

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

Mail Stop "PATENT BOARD"

Patent Trial and Appeal Board

U.S. Patent and Trademark Office

P.O. Box 1450

Alexandria, VA 22313-145

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 electroabsorption 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. For purposes of this declaration, I apply Samsung's definition of a person of ordinary skill in the art, *i.e.*, one who, at the time of the invention (2008-2009), would have had a Bachelor's degree in chemistry, physics, or a comparable field of study, and at least three years of research or industrial experience with OLEDs.

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 '164 inventions.

IV. The '164 Patent and The Technology Background

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.

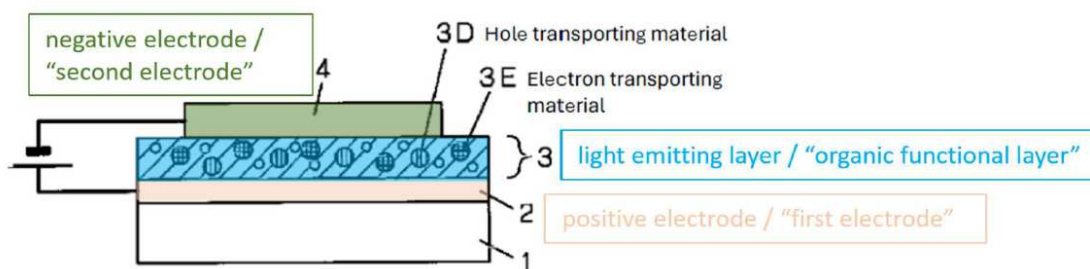
30. Hence, by specifying that the second (hole transport) matrix material has a HOMO that is the highest in energy level among the HOMOs of the three matrix materials and that the third (electron transport) matrix material has a LUMO that is the lowest in energy level among the LUMOs of the three matrix 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.

32. In the context of the ‘164 patent, because the second and third matrix materials are responsible respectively for hole and electron transport, a person of ordinary skill in the art would understand that they are contemplated to have sufficiently close molecular distance to have good charge carrier mobility. As such, a person of ordinary skill in the art would understand that they would exist in sufficient quantities in the organic functional layer (such as in the emission layer) so the charge carriers can be sufficiently close to one another to facilitate charge transport.

33. That is why both the second and third materials are claimed as “matrix materials,” as opposed to simply “materials” or “dopants.” Put another way, in the context of the ‘164 patent, the matrix materials each exist in more than a dopant-level such that each forms a more or less continuous phase in the organic functional layer in which it is deposited. *See* EX1001, 6:13-15 6:48-49 (describing the emission layer as being “doped” with an emitter material that can have up to 10 wt% in concentration).

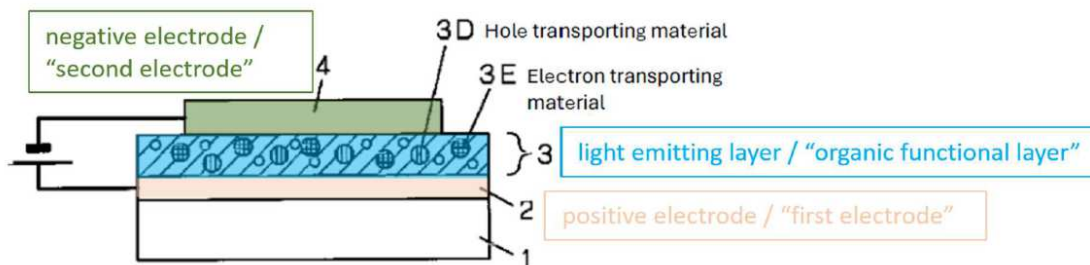
34. In other words, matrix materials—or materials for forming one or more matrices—should not exist as “islands in a sea,” such as 3D and 3E in the figure below. The term connotes a more or less continuous phase in which other materials can be embedded.



35. In some of the embodiments, the first matrix material serves to modulate the concentrations of the second and third matrix materials, and hence 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. 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.

36. In a system depicted below where the hole transporting material 3D and electron transporting material 3E are depicted as discrete and disconnected particles, a person of ordinary skill in the art 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).



37. 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. Thus, materials 3D and 3E would be regarded as having the same structural nature as the emitter materials—they are all dopants, not matrix materials.

V. TPD Loading in Choulis

38. I have reviewed the Choulis application (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”).

39. 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. Given Yang's disclosure, a POSITA would not have increased TPD concentrations to a level that would turn it from a dopant into a matrix material. *See* EX1017, 2478 ("We ... 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.").

40. They would have even less reason to do so in Choulis because Choulis states that it incorporates the hole transport moiety TPD and the electron transport moiety PBD in PVK in the emission layer to "move[] the holes and electrons throughout the material, as well as inject them to the light emitting material." EX1004, [0032]. A person of ordinary skill in the art therefore would not modify Choulis's emission layer composition to disturb its balance of carrier injection and transport, which according to Yang would occur at a TPD concentration of above 13 wt%. Otherwise, the objective of Choulis would be undermined.

VI. Use of PMMA in Place of PVK or Rubrene instead of Ir(mppy)₃ in Choulis

41. I understand that Samsung suggests replacing Choulis's PVK host with PMMA for some claims. A person of ordinary skill in the art would not do so, 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.

42. Additionally, Samsung has not given a reason to swap PMMA for PVK. For instance, Samsung states that “[a] POSITA would have understood that

the host material, which serves as a matrix in which guest materials 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.” Petition at 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 replace it 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 upset the hole and electron balance, would affect hole-charge recombination and would degrade the performance of the resulting OLED system. A person of ordinary skill in the art 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.

43. Samsung also suggests replacing Ir(mppy)₃ with rubrene, which has a LUMO lying about 0.75eV below the LUMO of PBD. But Choulis’s design aims to match the LUMO level of the interfacial layer (also PBD) to be as close to the LUMO level of the emitter material as possible so direct electron injection can occur. EX1004, [0006]-[0007], [0015], [0029]. The 0.75eV difference in LUMO energy levels would make rubrene an electron trap and render PBD an ineffective electron transporter because no electrons are created in PBD anymore. That would

affect the device's recombination zone, making it shift towards the electron transport layer and could significantly reduce the OLED's performance. If rubrene is desired, a different ETL with lower lying LUMO that is much closer in energy level to rubrene would be needed. But given the use of PBD as the electron transporting material, a person of ordinary skill in the art would not have used rubrene as emitter material.

VII. Charge Carrier Transport

44. I have also been asked to comment on whether the fact that a material has a wide band gap necessarily means that it has low charge carrier mobility. That is not correct. For example, the Holmes paper discussed UGH1 and UGH2, both of which were described as "effective hole blocking materials, although both molecules transport electrons" EX1016, 3820. There are indeed many factors that influence charge carrier mobilities in organic semiconductors, but charge carrier mobility and band gap are two distinct concepts.

45. And when a wide band gap material does not participate in charge transport, "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. For instance, PMMA (or polystyrene) has a low lying HOMO and a high lying LUMO, making it hard to inject holes or electrons into PMMA (or polystyrene) in order to create holes or electrons, which can lead to a negligible number of holes/electrons

created. Samsung has not provided any analysis to show whether the lack of hole/electron transport in PMMA or polystyrene was caused by effectively no holes or electrons created, the low charge carrier mobility, and/or both.

VIII. PVK Deposition

46. Samsung has suggested depositing PVK using evaporation. Generally, polymers are deposited using a solution-based process because evaporating a polymer would lead to degradation of the polymer. For example, when PVK was processed using a vapor process, PVK was degraded, forming lower molecular weight polymers, oligomer and even monomers. *See* EX1023, 132-33 (authors observed that “not only the chain length of the evaporated polymer thin film is *far smaller*, ... but the emission spectrum is sensibly different to that of the PVK reference power” and “after evaporation PVK films are formed of vinylcarbazole oligomers with an emission spectrum corresponding to a mixture of PVK and vinylcarbazole”). Generally, a person of ordinary skill in the art would not use a deposition method that would lead to degradation of the material to be deposited. This is because degradation would disrupt the charge balance in the emitting layer by altering the resulting materials’ charge carrier mobilities and their HOMO levels (which in turn affect the ability to create charge carriers). That is why PVK was normally processed using a solution based process, and I have not

seen any evidence that Choulis or Yang suggests processing their emission layers using an evaporation based process in place of spin coating.

IX. Creating Emitter Concentration Gradient Using a Solution-Based Process

47. I have also been asked to comment on whether a solution-based process can create a concentration gradient of emitter materials. Based on my experience of solution-based process, that would be beyond the skill level of even a person with above average skills and generally it would be extremely difficult to do. Stepping back, I would note that it is already challenging to produce a film with emitter molecules that are evenly distributed throughout the host matrix because of a tendency for a binary, tertiary or higher blend to phase separate. This is especially true when spin-coating is chosen as the deposition process, since the solvent evaporation rate can be so fast that even small differences in solubility between the component materials can lead to one of the materials effectively “crashing out” of the solution before another one. So, creating a film with a controlled concentration *gradient* of emitter molecules, i.e. a constantly increasing/decreasing concentration on going from one side of the film to the other, should be viewed, at the very least, to be extremely challenging, and not reproducibly. Based on my knowledge of the practice in the industry and the skill levels of the practitioners, a person of ordinary skill in the art would not have had a

reasonable expectation of success in obtaining a film having a concentration gradient of the emitter materials using a solution-based process.

48. The production of films with a concentration gradient of emitter molecules by co-evaporation, on the other hand, is relatively straightforward, and can be achieved by gradually changing the relative evaporation rates of the host and emitter molecules during the deposition process.

49. In this respect, I would like to emphasize the difference between solution-based and vacuum-deposition-based film formation. As noted above, at DuPont, I examined the reasons behind the reduced performance for solution-processed printed OLEDs as compared to their evaporated counterparts. My colleague and I discovered that the process of spin-coating or printing of an emissive layer and its subsequent annealing to remove residual solvent, 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. Solution-based processes also led to significantly broadened recombination zones. Additionally, choice of solvents used to dissolve the components for the organic layer can also affect subsequent phase homogeneity versus controlled microscopic phase separation. For example, as described above, if one component has better solubility or higher concentration than the other component, then as the solvent is removed, the component with

poorer solubility and/or higher concentrations will cross its solubility limit first and consequently separate from the solution-phase before the other component does.

For example, Sugiura's structure, where hole transport and electron transport materials are shown as separate particles from each other and the emitter, could be achieved with a carefully tailored solution-based process, but would not be practical in an evaporated process where the molecules are co-deposited in a co-mingled fashion throughout the organic layer.

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 October 28, 2024, in Santa Barbara, California.

A handwritten signature in black ink, appearing to read 'Marc Sims', written over a horizontal line.

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*