patent Owner.

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

DECLARATION OF DR. MARC SIMS

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I, Marc Sims, declare as follows:

I. INTRODUCTION

1. I have been retained as an independent expert on behalf of Pictiva Displays International Ltd. (“Patent Owner”) to provide certain technical background for technologies at issue in U.S. Patent No. 8,723,164 (“the ‘164 patent”).

2. For this service, I am compensated for my time at my normal consulting rate. My compensation does not depend on the outcome of any matter or on any of the opinions provided below. I have no financial interest in this matter.

3. My testimony herein is based on my technical background, my years of experience in the field of organic light emitting diodes (“OLED”) and my review of the materials cited herein.

4. I provide my testimony from the perspective of a person of ordinary skill in the art at the time of the invention (further address below). I have been working in the OLED field for more than 25 years and am familiar with the skill level of researchers and engineers working in the field as well as the knowledge they may possess.

5. By 2008-2009, I had interacted with many professors, postdocs, professional scientists, engineers and researchers who had had at least a bachelor's degree in chemistry, physics or a comparable field of study, and at least three years of research or industrial experience with OLEDs.

II. QUALIFICATION AND EXPERIENCE

6. I am currently Director of R&D at Margik, Inc., in charge of Margik's OLED product design and development. In that role, I design and prototype flexible OLED-based devices for a diverse set of applications within the fields of consumer electronics, defense, and biomedicine. I am also responsible for generating IP and for the company's patent portfolio.

7. I have worked in the field of OLEDs and optoelectronics since at least 2002 when I was a postdoctoral research associate at Professor Bradley's laboratory in experimental solid-state physics at the Department of Physics, Imperial College London, U.K. My research within the field of polymer electronics focused on, among other things, structure-property relationships, photophysics and charge transport properties of conjugated polymers within the context of polymer-based OLEDs. One of my more notable contributions in this area is the now highly-cited works that describe definitively the origin of the parasitic green emission band in oxidized poly(9,9-diocylfluorene). Other notable contributions include the first use of photoluminescence to monitor thermal

transitions in conjugated polymer thin films, detailed studies on the effect of sidechain length on the charge transport properties of conjugated polymers as well as how exciton migration can be affected by thin film morphology. In my four years as a postdoc, I published almost 20 peer reviewed articles in the field of organic electronics and presented over 10 invited talks and seminars internationally.

8. After my postdoctoral research, in 2006, I moved to the United States on an O-1 visa (“*aliens of extraordinary ability in the arts, business, athletics, or the sciences*”) and joined DuPont Displays in Santa Barbara, California, as a senior device scientist. I remained at DuPont Displays until 2014. There, I conducted fundamental research and development in printable OLED materials and devices for display and lighting applications.

9. At DuPont, my work was initially focused on understanding the reasons behind the reduced performance for solution-processed as compared to evaporated OLEDs. This included efficiency, operating voltage and importantly, OLED stability. To this end, I co-led an advanced characterization laboratory at DuPont Displays and developed several experimental techniques for analyzing DuPont’s OLEDs. One of the more notable techniques that I developed was charge modulation and electro-absorption spectroscopies that were designed specifically to monitor internal electric field and charge density distributions inside OLEDs in

their “on” state. This tool in conjunction with displacement current measurements gave important insight into sources of excess charge density in the emissive layer of OLEDs which was later found to correlate directly with efficiency and lifetime.

10. I also used charge modulation spectroscopy to help with the development of DuPont’s hole injection materials since the technique could directly measure the amount of charge transfer that occurs at the HIL|HTL¹ interface, a prerequisite for efficient hole injection and low operating voltage.

11. Another important outcome of my OLED research at DuPont was a definitive understanding of reduced efficiency in printed OLEDs compared to their evaporated counterparts. A colleague and I discovered that the process of spin-coating or printing of an emissive layer leads to an isotropic orientation of emitter molecules and in turn, a 33% loss of out-coupled light from the emissive layer as compared to a 15% loss for relatively oriented emitter molecules in evaporated emissive layers. Reduced out-coupling due to a broadened recombination zone in solution processed OLEDs was identified as an important, but secondary factor for the efficiency gap. These findings were presented to the Society for Information Display in an invited talk in 2013.

¹ “HIL” stands for hole injection layer and “HTL” stands for hole transport layer.

12. In addition to the fundamental R&D work outlined above, I ran an OLED fabrication line designated for new materials screening, and I co-led DuPont's solution processed high efficiency green OLED team as well as a printed color-tunable OLED lighting program sponsored by the Department of Energy.

13. After DuPont, I joined Solvay OLED's Corporate Research and Innovation Division as its Device Group Manager in Pittsburgh, Pennsylvania. At Solvay, I oversaw all device R&D activities to drive materials development, including the establishment of a hybrid OLED fabrication line with state-of-the-art baseline performance. Other work included steering Solvay's development of hole-injection, electron transport and injection layers and leading strategic collaborations with external industrial and academic partners. One of our main outcomes was the development of a non-aqueous hole-injection-layer formulation that improved bottom-emitting OLED lifetime, color purity and out-coupling efficiency. These materials were later licensed to Nissan Chemical.

14. After Solvay, I joined Kateeva in Newark, California, as a senior staff engineer in the process engineering department. There, in partnership with OLED materials companies such as DuPont, Merck, Sumitomo and Nissan, I helped develop OLED displays using Kateeva's proprietary ink-jet printers. My initial contributions included the fine adjustment of printed OLED layer thicknesses to

match the performance of DuPont's OLED baseline, as well as to modify aspects of front-end substrate treatments in order to improve OLED display lifetime.

15. I was promoted first to Device Technology Manager and then, after the establishment of a new "Shared Labs" department, I was promoted to Senior Manager, characterization and advanced technology. In this role, I oversaw OLED display test and characterization which expanded into work related to printed quantum dot-PL-color filters. A notable aspect of the role was to conceive and develop display characterization tools that could provide metrics and enable fast feedback on print quality to the process engineering team. Camera-based tools were developed for various stages of display processing including pixel thickness mapping using white light transmission, mura characterization using electroluminescence mapping (short-range uniformity and just-noticeable difference) and photoluminescence mapping for printed quantum dot-PL-color filters.

16. Between November 2019 and September 2021, I was a principal investigator and senior research scientist at King Abdullah University of Science and Technology in Saudi Arabia, where I was appointed to design and build from ground up a 1.6 million thin film LED laboratory and research program for new display technologies. The laboratory has been used for OLED reliability research by Merck and for commercial R&D by start-ups like PeroLED.

17. I returned to the United States in September 2021, first as a device physicist and staff scientist at Nanosys (now Shoei Chemical), where I worked on stabilizing blue quantum-dot electroluminescence (QDEL). I developed electrical transient measurements to gain physical insight to the mechanisms behind instability that would then be used to guide device architecture development and materials development. Since September 2022, I have been Director of R&D for Margik Inc. where I have overseen OLED product development and helping it to build its patent portfolio.

18. As a result of these industrial experiences, I am familiar with the considerations applied in materials selection, understand the complexity, trade-off and unpredictability in material selection, and have deep knowledge of the techniques used to characterize materials and measure the relevant properties. I am also familiar with simulation techniques, for example, those used to optimize the optical output characteristics for a multi-layered OLED stack.

19. I have six patent families in OLED materials as well as 20+ peer-reviewed articles on organic electronics, and multiple invited talks at conferences and seminars.

20. A copy of my CV is attached as Appendix A.

III. SKILLED ARTISAN

21. Samsung's definition of a person of ordinary skill in the art ("POSITA") for the '164 patent is an individual who had, at the time of the invention (2008-2009) a Bachelor's degree in chemistry, physics, or a comparable field of study, and at least three years of research or industrial experience with OLEDs. *See* Pet., 12. While I generally agree with that educational requirement, in my opinion a POSITA would have had at least four or five years of experience or higher education. Nonetheless, because my analysis is substantially the same under either definition, for purposes of this declaration I have applied Samsung's definition, as I did in my Pre-institution Declaration (EX2001).

22. I received my Ph.D. in Physics in 2002, and by 2008, had had at least six years of experience in OLEDs, first as a postdoctoral researcher at the Department of Physics, Imperial College in London, U.K., and then as a senior device scientist at DuPont Displays in Santa Barbara, California.

23. Thus, I was at least a person of ordinary skill in the art, if not one with above average skills, at the time of the inventions described in the '164 patent.

IV. OVERVIEW OF THE '164 PATENT

24. The inventors of the '164 patent summarized the problem they intended to solve as follows:

Electronic devices, such as organic light-emitting diodes (OLEDs), consist of a sequence of several functional organic layers. Emission layers thereby have a matrix material, which is doped with emitter molecules. In the emission layer, excitons are formed by a recombination of electrons and “holes,” which lead to light emission. In order to obtain a high efficiency of the electronic device, the ratio between electrons and “holes” which are transported in the emission layer is decisive. A nonbalanced ratio between hole and electron transport results in a low radiation efficiency of the device.

EX1001, 1:20-29.

25. As a solution, the inventors proposed to include in the emission layer at least three matrix materials, one with hole transport property, another with electron transport property and a third one that could be used to adjust the “concentrations” of the hole and electron carriers so that the distances between hole carriers and those between electron carriers could be fine-tuned. EX1001, 1:46-48, 2:24-29, 3:17-34.

26. As noted by the inventors, charge carrier transport depends on both charge carrier mobility and the number of charge carriers present. *See* EX1001, 2:64-3:1 (“If a charge carrier transport does not take place in a matrix material, ..., then that can be attributed to the fact that charge carriers are not created or that there is no mobility of the charge carrier.”).

27. Creation of charge carriers was ensured by specifying the “position of the energy level of HOMO [highest occupied molecular orbital] and LUMO [lowest unoccupied molecular orbital] of the matrix materials.” EX1001, 2:40-44. This is because “[t]he HOMO and LUMO of a material are ... responsible for the charge carrier injection.”

28. In particular, the inventors proposed that the second matrix material, serving as a hole transport material, should have a HOMO that is “energetically higher than the HOMO of the first matrix material and the HOMO of the third matrix material.” EX1001, 1:52-54, 2:26-27. As the inventors noted, “[t]o create a hole in the matrix, which is composed of the three matrix materials, an electron must be removed from the HOMO, for example, which is more difficult with an energetically low HOMO than with an energetically higher one.” *Id.*, 2:46-49. A high lying HOMO, meaning a HOMO at a higher energy level, in the second matrix material thus helps ensure that holes can be preferably injected into the second (hole transport) material, compared to the first and third matrix materials that have HOMOs at lower energy levels.

29. Similarly, the inventors proposed that the third matrix material, serving as an electron transport material, should have a LUMO that is “energetically lower than the LUMO of the first matrix material and the LUMO of the second matrix material.” EX1001, 1:48-51, 2:24-26. As the inventors noted,

“creation of electrons in LUMOs ... is energetically favored with energetically lower LUMOs.” *Id.*, 2:52-55. This ensures that electrons can be preferably injected into the third (electron transport) material compared to the first and second matrix materials that have LUMO levels that lie higher in energy levels than the LUMO of the third matrix material.

30. Hence, by specifying that the second (hole transport) matrix material has a HOMO that is the highest in energy level among the HOMOs of the three matrix materials and that the third (electron transport) matrix material has a LUMO that is the lowest in energy level among the LUMOs of the three matrix materials, the inventors design a system where holes are preferably created in the second matrix material and electrons are preferably created in the third matrix material.

31. Once hole and electrons are created, “the mobility of these charge carriers [hole and electron carriers] in the material plays a role.” EX1001, 2:58-59. The inventors noted, “[t]he mobility of electrons and holes ... depend on the molecule distance—that is, the average distance between charge carrier-transporting molecules in the individual matrix material.” EX1001, 3:17-20.

V. CLAIM CONSTRUCTION

32. I understand that, in an IPR, terms of a patent claim are to be construed in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining

to the patent. I further understand that, although the words of a claim are generally given their ordinary and customary meaning, as would be understood by a POSITA at the time of the invention, that understanding is from the perspective of a POSITA who has read the claim term in the context of the particular claim in which the disputed term appears and in the context of the entire patent, including the specification.

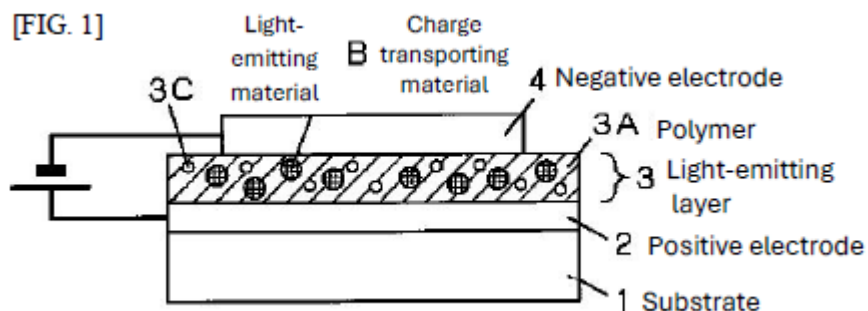
A. The Term “Matrix Material” Refers to a Material in a More or Less Continuous Phase And Into Which Other Materials Can Be Embedded

33. A POSITA would understand that a matrix material refers to a continuous phase of materials, which is consistent with the construction Samsung proposed in the district court (EX2005, 16-17), as well as Samsung’s claim construction expert, Dr. Schubert. For example, when Dr. Schubert was asked what “continuous phase” means in Samsung’s definition of “matrix,” its expert testified that “[c]ontinuous phase means that there are no regions ... in which we have phase separation.” EX2018, 112:8-14. And when asked about Sugiura’s light-emitting layer 3 shown below, Dr. Schubert testified that the figure “does not include a continuous phase of” 3A, 3B and 3C:

If these little circles contain only one matrix material,
then I would say that this is not a matrix because it does
not include a continuous phase of matrix materials. But

rather agglomerations of materials as expressed by the circle features or circular features.

Id., 114:13-21.



EX1006 (Sugiura), FIG. 1.

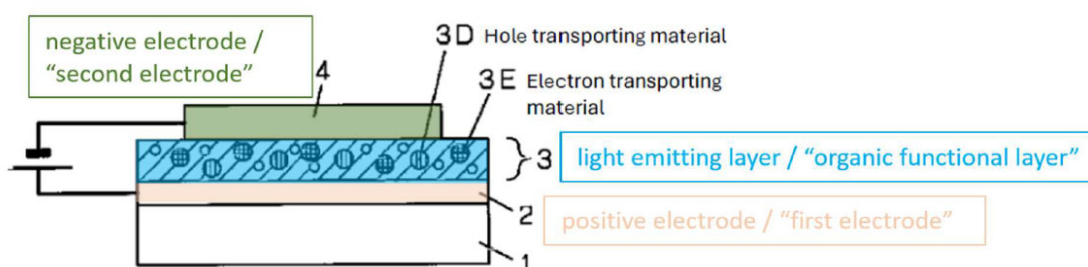
34. Also, according to Dr. Schubert, “[t]o be effective, a matrix needs to be in a continuous phase to not only encourage the efficient transport of electrons and holes through, e.g., the electron transporting material and hole transporting material in the matrix, but to also ensure the desired distribution and stable housing of the emitter material.”. EX2016, ¶129. This understanding that a matrix, in the context of materials, refers to a continuous phase of materials is consistent with the common meaning. *See e.g.*, EX2005, 16-17 (dictionary definitions for “matrix” include “[a] continuous solid phase in which particles ... are embedded” and “[m]ore or less continuous matter in which something is embedded”); EX2002 (Dictionary of Chem Oxford) (“(in chemistry) A continuous solid phase in which particles (atoms, ions, etc.) are embedded”); EX2003 (Merriam-Webster), 766 (3b: “material in which something is enclosed or embedded”); EX2004 (Cambridge

Dictionary), 770 (“a substance in which other things are fixed, buried, etc.”); EX2005 (Samsung PR4_2), 16-17 (Samsung quoting dictionary definitions for “matrix,” including “[a] continuous solid phase in which particles ... are embedded” from EX2012, 364 and “[m]ore or less continuous matter in which something is embedded” from EX2013, 744).

35. In the context of the '164 patent, a “matrix material” refers to a material in a more or less continuous phase into which other materials can be embedded. This is not only consistent with the general meaning of the term, but directly follows from the fact that the second and third matrix materials are responsible respectively for hole and electron transport, which a POSITA would understand to have sufficiently short molecular distances to facilitate electron and hole hopping. For example, in some of the embodiments, I note that the first matrix material serves to modulate the concentrations of the second and third matrix materials, which would necessarily modulate the molecular distances between hole carriers and electron carriers, respectively. EX1001 ('164 patent), 3:17-28. The '164 patent explains that, “[t]he microscopic charge carrier transport depends on the molecule distance between the charge carrier-transporting molecules in the individual matrix material, so that by the adjustment of the concentration, the mobility of electrons and holes in the matrix, which has at least three matrix materials, can be absolutely adjusted separately from one another. *Id.*,

3:28-34. A POSITA would understand that for a material to meaningfully contribute to the fine adjustment of the distances between charge carrier molecules, it would need to exist in sufficient quantities to effectuate the modulation of such molecular distances to a desired level. Hence, it also needs to exist in a sufficiently continuous phase. Thus, the '164 patent teaches fine-tuning charge carrier mobilities by depositing the first, second and third materials as part of the matrices and not as dopants.

36. In other words, matrix materials—or materials for forming one or more matrices—should not exist as “islands in a sea,” such as 3D and 3E in the figure below, which are not in a more or less continuous phase in which other materials can be embedded.



37. In some of the embodiments, the first matrix material serves to modulate the molecular distances between hole carriers and molecular distances between electron carriers. EX1001, 3:17-28. The inventors state, “[t]he microscopic charge carrier transport depends on the molecule distance between the charge carrier-transporting molecules in the individual matrix material, so that by

the adjustment of the concentration, the mobility of electrons and holes in the matrix, which has at least three matrix materials, can be absolutely adjusted separately from one another.” *Id.*, 3:28-34. For a material to play a role in finely adjusting the distances between charge carrier molecules, it is contemplated to exist in sufficient quantities to effectively modulate (*e.g.*, increase) the molecular distances to a desired level. Hence, it also needs to exist in a sufficiently continuous phase. In other words, the inventors found a way to adjust the hole and electron mobilities in the emission layer to control the recombination zone. The inventors also found that sometimes lower charge carrier mobility could lead to better performance. EX1001, 6:57-7:2 (simulation suggests that “a reduction in the absolute value of the charge carrier mobility in the emission layer 30, in comparison to the hole transport layer 31 and the electron transport layer 32, the recombination zone is shifted from the borders of the emission layer to the middle.”), 1:25-29. The ’164 patent therefore teaches fine-tuning charge carrier mobilities by depositing the first, second and third materials as part of the matrices and not dopants.

38. I understand that the Board, at institution, did not agree that the ’164 patent “defines, with any precision or clarity, the term “matrix material” as a continuous phase or a material present in any certain amount.” Paper 11 (DI), 24-25. While the ’164 patent does suggest a 10 wt% threshold, term “matrix material”

has a meaning and does not refer to the material existing in any amounts or existing only in discontinuous phases, as Samsung's expert acknowledges. EX2016, ¶¶129-131. However, based on the issues raised in the Petition, the dispute in this IPR does not appear to require reaching the issue as to whether a matrix material must be more or less continuous or exist in a certain amount. Instead, it appears the Board need only determine whether the term "matrix material" encompasses dopants and whether the term encompasses dispersed agglomerations. This is because, if the Board determines that the term "matrix material" does not encompass dopants, then the challenges under Grounds 1, 2 and 4 would fail because those grounds expressly rely on dopants to satisfy one or more of the claimed "matrix materials." And, if the Board determines that the term "matrix material" does not encompass dispersed agglomerations, then the challenge under Ground 3 fails because that ground expressly relies on dispersed agglomerations to satisfy one or more of the claimed "matrix materials."

39. Accordingly, below in Sections V.B-V.C I address why a POSITA would understand that the term “matrix material” excludes dopants and dispersed agglomerations.²

B. The Term “Matrix Material” Does Not Encompass Dopants

40. Both the claims and specification of the ’164 patent distinguish a “matrix material” from dopants, such as emitter materials. For example, the ’164 patent states that “[e]mission layers thereby have *a matrix material, which is doped with emitter molecules.*”). EX1001, 1:22-23. The ’164 patent further teaches that “[t]he emission layer 30 can have a first, a second, and a third matrix material and be doped with an emitter material.” *Id.*, 6:14-16; *see also id.*, 7:12-15 (describing how “matrix materials and/or doping substances can be evaporated onto the deposition substrate 60.”); 7:15-17 (“In order to be able to determine the individual concentration of the matrix material and/or the doping substances precisely”).

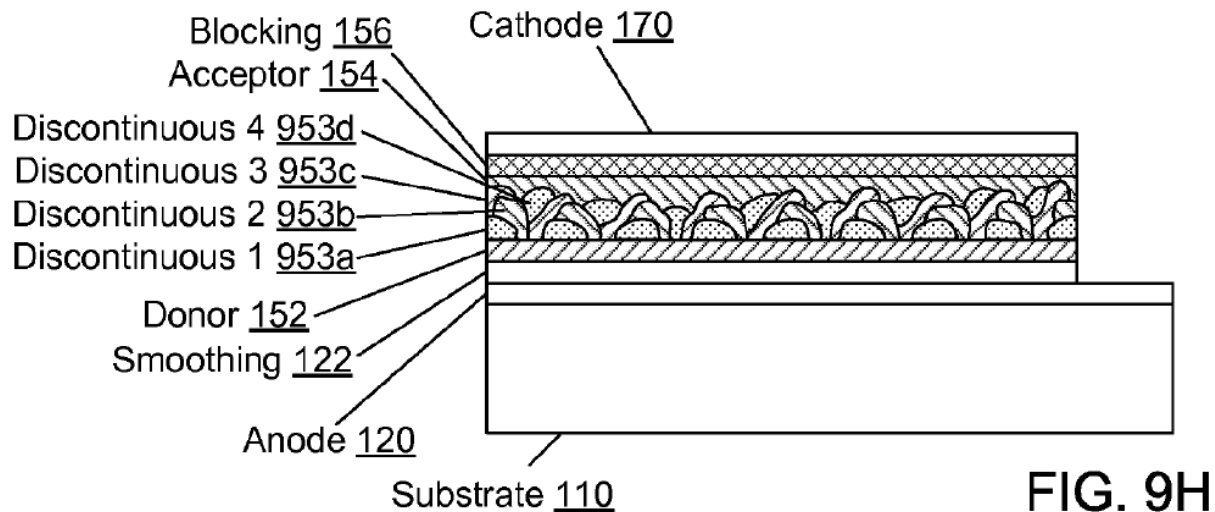
41. When discussing doping, the ’164 patent consistently refers to an emitter material, not the matrix material. *See id.*, 3:61-63 (“The organic functional

² That the term “matrix material” excludes dopants and dispersed materials is fully consistent with the fact that a matrix material is a more or less continuous phase into which other materials can be embedded.

layer can be an emission layer and be doped with at least one emitter material.”); 4:15-16 (“By not doping with emitter materials, it is possible to produce transport, intermediate, and blocking layers.”); 6:13-15 (“The emission layer 30 can have a first, a second, and a third matrix material and be doped with an emitter material”).

42. The claims similarly distinguish between matrix materials and dopants, such as an emitter material. For example, claim 1 recites “wherein the at least one organic functional layer has at least a first matrix material, a second matrix material, and the third matrix material.” EX1001, 9:10-12. Then, claim 1 goes on to further recite that “the organic functional layer is an emission layer and is doped with at least one emitter material.” *Id.*, 9:21-22. Thus, the claims distinctly recite a dopant in the form of an emitter material, and first, second and third matrix materials. This usage is consistent with the common understanding. *See supra*, Section V.A. It is not by chance that the ’164 patent disclose “matrix materials” as being distinct from dopants for the reasons I discussed above. *See id.*

43. I also note that there is nothing the prosecution history for the ’164 patent which suggests that a matrix material can encompass a dopant. For example, the examiner initially rejected claim 1, citing to three of Forrest’s discontinuous layers 953a-953c as being the claimed first, second, and third matrix materials. EX1002, 233.



EX2029 (Forrest), FIG. 9H.

44. Forrest’s discontinuous layers are clearly not dopants because they are not guest materials embedded in or added to a host material. Instead, the discontinuous layers exist as separate vertically continuous layers, which Forrest explains as being “in direct contact with material of at least one adjacent discontinuous layer” *Id.*, [0026].

45. That matrix materials do not encompass dopants is also commonly understood, including by Samsung’s district court expert on validity, Dr. Kymissis. For example, in his report on validity, Dr. Kymissis stated that:

In OLED design, “doping” refers to the intentional introduction of a foreign material (or impurity) into a host at low concentrations to modify its electronic or optical properties. This is a well-known concept that a skilled practitioner in the field would recognize. Emission layers often use a guest–host system where the host material forms the bulk of

the emission layer and the guest (emitter) material is added in small amounts. This doping approach enables efficient energy transfer from the host to the emitter, thereby optimizing light emission while preventing issues like aggregation or quenching that can occur at higher concentrations.

EX2031 (Kymissis Opening Report), ¶ 814 (emphasis added).

46. I also note that Samsung's claim construction expert relied on there being a general understanding of a distinction between a dopant and a matrix material. EX2016 (Schubert), ¶ 140 (“[T]he presence of dopant/guest molecules changes the electronic structure around the matrix molecules.”).

47. The prior art cited in the Petition also distinguishes matrix materials from dopants. For example, Thompson states that, “[i]f a dopant capable of producing blue phosphorescence is inserted in such a device utilizing the existing materials and structures, the emission will only come, if at all, inefficiently **from the matrix material, and not from the phosphorescent dopant material.**” EX1007, [0006]; *see also id.*, [0023], (“The HOMO energy levels of the phosphorescent dopants are typically higher in energy than those of the matrix materials into which they are doped. This means that the dopants are capable of trapping holes and transporting them through the matrix if the doping level is high enough.”), [0025] (“the emissive material is dispersed in the host matrix together with the charge carrying dopant material”), [0057] (“The polystyrene acted as an inert matrix in

which the dopants were supported.”). Addition patents by Thompson confirm this understanding. *See* EX2100 (US10,333,070), 4:30-36, 8:4-7 (“Dopants can be present in the organic matrix material in an amount sufficient to increase conductivity relative to undoped organic matrix.”); EX2102 (US10586926), 1:22-27 & 2:33-40, Abstract (“organic doping agent for doping an organic ... matrix material”), 2:21-24 (“HOMO of the matrix material” and “LUMO of the doping agent”); EX2103 (US 8,119,037), 3:13-18 (“an organic ... matrix material that is doped with at least one dopant in order to change the electronic properties of the ... matrix material”), 3:23-27 (“dopant for doping an organic ... matrix material”); EX2104 (US8,212,245), 12:41-45 (“matrix material and dopant precursors substantially homogeneously embedded therein”); EX2024 (US7,911,129), 5:9-13, 7:19-35 (distinguishing between “matrix material” and “dopants,” such as emitters).

48. A POSITA would also understand that the term “matrix material” is synonymous with the term “host” or “host material.” For example, Choulis uses the term “host” material interchangeably with “matrix.” *E.g.*, EX1004 (Choulis), [0044] (“In some embodiments, the light emitting layer includes materials that are insulated *matrices*, that is, *the host* does not have transport properties”). Thompson also uses the terms interchangeably. EX1007 (Thompson), [0035] (“wide gap host material layer 40, also referred to as matrix material”), [0023],

[0025], [0028]-[0029]; EX2020, 266:4-18 (Dr. Holmes acknowledging that Thompson uses the term “host matrix” in the same way as “matrix material” is used). This is confirmed by other patents by Thompson. *See* EX2100 (US10,333,070), 4:7-13 (“an **organic matrix (or host) material**”); EX2101 (US8,679,647), 89:50-51 (“a matrix material (host) and a dopant”). Dr. Holmes’s prior publications also use “host” and “matrix” interchangeably. *See* EX1016, 3 (p. 3819) (“With a UGH2 **host** also **doped** with 10% FIr6”), 4 (p. 3820) (“Thus, for guest concentrations >5%, both electrons and holes are transported by FIr6, with UGH2 acting as an inert **host matrix**.”). I also note that Dr. Rand, an expert from an IPR involving another OLED patent having several common inventors as the ’164 patent, testified that he understands the term “matrix material” refers to host, where usually “the host or matrix is there in larger quantities.” EX2025 (Rand), 165:11-14. Dr. Rand also testified that he would not consider the emitter to be a matrix material. *See id.*, 162:8-13 (“In the emitting layer, especially in a phosphorescent OLED, I would consider the emitter to be, to not be the matrix”); 164:10-165:6 (associating the term “matrix” with “host”).

49. U.S. Pat. No. 7,911,129 similarly equates “matrix material” with host material. EX2024, 4:24-26 (“An organic matrix material in the sense of the invention is every organic host material to which further materials such as dopants or emitter substances”). In addition, I note that the ’129 patent describes a

study by He et al. EX2024, 3:4-22; EX2026. The '129 patent explains that He's structure, which I have reproduced below, "contains at least four matrix materials."

In He's structure, there are 4 host materials and 3 dopants (green text) in the organic layers: Bphen, Cs, TCTA, Ir(ppy)₃, Spiro-TAD, MeO-TPD, F4-TCNQ.

See EX2026, 5773 (describing Ir(ppy)₃ and F4-TCNQ as dopants), 5774

(describing Cs as a dopant). By describing the structure as having "at least four" instead of "at least seven" matrix materials, thereby accounting for the 3 dopants as well, suggests to a POSITA that the literature does not regard a matrix material as encompassing dopants. See also EX2024, 4:24-27 ("An organic matrix material ... is every organic host material to which further materials such as dopants or emitter substances, ... can be admixed (doping)."), 16:7-8 ("an emission layer comprising k (k=1, 2, 3, ...) organic matrix materials").

Al
Bphen:Cs
Bphen
TCTA:Ir(ppy)₃
Spiro-TAD
MeO-TPD:F4-TCNQ
ITO substrate

p-i-n

(EX2026, Fig. 1)

50. In light of the fact that the term “matrix material” is synonymous with the term “host,” I note that additional publications by Thompson explain that host materials do not include dopants. *See* EX2027 (US6,303,238), 2:42-44 (“Whenever a dopant is present, the predominant material in the charge carrier layer may be referred to as a host compound or as a receiving compound. Materials that are present as host and dopant are selected so as to have a high level of energy transfer from the host to the dopant material.”); *see also id.*, 8:52-67 (“The host compounds as defined herein are compounds which can be doped with dopants that emit light with the desired spectral characteristics.... The term ‘host’ is used to refer to the compound in the emissive layer that functions as the component, that is, ‘receiving compound’ which receives the hole/electron recombination energy and then by an emission/absorption energy transfer process, transfers that excitation energy to the dopant compound, which is typically present in much lower concentrations. The dopant may then relax to an excited state having a slightly lower energy level, which preferentially radiates all of its energy as luminescent emission in a desired spectral region.”).

51. Therefore, the term “matrix material” would be understood by a POSITA to not include dopants. The terms matrix material and dopant are mutually exclusive.

C. The Term “Matrix Material” Does Not Encompass Dispersed Agglomerations

52. As I described above in Section V.A., in the context of the ‘164 patent, a matrix material would be in a more or less continuous phase into which other materials can be embedded. Dr. Schubert, apparently agrees with that view. EX2016, ¶129 (“To be effective, a matrix needs to be in a continuous phase to not only encourage the efficient transport of electrons and holes through, e.g., the electron transporting material and hole transporting material in the matrix, but to also ensure the desired distribution and stable housing of the emitter material.”).

53. However, the prior art presents the more discrete issue of whether the term “matrix material,” in the context of the ’164 patent, can encompass dispersed agglomerations—namely, dispersed agglomerations embedded within a matrix, which I understand the Board provisionally found to be encompassed by the term “matrix material.” DI, 29. For the reasons below, it cannot.

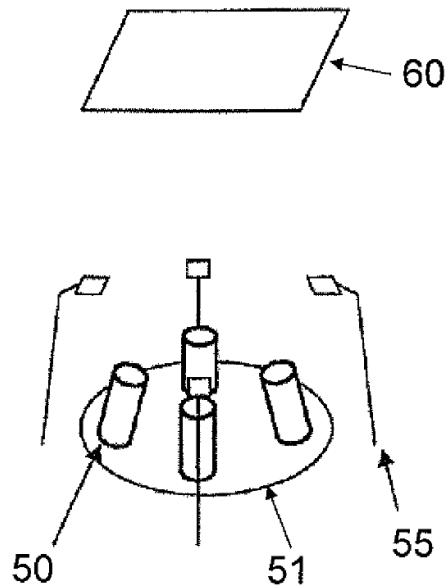
54. Both the claims and the specification indicate that the term “matrix” modifies the immediately following term, “material,” not some other material into which the claimed “matrix material” may be embedded. This would be understood by a POSITA for several reasons. First, the claims of the ’164 patent do not recite a further “matrix” or an embedding step, or otherwise use the term “matrix” outside of defining a property of the first, second, and third materials. Second, the

claims and the specification indicate that the three matrix materials are located in “at least one organic functional *layer*” (i.e., “layer,” not “matrix”). This would clearly suggest to a POSITA that the inventors decided to limit the location of the three matrix materials, and did so in the form of organic *layers*, not in the form of being embedded in a further *matrix*.

55. I also note that the claims recite an “emitter material” (as opposed to an emitter matrix material), which is also included in the same “at least one organic functional layer.”

56. Even though the first, second, and third matrix materials can be embedded into a matrix in some embodiments (EX1001, 4:24-26), the specification is also clear that a matrix material is not required to be embedded into a matrix. *See id.*, 1:22-23 (describing an emission layer with a single matrix material). Yet, “matrix” is a claim term and limits the scope of the claim in all configurations. Thus, the term would not be understood to limit an optional feature (i.e., a further matrix) over defining or limiting a required feature (i.e., the first, second, and third materials, respectively).

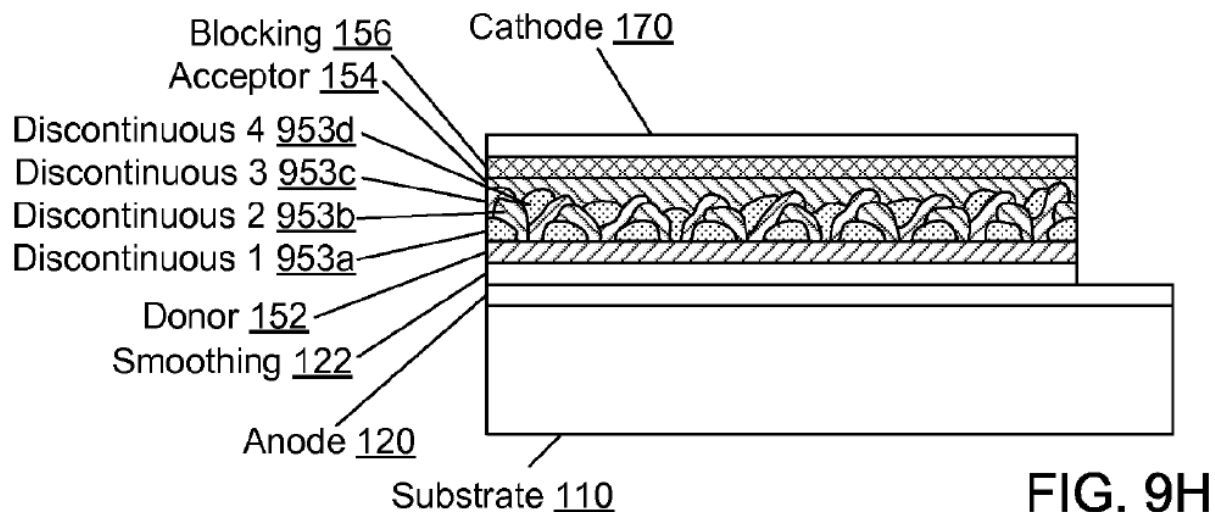
57. Moreover, in the embodiment of FIG. 5 shown below, the specification describes using evaporation deposition to apply matrix materials and emitter from a number of evaporation sources 50 onto a substrate 60.



58. Specifically, the specification states that “[f]our evaporation sources 50 are applied on a holder 51, for example, from which matrix materials and/or doping substances can be evaporated onto the deposition substrate 60.” A POSITA would understand that each evaporation source 50 is providing a single type of material, three of which are “matrix materials” and the fourth is a doping “emitter material.” And a POSITA would understand that, unlike solution-based approaches, the three matrix materials formed by joint evaporation would be continuous, and not as a mixture of dispersed agglomerations.

59. Thus, while the claims do not preclude the first, second, and third matrix materials from being embedded into a further matrix, a POSITA would understand the term “matrix” must describe the nature of the “material” itself.

60. I also note that there is nothing in the prosecution history for the '164 patent which suggests that a matrix material can encompass dispersed agglomerations. For example, as I noted above, the examiner initially rejected claim 1, citing to three of Forrest's discontinuous layers 953a-953c as being the claimed first, second, and third matrix materials. EX1002, 233.



EX2029 (Forrest), FIG. 9H.

61. Forrest does not disclose dispersed agglomerations, nor did the examiner suggest that it does. Instead, Forrest uses the term “discontinuous” and “continuous” to describe types of layers. For example, Forrest describes depositing “continuous layers” or “discontinuous layers” in the production of photosensitive optoelectronic device. *See id.*, [0026]. As Forrest shows in FIG. 9H, a “continuous donor layer 152” is deposited prior to deposition of a number of “discontinuous layers 953,” after which a “continuous acceptor layer 154 fills

exposed gaps and recesses in the underlying discontinuous layers 953 a-d.” *Id.*, [0081]-[0083].

62. According to Forrest, the “material of each discontinuous layer [is] in direct contact with material of at least one adjacent discontinuous layer ...” *Id.*, [0026]. As a result, “[m]ost of the nanocrystals of the donor material shown in the cross-section directly contact the continuous donor layer 152, providing electrically conductive pathways for dissociated holes from [discontinuous] layer 953c to the anode 120 in the finished device.” *Id.*, [0081]. Similarly, “[m]ost of the nanocrystals of acceptor material in discontinuous layer 953b shown in the cross-section directly contact the continuous acceptor layer 154, providing electrically conductive pathways for dissociated electrons from layer 953b to the cathode in the finished device.” *Id.*, [0082]; *see also* [0035] (“[T]here are a plurality of discontinuous layers composed of an acceptor material or materials forming conductive pathways with the continuous acceptor layer.”).

63. Based on Forrest’s description above and figures, a POSITA would recognize that although the discontinuous layers in Forrest may be horizontally discontinuous with gaps filled by subsequent layers, the layers are at least vertically continuous. This is evidence from the fact that Forrest describes the presence of conductive pathways through the respective discontinuous layers, which would not be the case if Forrest’s discontinuous layers were implemented

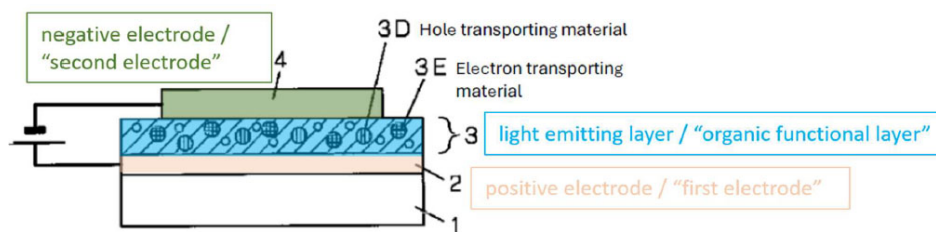
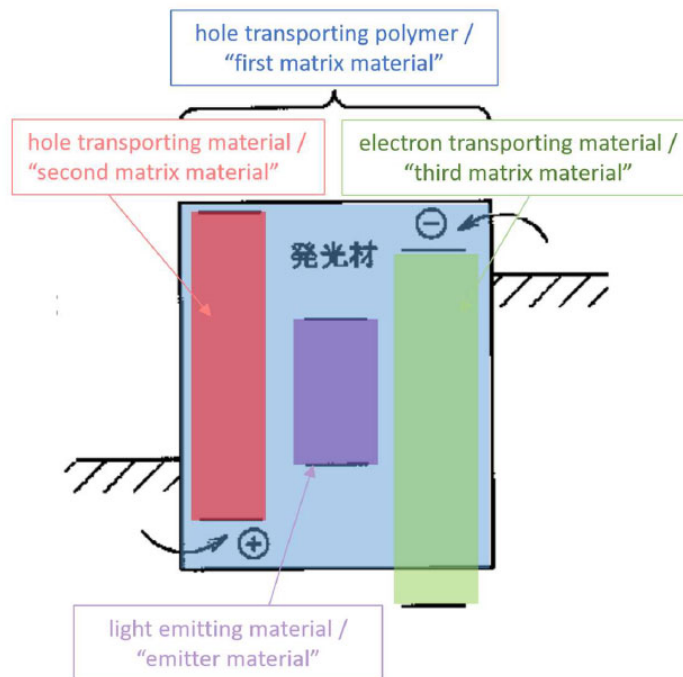
using dispersed agglomerations. Therefore, Forrest does not disclose or suggest that a “matrix material” can encompass dispersed agglomerations.

64. That the term “matrix material” does not include dispersed agglomerations is consistent with the general understanding of matrix material. EX2002 (Dictionary of Chem Oxford) (“(in chemistry) A continuous solid phase in which particles (atoms, ions, etc.) are embedded”); EX2003 (Merriam-Webster), 766 (3b: “material in which something is enclosed or embedded”); EX2004 (Cambridge Dictionary), 770 (“a substance in which other things are fixed, buried, etc.”). This is also consistent with evidence Samsung cited in the parallel litigation in support of its claim construction position. See EX2005 (Samsung quoting dictionary definitions for “matrix,” including “[a] continuous solid phase in which particles ... are embedded” from EX2012, 364 and “[m]ore or less continuous matter in which something is embedded” from EX2013, 744). I note that even more generally in the context of composite materials, a “matrix material” refers to the “continuous material phase” while the “reinforcement material” refers to the “dispersed material phase.” See <https://compositeskn.org/KPC/A100>.

D. The Petition’s Matrix Material Mappings Result in the Term “Matrix” Having Inconsistent Meanings

65. I understand that claim terms should have the same meaning throughout a claim. However, Dr. Holmes’s mapping for at least Sugiura (Ground

3) requires the term “matrix” in the phrase “material matrix” have inconsistent meaning. Specifically, Dr. Holmes maps the term “matrix” in “first matrix material” to a physical characteristic of the immediately following “material,” namely to polymer 3A which Dr. Holmes has annotated in blue in FIGs. 4 and 8 from Sugiura. See below.



EX1003, ¶¶ 174, 177, 180 (annotating FIGs. 4 and 8 from Sugiura).

66. As shown above, the alleged “first matrix material” of Sugiura is depicted with blue annotation as a continuous phase matrix, or at least a material which is capable of having other materials embedded therein. Thus, according to Dr. Holmes “matrix,” in the phrase “first matrix material,” means the material itself forms a matrix in the sense that it forms a continuous phase or at least is capable of having other materials embedded therein.

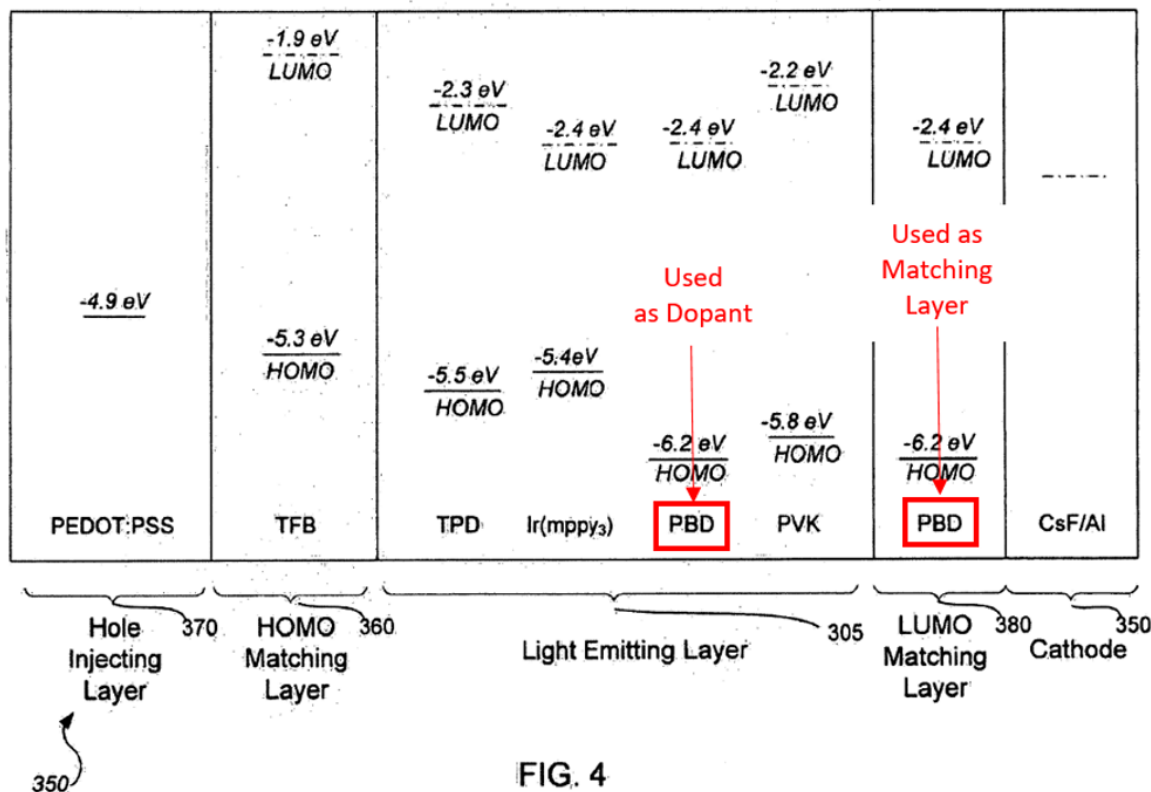
67. In contrast, however, the alleged “second matrix material” and “third matrix material” do not form a continuous phase matrix themselves, nor does it appear that Dr. Holmes contends that they do. Instead, the alleged “second matrix material” and “third matrix material” are embedded within the host matrix (blue material). What this appears to mean is that the term “matrix” in the phrase “second matrix material” and “third matrix material” no longer refers to or defines a *physical property* of the materials themselves, under Dr. Holmes’s theory. Instead, it appears that what makes the materials “matrix materials” to Dr. Holmes is only the fact that they are embedded in another matrix (blue material). This means that the term “matrix” in “first matrix material” defines a physical property of the material, while the term in “second matrix material” and “third matrix material” refers only to a *location* of the material, i.e., embedded in a matrix. Thus, Dr. Holmes’ mappings at least with respect to Ground 3 are based on the same term (matrix) having inconsistent meanings.

VI. GROUND 1: CHOULIS (CLAIMS 1-8 AND 10-16)**A. The TPD and PBD Materials in Choulis Are Dopants, Not Matrix Materials.**

68. Dr. Holmes identifies Choulis's "host material" PVK, "first organic moiety" (TPD), and "second organic moiety" (PBD) as allegedly reading on the first, second, and third matrix materials. EX1003, ¶¶ 85-86. I do not agree because, for the reasons I described above in Section V.B, the term "matrix materials" does not encompass dopants.

69. Choulis is consistent with this general understanding that the term "matrix materials" does not encompass dopants. For example, Choulis first characterizes PVK as a "host" material, a term which is widely used interchangeably with "matrix," including by Choulis itself. *E.g.*, EX1004, [0044] ("In some embodiments, the light emitting layer includes materials that are insulated *matrices*, that is, *the host* does not have transport properties"). Next, Choulis describes TPD and PBD as "organic moieties." *See e.g.*, EX1004, [0030] (describing FIG. 4 as including "a first organic moiety 330, triphenyldiamine (TPD) and a second organic moiety 335, PBD."); [0031] ("The PBD is used as a moiety in the light emitting layer rather than as a thin matching layer, as above."). According to Choulis, its moieties are used as dopants in the light emitting layer. *See id.*, [0032] ("the light emitting layer can be *co-doped with organic moieties*").

Choulis's description of TPD and PBD as being dopants, specifically, is purposeful because Choulis contrasts the use of PBD as a dopant in the light emitting layer, on the one hand, with the *separate* use as a matrix material in the LUMO matching layer 380, on the other hand. *See id.*, [0031] ("PBD is *also* used as a LUMO matching layer (or interfacial layer) between the light emitting layer 305 and a cathode 350."). This distinction is illustrated by Choulis in FIG. 3 below.



EX1004, FIG. 4 (red annotations added); EX1022, 203502-1 (PVK host "doped with" TPD and PBD") *versus* 2023502-2 ("PBD ...based electron injected interfacial layer").

70. Moreover, I have reviewed the Choulis reference (EX1004), the two Choulis papers (EX1018 and EX1022) and the Yang paper cited in the Choulis papers (EX1017). It is readily apparent that Choulis used one of Yang's "optimized" test composition for its emission layer:

Choulis (EX1004)	Yang and Neher (EX1017)
[0054] ("The light emitting layer includes 61% PVK, 24% PBD, 9% TPD and 6% Ir(mppy) ₃ .").	EX1017, 2478, Figure 3 caption ("... a device containing PVK (0.61) + PDB (0.24) + Ir(mppy) ₃ (0.06) + TPD (0.09)..."); EX1017, 2478 ("Figure 3 shows the current density-brightness-voltage properties of a device with ~ 6 wt% Ir(mppy) ₃ and 9 wt% TPD").

71. Yang arrived at the optimized composition after fine tuning the TPD and emitter concentrations. See EX1017, 2477-78, Table 1. Yang observed that

[I]n a series of devices an Ir(mppy)₃ concentration of ~6 wt% and different amounts of TPD (Table 1), the peak luminescence efficiency increases largely when adding ~ 6 wt% of TPD, but further addition of TPD affects the driving voltages and peak efficiencies only slightly. Moreover, the luminous efficiency begins to decrease *for TPD concentrations larger than 13 wt%*, indicating that *a large*

concentration of TPD disturbs the balance of carrier injection and transport.

EX1017, 2477-78. Yang then goes on to describe the expectation “that *co-doping with hole-transporting moieties such as TPD* may be a general scheme to improve the efficiency of PVK:PBD based devices.” EX1017, 2478.

72. The concentrations of TPD doping in Choulis is 9wt%, the same as in the Choulis papers and as in some examples of Yang. EX1004, [0054], [0024], [0032]; EX1018, 113503-2 (exhibit p. 3 of 4); EX1022, 203502-2 (exhibit p. 3 of 4); EX1017, 2478 (exhibit p. 4 of 4). But Dr. Holmes does not explain or present evidence that TPD at this concentration is capable of being a matrix or host materials. Thus, Choulis is clear that TPD and PBD are dopants, not matrix materials.

73. Another reason why Choulis’s TPD and PBD materials are not matrix material is because, under Samsung’s mapping, in order for Choulis’s TPB, PBD and PVK to achieve continuous phases in the emissive layer, they should be finely blended. This will ensure a modulation of the inter-molecule distance and provide a degree of mobility tuning, as discussed above. More explicitly put, PVK chains must mix finely with TPD and PBD, to an extent that individual PVK chains will act to separate TPD and/or PBD molecules. This is a very fine mixture and is not typically achieved when spin-coating, like Choulis discloses.

74. In contrast, the '164 patent uses an evaporative method to obtain the mixture of the three matrix materials and the emitter because it reliably provides a fine intermolecular mixing of the materials as needed and is compatible with more small molecule OLED materials. The degree of mobility fine tuning can thus be controlled to a much higher degree to prevent phase separation within a matrix. Thus, at least because of Choulis's reliance on PVK, it is forced to use a very different approach than what is used by the inventors of the '164 patent.

75. I note that Dr. Holmes appears to contend that Choulis not only anticipated claims 1-8 and 10-16, but that it also renders those claims obvious. See EX1003 (heading for Section VIII.A). But Dr. Holmes does not mention obviousness again when discussing at least claim 1, let alone present any specific modification or supplementation to Choulis's disclosure, nor any particular reason for modifying or supplementing Choulis's disclosure.

B. Use of PMMA in Place of PVK in Choulis for Claims 2, 4, 15, and 16

76. Claims 2 and 15 both require that "the first matrix material ha[ve] a LUMO which is energetically higher than the LUMO of the second matrix material and the LUMO of the third matrix material, and a HOMO which is energetically lower than the HOMO of the second matrix material and the HOMO of the third matrix material." EX1001, 9:23-28, 10:35-40.

77. Claims 4 and 16 both require that “the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.” *Id.*, 9:34-37, 10:58-60.

78. Dr. Holmes suggests replacing Choulis’s PVK host with PMMA for claims 2, 4, 15, and 16, apparently because PVK does not satisfy the additional limitations for the recited “first matrix material.” EX1003, ¶¶ 97-100, 104-105, 149 (referring to claim 2 for Element 15[h], 159 (referring to claim 4 for Element 16[h]); *see also* Pet., 26, 44, 47 (annotating PVK as the “first matrix material” for claim 1, element 15 [e], and element 16[e]) *with* Pet. 29, 33, 45, 48 (relying on PMMA for claims 2, 4 and elements 15[h] and 16[h]). However, a POSITA would not do so, at least because the observed improvement in electroluminescence efficiency and other benefits with TPD doping is specific to PVK:PDB based devices. Yang, whose emission layer composition was used by Choulis, stated that “[w]e ... expect that co-doping with hole-transporting moieties such as TPD may be a general scheme to improve the efficiency of PVK:PBD based devices.” EX1017, 2478. Yang therefore does not suggest that TPD would improve performance in other systems and there would also not be a reasonable expectation that it would work in other systems. That is because OLED devices need to be designed with particular care with delicate balance of material compatibility, energy level match, charge carrier mobilities, as well as durability and reliability.

Thus, one cannot simply swap out PVK with PMMA and hope that the resulting system would work. For example, PMMA and PVK may have very different miscibility with TPD or the solvent used for spin coating. There is no demonstration, for example, a suitable solvent could be found to process PMMA, TPD, PBD and the emitter at the desired concentrations. To illustrate this point, in my past work, in an effort to create thin films in which individual polyfluorene chains were isolated from one another, it was found that co-dissolution of polyfluorene with PMMA did not work because the polymers tended to phase separate once the films were processed. On the contrary, when polyfluorene was instead co-dissolved with polystyrene, phase separation did not occur, and the polyfluorene chains in the resultant films were found to be in isolation of one another.

79. PVK was chosen as the host material to “ensure the confinement of the triplet excited state in the Ir(mppy)₃ guest phosphorescence molecule, and thus prevent luminescence quenching.” EX1022, 2. This is because luminescence quenching prevention is critical in OLED designs. This is important in phosphorescent OLEDs which rely on emission from the lowest lying triplet state of the phosphorescent emitter. Therefore, host materials and layers adjacent to the EML must be designed to have higher T1 levels so that they cannot quench triplets from phosphorescent emitters. Dr. Holmes presents no evidence that PMMA can

similarly confine the triplet energy of Ir(mppy)₃ in Choulis's emissive layer.

Relatedly, I note that Yang has formulated a mixture of TPD and PBD in polystyrene to investigate the formation of exciplexes between TPD and PBD.

EX1017, 2477. However, Yang tellingly does not report any OLED devices built with that mixture, which supports the fact that a POSITA would not simply substitute PVK with another random host material.

80. Additionally, Dr. Holmes does not provide a valid reason to swap out PVK for PMMA. For instance, Dr. Holmes states that “the host, which serves as a matrix in which the other three components are dispersed, preferably would have a wide energy gap so as not to interfere with the charge transport of the second and third matrix materials.” EX1003, ¶ 100 (cited at Pet., 31). But to the extent that PVK's HOMO level is sufficiently low that holes are injected directly into TPD, PVK is a passive matrix material already because there is no charge carrier created in it even though it can transport holes. In that regard, there is no benefit to replacing PVK with PMMA. But to the extent that PVK participates in hole transport, then swapping it out for PMMA that allegedly has no charge carrier properties at all would (i) upset the hole and electron balance, (ii) affect hole-charge recombination, and (iii) degrade the performance of the resulting OLED system. Thus, a POSITA would not have just swapped out PVK with PMMA without also adjusting the other materials in the emission layer in order to achieve

the hole-electron balance and desired conductivity. And on that issue, Dr. Holmes does not explain what adjustments to the other materials need to be made, or whether those materials would continue to satisfy the HOMO and LUMO limitations of the second matrix material and third matrix material, respectively.

81. Dr. Holmes and the Petition cite to paragraph [0044] of Choulis, which states:

The light emitting layer can include a host material. The hole material can be PVK, *as described above*, which is a non-conjugated polymer having mostly hole transporting properties. ... *In some embodiments*, the light emitting layer includes materials that are insulated matrices, that is, the host does not have transport properties, such as polycarbonate (PC), polymethyl methacrylate (PMMA) or polystyrene sulphonate (PSS).

EX1004, [0044].

82. But PVK is referenced by Choulis in connection with the embodiment of Figure 4. *See* EX1004, [0030] (when discussing “FIG. 4,” noting the light emitting layer 305 includes a host material 310, PVK, along with TPD and PBD). Thus, a POSITA would understand the reference to “as described above” for PVK refers to its use in the Figure 4 embodiment. Instead, PMMA is used as an example of “insulated matrices.” EX1004, [0044]. Dr. Holmes does not contend that PVK, which is capable of transporting holes, is an insulative matrix.

83. I note that the Petition also cites to paragraphs [0031] and [0041] in Choulis, apparently in support of the proposition to substitute PMMA for PVK. However, paragraph [0031] merely discusses the relative HOMO level of TPD and the LUMO level of PBD as compared to those of the emitter material to facilitate hole and electron injection and, in that context, suggests that other “suitable materials ... can ... be selected according to the properties described herein.” EX1004, [0031]. But that does not suggest to a POSITA to use a wide energy gap material for the first matrix material so that it does not interfere with the charge transport of the second and third matrix materials.

84. Further, paragraph [0041] of Choulis describes suitable materials for “the organic material that emits light,” *i.e.*, the emitter material rather than the host or first matrix material. Thus, that paragraph also does not suggest to a POSITA to use a wide energy gap material for the first matrix material so that it does not interfere with the charge transport of the second and third matrix materials.

85. Elsewhere, Dr. Holmes mentions preferred properties of hole and electron transport materials (*i.e.*, second and third matrix materials) (EX1003, ¶ [0030], and the use of “ultra-wide energy gap” (UGH) materials (*Id.*, ¶ [0031])). But again, neither of those paragraphs explains why a POSITA would have found it desirable to use PMMA in place of PVK in Choulis’s devices. For example, the first reference to UGH is a Holmes paper which contains only UGH and an emitter

material, with second or third matrix materials or use of PMMA. *See* EX1016, Abstract (referencing doping a blue phosphorescence in two UGH's where Dr. Holmes, the declarant and the author of the paper, does not assert that either UGH is PMMA). Both UGH1 and UGH2 referenced in the Holmes paper admittedly "transport electrons," even though they block hole transport. EX1017, 3820. Hence, to the extent that Dr. Holmes contends that UGH1 and UGH2 would not "interfere with the charge transport of the second and third matrix materials," that contention would be wrong because those materials at least facilitate electron transport.

86. To the extent Dr. Holmes contends that the Yang paper (EX1017) supports substituting PMMA for PVK, I disagree because Yang discloses using the same combination of materials as Choulis, *i.e.*, TPD, PBD, Ir(mppy)₃ in a PVK host. *See supra*, ¶¶ 70-72.

87. In short, Dr. Holmes has not identified any teaching for a UGH that meets the limitations of claims 2, 4, 15 and 16. In fact, Dr. Holmes' own paper demonstrates that UGHs (alleged suitable material for the first matrix material) can participate in electron transport, while Yang and Choulis demonstrate that a UGH, such as PVK, not only can participate in hole transport, but can also have HOMO and LUMO levels that do not meet the recited requirements. *See* EX1004, Fig. 4 (PVK has a HOMO that is higher in energy than PBD), [0044] (PVK is a hole

transport material).

88. Even if a UGH is preferred for some unexplained reason, that would not further explain why a POSITA would have used PMMA, in particular, with Choulis's PBD, TPD and Ir(mppy)₃.

89. Moreover, the notion that PMMA has a lower charge carrier mobility because it is described as not having transport properties is also of questionable logic. *See* EX1003, ¶ 105; Pet., 33. For example, as the '164 patent explains, "[i]f a charge carrier transport does not take place in a matrix material, ... then that can be attributed to the fact that charge carriers are not created *or* that there is no mobility of the charge carrier." EX1001, 2:64-3:1. In other words, Dr. Holmes does not address why the lack of charge transport must be due to low charge carrier mobility as opposed to being due to the fact that no charge carriers are created. This is not theoretical. If PMMA does have a deep lying HOMO and high lying LUMO, then it may be more difficult to create holes and electrons, leading to a negligible number of holes/electrons created. *See* EX1017, 2476 (noting "the rather large hole-injection barrier of ~0.7 eV from the ... (PEDT:PSS) anode into the(HOMO) level of PVK," which barrier would increase by a further 1.5eV for PMMA as PMMA's HOMO allegedly lies at -7.3eV versus -5.8eV for PVK); EX1001, 2:46-57 (creating a hole "is more difficult with an energetically low HOMO than with an energetically higher one" and creating electrons "is

energetically favored with energetically lower LUMOs”). The lack of holes and electrons can also result in (pure) PMMA not participating in charge transport. *See* EX1001, 2:64-3:1. Thus, Dr. Holmes has not established that PMMA’s charge carrier mobility is lower than those of TPD and PBD, which are relied on as the second and third matrix materials.

C. Use of Rubrene instead of Ir(mppy)₃ in Choulis for Claim 10

90. Claim 10 requires the LUMO of the emitter material to be energetically lower than the LUMO of all three matrix materials and the HOMO of the emitter to be energetically higher than the HOMO of all three matrix materials. EX1001, 9:55-59. However, Choulis’s Ir(mppy)₃ does not have the claimed property because its LUMO lies at the same level as PBD. *See* EX1004, Fig. 4.

91. Dr. Holmes suggests replacing Ir(mppy)₃ with rubrene, which has a LUMO lying about 0.75eV below the LUMO of PBD. EX1003, ¶ 115. But Choulis does not describe rubrene as a suitable emitter material for the Figure 4 embodiment. EX1001, [0043]. Instead, Choulis desires to have the LUMO energy level of the emitter material to be substantially the same as the LUMO level of at least one of the interface materials on the cathode side, that is, within 0.1-0.2eV of the LUMO energy level of an interface material on the cathode side. *See* EX1004, [0015] (“The first electrode can be a cathode and the first charges can be electrons. The first interface layer can have a LUMO level substantially equal to a LUMO

level ... of the phosphorescent organic material. ... The first interface layer can have a LUMO level that is within 0.2 eV, such as within 0.1 eV, of a LUMO level ... of the phosphorescent organic material.”). Against that backdrop, for the Figure 4 embodiment Choulis discusses using a PBD interface or matching layer whose LUMO level at -2.4 eV is “approximately equal to that of Ir(mppy)₃,” to facilitate “directly inject[ing] electrons into the Ir(mppy)₃.” *Id.*, [0029]; *see also id.*, [0028] (LUMO for Ir(mppy)₃ is -2.4 eV). But according to Dr. Holmes, rubrene has a LUMO of -3.15eV, which is about 0.75eV lower than the -2.4eV LUMO level reported for PBD. EX1003, ¶ 115; EX1004, Fig. 4.

92. Thus, Dr. Holmes’ suggestion of replacing Ir(mppy)₃ with rubrene is contrary to Choulis’s express and repeated teachings to match levels of the emitter material with the LUMO level of the matching material (which is PBD) on the cathode side. *See* EX1004, [0006] (“adding a matching layer on one or both sides of the light emitting layer” with the “matching layer ha[ving] an energy level similar to that of the emitter material”), [0007] (“organic moieties within the light emitting layer have energy level similar to that of the matching layers”), [0015] (first interfacial layer on the cathode side “can have a LUMO level substantially equal to a LUMO level or about equal to a triplet energy level of the phosphorescent organic material”), [0031] (“PBD has a LUMO level that is approximately equal to that of the Ir(mppy)₃). The PBD is used as a moiety in the

light emitting layer rather than as a thin matching layer, as above. PBD is also used as LUMO matching layer ... between the light emitting layer 305 and a cathode 350.”).

93. Under Choulis’s design principle, if the emitter’s LUMO is decreased to about -3.15eV, as would be case when using rubrene, the electron transport material and the ETL matching layer’s LUMO would accordingly need to decrease to a similar level. But Dr. Holmes does not explain what, in that case, would be the appropriate electron transport material and whether the requirements for HOMO/LUMO levels for the first, second and third matrix materials would still hold in that case. Thus, Dr. Holmes has not established that a POSITA could have replaced Ir(mppy)₃ with rubrene in a way which does not violate Choulis’s design principles, while still satisfying the other claim requirements.

94. A POSITA would recognize that, given the large difference in the LUMO levels of rubrene and PBD, rubrene would act as an electron trap (that is, electrons would be injected into rubrene and be trapped there). PBD would stop participating in electron transport as no electrons are created in it any more. That would affect the device’s recombination zone, making it shift towards the electron transport layer and could significantly reduce the OLED’s performance.

95. Dr. Holmes also cites to Kang (EX1010) and Hamada (EX1-24), but neither suggests using rubrene as an emitter material. Kang, for example, uses

DCJTb as the emitter. *See* EX1010 (Kang), Abstract (“We have studied the electroluminescence (EL) properties with a red fluorescent dye ... (DCJTb), doped into a mixed matrix of tris-(8-hydroxyquinoline)aluminum (Alq₃) and rubrene.”). Hamada uses rubrene as an emitting assist. EX1024 (Hamada), Abstract (“We propose an emitting assist (EA) dopant system The EA *dopant (rubrene) did not itself emit* but assisted the energy transfer from the host (Alq₃) to the red emitting dopant (DCM2).”). Moreover, in neither system was rubrene used with PBD.

96. I note that. Dr. Holmes also states that a POSITA would have used PQIr (LUMO -2.7 eV) and DCM2 (LUMO -3.11 eV) as the emitter materials, citing to Kanno (EX1025) and Hamada (EX1024) in support. EX1003, ¶ 115. But these materials do not appear to comply with Choulis’s operating principle of having matching HOMO/LUMO energy levels between the emitting material and at least the interfacial materials, as I described above. *See supra*, ¶¶ 92-93. For example, the LUMO levels would be 0.3 eV and 0.7 eV lower than the LUMO of the LUMO matching layer material (PBD), higher than the 0.2eV deviation taught by Choulis. Moreover, neither Kanno nor Hamada discloses using PQIr or DCM2 with TPD, PBD or PVK. *See* EX1025 (Kanno) (using PQIr with CBP); EX1024 (Hamada) (using DCM2 with Alq₃ and rubrene). Therefore, I see no reason why a POSITA would have used PQIr or DCM2 with Choulis’s emission layer materials.

97. Dr. Holmes makes the further general assertion that a POSITA would have found it obvious to have the LUMO of the guest emitter material lower than those of other materials in the light emitting layer, and the HOMO level of the guest emitter material higher than those of other materials in the light emitting layer. EX1003, ¶ 115. But Dr. Holmes own citations do not support that contention. For example, Kanno depicts a blue-green phosphor, Ir(flz)₃ doped in mCP. EX1025, 340. The LUMO level of Ir(flz)₃ “is at least 0.5 eV above those of mCP and CBP, as well as other dopants[.]” *Id.*; *see also id.*, Fig. 2 (LUMO for Ir(flz)₃ and mCP is 1.9 and 2.4 eV respectively). According to Kanno, that is favorable as it “prevent[s] electron leakage from the EML into the adjacent layers.” *Id.* In other words, an emitter with a LUMO *higher than*, not lower than, the host material is described as advantageous. *See also* EX1007 (Thompson), Fig. 4 (annotated by Dr. Holmes below) (emitter (HT or ET) does not have both a LUMO that is lower than the other two materials or a HOMO that is higher than the other two).

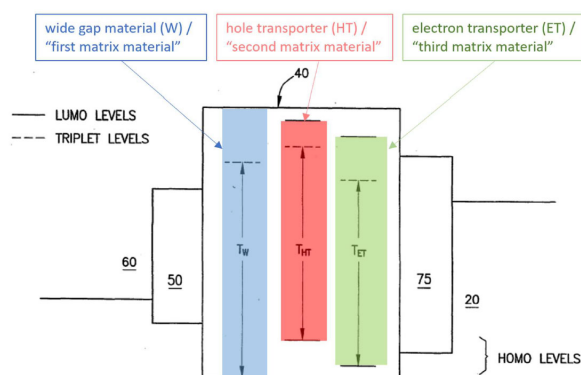


Fig. 4

98. The '164 patent disclose the use of a narrower bandgap for the emitter materials than the matrix materials in order to make an “ambipolar charge transport” “possible” in the emission layer. EX1001, 4:44-54. This is a feature not taught or suggested in the prior art identified by Dr. Holmes.

99. In sum, Dr. Holmes has not established that Choulis anticipates claim 10, that a POSITA would have been motivated to replace the emitter material used in the Figure 4 example with rubrene, PQIr or DCM2.

D. Evaporating or Replacing PVK

100. For Element 13[d] requires that “at least the first matrix material, the second matrix material, and the third matrix material are simultaneously applied,” while Claim 14 requires that “the first matrix material, the second matrix material and the third matrix material are applied by evaporation coating.” For these limitations, Dr. Holmes contends they are disclosed by Choulis, or met by either evaporating PVK or replacing PVK with some unspecified small molecules.

EX1003, ¶¶ 130-138. However, Choulis only suggests process polymers as “solutions or suspensions,” not through evaporation. EX1004 (Choulis), [0043]-[0044], [0048]. Regarding evaporating PVK, Djobo demonstrates that evaporation of PVK leads to decomposition, and there is no demonstration that the resulting material would have the same HOMO/LUMO levels as PVK or that the decomposed materials would provide acceptable performance. EX1023, Abstract (“When PVK is deposited by classical thermal evaporation there is a shortening effect of the chain length”).

101. In no part of Choulis does it suggest that its EML could be produced by evaporation because Choulis knows that PVK cannot be evaporated. Choulis is specifically about solution processing a multicomponent EML that contains an inert polymeric matrix material. Both the HIL/ABL and HTL matching layer (TFB) were solution processed by necessity because they must not be re-dissolved during the EML spin-coating step. Solution processing offers the advantage of low-temperature processing and is therefore much cheaper than physical vapor deposition.

102. As to replacing PVK with some unspecified small molecules, Dr. Holmes does not establish that the unspecified small molecules would satisfy the required HOMO/LUMO levels of the claims.

VII. GROUND 2: CHOULIS AND YONG (CLAIM 9)

103. Claim 9 recites that “the concentration of the emitter material in the emission layer has a gradient.” EX1001, 9:52-54. Because Choulis does not disclose this limitation, Dr. Holmes relies on the disclosure in Yong for this limitation. EX1003, ¶¶ 160-161.

104. Dr. Holmes cites to Choulis’s background reference to a prior art study that “[t]he recombination current in any of the layers ... can be controlled ... by adjusting dopant concentration,” in apparent support of his conclusion that it would have been obvious to apply the emitter material in Choulis’s emission layer such that the concentration of the emitter has a gradient. EX1003, ¶ 160. I do not agree with Dr. Holmes’ conclusion. For example, Dr. Holmes does not explain why trends observed for *different* devices, all with a uniform emitter concentration within the emission layer, would have suggested having different emitter concentrations throughout the emission layer in the *same* device. Indeed, Choulis does not teach or suggest a concentration gradient within the device because the inventors of Choulis would have known controlled concentration gradients cannot be achieved via spin-coating. The ability to grow concentration gradients throughout a multicomponent layer is a unique capability of physical vapor deposition.

105. I also note that Choulis discloses specific deposition techniques as

being preferable for small-molecule light emitting materials, not simply that “various methods and techniques” can be used, as Dr. Holmes contends. EX1003, ¶ 160; EX1004, [0043].

106. Dr. Holmes further contends that “a gradient in emitter material was well generally known in the art prior to the ’164 patent” EX1003, ¶ 161. I do not agree. For example, Dr. Holmes cites to a single Chinese patent, Yong, which does not evidence general knowledge in the art. Even in the case of Yong, it’s disclosure would not have motivated a POSITA to apply concentration gradient to Choulis’s system. This is because Yong suggests gradient doping of emitter materials because “[i]n general devices, holes are majority carriers, while electrons are minority carriers,” such that “[i]n the light emitting layer of phosphorescent devices, the concentration distribution of electrons shows a non-linear decreasing trend along the direction from the electron transporting layer to the hole transporting layer.” EX1009, 10 (second paragraph). Yong utilizes one such traditional OLED device, where the emission layer included only a host material and the emitter material. *See* EX1009, 19 (paragraph 3, disclosing using “host materials DCB and FIrpic” for the emission layer), 18 (“4 is an organic light emitting layer, using small molecule materials as the host material”).

107. In contrast, Choulis’s emission layer relied on for claim 1 requires not only a host material, PVK, but also TPD and PBD dopants. Dr. Holmes

characterizes TPD as a hole transport material and PBD as an electron transport material. EX1003, ¶¶ 107, 109; EX1004, Fig. 4 (annotated in EX1003, ¶ 102). This means that, unlike Yong's traditional devices, Choulis is relied on as including both hole transport and electron transport materials in the emission layer. Dr. Holmes ignores this critical distinction, however. Moreover, according to Yang, the particular composition (at 9 wt% TPD) has good charge carrier balance. EX1017, 2477-78 (TPD concentration above 13 wt% "disturbs the balance of carrier injection and transport").

108. Dr. Holmes provides no evidence that Choulis suffers from the same problem as Yong, which has a completely different architecture, which is that the "concentration distribution of electrons [also] shows a non-linear decreasing trend along the direction from the electron transporting layer to the hole transporting layer," as is the case in Yong's different architecture. EX1009, 3.

109. Yong's invention was specifically designed to address the non-linear decrease in electron concentrations from ETL to HTL, as described above. EX1009, 10. Because there is no reason to believe that Choulis's specific device experiences any such concentration gradient of electrons from the ETL side to the HTL side, a POSITA would not have been motivated to complicate Choulis with addition steps to include a concentration gradient like Yong where the problem solved by Yong's concentration gradient does not exist in the first place.

110. I also note that Choulis asserts that “[b]y shifting the hole and electron transfer to the matching materials in the light emitting materials, charge transport can be separated from exciton formation,” which can in turn result in “less voltage application to the device overall” as well as “[e]xpand[] the recombination zone” from the surface of the emitting layer to “throughout the light emitting layer.” EX1004, [0056]. This means that Choulis, and its emission layer purported to incorporate both hole and electron transport materials, would be expected to have already achieved the solution sought by Yong with its emitter concentration gradient. See EX1004, [0056]-[0057] (*i.e.*, a recombination zone throughout the emission layer, “[m]ore efficient use of the phosphorescent material” and “extend[ing] the lifetime of the device”); EX2020, 180:7-10 (Dr. Holmes acknowledging the inventions of Yong and Choulis have the “[s]ame general goal”).

111. For example, Choulis suggests that “by using a specific amount of hole and electron injecting materials within the light emitting layer, the charge balance within the light emitting layer can be optimized” and that “[i]ncorporating matching layers into the light emitting layer can also control the charge balance within the light emitting layer.” *Id.*, [0058]. Given that Choulis has already addressed the root problem of charge imbalance in the emitting layer, a POSITA

would not have increased the complexity of Choulis's approach by applying Yong's emitter concentration gradient.

112. Dr. Holmes has also not established that a POSITA would have had a reasonable likelihood of success in modifying Choulis with Yong to achieve the claimed concentration gradient. This is because, for claim 1 Dr. Holmes relies on PVK, TPD and PBD as the first, second and third matrix materials. *See* EX1003, ¶¶ 85-93. Moreover, Dr. Holmes only asserts that concentration gradient could be achieved via "evaporation" deposition. *See* EX1003, ¶ 165; EX2020, 172:5-8 ("Q You are not contending that a solution-based process will yield a concentration gradient of the emitter material; is that right? A No. I'm using Yong with evaporation."). But Choulis does not disclose or suggest using evaporation to deposit its blend of PVK-based emission layer materials. *See* EX1004, [0048] (suggesting applying polymer organic layers with "ink-jet printing" or "spin-coating"), [0044] (describing PVK as "a non-conjugated polymer"). Dr. Holmes also does not contend for this claim that evaporation is a viable deposition method for the PVK material used in Choulis. EX2020, 163:13-165:6 (Dr. Holmes testifying that he is not aware of any literature or anyone who has used evaporation to process PVK). Contemporaneous articles used spin coating to deposit light emitting layers having the same matrix composition as the Choulis application. EX2007, 054702-2; *see also* EX1017, 2476 (blending PVK, PBD, TPD and

Ir(mppy)₃, including mixtures with the same composition as Choulis (*see* 2478-Fig. 3 caption), in chlorobenzene for spin coating).

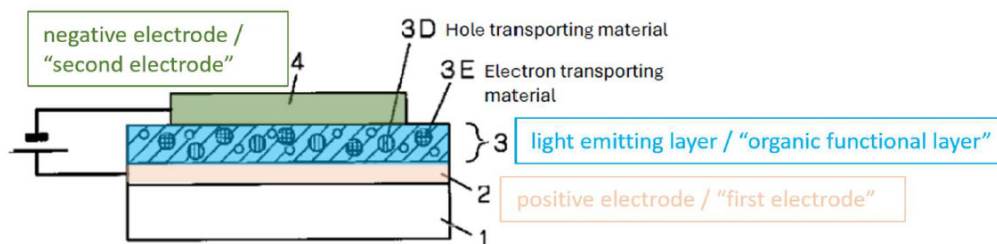
EX1004, [0054]	EX2007,054702-2
“The light emitting layer includes 61% PVK, 24% PBD, 9% TPD and 6% Ir(mppy) ₃ .”	“The green emitting layer (<i>EML</i>) <i>was then spin coated</i> ... to yield a light emitting layer thickness of around 70 nm. The light emitting layer was then annealed at 80 °C for 30 min. The solution for the EML consisted of 24% (wt) 2-4-(biphenyl)-5-(4- <i>tert</i> -butylphenyl)-1,3,4-oxadiazole (PBD), 9% (wt) 4,4'-bis-(<i>m</i> -tolylphenylamino)biphenyl (TPD), 6% (wt) fac-tris(2-phenylpyridine)iridium Ir(ppy)₃ , and 61% (wt) polyvinylcarbazole (PVK) in chlorobenzene.”

113. Dr. Holmes does not contend that a concentration gradient of the emitter material could be created via a solution-based process such as spin-coating. Based on my years of experience in the industry, including in solution-based OLEDs, doing so would be beyond the skill level of even a person with above average skills and generally it would be extremely difficult to do. Issues such as phase separation would make it extremely challenging and not reproducible to create films with controlled concentration gradients. As a result, Dr. Holmes has not shown that a POSITA would have had a reasonable expectation of success to create a concentration gradient of the emitter material in Choulis’s emitting layer

consisting of PVK, PBD and TPD. Nor has Dr. Holmes shown that Choulis could be modified by Yong's system in a way which would have continued to satisfy the requirements for claim 1.

VIII. GROUND 3: SUGIURA (CLAIMS 1, 3, 5-8, 10-13)

114. Dr. Holmes identifies Sugiura's PVK polymer 3A as the "first matrix material," the hole transporting material 3D as the "second matrix material," and the electron transporting material 3E as the "third matrix material." See below.

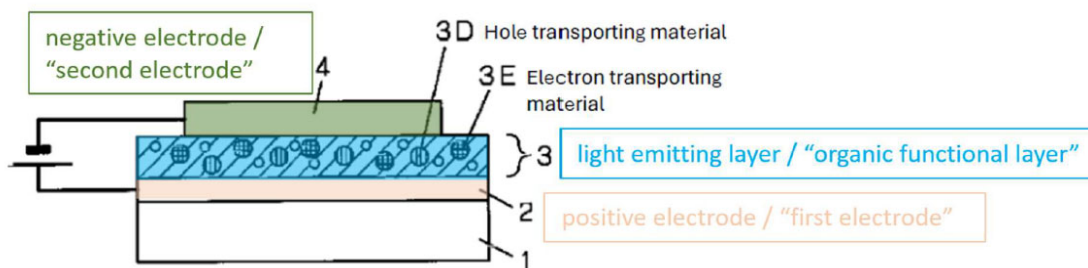


EX1003, ¶ 177 (annotating Sugiura, FIG. 4)

115. I do not agree that the hole transporting material 3D and the electron transporting material 3E are matrix materials, within the meaning of the '164 patent. In particular, the hole transporting material 3D and the electron transporting material 3E are distributed as segregated and dispersed agglomerations or "islands" in polymer 3A with no interconnections between any of the 3D or 3E agglomerations. EX1006, [0041] (when describing Fig. 1, noting "[t]he light emitting layer includes a charge transporting material 3B, a light-emitting material 3C, and *a polymer 3A for dispersing these.*"), Fig. 1 (showing

3B and 3C dispersed as separate agglomerations in polymer 3A, just like 3D and 3E are dispersed in 3A in Figure 4). As I explained above in Section V.C., which I incorporate here by reference, the term “matrix materials” does not encompass dispersed agglomerations. Moreover, materials 3D and 3E are also not disclosed as being capable of having another material embedded therein, which is another requirement of a “matrix material.” See Section V.C. For example, the emitter particles, depicted in FIG. 4 as circles with no patterns, are dispersed only within the host material 3A, and not within 3D or 3E.

116. In Sugiura’s system, depicted below, where the hole transporting material 3D and electron transporting material 3E are discrete and disconnected agglomerations, a POSITA would not have viewed them as matrix materials, but rather as dopants dispersed in a host material (the one illustrated as the blue shaded area).



117. I understand that Samsung has proposed in the district court action that “matrix” means “a continuous phase of the mixture of matrix materials” and the first, second and third matrix materials “are different materials and are part of

the same matrix.” EX2005, 16-17. To the extent that Samsung’s proposal covers a situation like the one shown in the figure above, that is not what a person of ordinary skill in the art would understand. In the context of the ’164 patent, a matrix material would be part of the continuous phase in a given organic layer in which guest materials can be embedded. That is, material 3D and material 3E in the above are guest materials and not matrix materials, because they are not part of any continuous phase of the organic functional layer. Specifically, neither material 3D nor material 3E forms a continuous phase, and only the host material (blue shaded material) provides the continuous phase in which the other materials are dispersed. That is, there is not a continuous phase of a mixture of the host material (3A, shaded blue areas), 3D and 3E, only a continuous phase of 3A. As depicted, the emitter material (small open circles) is dispersed in the host material with no other materials embedded in it. Likewise, materials 3D and 3E are dispersed in the host material with no other materials embedded in either. I note that Dr. Holmes acknowledged that 3B and 3C are shown as discontinuous and *not* as a matrix. EX2020, 96:5-97:3. Phase separation would imply that no modulation of inter-molecule distances takes place in these regions and the individual phases will exhibit bulk transport properties of the corresponding component. Thus, materials 3D and 3E would be regarded as having the same structural nature as the emitter

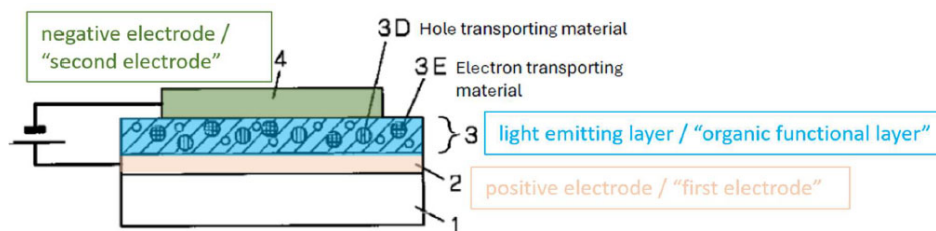
materials (circles in FIG. 4 with no pattern)—they are all dopants, not matrix materials.

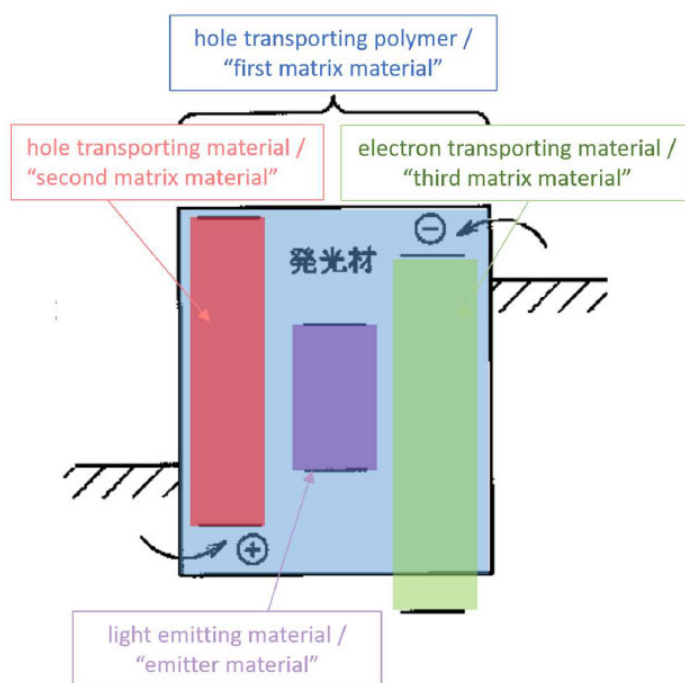
118. That Sugiura's system is based on using dispersed agglomerations for the hole transporting material 3D and electron transporting material 3E is no accident. Specifically, a POSITA would recognize that the configuration of islands of 3D and 3E in a sea of polymer host 3A would beneficially avoid potential HT-ET exciplex formation that could lead to inefficiency and reduction in color purity. This is because the exciplex does not have a well-defined ground state so the oscillator strength is low and the radiative decay rate is therefore low. Once the exciplex does finally decay, the molecules instantaneously repel one another. *See* EX2030 (US9403849), 2:39-41 ("A further disadvantage of AlQ3 is the instability to holes ... which can always result in problems in the component on long-term use").

119. I note that the mixture of materials 3A, 3D and 3E does not form a continuous phase in the emission layer; instead, the only non-dispersed phase is formed by host material (blue shaded areas) with materials 3D and 3E embedded therein at discrete locations like "islands in a sea." Indeed, given that materials 3D and 3E, like the emitters, are dispersed in host 3A with no other materials embedded in them, materials 3D and 3E would be regarded as having the same structural nature as the emitter materials—they are all dopants, not matrix

materials. And, for the further reasons described above in Section III.A, a POSITA would understand that matrix materials do not encompass dopants.

120. I further note that Dr. Holmes' mapping of materials appears to result in an inconsistent meaning of the term "matrix." For example, the term "matrix" in "first matrix material" appears to describe a physical characteristic of the immediately following "material" (polymer 3A, annotated by Dr. Holmes below in blue), while the terms "matrix" in "second matrix material" and "third matrix material" do not describe a physical characteristic of the immediately following "materials" (3D and 3E, respectively), but instead appear to refer back to a different material, namely, polymer 3A as being a matrix.





EX1003, ¶¶ 177, 180 (annotating FIG. 4 and 8 of Sugiura).

121. As such, Dr. Holmes has not established that Sugiura discloses three matrix materials, as required by the claims.

122. I also note that Sugiura does not disclose HOMO or LUMO levels. Instead, Dr. Holmes cites only to Sugiura's FIG. 8 and paragraph [0049]. EX1003, ¶¶ 183-185. But paragraph [0049] only mentions "ionization potential of the hole transporting material." EX1006, [0049].

123. Dr. Holmes provides no real analysis as to how or why Sugiura discloses HOMO and LUMO, or how ionization potential and electron affinity are related. I note that Dr. Holmes' evidence suggests they can be different. For example, Sugiura discloses that Alq₃ has an ionization potential of 5.7 eV and an

electron affinity of 3.0 eV. EX1006, [0053]. On the other hand, Manninen reports that Alq₃'s HOMO and LUMO levels are respectively -5.5eV and -2.4 eV, while Kang discloses that Alq₃'s HOMO -5.62eV and LUMO is -2.85 eV. *See* EX2023 (Manninen), Fig. 5; EX1010, Fig. 1. Dr. Holmes also does not explain how the various unlabeled and unexplained horizontal lines in Figure 8 demonstrate the HOMO and LUMO relationships recited in the claims.

124. Regarding claim 10, I note that the embodiment of Sugiura relied on by Dr. Holmes uses PVK, Alq₃, and TPD as the matrix materials, and Nile red as the emitter material. EX1003, ¶¶ 178-181 (claim 10 includes the same matrix materials and emitter materials of claim 1); EX1006, [0052] (“Nile Red, a laser dye, was used for the light-emitting material”). But Choulis discloses that TPD has a HOMO energy level of -5.5 eV, and a LUMO energy level of -2.3eV. EX1004, Fig. 4. Additionally, the HOMO and LUMO levels for Nile red are -5.5 eV and -3.2 to -3.5eV respectively. *See* EX2008, 8910, Table 3.

Material	HOMO (eV)	LUMO (eV)
TPD	-5.5	-2.3
Nile Red	-5.5	-3.2 to -3.5

125. Thus, the HOMO level of Nile red is not “energetically higher than the HOMO of the first, second, and third matrix materials” as required by claim 10,

even if TPD could be regarded as a matrix material (which it cannot be).

IX. GROUND 4: THOMPSON (CLAIMS 15-16)

126. Claims 15 and 16 each requires “at least one organic functional layer [that] has at least a first matrix material, a second matrix material, and a third matrix material.”

127. Dr. Holmes relies on Thompson’s “wide gap host material” to satisfy the “first matrix material.” EX1003, ¶¶ 231-232. Dr. Holmes then relies on Thompson’s “charge carrying dopant material: and “phosphorescent dopant material” as allegedly satisfying the “second matrix material” and “third matrix material,” respectively. *See id.* Specifically, Thompson discloses that “the emissive layer comprises a wide gap host material *doped with both a charge carrying dopant material and a phosphorescent dopant material.*” EX1007, [0008].

128. As I described above, however, a POSITA would understand that a “matrix material,” within the meaning of the ’164 patent, does not encompass dopants, such as emitter materials. *See* Section V.B. In addition, Thompson itself also distinguishes between a dopant and a matrix material: “The HOMO energy levels of the *phosphorescent dopants* are typically higher in energy than those of *the matrix materials into which they are doped.*” *Id.*, [0023].

129. A POSITA would understand that Thompson teaches away from the

claimed arrangement. Specifically, Thompson teaches that the OLED “includes a wide gap inert host material doped with two dopants. One of the dopants is an emissive phosphorescent material that can transport either electrons or holes. The other dopant is a charge carrying material that can transport whichever of the electrons and holes that is not transported by the phosphorescent dopant.” EX1007, Abstract. Thus, Thompson in fact restricts its emission layer materials to specifically include 1) a wide band gap layer, 2) an emitter dopant, and 3) a charge carrying dopant opposite the charge carrying type of the emitter dopant.

130. I also note that the '164 patent distinguishes, not only between a dopant and a matrix material, but also between an emitter material (a type of dopant) and a matrix material. *See supra*, Section V.A-V.B. This is significant because a POSITA would understand Thompson’s phosphorescent dopant is an emitter material, as Thompson expressly notes (EX1007, [0042] “emitter dopant”), which is distinct and claimed in the '164 patent separately from the matrix materials. *See* EX2025, 162:11-13 (Dr. Rand testifying that “especially in a phosphorescent OLED, I would consider the emitter ... to not be the matrix”). The fact that Thompson’s “emitter dopant” has hole transporting properties does not change the nature of the material as being an emitter dopant. EX1007, [0023] (Thompson acknowledges that when “[t]he HOMO energy levels of the phosphorescent dopants are ... higher in energy than those of the matrix materials

into which they are doped,” “the dopants are capable of trapping holes and transporting them throughout the matrix if the doping level is high enough.”).

131. I also note that the '164 patent discloses emitter materials with a HOMO energy level higher than the matrix materials. *See* EX1001, col. 7, table 1 (emitter rubrene has a HOMO level of -5.5eV, higher than the three matrix materials mCP, TCTA and TPBi), 4:44-54 (HOMO of emitter higher than those of the first, second and third matrix materials), Fig. 2 (emitter materials 30E's HOMO level above those of the matrix materials 30N, 30A and 30B). This means that the emitter materials disclosed in the '164 patent would also be expected to transport holes, but were never characterized as matrix materials. *See* EX1001, 8:27-30; *see also* EX2020, 299:20-300:7; EX1017 (Yang) at 2477 (Ir(mppy)₃ “participates in charge transport,” but never described as a host”). *See* EX1007, [0023] (expecting emitter with HOMOs higher than the matrix material to transport holes); EX1017, 2477 (“This implies that Ir(mppy)₃ itself participates in charge transport” and Ir(mppy)₃ has a HOMO level higher than those of PVK, PBD and TPD used in EX1017's emission layer, per Choulis, Figure 4).

132. Claim 16 further recites that “the first matrix material has a charge carrier mobility which is lower than the charge carrier mobilities of the second and third matrix materials.”

133. Dr. Holmes assumes, without evidence, that because Thompson's host

material layer 40 is inert and does not function as a charge carrying material, that it “would therefore have a lower charge carrier mobility than that of the second matrix material, which acts as a hole transporter, and that of the third matrix material, which acts as an electron transporter.” EX1003, ¶ 256. I do not agree that it necessarily follows that Thompson’s host material layer 40 would have a lower charge carrier mobility than the alleged second matrix material and third matrix material of Thompson.

134. For example, if the first matrix material has a deep lying HOMO and/or high lying LUMO, it may be more difficult to create holes and electrons to begin with, potentially leading to a negligible number of holes/electrons being created. *See* EX1001, 2:46-57 (creating a hole “is more difficult with an energetically low HOMO than with an energetically higher one” and creating electrons “is energetically favored with energetically lower LUMOs”). This lack of hole/electron creation can result in the first matrix material not participating in charge transport. *See* EX1001, 2:64-3:1.

135. I also note that Thompson discloses the use of polystyrene as the inert matrix. EX1007, [0054]. However, it has been reported that at 80°C, “the hole mobility in practically amorphous polystyrene” was $5 \times 10^{-5} \text{ cm}^2\text{sec}^{-1}\text{V}^{-1}$. *See* EX2009, Abstract. I have not seen any evidence that the dopants’ charge carrier mobilities are higher than $5 \times 10^{-5} \text{ cm}^2\text{sec}^{-1}\text{V}^{-1}$ at 80°C. For instance, it has also

been reported that “light doping of NPB with Ir(ppy)₃ almost do not alter the hole mobility” of NPB. EX2010, Abstract. Specifically, the HOMO of Irppy₃ (HOMO) is greater than the HOMO of NPB. Therefore, at low concentration, Irppy₃ will act as a mild hole trap in NPB (only ~0.3 eV trap depth) and NPB will likely dominate hole transport. This suggests that the iridium-based phosphor is not contributing to hole transport. This undercuts Dr. Holmes’s assumption that, if a substance does not participate in charge carrier transport, then it has no appreciable charge carrier mobility. Under that logic, Ir(ppy)₃ would have no mobility, and therefore a lower mobility than polystyrene. This is course makes no sense since Ir(ppy)₃ is an emitter dopant which is selected at least in part because of its favorably high charge carrier mobility.

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 May 5, 2025.

/Marc Sims/

Marc Sims, Ph.D.

APPENDIX A

TECHNICAL LEAD, DISPLAY TECHNOLOGY

Seasoned team leader with a track record of driving successful innovation in industry, most notably in the OLED / QD and display space including the development of materials, process and manufacturing equipment. Highly skilled in failure & root-cause analysis, device fabrication and characterization, with a solid understanding in device physics, spectroscopy, photophysics, materials science, nanomaterials, and polymers. Creative, adaptable problem solver and strategic thinker, experienced in forging external partnerships and building consensus across multiple organizational levels to advance cohesive operations. Uniquely qualified to work effectively in display hardware development. Six patent families in OLED materials, 20 peer reviewed journal papers in organic electronics and multiple invited talks and seminars internationally.

PROFESSIONAL EXPERIENCE

MARGIK, INC., Remote

Sept 2022 – present

Director of R&D

In charge of OLED product design and development, IP generation

NANOSYS, INC., Milpitas, CA

Sept 2021 – August 2022

Device Physicist/Staff Scientist

Developed electrical transient measurements to build device physics models for QDEL devices. Utilized models to understand reliability issues, provide feedback and guide device development efforts and synthetic chemistry.

KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, Saudi Arabia

Nov 2019 – Sept 2021

Principal Investigator/Senior Research Scientist: Thin Film LED Fabrication and Characterization

Appointed to design and build a thin film LED laboratory and research program in the area of new display technologies. In addition to academic projects, the \$1.6 million lab is being used for OLED reliability research with Merck (Darmstadt, Germany) and will be used for commercial R & D by a perovskite LED start-up, PeroLED (<https://peroled.com/>)

- Directed operations, including installations and trainings, and manage two Postdoctoral Fellows.
- Successfully established a cooperation with Merck Performance Materials & Display Solutions and, as the Principal Investigator, have:
 - Secured the supply of reference OLED VTE materials to benchmark our new fabrication line and to conduct coordinated research for both Merck and KAUST projects.
 - Benchmarked our new characterization facility using reference OLED devices from Merck.

KATEEVA, INC., Newark, CA

September 2016 – June 2019

Senior Manager, Characterization and Advanced Technology

Cross-functional role as lead technical liaison for the Shared Labs department, leveraging device physics expertise to serve a broad range of programs. Provided scientific guidance and identified appropriate projects to resolve technical issues, negotiating timelines and deliverables with program managers. As the head of Characterization and Test Labs, conceptualized, designed, and supervised research projects and instrumentation development on a tight budget for the build out of inkjet-printed devices for display applications.

- Led a team of engineers responsible for characterization, optical modeling, design and 3D printing of test fixtures, substrate and evaporation mask design, and failure analysis.
- Innovated optical tools and adapted established techniques for new applications, including:
 - Mura characterization tools for printed OLED panels (just-noticeable-difference and microscopic colorimetry, short range luminance uniformity by high-res image analysis) and for printed Quantum Dot-PL-Color Filters (65" light table for white light transmission mapping and blue light box for PL-based SRU). Built a transportable colorimetric microscope for customer site in Asia.
 - An optical screening tool for incoming OLED ink inspection based on time-resolved PL.
 - Optical metrology tools for measuring in-pixel printed layer thickness across large areas for the OLED program (multilayer large area color interferometry [LACI]) and the QD-PL-CF program (red light transmission maps).
 - Advanced characterization tools for the OLED program (voltage-frequency-capacitance, time resolved EL, displacement current measurement, angular dependence of luminance and color) and QD-PL-CF program

(thin film PLQE, QD forward conversion efficiency, angular dependence of blue light leakage and QD emission).

- Created a new automated test facility for 200mm (25-up) inkjet-printed and VTE OLED coupons (JVL, EQE, temperature-accelerated lifetime).
- Led development of OLED VTE baseline. Improved baseline lifetime of blue fluorescent VTE device from T95 ~15 hrs to T95 ~300hrs at 22mA/cm² while V10 variability was kept at +/- 0.15V.
- Promoted to Senior Manager after proven results as Device Technology Manager & Senior Staff Engineer.

SOLVAY OLED, Corporate Research and Innovation, Pittsburgh, PA

September 2014 – February 2016

Device Group Manager

Oversaw all device R & D activities to drive materials development. Led a group of seven scientists, engineers, and technicians. Established external collaborations with leading academic and commercial entities.

- Steered HIL and ETL materials development, resulting in five patent families in organic electronic materials. Discoveries included a common triplet-induced OLED degradation mechanism that aided HIL development.
- Built a new OLED fabrication facility with state-of-the-art baseline performance (+/- 0.1V at 16.6mA/cm²).
- Led a collaboration focused on OLED stability with Kyulux (<https://www.kyulux.com/>) and achieved T95 = 1500 hrs at 1000 cd/m² in green TADF-based OLEDs
- Developed a general hybrid architecture that surpasses equivalent state-of-the art green VTE OLED performance (T₉₅ = 250 hrs. at 16.6mA/cm²; 4.1V at 10mA/cm²; (0.27, 0.66); 23% EQE at 1000 cd/m²).
- Co-developed a non-aqueous HIL formulation that improves color saturation and stability, as well as outcoupling efficiency.

DUPONT DISPLAYS, Santa Barbara, CA

February 2006 – September 2014

Senior Device Scientist

Research and development in printable OLED materials and devices for display and lighting applications. Roles and responsibilities:

- Continuously pushed efficiency, lifetime and reduced voltage through two approaches:
 1. Innovate new processes by electro-optical device analyses.
 2. Empirical screening of new materials.
- Management of an OLED fabrication line for materials' screening (baseline management, SPC).
- Managed device fabrication technicians.
- Co-led the solution processed high efficiency green OLED team.
- Co-led DuPont's printed, color-tunable OLED Lighting program.

Research advancements included:

- Identified root causes of external quantum efficiency loss in solution processed OLEDs to help improve materials' properties and fabrication process (experimental setups incl.: p-polarized PL, time-resolved PL, UV-vis-NIR absorption spectroscopy, electro-absorption spectroscopy, time-resolved EL)
 1. Using time-resolved PL (TCSPC) and p-polarized PL, mapped out device thickness regimes corresponding to plasmon-losses and the Purcell effect, which enabled the optimization of EQE.
 2. Applied SETFOS simulation SW to the above data in order to extract emission dipole moment orientation in solution-processed and VTE OLED counterparts.
 3. Combining the results of charge-modulation spectroscopy and assuming the Langevin capture radius of a static charge, demonstrated that IQE is equal to 100% in devices with DuPont HIL and LiQ/LiF doped EILs.
- Identified charge transfer efficacy across the HIL|HTL interface as a key driver of voltage reduction in solution processed OLEDs.
- Application of electro-absorption and charge-modulation spectroscopies, displacement current measurement / voltammetry to understand root-causes of intrinsic OLED degradation.

IMPERIAL COLLEGE LONDON, Department of Physics

2002 – 2006

Postdoctoral Research Associate in Experimental Solid-State Physics (EXSS)

EDUCATION

PhD, Experimental Condensed Matter Physics (Supervisor: Prof. DDC Bradley), University of Sheffield, UK

Master of Physics, MPhys, University of Sheffield, UK

PUBLICATIONS

- M. Ariu, D.G. Lidzey, M. Sims, A.J. Cadby, P.A. Lane, D.D.C. Bradley "The effect of morphology on the temperature-dependent photoluminescence quantum efficiency of the conjugated polymer poly(9,9-dioctylfluorene)", *J. Phys.: Condens. Matt.* 14, 9975 (2002)
- M. Ariu, M. Sims, M.D. Rahn, J. Hill, A.M. Fox, D.G. Lidzey, M. Oda, J. Cabanillas Gonzalez, D.D.C. Bradley "Exciton migration in beta-phase poly(9,9-dioctylfluorene)", *Phys. Rev. B* 67, art. no. 195333 (2003)
- M. Sims, M. Ariu, A. Asimakis, M. Koeberg, M. Stouff, M. Fox, D.D.C. Bradley "The interchain origin of the green emission band in oxidized poly(9,9-dioctylfluorene) (PFO)", *Proc. SPIE* 5214, 216 (2003)
- M. Sims, D.D.C. Bradley, M. Ariu, M. Koeberg, A. Asimakis, M. Grell, D.G. Lidzey "Understanding the origin of the 535nm emission band in oxidised poly(9,9-dioctylfluorene): The essential role of interchain/inter-segment interactions", *Adv. Funct. Mat.* 14, 765 (2004)
- M. Sims, A. Asimakis, M. Ariu, D.D.C. Bradley INVITED PAPER: "Thermodynamic constants for excimer formation and dissociation in oxidized poly(9,9-dioctylfluorene) (PFO)", *Proc. SPIE* 5519, 59 (2004)
- M. Sims, K. Zheng, M. Campoy Quiles, P. Etchegoin, P.N. Stavrinou, D.D.C. Bradley "On the use of optical probes to monitor the thermal transitions in spin-coated poly(9,9-dioctylfluorene) films", *J. Phys.: Condens. Matt.* 17, 6307 (2005)
- M. Campoy Quiles, M. Sims, P. Etchegoin, D.D.C. Bradley "Thickness-dependent thermal transition temperatures in thin conjugated polymer films", *Macromolecules* 39, 7673 (2006)
- M. Sims, S. M. Tuladhar, J. Nelson, R.C. Maher, M. Campoy Quiles, S.A. Choulis, M. Mair, D.D.C. Bradley, P. G. Etchegoin, C. Tregidgo, K. Suhling, D.R. Richards, P. Massiot, C. B. Nielsen, J.H.G. Steinke "Correlation between microstructure and charge transport in poly(2,5-dimethoxy-1,4-phenylenevinylene)", *Phys. Rev. B* 76, art. no. 195206 (2007)
- T.A.M. Ferenczi, M. Sims, D.D.C. Bradley "On the nature of the fluorenone-based emission in oxidised poly(dialkylfluorene)s", *J. Phys.: Condens. Matt.* 20, 045220 (2008) ("IOP Select")
- M. Sims, S.W. Venter, I. D. Parker "A Novel Technique to Study OLED Function", *SID technical digest* 39, 223-227 (2008)
- S. M. Tuladhar, M. Sims, J. Kirkpatrick, R.C. Maher, A.J. Chatten, D.D.C. Bradley, J. Nelson, P. Massiot, C.B. Nielsen, J.H.G. Steinke "Influence of alkyl chain length on charge transport in symmetrically substituted poly(2,5-dialkoxy-p-phenylenevinylene) polymers", *Phys. Rev. B* 79, art. no. 035201 (2009)
- S.M. Tuladhar, M. Sims, S.A. Choulis, C.B. Nielsen, W.N. George, J.H.G. Steinke, D.D.C. Bradley, J. Nelson "Influence of side chain symmetry on the performance of poly(2,5-dialkoxy-p-phenylenevinylene: fullerene blend solar cells" *Organic Electronics* 10, 562 (2009)
- K-L. Chan, M. Sims, S. I. Pascu, M. Ariu, A.B. Holmes, D.D.C. Bradley "Understanding the nature of the states responsible for the green emission in oxidised poly(9,9-dialkylfluorene)s: Photophysics and structural studies of linear dialkylfluorene / fluorenone model compounds", *Adv. Funct. Mat.* 19, 2147

(2009) (Front cover article)

M. Sims, I. D. Parker INVITED PAPER: "Optically-detected charge density dynamics in organic light-emitting diodes (OLEDs)" *Proc. SPIE* 7415, 12 **(2009)**

S. Prakash, M. Sims, I. Meinel, I. D. Parker, D. Y. Kondakov, W. Gao INVITED PAPER: "Solution-processed OLEDs: Unique challenges and advantages", *SID technical digest* 44, 678-681 **(2013)**

Y. Zhang, M. Sims, S. Li, H. Aziz "Triplet-induced degradation: An important consideration in the design of solution-processed hole injection materials for organic light-emitting devices", *Organic Electronics* 48, 217 **(2017)**

M.Sims, K.L. Chan, A.A. Mikhailovsky, D.D.C. Bradley "Effect of varying ground state interaction on the intermolecular emission in fluorenone-centred oligofluorenes: Evidence of a well-defined excited state configuration underlying the green emission band", *in preparation*

I. T. Papadas, S. M. Pozov, I. Hamilton, M. Sims, I. Vamvasakis, G. S. Armatas, D. D. C. Bradley, S. A. Choulis "Low Temperature Solution Combustion Synthesized CuS nanoparticulated functional thin films: Structural and optoelectronic characterization studies", *submitted*

I. Hamilton, M. Sims, D. D. C. Bradley "Quinolate doped electron transport layers leading to reduction in spontaneous orientation polarisation and enhanced deep blue OLED lifetime", *in preparation*

PATENTS

M. Sims et al., "Nanoparticle-conducting polymer composite for use in organic electronics", WO2017115467A1

M. Sims et al., "Spirobifluorene derivatives having Nitrogen-containing heteroaryl rings and their use in organic electronics", WO2017116625A1

R. Swisher et al., "Non-aqueous ink compositions containing transition metal complexes, and uses thereof in organic electronics", WO2017126677A1

O. Gaudin et al., "Spirobifluorene derivatives and their use in electron injection layers of organic electronic devices", WO2017151535A1

O. Gaudin et al., "Spirobifluorene derivatives and their use in electron transport layers of organic electronic devices", WO2017151537A1

M. Sims et al., "Low energy usage lighting device", *in preparation*