

UNITED STATES PATENT AND TRADEMARK OFFICE

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BEFORE THE PATENT TRIAL AND APPEAL BOARD

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BOE TECHNOLOGY GROUP CO., LTD.,  
Petitioner,

v.

138 EAST LCD ADVANCEMENTS LIMITED,  
Patent Owner.

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Case No. IPR2024-00977  
U.S. Patent No. 9,557,606

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**DECLARATION OF E. FRED SCHUBERT, PH.D.**

I, E. Fred Schubert, of Troy, New York, declare that:

## **I. ASSIGNMENT**

1. I have been retained by Robins Kaplan LLP on behalf of 138 East LCD Advancements Ltd. (“138 East”) as an expert with regard to this matter. I understand that Petitioner BOE Technology Group Co., Ltd. (“BOE” or “Petitioner”) is requesting that the Patent Trial and Appeal Board (“Board”) institute *inter partes* review (IPR) of U.S. Pat. No. 9,557,606 (“the ’606 patent”). Ex. 1001.

2. In my capacity as an expert, I have been asked to provide my independent analysis and opinions regarding the ’606 patent, the prosecution history of the ’606 patent, the alleged prior art relied upon by Petitioner, the meaning of various claim terms from the ’606 patent from the perspective of a person of ordinary skill in the art (“POSITA”), and the opinions offered by Petitioner’s expert, Dr. Alex Kattamis, in his declaration. Ex. 1004. My opinions and conclusions are fully discussed in this declaration.

3. I am an independent consultant, and I am not, and have never been, an employee of 138 East or BOE. I received no compensation for this declaration beyond my normal hourly compensation (\$600) based on my time spent analyzing the ’606 patent, the prosecution history of the ’606 patent, the prior art publications relied upon by Petitioner, the Kattamis Declaration, and other related materials. I

will not receive any added compensation based on the outcome of any IPR or other proceedings involving the '606 patent.

4. This declaration and my opinions are in support of Patent Owner's Preliminary Response, and I understand that the content of this declaration may be expressed and reproduced in the POPR.

## **II. BACKGROUND AND QUALIFICATIONS**

5. I am currently an active, tenured, full professor in the Department for Electrical, Computer, and Systems Engineering at the Rensselaer Polytechnic Institute (RPI) located in Troy, New York.

6. I also held other positions at RPI. For example, from 2002 to 2012, I was a professor in the Department of Physics, Applied Physics, and Astronomy. In 2008-2009, I served as the founding director for RPI's Engineering Research Center for Smart Lighting, which was funded by the U.S. National Science Foundation (NSF).

7. Before I moved to RPI, I was a professor in the Department of Electrical and Computer Engineering at Boston University, from 1995 to 2002. I also served as the director of Boston University's Semiconductor Devices Research Laboratory.

8. Prior to my university career, I was a post-doctoral member of the technical staff, member of the technical staff, principal investigator, and member

of management at AT&T Bell Laboratories in Holmdel and Murray Hill, New Jersey, from 1985 to 1995.

9. I earned my Ph.D. in 1986, Master of Science in 1981, and bachelor's degree in 1978, all in Electrical Engineering, at the University of Stuttgart, Germany.

10. My Curriculum Vitae ("CV") is attached as **Appendix A**. As shown by my CV, I have substantial experience in the design and implementation of flat panel display devices, including the design, fabrication, processing, and packaging of the components that are commonly used in liquid crystal displays (LCDs) and light emitting diode (LED) displays.

11. I have published over 300 technical articles, mostly at competitive technical conferences and rigorously refereed technical journals. These articles relate to Liquid Crystal Displays (LCDs), LEDs, semiconductor electronics (e.g., field-effect transistors and bipolar junction transistors), semiconductor lasers, and photo-detectors, that is, the technologies which form the foundations of flat panel displays.

12. As an example of my research activities in the field of LCDs, I refer to a U.S. patent issued in 2012: Jaehee Cho, E. Fred Schubert, and Xing Yan "Liquid crystal display with refractive index matched electrodes" US Patent No. 8,164,727; filed on April 28, 2010; issued on April 24, 2012. During my tenure in

industry (AT&T Bell Laboratories), I was part of a working group on LCDs. I have also performed technical consulting services in the field of LCDs and associated TFTs (thin film transistors). One project concerned the enhancement of the carrier mobility in amorphous silicon TFTs. At my university (RPI), I regularly teach courses on microelectronic devices and displays, including TFTs and LCDs. Light emitting diodes are routinely used as a back lighting source for LCDs and I have worked on and developed LEDs for backlighting units.

13. I am also the author or editor of several books. For example, I authored the textbook “Light-Emitting Diodes,” (1st, 2nd, 3rd, and 4th editions) initially published by Cambridge University Press, Cambridge, UK, with the later editions published on Google Books. In the LED book, I provide a comprehensive review of the state-of-art technologies for designing, fabricating, processing, and manufacturing LEDs, all of which are relevant to LCDs, specifically the associated back-lighting units.

14. In addition to my research, I have been teaching for more than 25 years. I have taught numerous undergraduate and advanced graduate courses in integrated optoelectronics, microelectronics technology, solid-state devices, semiconductor devices, display devices, and light-emitting diodes, all pertinent to the subject matter in the present case. I have also advised close to 50 Ph.D. and M.S. students while at the RPI and Boston University, in areas such as LEDs,

semiconductor electronics, semiconductor lasers, and solar cells.

15. I am the co-inventor of more than 35 issued U.S. patents and associated foreign patents. I was identified as one of the top 1% inventors in the field of optoelectronics, in a 2011 study conducted by Professor Erica Fuchs of Carnegie Mellon University under the support of NSF. Examples of my issued U.S. patents include:

- U.S. Patent No. 7,560,746; issued on July 14, 2009, titled “Light emitting diodes and display apparatuses using the same.”
- U.S. Patent No. 8,164,727, issued on April 24, 2012, titled “Liquid crystal display with refractive index matched electrodes.”

16. I have been actively involved in multiple technical societies, including the American Physical Society (APS), Institute of Electrical and Electronics Engineers (IEEE), Optical Society of America (OSA), Society for Optical Engineering (SPIE). I have served in the organizing committee of multiple technical conferences, including, for example:

- Program committee member and chair of “Display and Solid-State Lighting Devices” conference for OSA/IEEE Conference on Lasers and Electro-Optics (CLEO), 2003 – 2005.
- Member of the International Advisory Committee of First International Conference on Display LEDs (ICDL), Seoul, Korea, January 31 –

February 2, 2007.

- Sub-Committee Chair of Track 6: Displays, Solid-State Lighting, Photovoltaics, and Energy-Efficient Photonics of Asia Communications and Photonics Conference (ACP), Shanghai, China, November 11 – 14, 2014. ACP is the largest and the most influential conference in Asia and Pacific Rim for communications and photonics technologies.

17. My research has been recognized by multiple organizations, universities, and institutions. The following list includes examples of honors that I have received:

- Elected Fellow of the IEEE in 1999. According to the IEEE definition, “the grade of Fellow is one of unusual professional distinction conferred by the Board of Directors only upon a person of extraordinary qualifications and experience.”
- Elected Fellow of the SPIE in 1999. According to the Society’s bylaws, a Fellow “shall be distinguished through his achievements and shall have made outstanding contributions in the field of optics, or optoelectronics, or in a related scientific, technical, or engineering field.”
- Elected Fellow of the OSA in 2001. OSA Fellows are elected by the OSA Board of Directors.
- Elected Fellow of the APS in 2001.

- Honored with RPI Medal as Senior Constellation Chair in 2002.
- Recipient of “Scientific American 50 Award” of 2007, as published in the January 2008 issue of Scientific American.
- Received “Rensselaer Polytechnic Institute Trustee Faculty Achievement Award” in 2002, 2008, and 2012.

18. My qualifications and accomplishments are further detailed in my CV, submitted as Appendix A.

### **III. LEVEL OF SKILL IN THE ART AND BASIS FOR OPINIONS**

19. Dr. Kattamis contends that a POSITA “would have had at least a bachelor’s degree in electrical engineering, computer science, physics, or a similar field and at least two years of experience designing semiconductor display devices, including LCD displays. Additional relevant work experience can compensate for less education, and *vice versa*. For example, a master’s degree in electrical engineering, computer science, physics, or a similar field can substitute for two years of experience designing semiconductor display devices, including LCD displays.” Ex. 1004 ¶82. I understand that Petitioner has adopted that definition of a POSITA.

20. For purposes of this Declaration, I do not dispute the level of skill for a POSITA as set forth by Dr. Kattamis and adopted by Petitioner. I note, however, that a bachelor’s degree recipient (in electrical engineering, computer science,

physics, or a similar field) with two years of experience in semiconductor display devices and a master's degree recipient (in electrical engineering, computer science, physics, or a similar field) with no experience in the field of semiconductor display devices, who, according to Petitioner, qualifies as a POSITA, has a relatively low level of skill in the relevant field.

21. Based on my experience and record of accomplishments, I am qualified to render opinions regarding the technology claimed and described in the '606 patent. Based on my expertise and qualifications, I am qualified to provide an opinion as to what a POSITA would have understood, known, or concluded as of approximately 2004.

22. In reaching my opinions and conclusions, I have relied upon my education, my work experience in the relevant field, and my training, and considered and relied upon my review and analysis of the Petition and its exhibits.

#### **IV. RELEVANT LEGAL PRINCIPLES**

23. For the purposes of this declaration, I have been informed about certain aspects of the law that are relevant to my analysis and opinions. I have applied these legal principles in rendering my opinions below.

##### **A. Claim Construction**

24. I understand that the ordinary and customary meaning of a claim term is the meaning that the term would have to a POSITA at the time of the invention.

25. In the absence of an express intent on the part of the inventor to give a special meaning to the claim terms, the words are presumed to take on the ordinary and customary meanings attributed to them by a POSITA.

26. I understand that it is the use of the words in the context of the written description, and as customarily used by those skilled in the relevant art, that accurately reflects both the ordinary and the customary meaning of the terms in the claims.

27. I understand that the basis for a term's ordinary and customary meaning may be derived from a variety of sources, including the words of the claims themselves, the remainder of the specification, the prosecution history, and extrinsic evidence concerning relevant scientific principles, the meaning of technical terms, and the state of the art at the time of the invention.

28. I have been instructed that dictionary definitions or definitions from technical references can be used to inform or confirm the ordinary and customary meaning of words found in a claim, but that in construing claim terms, the general meanings gleaned from reference sources, such as dictionaries, must always be compared against the use of the terms in the context of the claim itself.

29. I understand that a patent applicant is entitled to be his or her own lexicographer (in other words, provide his or her own meaning to a word or phrase) and may rebut the presumption that claim terms are to be given their plain and

ordinary meaning. To do so, the applicant must clearly set forth a definition of the term that is different from its ordinary and customary meaning. Where the applicant provides an explicit definition for a term, that definition will control interpretation of the term as it is used in the claim in which it appears. I understand that the specification can also be relied on for more than just explicit lexicography to determine the meaning of a claim term. For example, I understand that the meaning of a particular claim term may also be determined by implication, that is, according to the usage of the term in the context of the specification.

## **B. Anticipation**

30. I understand that under U.S. Patent Law, 35 U.S.C. § 102, a claim is invalid as anticipated if all elements of the claims are disclosed, expressly or by necessary implication, in a single publication that qualifies as “prior art” to the patent in question and in a way that enables a person having ordinary skill in the art to make and use the invention.

31. I understand that a prior art reference describes the claimed invention if it either expressly or inherently describes each and every feature set forth in the claim; that is, in determining whether a single prior art reference anticipates a patent claim, one should take into consideration not only what is expressly disclosed in that reference, but also what is inherently present as a natural result of the practice of the system or method disclosed in that reference.

32. I understand that to establish inherency, the evidence must make clear that the missing descriptive matter is necessarily present in the item of prior art and that it would be so recognized by a person having ordinary skill in the art.

**C. Obviousness**

33. I understand that under U.S. patent law, 35 U.S.C. § 103, a claim is invalid as obvious if the differences sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.

34. I am informed that an obviousness analysis requires an assessment of the scope and content of the prior art, the differences between the art and the claims at issue, and the level of ordinary skill in the art. I am told that it is against this backdrop that obviousness is assessed.

35. I am informed that a POSITA is a hypothetical person who is presumed to be aware of all the pertinent prior art. I am also informed that an obviousness analysis may take account of the inferences and creative steps that a POSITA would employ.

**V. THE '606 PATENT**

**A. Overview of the '606 Patent**

36. The '606 patent, titled "Liquid crystal display device having

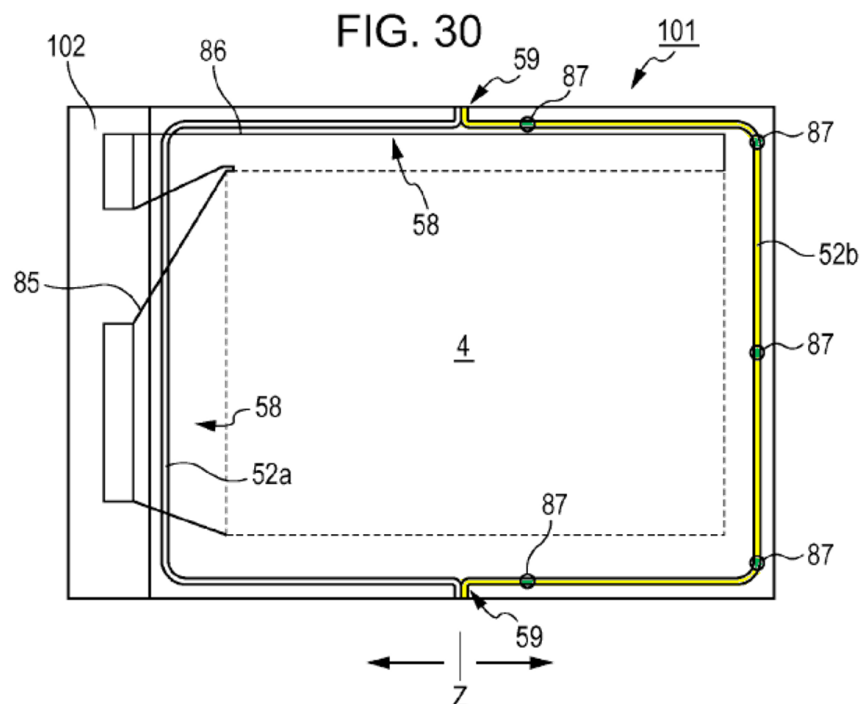
rectangular close-shape seal members,” describes improved liquid crystal display layouts and seal arrangements. Liquid crystal displays include “a first substrate and a second substrate facing each other with a liquid crystal layer interposed therebetween, and a sealing member formed in a peripheral portion of at least one of the substrates.” Ex. 1001 at 3:64-67. The seal surrounds and provides containment for the liquid crystal material.

37. The '606 patent describes various methods for forming the seal and adding the liquid crystal. The '606 patent describes the “dropping assembly method” “in which liquid crystal is dropped onto one substrate in which a frame-shaped sealant is provided with no liquid crystal injection hole, and the other substrate is then bonded to the one substrate.” *Id.* at 1:44-50. The dropping assembly method provides advantages over, for example, the injection method, including a continuous seal formed with no injection hole. *Id.* at 1:23-2:10. Further, “unlike the related art liquid crystal injection method, the amount of liquid crystal used can be reduced, and the injection/sealing process can be omitted, such that tact time can be reduced.” *Id.* at 2:7-10. The '606 patent also describes optimized seal dispensing techniques—e.g., in “one stroke of a brush”—when used in combination with the dropping assembly method. *See, e.g., id.* at 10:8-25, 11:7-13.

38. Relevant to the claimed inventions, the '606 patent describes a

closed-ring seal formed continuously around the display region (no injection hole), the seal including at least one part that includes conductive particles. *See, e.g., id.* at claim 7. The '606 patent describes conductive particles, for example, metal-plated resin spheres. "The conductive particles have elasticity," and when the seal bonds the substrates, electrodes on the substrates "press the conductive particles" to create electrical connectivity. *Id.* at 16:19-30. The '606 patent also describes providing at least one part of the seal that does *not* include conductive particles, or at least one part that does not connect to conductive portions, to protect wiring lines crossing the seal. *Id.*

39. For example, in Figure 30, "[t]he conductive sealing member 52b [yellow] is formed on a right side . . . , and the insulating sealing member 52a is formed on a left side . . . . In such a configuration, when each of the sealing members 52a and 52b is drawn by a separate dispenser, tack time of the apparatus can be arranged, and the liquid crystal device 101 can be efficiently produced. Further, the TFT substrate 102 and the counter substrate are electrically connected by the conductive sealing member 52b formed on the dot conductive portions 87 [green]."



*Id.*, Fig. 30.<sup>1</sup>

40. Thus, the '606 patent describes and claims an improved LCD layout that combines the benefits of a closed-ring, continuous seal, a seal that provides electrical conductivity between the two substrates (electrode substrates) along a particular side of the display, and an arrangement that protects wiring lines crossing the seal from those conductive points. Claim 7 recites this improved layout:

7. A display device, comprising:

a first substrate including a pixel region and a seal region

which is defined around the pixel region on a first

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<sup>1</sup> All annotations added to figures throughout, unless otherwise noted.

surface of the first substrate, the pixel region including a plurality of pixels and a plurality of active elements, and the seal region forming a rectangular ring shape, wherein the active elements are thin film transistors disposed on the first substrate; and

a second substrate including a common electrode on a second surface; and

a seal member bonding the first substrate and the second substrate so that the first surface faces the second surface and the common electrode is disposed opposite to the plurality of pixels,

wherein the first substrate includes a protruding region which protrudes over the second substrate in a plan-view of the first substrate,

the seal region includes a first side, a second side, a third side and a fourth side, the first side is positioned between the pixel region and the protruding region, and opposed to the third side, and the second side is opposed to the fourth side,

the seal member is disposed between the first substrate and the second substrate, and positioned on the first side, the second side, the third side and the fourth side continuously, forms a closed-ring shape in which the pixel region is positioned without protruding from the second substrate in the plan-view of the first substrate, and is formed continuously around the entire pixel region without the use of a plug,

a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles,

a plurality of dot conductive points are disposed on the third side of the first substrate, all of the plurality of the dot conductive points are electrically connected to the common electrode, and

each of the plurality of the dot conductive points are spaced apart from each other,

wherein the first substrate includes a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.

*Id.* at claim 7.

### **B. Related District Court Litigation**

41. I am aware of a related District Court case involving the same parties, and where the '606 patent has been asserted and validity of the '606 patent claims has been challenged.

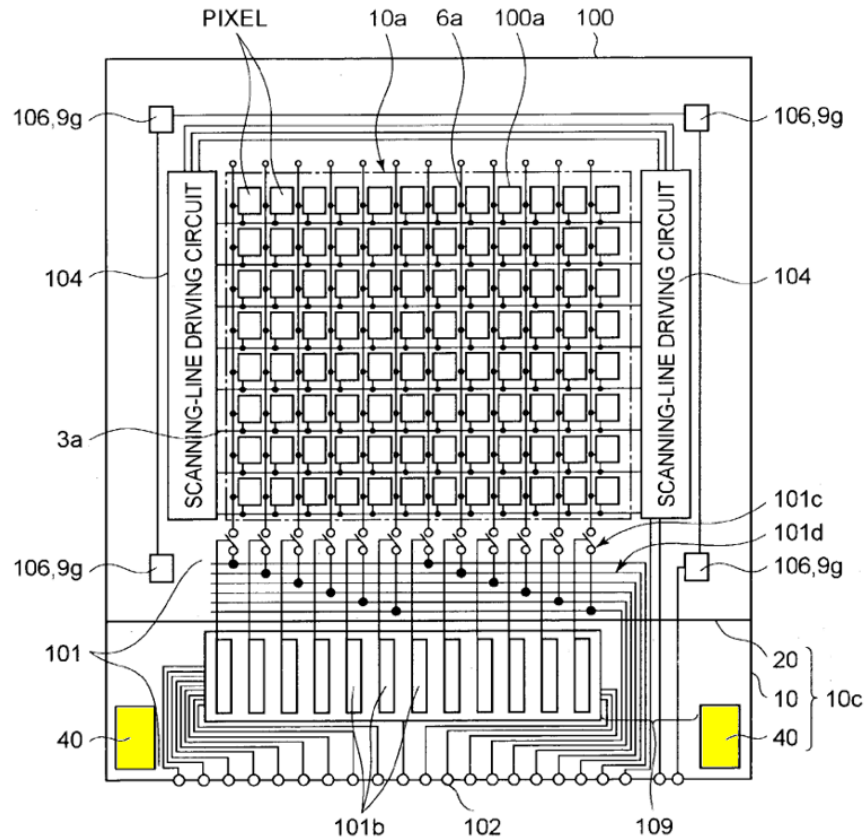
## **VI. ANALYSIS OF FUJIKAWA (GROUNDS 1 AND 2)**

### **A. Overview of Fujikawa**

42. Fujikawa relates to LCD device layouts and, in particular, adjusting peripheral circuit layouts to create additional space and, thus, to narrow the non-display region (or the “frame region”). Ex. 1005 ¶¶[0010]-[0011] (“an object of the present invention is to provide an electrooptic device and an electronic device in which a region that does not directly contribute to the display can be narrowed by improving the layout of peripheral circuits”). The non-display region accommodates peripheral circuits (e.g., data line driving circuit, scanning line driving circuits), wiring lines, conductive electrodes, and identification marks. *Id.*

¶[0010]. For quality control purposes, “[t]he identification marks 40 are required to be visible or mechanically readable after the TFT array substrate 10 and the counter substrate 20 are bonded together. Therefore, the identification marks 40 are formed in an extended portion 10c of the TFT array substrate 10 that protrudes from the edge of the counter substrate 20 so that the terminals 102 are exposed.”

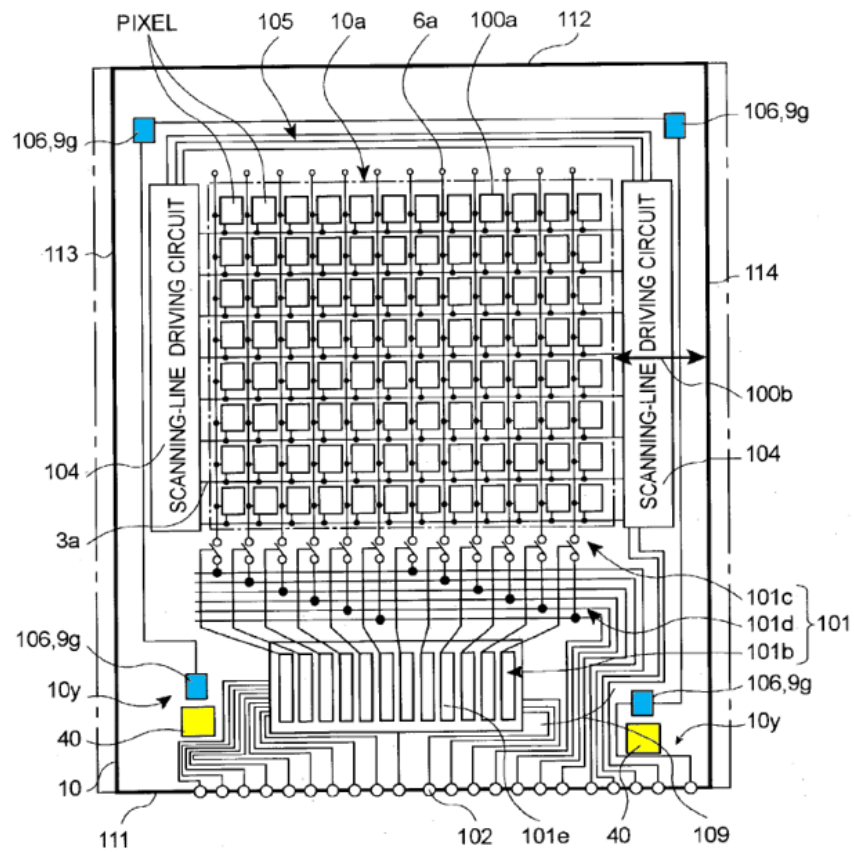
*Id.* ¶[0009]. Fujikawa’s Figure 19 illustrates “identification marks 40” (yellow) requiring space in the non-display region:

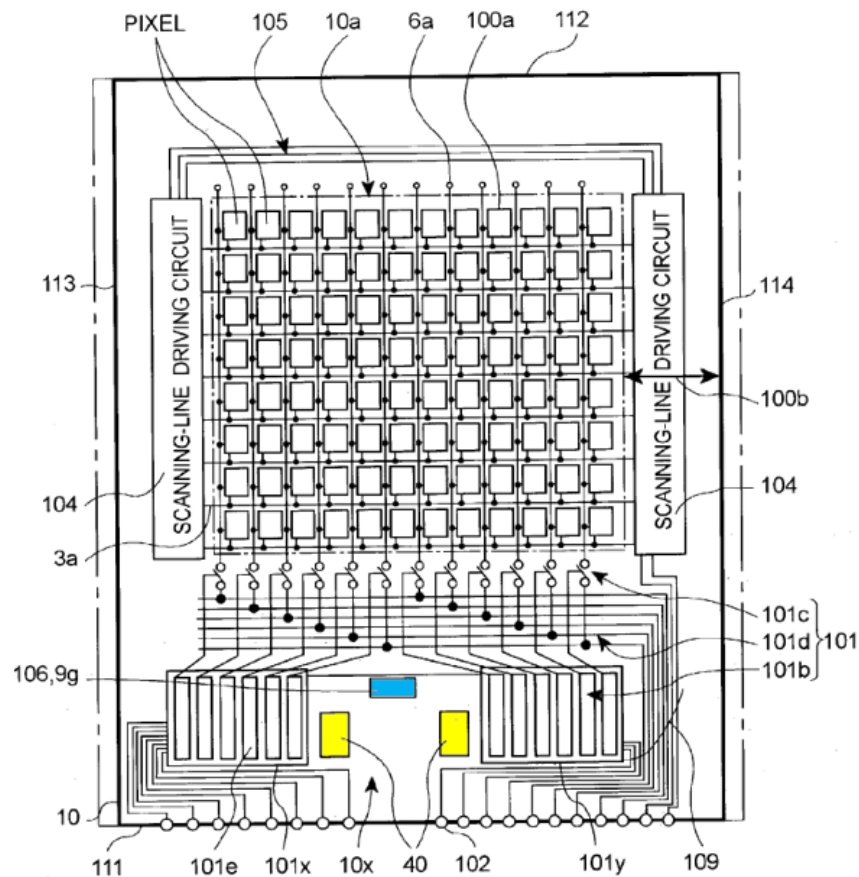


*Id.*, Fig. 19, ¶[0009]-[0011].

43. Fujikawa describes adjusting peripheral circuit layouts—in particular,

[illegible]





*Id.*, Figs. 14-15.

**B. The teachings of Fujikawa do not satisfy all elements of any of claims 7-13 or 15-20 of the '606 patent.**

44. In my opinion, Fujikawa does not disclose or render obvious all limitations of any challenged claim.

*1. Claim 7*

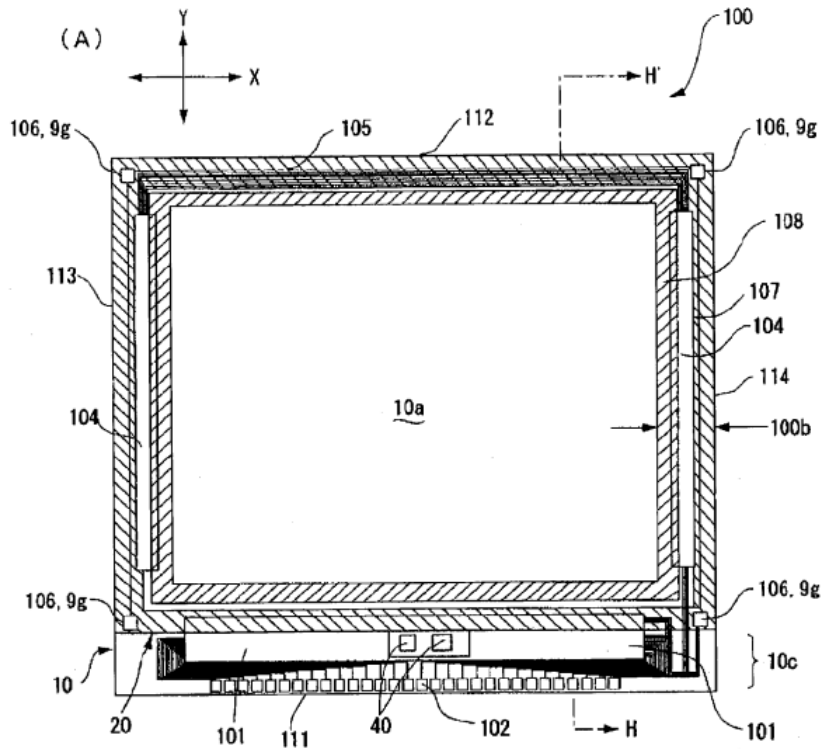
45. In my opinion, Fujikawa does not disclose or render obvious (1) a seal member “formed continuously around the entire pixel region without the use of a plug”; (2) “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a

plurality of conductive particles”; or (3) “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Claim limitations 7[h], [i], [l].

*a. a “seal member . . . formed continuously around the entire pixel region without the use of a plug” (claim 7[h])*

46. I disagree with Dr. Kattamis’s opinion that Fujikawa discloses a seal member “formed continuously around the entire pixel region without the use of a plug.” *See* Ex. 1004 ¶¶107-111.

47. Dr. Kattamis relies on Fujikawa’s Figure 1A, suggesting that a “POSITA would have understood that, looking at this plan view in *Fujikawa*,” the figure discloses “without the use of a plug” because “sealing material 107 fills the entire rectangular ring-shaped area shaded by the downward-slanting lines that represent the ‘seal region.’” *Id.* Dr. Kattamis argues that “[i]f a gap was contemplated and a plug required, the plan view would show as much.” *Id.* ¶110.



Ex. 1005, Fig. 1A.

48. In my opinion, Dr. Kattamis's assertion about Fujikawa Figure 1A is unsupported.

49. The '606 patent describes two methods for filling an LCD device with liquid crystal material. The first method is the liquid crystal injection method, during which the cell gap is filled with the liquid crystal material by dipping the LCD device, including an injection hole in the seal, into the liquid crystal material to fill the cell gap, using a pressure differential caused by a vacuum. This method uses an injection hole that is sealed when the filling process has been completed. Ex. 1001 at 1:23-45. The second method is the liquid crystal dropping method, or one-drop fill, during which the cell gap is filled with the liquid crystal material by

dropping the exact amount of liquid crystal material onto an LCD substrate that has its rectangular sealing member in place, thereby providing confinement to the dropped liquid crystal material. *Id.* at 46-61. The LC dropping method also employs a vacuum and, according to the Petition, was developed in the early 2000s. Ex. 1004 ¶48. The LC dropping method does not employ an LC injection hole.

50. Fujikawa does not describe how to form a seal or how to add liquid crystal. Fujikawa is silent on these points. *See generally* Ex. 1005. Fujikawa provides only that “sealing material 107 . . . is formed on a TFT array substrate 10 of a liquid crystal device 100 (electrooptic device) along the edge of a counter substrate 20” and that “liquid crystal 50 is held in the space.” *Id.* ¶¶[0046], [0049]. Dr. Kattamis does not explain why Figure 1A “would show as much” if a plug were contemplated; Fujikawa’s disclosure does not relate to forming a seal or adding liquid crystal.

51. Dr. Kattamis cites other references that include disclosures related to forming seals. Ex. 1004 ¶109. Those references do not inform my opinion about what Fujikawa discloses.

52. I am aware of at least one other reference—a Seiko Epson patent, with an application filed on July 12, 1991—that suggests that a POSITA cannot infer “without the use of a plug” from Fujikawa’s Figure 1A. For example, an earlier Seiko Epson patent include figures similar to Fujikawa’s Figure 1A:

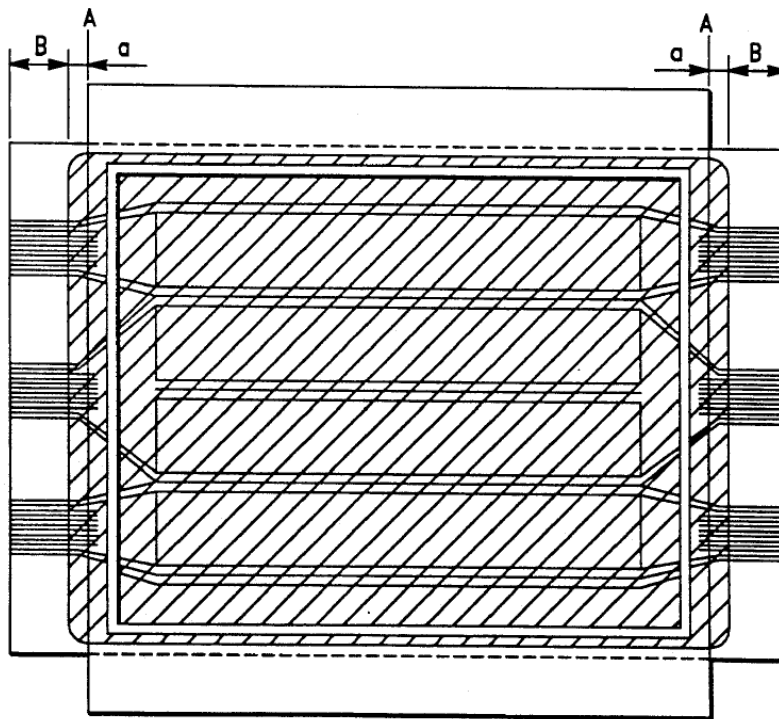


FIG.-7

Ex. 2002, Fig. 7. This patent (Ohara) does not describe forming a seal member without the use of a plug. In fact, the patent predates the one-drop fill method that would facilitate forming a seal member without the use of a plug. Dr. Kattamis acknowledges that researchers developed the one-drop fill method about ten years later. Ex. 1004 ¶48. Based on the Ohara patent's date and the state of the art at that time, in my opinion, a POSITA would understand that the figure does not disclose forming a seal member without the use of a plug. This example shows that when a reference is silent on the LC filling method, it cannot be assumed to use the LC dropping method. Given that Fujikawa's priority date is March 2002, given that the

LC dropping method, according to Petitioner, was developed in the early 2000s, and given that Fujikawa is silent on the LC filling method, in my opinion, it is highly likely that Fujikawa employed the LC injection method.

53. Thus, in my opinion, the Petition fails to show that Fujikawa discloses a seal member “formed continuously around the entire pixel region without the use of a plug.”

b. *“a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles” (claim 7[i])*

54. I disagree with Dr. Kattamis’s opinion that Fujikawa discloses or renders obvious “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles.” Ex. 1004 ¶¶112-115.

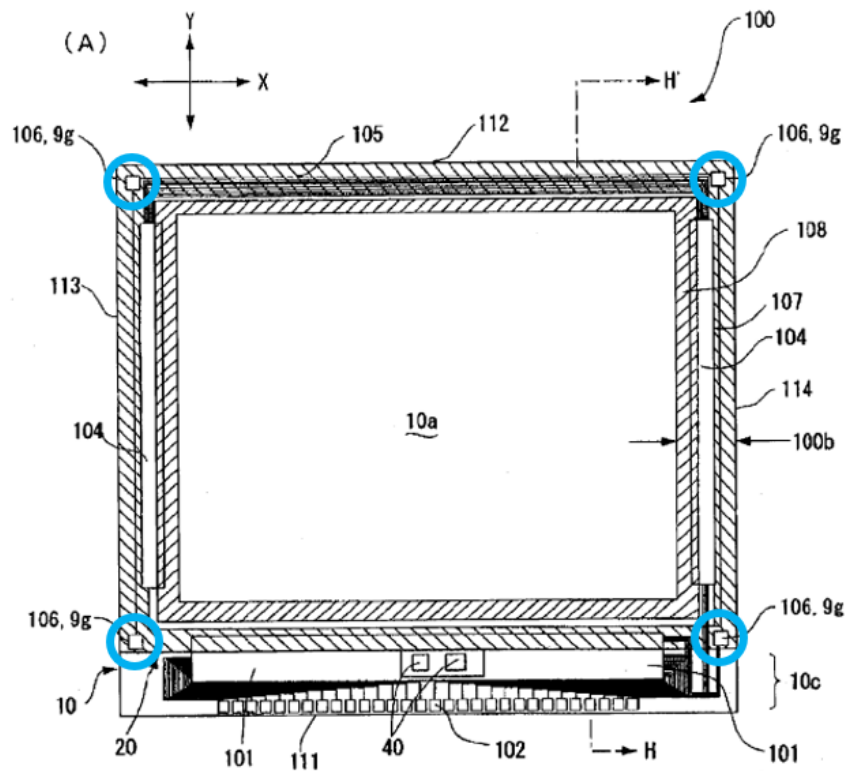
55. Dr. Kattamis asserts that “in sealing member 107 are ‘conductive materials 106 corresponding to the four corners of the counter substrate 20.’” *Id.* ¶114. In my opinion, Dr. Kattamis’s assertion is not supported and contrary to Fujikawa’s disclosure.

56. In my opinion, Fujikawa discloses sealing material 107 and, separate, conductive material 106—it does not disclose sealing material that includes conductive particles. Ex. 1005 ¶¶[0046]-[0047]. Fujikawa describes forming the

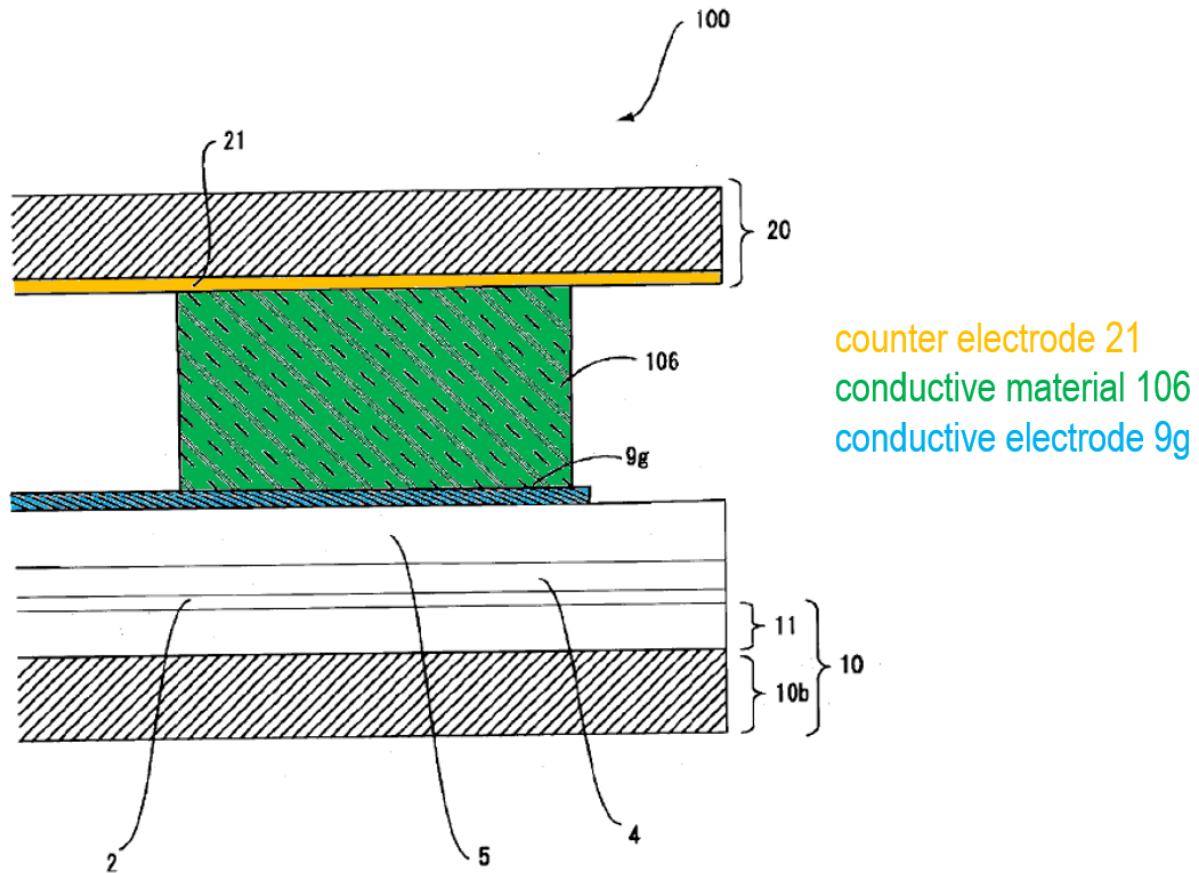
“sealing material” and, separately, forming the conductive material “in areas corresponding to four corners of the counter substrate.” *Id.* Fujikawa discloses that the sealing material may include “a photosetting or thermosetting resin” “mixed with a gap material, such as glass fibers or glass beads,” and that the conductive material may include an epoxy resin adhesive and conductive particles. *Id.*

¶[0049]. Thus, the sealing material 107 and the conductive material 106 are separate materials, and the sealing material 107 does not include conductive particles. Fujikawa does not describe, and no figure shows, that the sealing material includes conductive particles.

57. Fujikawa’s Figure 1A shows that the sealing material does not fill the entire rectangular ring-shaped area. Conductive material fills four gaps in the seal, over conductive electrodes 9g (no downward-slanting lines in those locations to indicate sealing material):



Ex. 1005, Fig. 1A. The cross-section (Figure 9) confirms that those locations do not include sealing material 107:



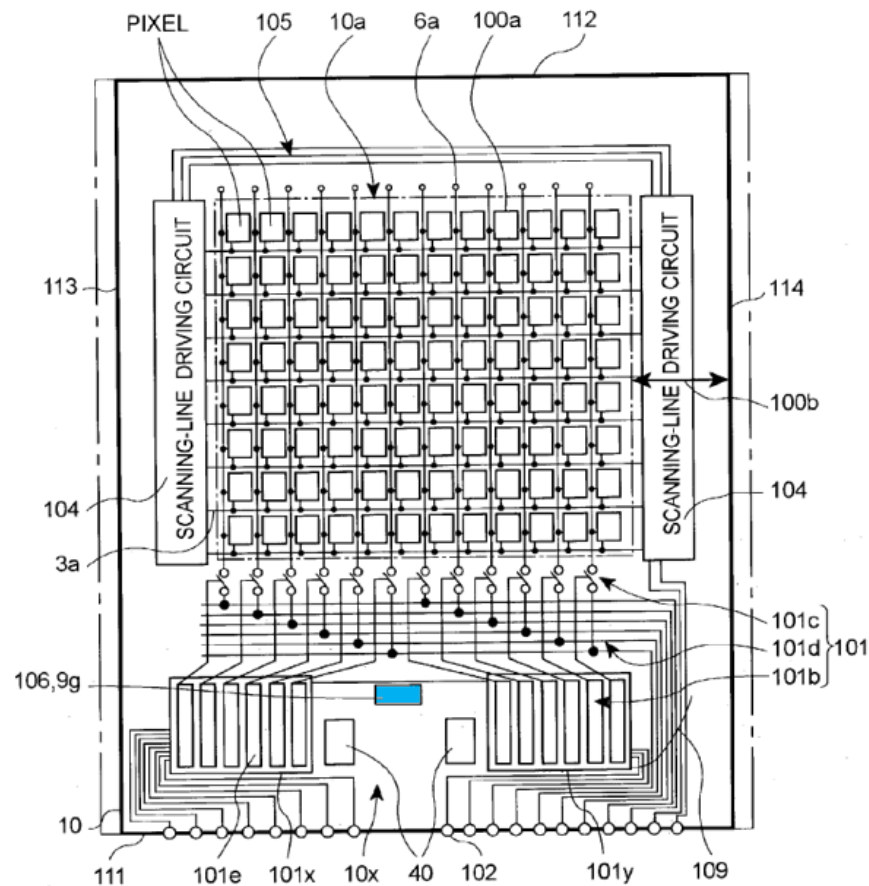
*Id.*, Fig. 9. Dr. Kattamis appears to acknowledge that rather than providing a seal member that includes conductive particles, other methods (by implication, Fujikawa) “introduc[e] a conductive material at individual gaps in the seals.”

Ex. 1004 ¶115. In my opinion, Fujikawa teaches introducing conductive material at individual gaps in the seal.

58. Further, in my opinion, Fujikawa does not disclose “a first part of the seal member *disposed on the third side* . . . includes a plurality of conductive particles.” As I mentioned, Fujikawa discloses forming conductive electrodes and conductive material “in areas corresponding to four corners of the counter

substrate.” Ex. 1005 ¶[0047]. Fujikawa does not disclose forming conductive electrodes and/or conductive material on a *side*.

59. Dr. Kattamis seems to suggest that Fujikawa teaches modifications to its arrangement that would satisfy the claim limitation, because Fujikawa suggests changing “[t]he number of the conductive electrodes 9g.” Ex. 1004 ¶114. But in my opinion, Dr. Kattamis does not show that Fujikawa discloses or renders obvious changing the number of conductive electrodes so that a part of a seal member on the third (upper) side of the device includes conductive particles. In this context, I also note that Fujikawa’s sealing material 107 does not contain conductive particles. Fujikawa teaches forming additional conductive electrodes on the *first* (lower) side, in “free regions” created in the driver circuit layout. *See, e.g.*, Ex. 1005 ¶¶[0013]-[0018], [0097], [0100], Figs. 14-15. And based on my review of Fujikawa, it teaches only one particular modification to its number of conductive electrodes: *reducing* from four to one. *Id.* ¶[0097], Fig. 15 (“In this example, an electric conduction between the substrates is established by the single conductive electrode 9g.”):



*Id.*, Fig. 15 (blue highlighting conductive electrode 9g). Dr. Kattamis offers no reason from Fujikawa to form additional conductive electrodes and conductive material on a particular side (the third side). Dr. Kattamis offers only a more general motivation: creating additional conductive points between the first and second substrates. Ex. 1004 ¶115.

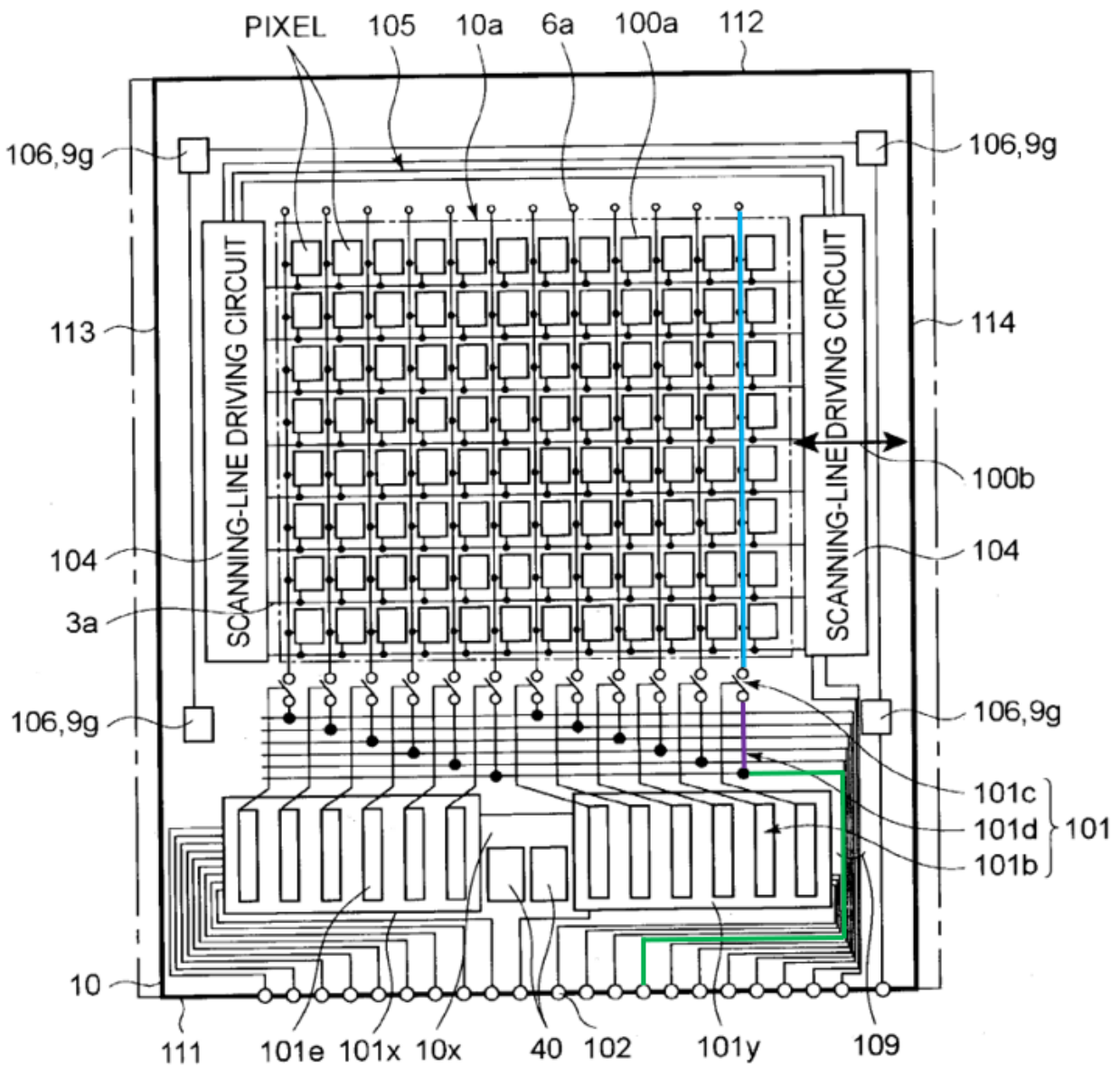
60. Thus, in my opinion, the Petition fails to show that Fujikawa discloses or renders obvious “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles.”

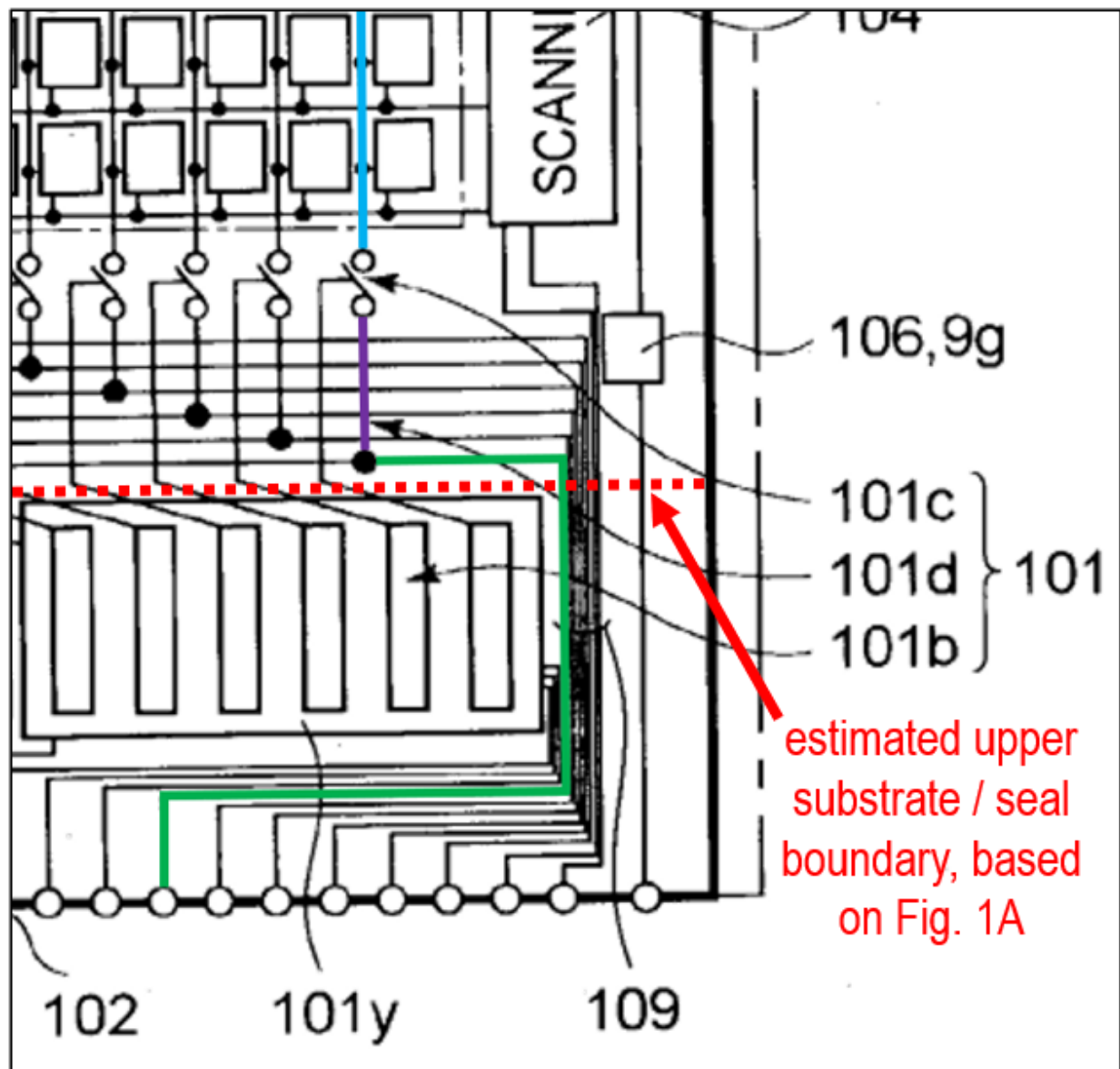
- c. *“a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points” (claim 7[l])*

61. I disagree with Dr. Kattamis’s opinion that Fujikawa discloses “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Ex. 1004 ¶¶121-122.

62. Dr. Kattamis appears to rely on three sets of wiring lines to disclose the claimed plurality of wiring lines: “[e]ach wiring line in *Fujikawa* comprises three line segments, i.e., data line 6a, image signal line 101d, and line 109.” *Id.* ¶122.

63. I disagree with Dr. Kattamis that Fujikawa discloses that those lines are “segments” of one set of wiring lines. In my opinion, Fujikawa does not disclose wiring lines that connect to active elements (e.g., TFTs) *and* extend onto the protruding region across the seal member. Only data lines 6a (blue) (and also scan lines, not discussed by Petition) connect to the TFTs, and they do not extend onto the protruding region:





Ex. 1005, Fig. 2.

64. I am aware of no teaching in Fujikawa that that suggests that data lines 6a, image signal lines 101d, and lines 109 comprise one line. To the contrary, lines 109 route signals to the data line driving circuit. Ex. 1005 ¶[0007]. The “lines” go through the data line driving circuitry: sample hold circuits 101c—

which include “analog switches to be operated in response to signals output from the shift register circuits 101b,” which in turn include “an inverter, two clocked inverters, and a level shifter”—stand between lines 109 and image signal lines 101d, on one side, and data lines 6a. Ex. 1005 ¶¶[0006], [0056]-[0057]. Dr. Kattamis’s suggestion that two separate lines straddling circuitry are *one* line is contrary to Fujikawa’s disclosure.

65. I note that the switches 101c (sample hold circuits) connect a few lines (extending onto the protruding portion) to many lines (the data lines). Accordingly, the disclosed configuration is a de-multiplexing configuration.

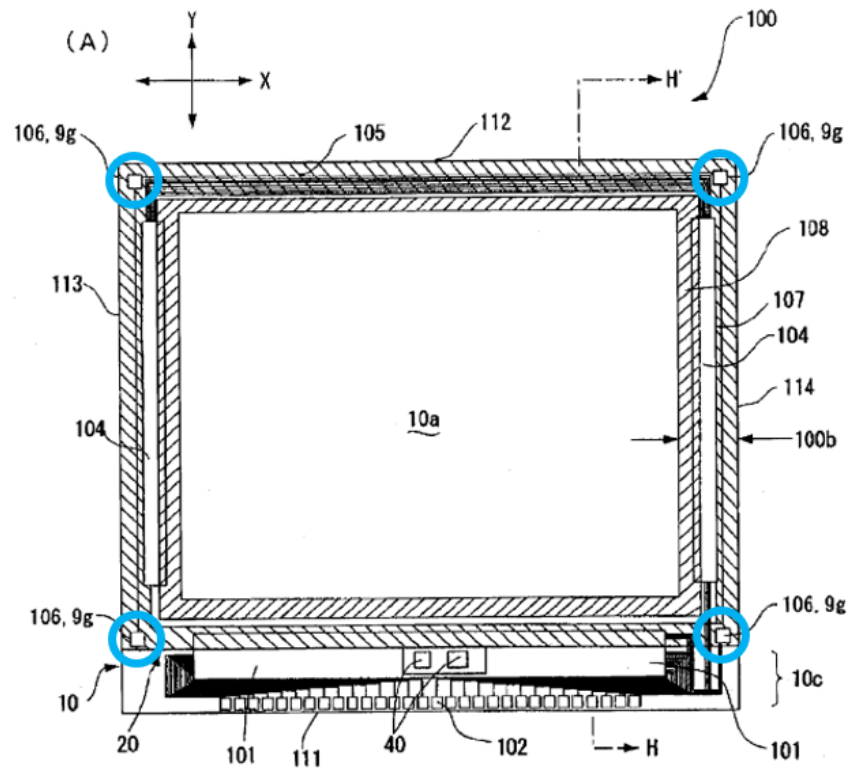
66. Thus, in my opinion, the Petition fails to show that Fujikawa discloses “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.”

## 2. *Claim 8*

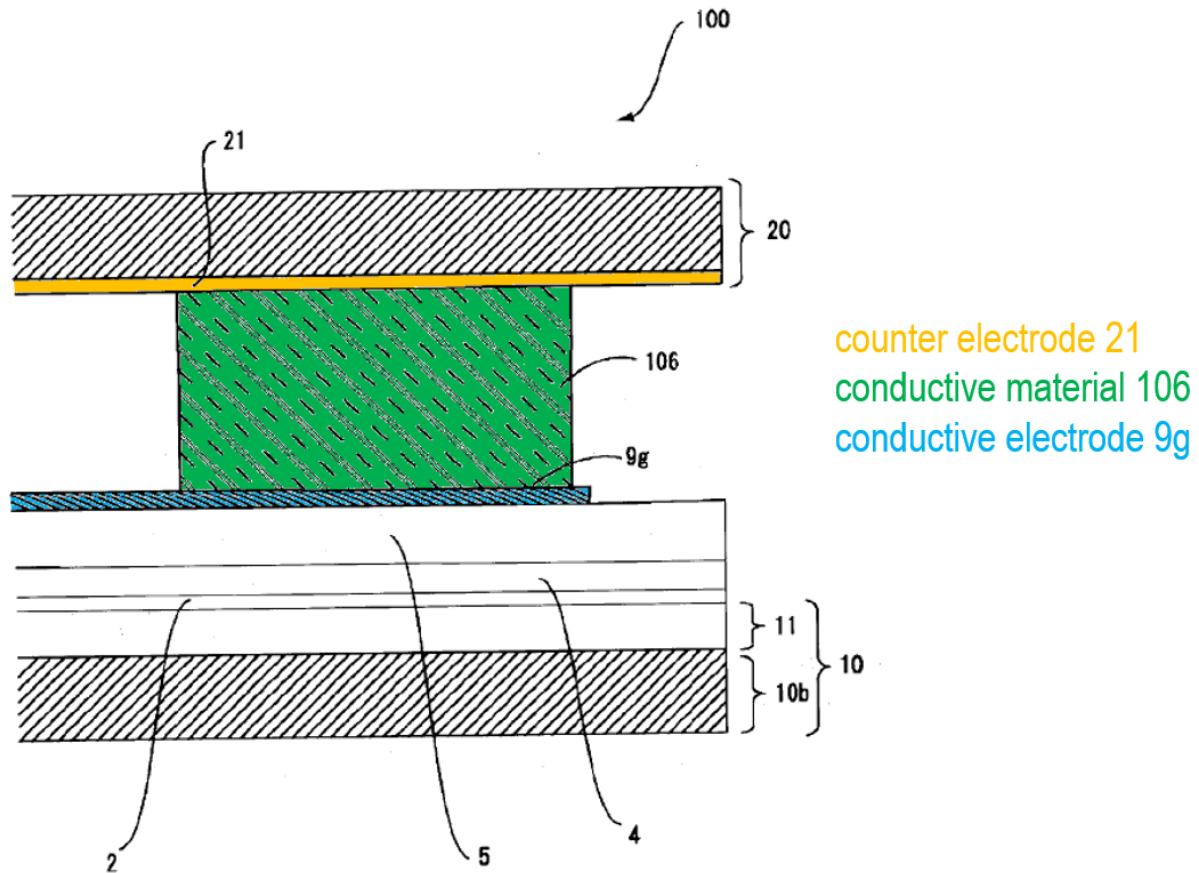
67. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa discloses claim 8.

68. Further, in my opinion, Fujikawa does not disclose or render obvious a seal member that extends “over the first conductive point on the second side.” As I discuss above, Fujikawa discloses sealing material 107 and, separate, conductive

material 106, and teaches forming conductive material—not sealing material—over conductive electrodes 9g:



Ex. 1005, Fig. 1A (no downward-slanting lines over 9g).



*Id.*, Fig. 9.

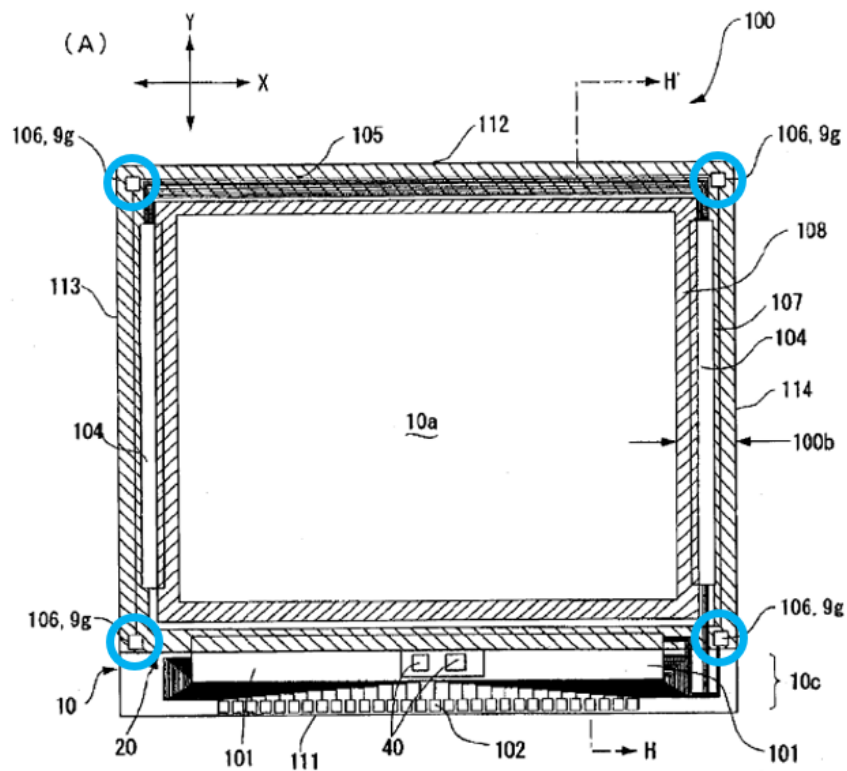
69. In addition, in my opinion, Fujikawa does not disclose or render obvious that “the second part of the seal member includes a plurality of conductive particles”—sealing material 107 is separate from conductive material 106, and the sealing material does not include conductive particles, as I discuss above.

3. *Claim 9*

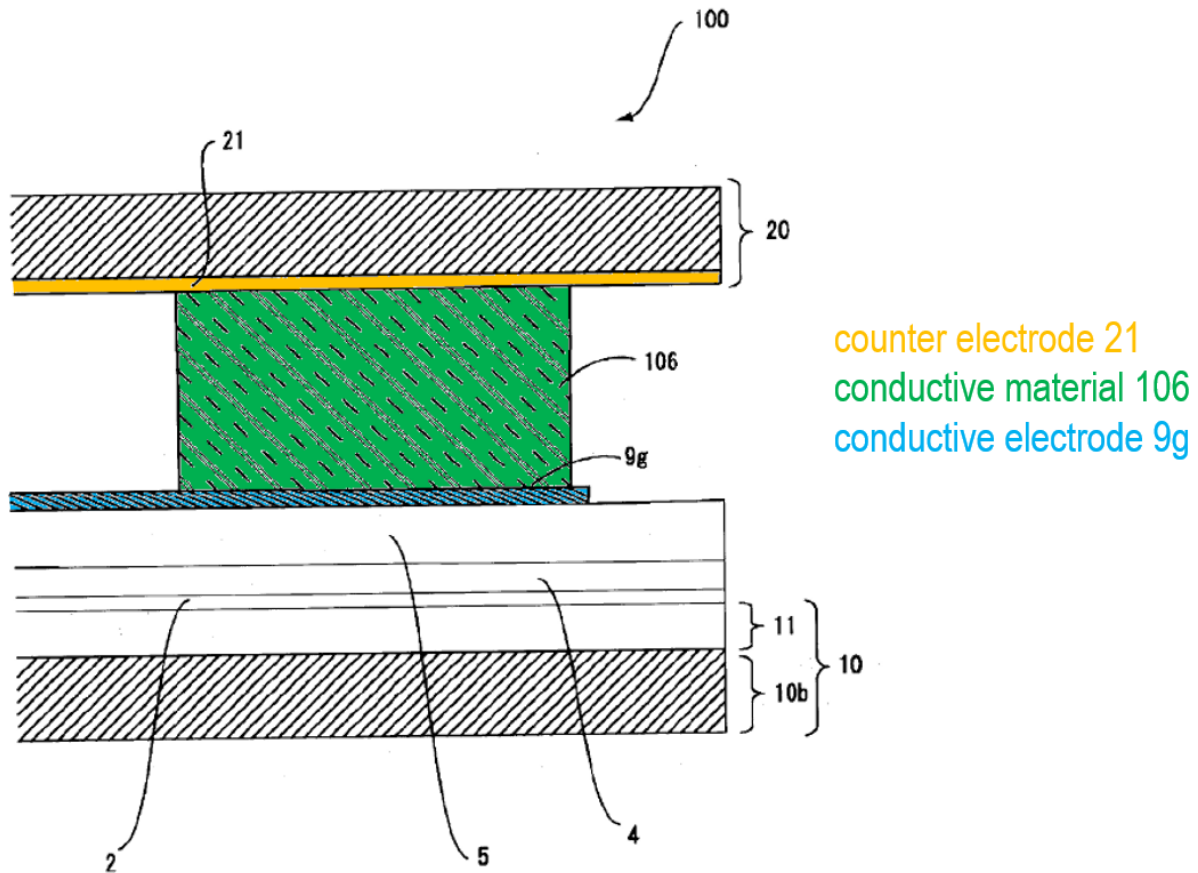
70. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 8 and, thus, fails to show that Fujikawa discloses claim 9.

71. Further, in my opinion, Fujikawa does not disclose or render obvious a seal member that extends “over the second conductive point on the fourth side.”

As I discuss above, Fujikawa discloses sealing material 107 and, separate, conductive material 106, and teaches forming conductive material—not sealing material—over electrodes 9g:



Ex. 1005, Fig. 1A (no downward-slanting lines over 9g).



*Id.*, Fig. 9.

72. In addition, in my opinion, Fujikawa does not disclose or render obvious that “the third part of the seal member includes a plurality of conductive particles”—sealing material 107 is separate from conductive material 106, and the sealing material does not include conductive particles, as I discuss above.

4. *Claim 10*

73. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa discloses claim 10.

5. *Claim 11*

74. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 10 and, thus, fails to show that Fujikawa discloses claim 11.

6. *Claim 12*

75. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa discloses claim 12.

7. *Claim 13*

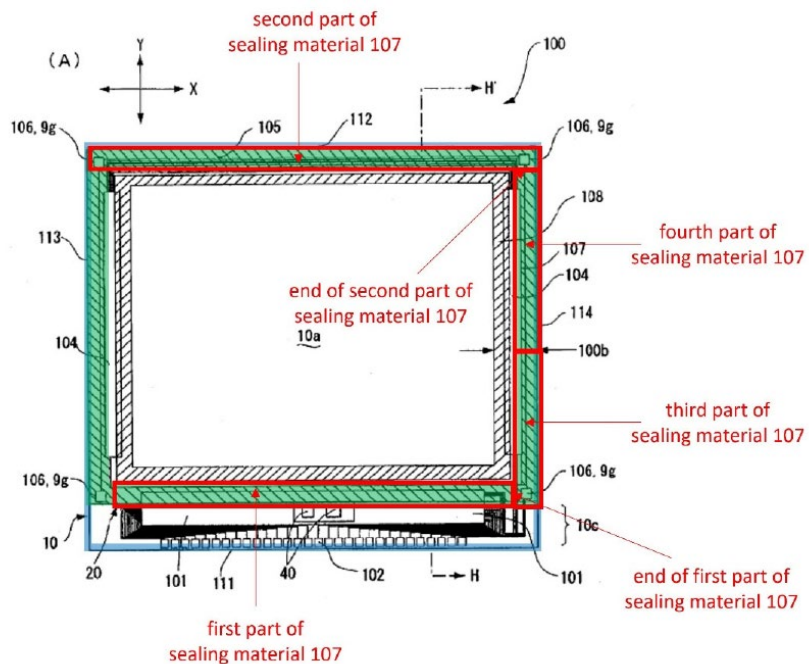
76. In my opinion, Fujikawa does not disclose or render obvious (1) “the seal member is formed continuously around the entire display region without the use of a plug”; (2) “the second part of the seal member includes a plurality of conductive particles”; or (3) “a plurality of wiring lines that connect to the plurality of active elements, . . . the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Claim limitations 13[f], [i], [a]&[l]. My opinions are the same as they are for claim 7, above.

8. *Claim 15*

77. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 13 and, thus, fails to show that Fujikawa

discloses claim 15.

78. Further, according to Dr. Kattamis, “the fourth part of the seal member” includes no conductive material and, thus, cannot include “a first plurality of conductive particles”:



Ex. 1004 ¶172.

79. Dr. Kattamis seems to suggest that Fujikawa teaches modifications to its arrangement that would satisfy the claim limitation, because Fujikawa suggests changing “[t]he number of the conductive electrodes 9g.” Ex. 1004 ¶¶114, 173. But as I discuss above, in my opinion, Dr. Kattamis does not show that Fujikawa discloses or renders obvious changing the number of conductive electrodes to form additional conductive electrodes and conductive material on a particular side of the

device, or as part of a particular part of the seal member.

80. Also, as I discuss above, the Petition cannot show that Fujikawa discloses or renders obvious that “the fourth part of the seal member . . . includes a first plurality of conductive particles”—the sealing material is separate from the conductive material, and the sealing material will not include conductive particles, even if a POSITA were to add conductive electrodes and conductive material to the “fourth part.”

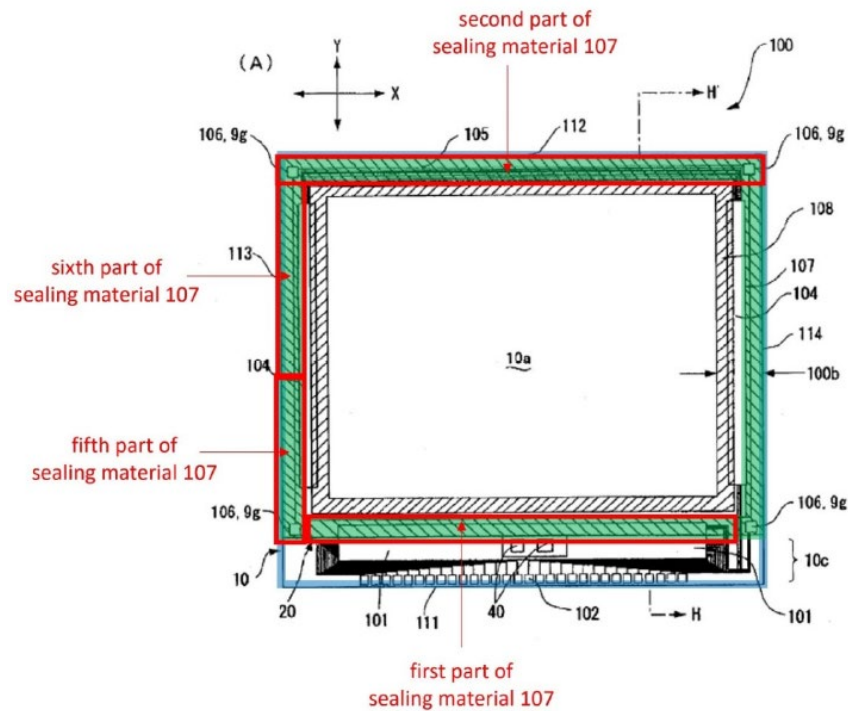
9. *Claim 16*

81. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 15 and, thus, fails to show that Fujikawa discloses claim 16.

10. *Claim 17*

82. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 16 and, thus, fails to show that Fujikawa discloses claim 17.

83. Further, according to the Petition, “the sixth part of the seal member” includes no conductive material and, thus, cannot include “a second plurality of conductive particles”:



Ex. 1004 ¶177.

84. Dr. Kattamis seems to suggest that Fujikawa teaches modifications to its arrangement that would satisfy the claim limitation, because Fujikawa suggests changing “[t]he number of the conductive electrodes 9g.” Ex. 1004 ¶¶114, 178. But as I discuss above, in my opinion, Dr. Kattamis does not show that Fujikawa discloses or renders obvious changing the number of conductive electrodes to form additional conductive electrodes and conductive material on a particular side of the device, or as part of a particular part of the seal member.

85. Also, as I discuss above, the Petition cannot show that Fujikawa discloses that “the sixth part of the seal member . . . includes a second plurality of conductive particles”—the sealing material is separate from the conductive

material, and the sealing material will not include conductive particles, even if a POSITA were to add conductive electrodes and conductive material to the “sixth part.”

*11. Claim 18*

86. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 17 and, thus, fails to show that Fujikawa discloses claim 18.

*12. Claim 19*

87. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 18 and, thus, fails to show that Fujikawa discloses claim 19.

*13. Claim 20*

88. The Petition fails to show that Fujikawa discloses or renders obvious the display device according to claim 13 and, thus, fails to show that Fujikawa discloses claim 20.

## **VII. ANALYSIS OF FUJIKAWA IN VIEW OF KANG (GROUND 3)**

### **A. Overview of Kang**

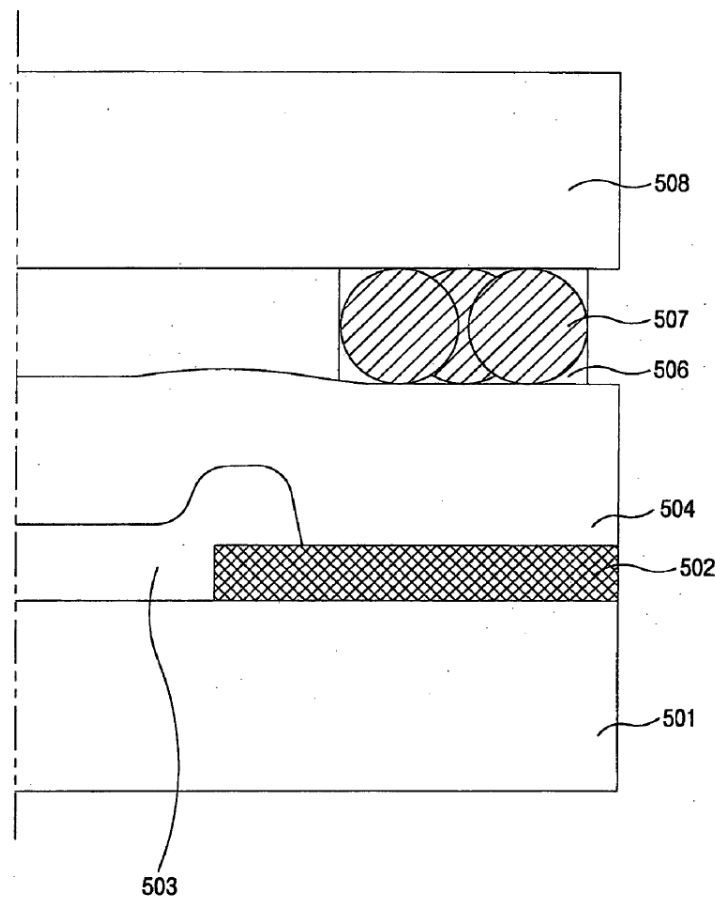
89. Kang “relates to a liquid crystal display panel, and more particularly, to a liquid crystal display panel capable of preventing air from flowing into an image display part of a liquid crystal display panel where a thin film transistor

array substrate and a color filter substrate are attached to each other.” Ex. 1006

¶[0003]. Kang describes a liquid crystal display panel including a thin film transistor (TFT) array substrate (lower substrate), a color filter substrate (upper substrate), “a seal pattern formed along the outer edge” of the panel, spacers on the TFT array substrate to create the desired cell-gap, and a liquid crystal layer between the substrates. *Id.* ¶¶[0007]-[0008]. Kang discloses adding glass fibers or glass balls to the seal pattern, to maintain the cell-gap when applying pressure to the seal pattern to attach the substrates to one another. *Id.* ¶[0036].

90. Kang describes a problem in which pressing the seal pattern creates cracks—in particular, in an over-coat layer and a black-matrix layer. *Id.* ¶¶[0032]-[0036]. When the layers crack, air enters the panel, degrading liquid crystal performance and breaking the seal. *Id.* Kang describes forming a thicker “over-coat layer” on a liquid crystal display panel’s seal pattern, to prevent “the black matrix from being depressed as the support member added to the seal pattern is pressed by the outer pressure caused in or after attaching the liquid crystal display panel.” *Id.*, Abstract. The over-coat layer prevents cracking between the over-coat layer and the black matrix, between the black matrix and the substrate, and in the seal pattern. *Id.* “That is, when the support member 507 added to the seal pattern 506 is pressed by the outer pressure caused in or after attaching the liquid crystal display panel, the over-coat layer 504 with a thickness of about about 1.2  $\mu\text{m}$  to about 5

μm functions as a buffer layer absorbing the external pressure and thereby preventing depression of the black matrix 502.” *Id.* ¶[0083].



*Id.*, Fig. 5.

91. Relevant here, Kang also discusses the liquid crystal injection method and the liquid crystal dropping method. *See, e.g., id.* ¶¶[0062]-[0074].

**B. The teachings of Fujikawa in view of Kang do not satisfy all elements of any of claims 7-13 or 15-20 of the '606 patent.**

92. In my opinion, Fujikawa in view of Kang does not disclose or render obvious all limitations of any challenged claim, for the same reasons that Fujikawa

does not disclose or render obvious all limitations of any challenged claim.

93. I understand that Dr. Kattamis opines only that Kang discloses claim limitations 7[h] and 13[f], forming a seal member “without the use of a plug.” Ex. 1004 ¶¶186-191, 199. It is my opinion that a transition from Fujikawa’s LC injection method to Kang’s LC dropping method would exceed the skills of Petitioner’s POSITA who, although having a master’s degree, has no experience with semiconductor display devices such as LCD devices.<sup>2</sup> Furthermore, Dr. Kattamis does not opine that Kang discloses or renders obvious “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles” or “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points” (claim 7); or “the second part of the seal member includes a plurality of conductive particles” or “a plurality of

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<sup>2</sup> I draw the same conclusion for a bachelor’s degree recipient who has two years of experience in the field of semiconductor display devices.

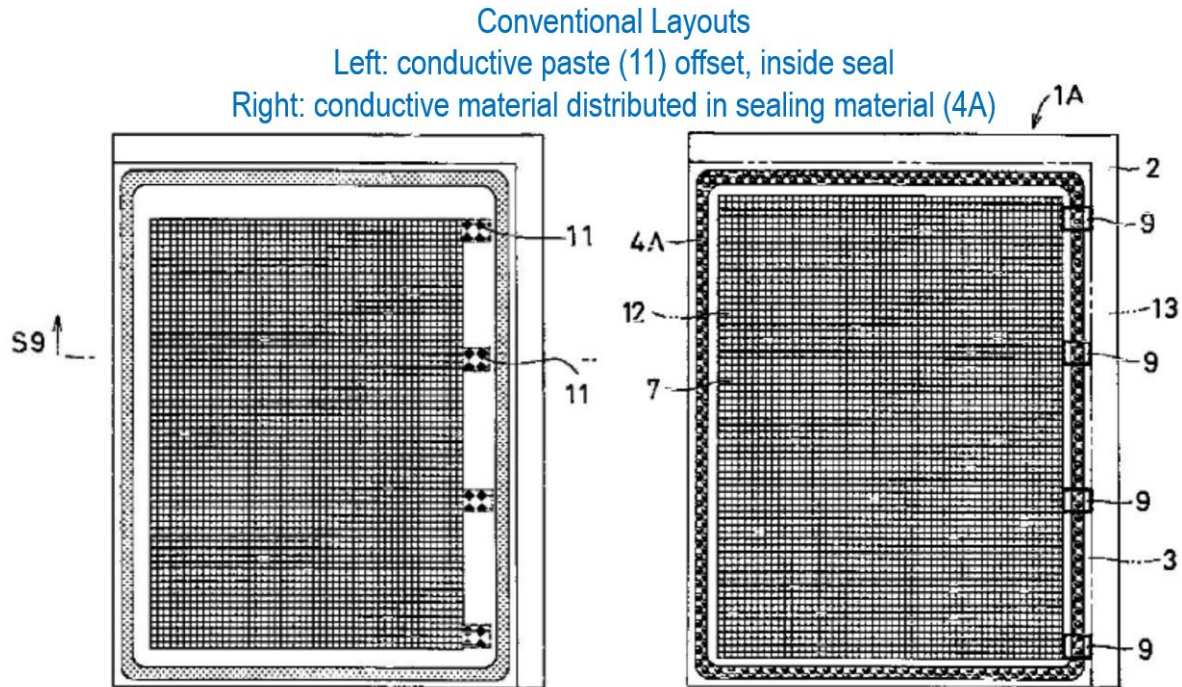
Dr. Kattamis uses the words “simple,” “obvious,” and “straightforward” in conjunction with LCD technology. The field of semiconductor display devices (such as LCDs) is interdisciplinary, multi-faceted, and complex. An engineer working in the field would in my opinion agree that the associated technology is interdisciplinary, multi-faceted, and complex rather than simple, obvious, and straightforward.

wiring lines that connect to the plurality of active elements, . . . the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points (claim 13).

## **VIII. ANALYSIS OF FUJIKAWA IN VIEW OF IKEGUCHI (GROUND 4)**

### **A. Overview of Ikeguchi**

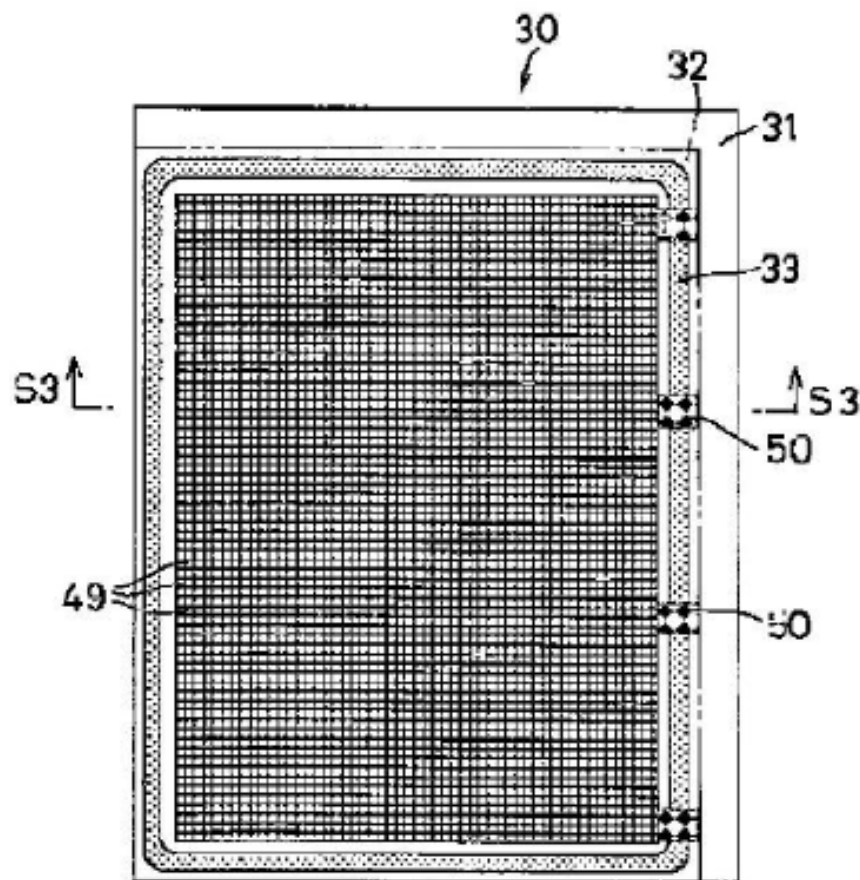
94. Ikeguchi relates to display elements and, like Fujikawa, discloses display element layouts to narrow the non-display region. Ikeguchi discloses that conventional display element layouts dispose conductive paste inside or outside of the display element seal (LCD substrate seal); the seal holds the liquid crystal material, and the conductive paste connects the upper electrode substrate to the driver integrated circuits, which are connected to the display element on the lower electrode substrate (TFT substrate). Ex. 1008 ¶[0006]. That layout creates a larger-than-desired non-display region. *Id.* Other conventional display element layouts save space, dispersing conductive material into the sealing material rather than next to the sealing material. But Ikeguchi explains that that layout creates connectivity problems: due to variations in cell-gap height (the space between the substrate layers), the conductive material does not always create a connection between the upper electrode substrate and the lower electrode substrate, and dispersing the conductive material into the sealing material requires additional insulating layers to protect crossing wiring. *Id.* ¶¶[0009]-[0012].



*Id.*, Figs. 8, 10.

95. Ikeguchi discloses a solution: depositing a display element seal and then depositing conductive material on common electrodes, and then bonding upper and lower electrode substrates, so as to create discrete electrical connections between upper and lower electrode layers:

FIG. 2



*Id.*, Fig. 2. “In this manner, the region in which the sealing material 33 is disposed and the region in which the common electrode 37, the connection electrode 48, and the conductive material 50 are disposed can be shared, a non-display region 53 can be made small, and the conductive material 50 can be reliably brought into contact with the common electrode 37 and the connection electrode 48 to achieve reliable conduction between the electrode substrates 31, 32.” *Id.*, Abstract.



96. In my opinion, Fujikawa in view of Ikeguchi does not render obvious all limitations of any challenged claim.

97. In my opinion, Fujikawa in view of Ikeguchi does not render obvious (1) a seal member “formed continuously around the entire pixel region without the use of a plug”; (2) “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles”; or (3) “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Claim limitations 7[h], [i], [l].

- a. *a “seal member . . . formed continuously around the entire pixel region without the use of a plug” (claim 7[h])*

98. As I discuss above, Fujikawa does not disclose or render obvious a seal member “formed continuously around the entire pixel region without the use of a plug,” and Dr. Kattamis does not argue that Ikeguchi discloses this limitation. Ex. 1004 ¶211. Thus, in my opinion, Fujikawa in view of Ikeguchi does not render obvious this limitation.

- b. *“a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points” (claim 7[i])*

99. I disagree with Dr. Kattamis’s opinion that Fujikawa in view of Ikeguchi renders obvious “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Ex. 1004 ¶¶212-217.

100. As I discuss above, in my opinion, Fujikawa does not disclose or render obvious “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles.” And Dr. Kattamis does not appear to opine that Ikeguchi discloses this complete limitation. *Id.* Dr. Kattamis appears to opine only

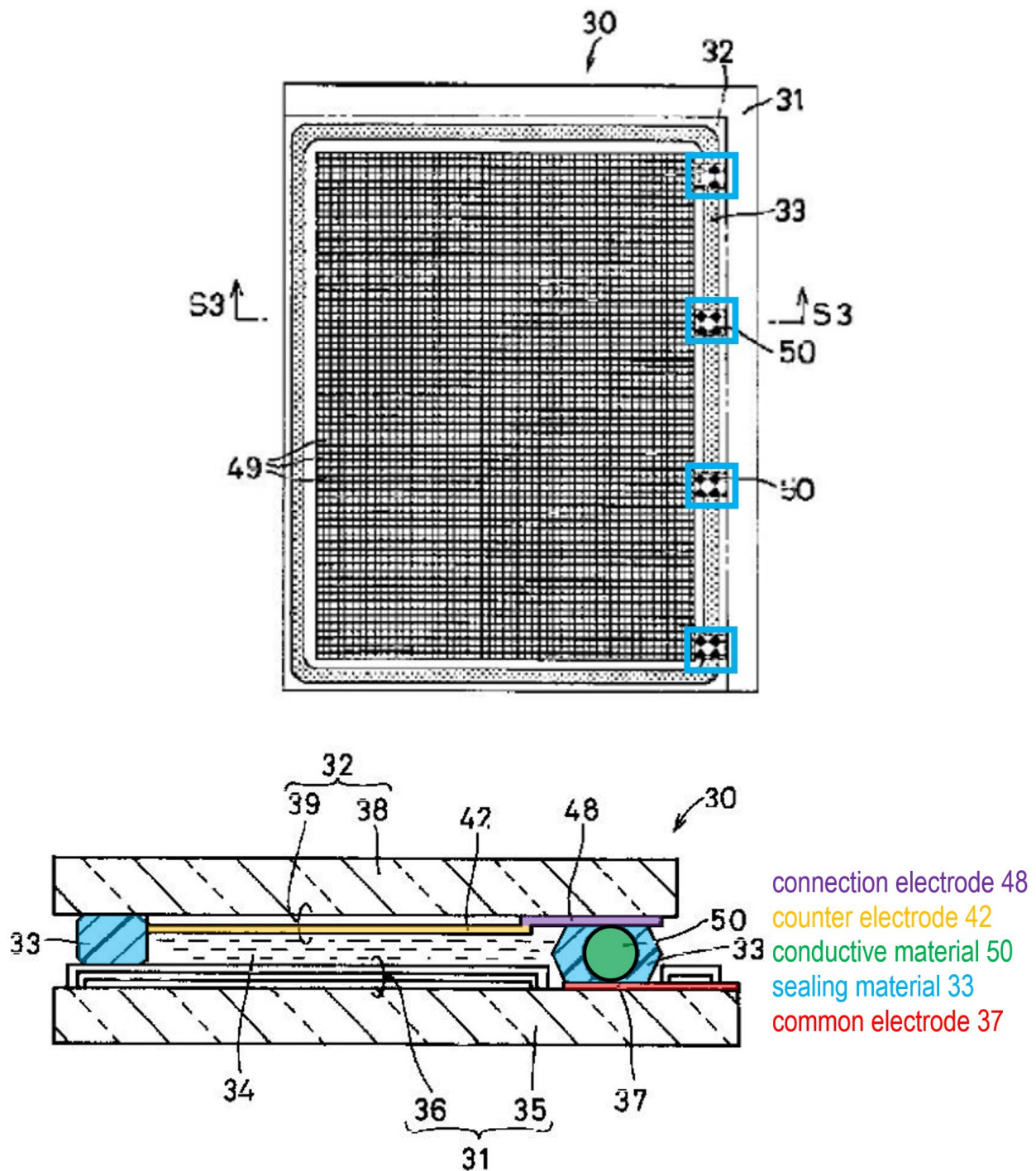
that “it would have been obvious to have additional conductive particles (with more conductive electrodes 9g” in Fujikawa’s design, in view of Ikeguchi. *Id.*

¶212.

101. In my opinion, Fujikawa in view of Ikeguchi does not render this limitation obvious for two reasons. First, Dr. Kattamis cites no evidence to suggest that Ikeguchi discloses a part of a seal member disposed on the third side that includes conductive particles. And second, Dr. Kattamis offers no reason to modify Fujikawa in view of Ikeguchi to satisfy the limitation.

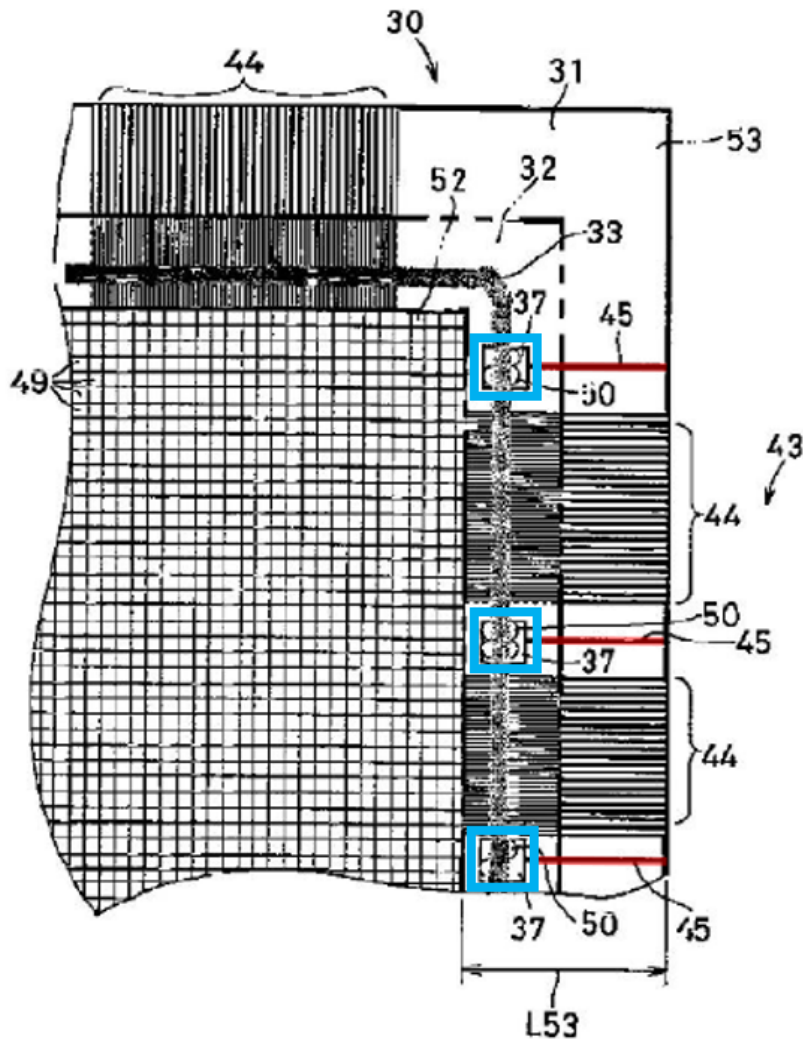
102. Like Fujikawa, Ikeguchi discloses forming a seal, including on the “third side” (opposite the protruding region), and, separately, depositing conductive material on discrete locations. Ex. 1008 ¶¶[0016], [0019], [0047]. Ikeguchi teaches away from a seal member including conductive particles. *Id.* ¶¶[0011]-[0012] (describing problems when dispersing conductive particles in sealing material, i.e., when “uniformly mixed”).

103. Moreover, Ikeguchi teaches depositing conductive material only along the protruding region:



*Id.*, Figs. 2, 3. Specifically, Ikeguchi discloses forming common electrodes over common line (or “other-substrate”) terminals and depositing conductive material on those common electrodes. *Id.* ¶[0037] (“When forming the other-substrate

terminals 45 on the first electrode substrate 31, a conductive portion for creating conduction between the transparent counter electrode substrate and the other-substrate terminals must be provided spanning between the electrode substrates 31, 32 in order to electrically connect the other-substrate terminals 45 and the transparent counter electrode of the second electrode substrate 31 [sic, 32].”). Ikeguchi teaches forming common line terminals along the protruding region, where driver integrated circuits connect to the display element. *Id.* ¶[0033]. So Ikeguchi’s conductive electrodes and, thus, Ikeguchi’s conductive material, are along the protruding region:



*Id.*, Fig. 1 (red identifying common line terminals, blue identifying conductive electrodes and conductive material). Ikeguchi does not disclose a part of a seal member disposed on the third side including conductive particles. It does not disclose forming conductive electrodes or conductive material on the third side. It discloses forming conductive electrodes on the first side, over driver integrated circuit terminals, and depositing conductive material on only those locations after forming the seal.

104. Second, Dr. Kattamis does not show how or why a POSITA would modify Fujikawa's sealing material 107 and conductive material 106 arrangement in view of Ikeguchi to satisfy this limitation. Dr. Kattamis suggests that a POSITA would "[a]dd[] additional conductive particles," citing three reasons. Ex. 1004 ¶¶215-217. I do not agree that these reasons are specific to satisfying this limitation.

105. First, Dr. Kattamis asserts that modifying Fujikawa to "have additional conductive particles in Fujikawa's sealing material 107" would reduce the size of the non-display region. *Id.* ¶215. But Dr. Kattamis does not explain how. Indeed, Fujikawa already provides conductive electrodes 9g and conductive material 106 in gaps in the sealing material within the seal region. *See* Ex. 1005, Fig. 1A. Fujikawa's arrangement reduces the size of the non-display region and does not waste space forming sealing material and conductive material in separate regions.

106. Second, Dr. Kattamis asserts that modifying Fujikawa to "have additional conductive particles in Fujikawa's sealing material 107" would "achieve reliable conduction between substrates." Ex. 1004 ¶¶215-216. Again, Dr. Kattamis does not explain how. Fujikawa already achieves conduction between its substrates. Even if a POSITA were to add conductive electrodes and conductive material to Fujikawa's arrangement in view of Ikeguchi's, Ikeguchi teaches

forming additional conductive electrodes and conductive material along the *first* (protruding) side, not the *third* side.

107. Third, Dr. Kattamis mentions improved “display quality and stability.” Ex. 1004 ¶215. But he does not explain how Ikeguchi’s arrangement would motivate a POSITA to modify Fujikawa’s to achieve something *more*.

108. In my opinion, neither reference discloses “a first part of the seal member disposed on the third side which is opposed to the protruding region with respect to the pixel region includes a plurality of conductive particles.” And the Petition does not show that Ikeguchi would motivate a POSITA to modify Fujikawa to satisfy the limitation. Thus, the Petition fails to show that Fujikawa in view of Ikeguchi renders obvious this limitation.

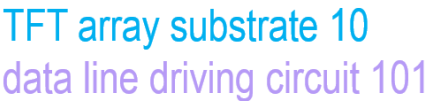
c. *“a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points” (claim 7[l])*

109. I disagree with Dr. Kattamis’s opinion that Fujikawa in view of Ikeguchi renders obvious “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Ex. 1004 ¶¶225-226.

110. First, in my opinion, Ikeguchi does not clearly disclose wiring lines

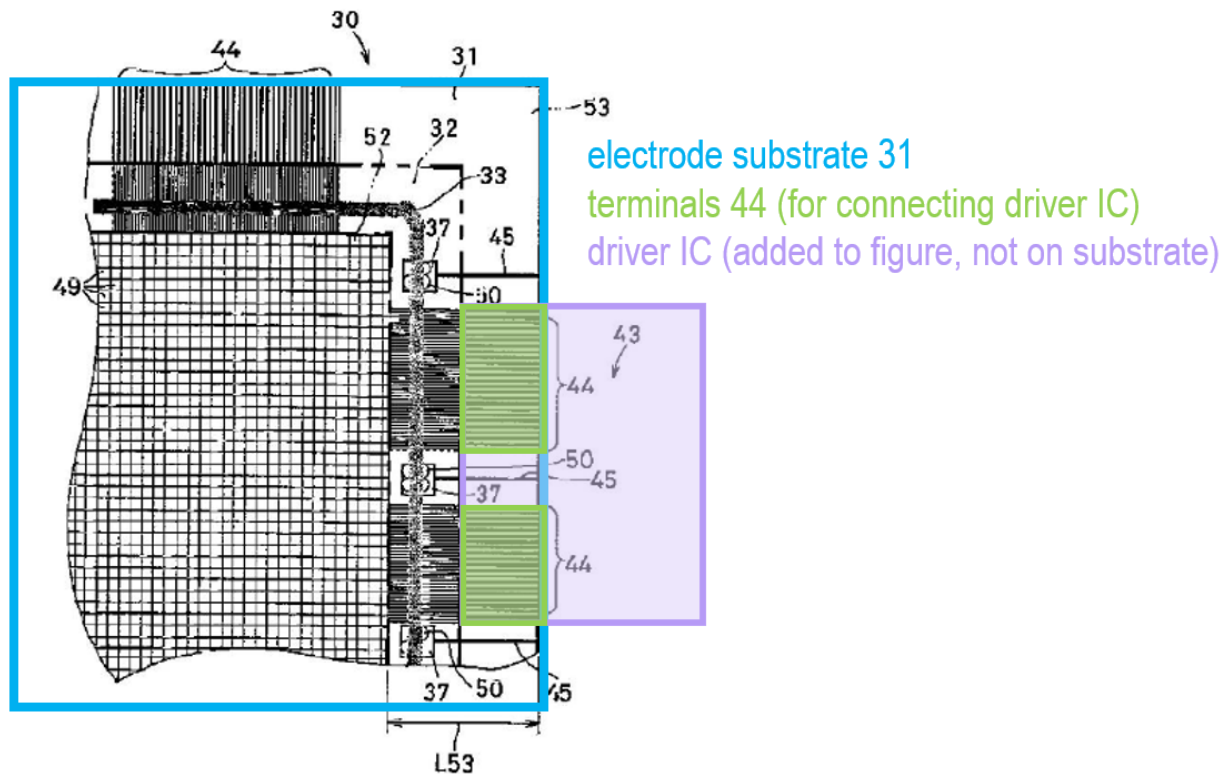
that connect to the active elements and extend onto the protruding region. Ikeguchi discloses “connection lines”: “[t]he one-substrate terminals 44 are electrically connected to the gate-line electrodes and the source-line electrodes via connection lines, and a different potential can be applied to each of the transparent pixel electrodes 49 by the driver IC.” Ex. 1008 ¶[0034]. Ikeguchi discloses little else about those connection lines, including whether they extend onto the protruding region. Figure 1 shows that terminals 44 are on the protruding region. But it does not show whether wiring lines extend onto the protruding region.

111. Second, Dr. Kattamis does not explain how or why Ikeguchi’s driver integrated circuit arrangement would motivate a POSITA to modify Fujikawa’s wiring lines arrangement, including its sample-hold switching circuitry (de-multiplexer circuit). In my opinion, it would not. Fujikawa discloses a display device including a data line driving circuit on a TFT substrate, in partial overlap with the sealing material and extending onto the protruding portion of the TFT substrate:



112. Ikeguchi, in contrast, describes a display element and separate driver integrated circuits—rather than circuits formed on the display element substrate. *See, e.g.*, Ex. 1008 ¶¶[0033]-[0035] (describing connecting terminals 44 on the display element for connecting driver integrated circuits and that “[i]n this manner, the display element 30 and the driver IC are electrically connected”). Dr. Kattamis misunderstands this difference between Fujikawa’s layout and Ikeguchi’s layout, misstating that Ikeguchi’s “driver integrated circuit can be either within the sealing region or outside the sealing region.” Ex. 1004 ¶226. That is not correct. A POSITA would not mount a driver IC chip, which has its own substrate, on the display device substrate in overlap with or inside of the seal. Ikeguchi does not

disclose a driving circuit arranged on the TFT substrate. Instead, Ikeguchi discloses a driver IC chip. In Ikeguchi and similar configurations, the driver IC chips are located off the LCD panel and are connected at the terminals, for example, via contact pads.



Ex. 1008, Fig. 1. Modifying Fujikawa in view of Ikeguchi would require significant changes to Fujikawa's existing wiring structure and peripheral circuit layout. Furthermore, Fujikawa's driving circuit including its sample hold switches (101c) (de-multiplexer circuit) allow Fujikawa to avoid the excessive number of terminals (44) that Ikeguchi discloses (see image above). Given Fujikawa's goal of reducing the non-display area, it would be counter-productive to adopt Ikeguchi's

data line configuration in Fujikawa.

113. The Petition’s suggestion that Ikeguchi would have motivated a POSITA to change Fujikawa’s wiring lines layout is conclusory and unsupported and overlooks critical distinctions between the references. Thus, the Petition fails to show that Fujikawa in view of Ikeguchi discloses or renders obvious “a plurality of wiring lines that connect to the plurality of active elements, and the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.”

2. *Claim 8*

114. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 8.

115. Further, the Petition fails to show that Fujikawa discloses or renders obvious additional limitation of claim 8, as I discuss above. And the Petition does not show that Ikeguchi discloses or renders obvious a seal member that extends “over the first conductive point on the second side” or that “the second part of the seal member includes a plurality of conductive particles”—Ikeguchi discloses conductive material on only one side of the panel.

3. *Claim 9*

116. The Petition fails to show that Fujikawa in view of Ikeguchi renders

obvious the display device according to claim 8 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 9.

117. Further, the Petition fails to show that Fujikawa discloses or renders obvious the additional limitation of claim 9. And the Petition does not show that Ikeguchi discloses or renders obvious a seal member that extends “over the second conductive point on the fourth side” or that “the third part of the seal member includes a plurality of conductive particles”—Ikeguchi discloses conductive material on only one side of the panel.

4. *Claim 10*

118. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 10.

5. *Claim 11*

119. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 10 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 11.

6. *Claim 12*

120. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 7 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 12.

7. *Claim 13*

121. In my opinion, Fujikawa in view of Ikeguchi does not render obvious (1) “the seal member is formed continuously around the entire display region without the use of a plug”; (2) “the second part of the seal member includes a plurality of conductive particles”; or (3) “a plurality of wiring lines that connect to the plurality of active elements, . . . the plurality of wiring lines extend onto the protruding region across the seal member without connecting to the dot conductive points.” Claim limitations 13[f], [i], [a]&[l]. My opinions are the same as they are for claim 7, above.

8. *Claim 15*

122. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 13 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 15.

9. *Claim 16*

123. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 15 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 16.

10. *Claim 17*

124. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 16 and, thus, fails to show that

Fujikawa in view of Ikeguchi renders obvious claim 17.

*11. Claim 18*

125. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 17 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 18.

*12. Claim 19*

126. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 18 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 19.

*13. Claim 20*

127. The Petition fails to show that Fujikawa in view of Ikeguchi renders obvious the display device according to claim 13 and, thus, fails to show that Fujikawa in view of Ikeguchi renders obvious claim 20.

**IX. ANALYSIS OF FUJIKAWA IN VIEW OF KANG AND IKEGUCHI (GROUND 5)**

128. Dr. Kattamis offers no new arguments in support of Ground 5. Thus, for the same reasons that the Petition fails to show that Fujikawa in view of Kang, and Fujikawa in view of Ikeguchi, renders obvious claims 7-13 and 15-20, the Petition fails to show that Fujikawa in view of Kang and Ikeguchi renders obvious those claims.

**X. ADDITIONAL REMARKS**

129. I reserve any right that I may have to supplement this declaration if further information becomes available or if I am asked to consider additional information or to submit an additional declaration if *inter partes* review is instituted. Furthermore, I reserve any right that I may have to consider and comment on any additional expert statements and testimony of Petitioner's expert in this matter.

130. I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare 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 and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Dated: September 20, 2024



E. Fred Schubert, Ph.D.

# APPENDIX A

## Curriculum Vitae: E. Fred Schubert

### Contact information

Department of Electrical, Computer, and Systems Engineering  
 Rensselaer Polytechnic Institute  
 110 Eighth Street, Troy, NY 12180  
 Telephone 518-276-8775 (office); Cell phone 518-253-3762  
 Email: EFSchubert@rpi.edu Homepage: <http://www.rpi.edu/~schubert>

### Citizenship

Born in Stuttgart, Germany (1956)  
 Naturalized United States Citizen (1995)

### Education

University of Stuttgart	Electrical Engineering	Vordiplom	(U. S. equivalent BSEE)	1978
University of Stuttgart	Electrical Engineering	Diplom Ingenieur (Honors)	(U. S. equivalent MSEE)	1981
Oregon State University	Electrical Engineering	Exchange Student		1977–1978
University of Stuttgart	Electrical Engineering	Doktor Ingenieur (Honors)	(U. S. equivalent Ph.D.)	1986

### Current appointment

2002 – present: Professor, Department of Electrical, Computer, and Systems Engineering; Rensselaer Polytechnic Institute, Troy NY

### Previous appointments

2002 – 2015: Head and Founder of the Future Chips Constellation; Rensselaer Polytechnic Institute  
 2002 – 2015: Wellfleet Senior Constellation Professor, Future Chips (Chaired Professor); Rensselaer Polytechnic Institute  
 2002 – 2012: Professor Department of Physics, Applied Physics, and Astronomy; Rensselaer Polytechnic Institute  
 2008 – 2009: Director, Founding Director, and Principal Investigator, NSF Engineering Center for Smart Lighting, Rensselaer Polytechnic Institute  
 2002 – 2003: Adjunct Professor, Boston University  
 1995 – 2002: Professor, Boston University, Department of Electrical and Computer Engineering; Director of the Semiconductor Devices Research Laboratory; Affiliated Faculty of the Photonics Center.  
 1988 – 1995: Member of Technical Staff; Principal Investigator; and Member of Management at AT&T Bell Laboratories in Murray Hill, New Jersey  
 1985 – 1987: Post-Doctoral Member of Technical Staff at AT&T Bell Laboratories in Holmdel, New Jersey.  
 1981 – 1985: Scientific Member of Staff in the Department of Solid-State Chemistry at the Max Planck Institute for Solid-State Research in Stuttgart, Germany. Ph.D. Dissertation title: “Modern Schottky gate field-effect transistors based on III–V semiconductors”

### Fields of Technical Expertise, Hands-on Experience, and Teaching

- Expertise, hands-on experience, and teaching in semiconductor opto-electronics including the following devices: LED, semiconductor laser, vertical cavity surface-emitting laser (VCSEL), solar cell, photo-detector, LED displays, micro-LED displays, LCD displays, and OLED displays. The activities include the design, fabrication, processing, and packaging of the devices, and the use of the devices in circuits and systems. (1981 to present)
- Expertise, hands-on experience, and teaching in semiconductor electronics including the following devices: MESFET, HFET, MOSFET, CMOS-FET, LDD MOSFET, LD MOS FET, FinFET, GAA FET, Vertical MOSFET (high-power MOSFET), thyristor, GTO thyristor, and IGBT. The activities include the design, fabrication, processing, and packaging of the devices, and the use of the devices in discrete and integrated circuits. (1979 to present)
- Expertise, hands-on experience, and teaching in thin-film deposition of metal, semiconductor, and insulator films by PVD (physical vapor deposition) and CVD (chemical vapor deposition) including PECVD (plasma enhanced CVD), MOCVD (metal-organic CVD), ALE (atomic layer epitaxy), ALD (atomic layer deposition), and bulk crystal growth (AlN, GaN, and sapphire). Epitaxial growth of silicon, III-V arsenide, phosphide and nitride epitaxial layers on GaAs, sapphire, Si, and GaN substrates by epitaxy including molecular beam epitaxy (MBE),

metal-organic chemical vapor deposition (MOCVD), and vapor-phase epitaxy (VPE). High-k materials, low-k-materials, phosphors, resins, polymers, encapsulants, alloy semiconductors and their deposition technologies such as epitaxy, CVD, and PVD. Doping of semiconductors by various means including delta doping and atomic monolayer doping. (1981 to present)

- Expertise, hands-on experience, and teaching in the design, operation, and usage of semiconductor devices in lighting systems, communication systems, and power-supply systems and in the analysis and development of LED power supplies using Boost and Buck Converters. (1993 to present)

### ***Technical Research Activities***

- Design, development and fabrication of a Si pressure sensor based on the piezo-resistivity of Si using a bridge configuration of four thin-film Si resistors (1979 – 1980)
- Design of a electro-optic Mach-Zehnder Interference Modulator based on Lithium niobate ( $\text{LiNbO}_3$ ) operating at a wavelength of 1300 nm (1980 – 1981)
- First study of hot electron effects in selectively doped  $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}$  heterostructures (1983)
- Demonstration and elimination of parallel conduction in  $\text{Al}_x\text{Ga}_{1-x}\text{As}/\text{GaAs}$  heterostructures (1984)
- First analysis of semiconductors doped with simultaneously shallow and deep donors (1984).
- Development and use of thyristor circuits (including GTO thyristor circuits) for the control of a lamp heating system (1984 – 1985)
- Proposal and demonstration of the  $\delta$ -doped field-effect transistor. Short-channel effects in sub-micron field-effect transistors can be reduced to their theoretical minimum by using  $\delta$ -doped structures (1985)
- Development of the theory of alloy broadening in luminescence spectra of alloy semiconductors such as  $\text{Al}_x\text{Ga}_{1-x}\text{As}$ . The current understanding of the low-temperature spectral linewidths of ternary and quaternary alloy semiconductors is based on this theoretical model. The publication analyzing the phenomenon of alloy broadening has been referenced far in excess of 100 times (1984)
- First demonstration of a light-emitting diode with a doping superlattice active region (1985)
- Application of  $\delta$ -doping to selectively doped heterostructures; Demonstration of high-electron-mobility transistors (HEMTs) with highest free electron concentrations; Analysis of structures by SEM, TEM, and SIMS (1986).
- Demonstration of delta-doped non-alloyed ohmic contacts with very low contact resistance and subsequent demonstration of self-aligned field-effect transistor with delta-doped non-alloyed ohmic contacts (1986)
- Demonstration of the spatial localization of dopants within 20 Å for a number of doping elements in delta-doped semiconductors including GaAs and Si for MESFET and lightly-doped drain (LDD) MOSFET applications and the analysis of delta-doped structures by SIMS (secondary ion mass spectrometry) (with colleague Henry S. Luftman, 1983-1995)
- Significant improvement of the optical properties of doping superlattices by employment of delta doping. Improvement is demonstrated by the first observation of quantized interband transitions in the absorption (1988) and in the emission spectra (1989)
- First demonstration of tunable doping superlattice laser (1989)
- First quantitative analysis of the capacitance-voltage (CV) profiling technique in semiconductors with quantum-confined carriers. Demonstration that resolution of CV profiles in quantum-confined semiconductors is not limited to the Debye screening length (1990)
- Invention and demonstration a new concept by which heterojunction band discontinuities occurring between two different semiconductors are eliminated. The *elimination of heterojunction barriers* is based on parabolic compositional grading of doped heterojunctions. This concept is widely used in the fabrication of vertical cavity surface emitting lasers and other heterojunction devices (1991)
- Invention and first demonstration of resonant cavity light-emitting diode (RCLED) which uses photon quantization in microcavities to enhance the spontaneous emission properties (1992)
- Demonstration of giant enhancement of luminescence intensity in Er-doped  $\text{Si-SiO}_2$  microcavities (1992)
- First demonstration of a resonant-cavity detector which is useful for wavelength-selective detection (1993)
- Demonstration of resonant-cavity light-emitting diode (RCLED) with very high brightness. The experimental brightness of the RCLED is five times higher than that of conventional LEDs. Based on calculations, the brightness of RCLEDs is expected to exceed that of conventional LEDs by more than a factor of ten (1994)
- Demonstration of delta doping in silicon for the fabrication of shallow junctions in scaled-down Si lightly-doped drain (LDD) MOSFETs for integrated circuits (Si ICs) (with colleague Dr. H. J. Gossmann, 1990 – 1995)
- Invention of a new concept, *superlattice doping*, for enhanced p-type doping of GaN. All acceptors in GaN are deep, resulting in a low electrical acceptor activation of only 5 %. The new concept of superlattice doping is expected to increase the electrical activation of acceptors by more than a factor of ten (with post-doctoral associate Dr. W. Grieshaber, 1995)

- Investigation of yellow luminescence in GaN and the use of microcavity effects in Ag / GaN / sapphire structures to determine the refractive index of GaN (with post-doctoral associate Dr. W. Grieshaber, 1996)
- Demonstration of the first GaN / GaInN double heterostructure laser. The laser has cleaved facets and was optically pumped. Laser action was demonstrated by (i) a threshold in the light-versus-current characteristic, (ii) spectral narrowing below  $kT$  above threshold, (iii) a TE / TM polarization ratio greater than one hundred above threshold, and (iv) increased slope efficiency with increasing back-side facet reflectivity (with graduate student D. A. Stocker, 1997)
- Co-inventor of photonic-crystal light-emitting diode, PC-LED, jointly with group of Prof. John D. Joannopoulos at MIT (publication by Shanhui Fan *et al.* appeared in *Physical Review Letters* in 1997; US patent 5,955,749 was issued in 1999)
- First demonstration of crystallographic etching of GaN (with graduate student D. A. Stocker, 1998). The discovery, crystallographic etching, can be implemented by wet chemical etching, including photo-enhanced electrochemical (PEC) wet etching. The discovery is widely used in the LED industry to strongly enhance light extraction from LED chips and is found in LED light bulbs.
- Experimental demonstration of a ten-fold enhancement of p-type doping activation in  $\text{Al}_x\text{Ga}_{1-x}\text{N}$ /GaN doped superlattices as compared to bulk GaN and  $\text{Al}_x\text{Ga}_{1-x}\text{N}$  (with graduate students D. A. Stocker and I. D. Goepfert, 1999)
- Invention and demonstration of the photon-recycling semiconductor light-emitting diode (PRS-LED) which emits *white* light and many other colors with very high luminous performance of  $> 300 \text{ lm/W}$  (with graduate students X. Guo and J. W. Graff, 1999). Invention of the monolithically integrated GaInN/GaN PRS-LED (with graduate students X. Guo and J. W. Graff, 2000)
- Invention and demonstration of polarization-enhanced ohmic contacts in p-type and n-type GaN (with graduate students Y.-L. Li and J. W. Graff 2000)
- Invention and demonstration of AlGaInP light-emitting diode with omni-directional reflector (ODR) for high light extraction efficiency (with post-doctoral associate Th. Gessmann and graduate student J. W. Graff, 2001)
- Developed novel model for high diodes ideality factors ( $n \gg 2.0$ ) in UV LEDs based on multiple rectifying elements (with graduate student J. M. Shah and Prof. Th. Gessmann, 2003)
- Developed new class of materials, low-refractive index materials, or low- $n$  materials, with an unprecedented low refractive index of  $n < 1.10$ ; use of these materials as low- $k$  materials for inter-metal-layer dielectrics in Si lightly-doped drain (LDD) MOSFETs in conjunction with ALD-deposited high- $k$  gate dielectric MOSFETs for integrated circuits (Si ICs) (with Dr. Jong Kyu Kim, "JQ" Xi, Professors Joel Plawsky, Bill Gill, starting in 2003)
- Developed theory for temperature coefficient of forward voltage in light-emitting diodes, particularly UV light-emitting diodes (with graduate student Yangang "Andrew" Xi, Dr. Jong Kyu Kim, and collaborators at Sandia National Laboratories, 2004, 2005)
- Invented highly efficient "remote phosphor configurations" in white light-emitting diodes (with Jong Kyu Kim, Hong Luo, and collaborators at SAIT-Samsung) (2004, 2005)
- Discovered whispering gallery modes in white LEDs with remote phosphors (with graduate student Hong Luo, Jong Kyu Kim, Yangang "Andrew" Xi, and collaborators at SAIT-Samsung, 2005)
- Developed graded-index antireflection coatings that, unlike conventional anti-reflection coatings, have broadband omni-directional characteristics; the graded-index antireflection coatings use novel low- $n$  materials (with Jingqun "JQ" Xi, Jong Kyu Kim, 2007)
- Developed efficiency-droop reducing GaInN / GaInN and GaInN / AlGaInN LED active regions grown by MOCVD and ALE that were demonstrated to reduce the efficiency droop by as much as 40% (with Jong Kyu Kim, Martin F. Schubert, Di Zhu, Jiuru Xu, Mary Crawford, and Dan Koleske, starting in 2007)
- Developed analytic model for efficiency droop based on drift-induced reduction of the carrier-injection efficiency (with Guan Bo Lin, Jaehee Cho, and others, 2012)

### **Honors and awards**

- Google Scholar profile, including the Hirsch-index (h-index) can be found at <http://scholar.google.com> > under profile "E. Fred Schubert"
- Elected to *Senior Member* of the *IEEE* "in recognition of professional standing" (1993)
- Recipient of the Literature Prize of the *Verein Deutscher Elektrotechniker (VDE)* for "Doping in III-V semiconductors" (Cambridge University Press, Cambridge, 1993). Citation: "The book concerns all aspects of doping in III-V semiconductors. Fundamental, practical, and technological issues of doping are addressed. The book covers the basic theory of shallow donors, shallow acceptors, deep levels, and their influence on the free carrier concentration. It also discusses doping during growth, epitaxy, diffusion, and ion implantation. In the field of semiconductor devices, the book emphasizes applications requiring highly controlled doping distributions. It is an excellent monograph equally suited for study, research, and industry" (1994)

- Elected as a member of the *Bohemian Physical Society* (Cornell University, Ithaca, NY). Citation: “For seminal contributions to the control of spontaneous emission by use of wavelength-size optical cavities, specifically the first demonstration in a glass host using rare earth implanted Si/SiO<sub>2</sub> resonant microcavities” (1994)
- Listed in “Who’s Who In Science And Engineering” and “Who’s Who in America” published by *Marquis Who’s Who*, publishers of the original *Who’s Who in America*. (*Marquis Who’s Who*, New Providence, NJ) ISBN 0-8379-5755-9 (1996 – present)
- Elected Fellow of the *SPIE* “For pioneering research in semiconductor doping and sustained contributions to the development of high-efficiency light-emitting diodes and lasers”. According to the Society’s bylaws, a Fellow “shall be distinguished through his achievements and shall have made outstanding contributions in the field of optics, or optoelectronics, or in a related scientific, technical, or engineering field” (1999)
- Recipient of the *Alexander von Humboldt Senior Research Award* of the Alexander von Humboldt Foundation, a Bonn-based non-profit organization promoting the exchange of scientific knowledge between German and highly qualified foreign scholars. According to the Alexander von Humboldt Foundation, academic qualification is the only selection criterion for the award. The award resulted in two extended visits with the Microoptics Laboratory of Professor Jürgen Jahns at the University of Hagen, Germany (1999)
- Elected to *Fellow of the IEEE* “for contributions to semiconductor doping and resonant-cavity devices”. According to the IEEE definition “the grade of Fellow is one of unusual professional distinction conferred by the Board of Directors only upon a person of extraordinary qualifications and experience” (1999)
- Listed in the “Dictionary of International Biography, 29<sup>th</sup> Edition” published by the *International Biography Center*, Cambridge, United Kingdom (2000)
- Recipient of the 2000 *Discover Magazine Award for Technological Innovation* presented by the *Christopher Columbus Foundation* in the category “Energy”. The prize was awarded “for the invention and demonstration of the photon recycling semiconductor light-emitting diode”, an all-semiconductor LED capable of emitting white light with very high efficiency, see < [www.discover.com/awards](http://www.discover.com/awards) > (2000)
- Recipient of the *RD100 Award* of the R&D Magazine that honors the “100 most technologically significant products of the year” (with Klaus Streubel of Osram-Sylvania Corp. and Rickard Marcks von Wurtemberg of Mitel Corp.). The prize was awarded for the “*Resonant-cavity light-emitting diode*” that uses enhanced spontaneous emission occurring in resonant cavities. The device is used in plastic optical fiber communication links, in telescopes for rifles, and many other applications (2000).
- Elected to *Fellow of the OSA* “for the invention and demonstration of the resonant-cavity LED and the photon-recycling semiconductor LED”. OSA Fellows are elected by the OSA Board of Directors (2001)
- Recipient of the Boston University Provost Innovation Fund Award (Provost Dennis D. Berkey) valued at \$ 25,000 for research and development of promising technologies (2001)
- Elected to *Fellow of the APS* “for pioneering contributions to the doping of semiconductors including delta doping, doping of compositionally graded structures resulting in the elimination of band discontinuities, and superlattice doping to enhance acceptor activation” (2001)
- Honored with RPI Medal as Senior Constellation Chair during Investiture Ceremony (2002)
- Received “2002 Rensselaer Polytechnic Institute Trustee Faculty Achievement Award” (2002)
- Inducted as Wellfleet Senior Constellation Professor, Future Chips, Rensselaer Polytechnic Institute, November 21 (November 2003)
- Distinguished Lecturer of the IEEE Electron Devices Society (2003–2006)
- Elected member in Eta Kappa Nu (2004)
- “Best Oral Presentation Award” was won by Ph. D. student Hong Luo (who was the presenter), J. K. Kim, Y. A. Xi, J. M. Shah, Th. Gessmann and E. F. Schubert “Improvement of extraction efficiency of GaInN light-emitting diodes by employment diffuse omni-directional reflectors” *Connecticut Microelectronics & Optoelectronics Consortium (CMOC)*, 14th annual symposium, New Haven CT, March 17 (March 2005).
- “Best Student Poster Award” of the *International Semiconductor Device Research Symposium (ISDRS)* was won by Ph. D. student J.Q. Xi (presenter), Jong Kyu Kim, Dexian Ye, Jasbir S. Juneja, T.-M. Lu, Shawn-Yu Lin, and E. Fred Schubert “Optical Thin Films with Very Low Refractive Index and Their Application in Photonic Devices”, *International Semiconductor Device Research Symposium (ISDRS)*, Dec. 7–9, Bethesda, MD (December 2005)
- “MRS Silver Award” of the Materials Research Society was won by Ph. D. student Yangang Andrew Xi (who was the presenter), K. X. Chen, F. Mont, J. K. Kim, C. Wetzel, E. F. Schubert, W. Liu, X. Li, J. A. Smart “Extremely high quality AlN grown on (0001) sapphire by using metal-organic vapor-phase epitaxy” *Materials Research Society (MRS) Fall Meeting*, Boston MA, November 27 – December 1 (2006) Boston MA (December 2006)
- “25 Most Innovative Micro- and Nano-Products of 2007 Award” in July 2007 issue of *R&D Magazine* and *Micro/Nano Newsletter*. This recognition was given for the “Non-Reflective Coating” product that was published in *Nature Photonics* in 2007; full citation: Xi, J.-Q., Martin F. Schubert, J. K. Kim, E. F. Schubert,

- Minfeng Chen, Shawn-Yu Lin, Wayne Liu, and Joe A. Smart “Optical thin-film materials with low refractive index for broadband elimination of Fresnel reflection” *Nature Photonics* **1**, 176, March 2007 (July 2007)
- “SCIENTIFIC AMERICAN 50 AWARD” of 2007, as published in the January 2008 issue of *Scientific American*. According to the *Scientific American Magazine*, this award “celebrates visionaries from the worlds of research, industry and politics whose recent accomplishments point toward a brighter technological future for everyone” (January 2008)
  - “EDITORS’ CHOICE” of *Science Magazine*, *Science*, Volume **319**, page 1163, February 29 (February 2008). This distinction was awarded for the publication: Jong Kyu Kim et al., “Light-extraction enhancement of GaInN light-emitting diodes by graded-refractive-index indium tin oxide anti-reflection contact” that appeared in *Advanced Materials* **20**, 801, 2008 (February / March 2008)
  - Received “2008 Rensselaer Polytechnic Institute Trustee Faculty Achievement Award” (2008)
  - “Best Oral Presentation Award” won by David J. Poxson (who was the presenter), Frank W. Mont, Jong Kyu Kim, and E. Fred Schubert “Multilayer nano-structured anti-reflection coating with broad-band omni-directional characteristics” *Connecticut Microelectronics and Optoelectronics Conference (CMOC)*, University of Connecticut, Storrs, Connecticut, April 9 (April 2008)
  - “Best Oral Presentation Award” for presentation: David Meynard, Sameer Chhajed, Jaehee Cho, E. Fred Schubert, Jong Kyu Kim, Daniel D. Koleske, and Mary H. Crawford “Temperature-dependent light-output characteristics of GaInN light-emitting diodes with different dislocation densities” *Connecticut Microelectronics and Optoelectronics Consortium (CMOC) Symposium*, New Haven CT, March 2 (March 2011)
  - Identified as top 1% of patentees in the field of optoelectronics by study conducted by Professor Erica Fuchs of Carnegie Mellon University under a study supported by the US National Science Foundation (July 2011)
  - Received “2012 Rensselaer Polytechnic Institute Trustee Faculty Achievement Award” (November 2012)
  - My “LinkedIn” profile was one of the top 10% most viewed “LinkedIn” profiles during 2012 (January 2013)
  - My graduate student, Mr. Ming Ma, received the \$ 30,000.00 Lemelson-Rensselaer Student Prize for the invention entitled “Graded-refractive-index (GRIN) structures for brighter and smarter light-emitting diodes”; The Prize is awarded annually by the Lemelson Foundation (March 2013)
  - Received the IEEE Life Fellow Award (2022)

### ***Service to the technical community***

- Current or former member of the *American Physical Society* (Member of the *Division of Materials Physics*, Member of the *Division of Condensed Matter Physics*), *Institute of Electrical and Electronics Engineers*, *Materials Research Society*, *Optical Society of America*, *Society for Optical Engineering (SPIE)*, and the *Verein Deutscher Elektrotechniker*
- Co-author of hundreds of research articles, co-inventor of more than 30 United States patents, and numerous foreign patents (1981 – present)
- Gave many invited talks at scientific conferences organized by the *American Physical Society*, *Institute of Electrical and Electronic Engineers*, *Materials Research Society*, *SPIE (The International Society for Optical Engineering)*, *Electrochemical Society*, *American Vacuum Society*, *Engineering Foundation*, and other professional societies (1985 – present).
- Co-editor (with A. M. Glass) of a Special Issue of the *Journal of Optical and Quantum Electronics* (Vol. **22**, 1990) on “Charge-transport assisted optical non-linearities in semiconductors” (1990)
- Symposium chair of the *American Vacuum Society Greater New York and New Jersey Chapter* on “Epitaxially grown semiconductors with atomic level control” (1991).
- Moderator of MRS Internet discussion on “Doping and Dopants in GaN” (*MRS Internet Journal*, 1995 – 1997)
- Member of review panels of the National Science Foundation (1995 – present)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (1997)
- Technical work has been featured in popular journals, magazines and newspapers including the *New Scientist*, *Discover Magazine*, *Wall Street Journal*, *Boston Globe*, *Focus*, and on National Public Radio (1996 – present)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (1998)
- Program Committee Member: IEEE IEDM, International Electron Devices Meeting (1999 and 2000)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (1999)
- Program Committee Member: ISBLLED, International Symposium on Blue Laser and Light-Emitting Diodes, Berlin, Germany, March 5 – 10 (2000)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (2000)

- Conference Chair and Co-Organizer of the TMS- and ONR-sponsored conference on “Doping, Dopants, and Low Field Carrier Dynamics in Wide Gap Semiconductors”, Copper Mountain, Colorado, April 2 - 6 (2000)
- Chair, IEEE LEOS, Central New England Chapter. During my tenure as Chair, the Central New England Chapter won the IEEE LEOS Chapter award for the highest membership growth (1999–2000)
- Expert Witness involving semiconductor materials, devices, and packaging including elemental and compound semiconductors such as Si, SiGe, SiC, as well as III–V arsenides, phosphides and nitrides (1998–present)
- Member of the Board of Governors, IEEE Laser and Electro-Optics Society (LEOS) (1999–2000)
- Member of the Optoelectronics Industry Development Association (OIDA) Roadmap Panel on Solid-State Lighting, Albuquerque NM Oct. 26–28 (2000)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (2001)
- Panel Member of National Research Council meeting on “Solid-State Lighting:” held at NAS and NAE, Washington DC, March 26 (2001)
- Program Committee Member of SPIE Photonics West conference on “Laser and LED Applications” chaired by Dr. Kurt Linden, San Jose CA Jan (2002)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose, CA (2002)
- Program Committee Member: ISBLLED, International Symposium on Blue Laser and Light-Emitting Diodes, Cordoba, Spain, March 11–15 (2002)
- Program Committee Member for subcommittee on “Semiconductor lasers and LEDs” for OSA Conference on Lasers and Electro-Optics and Quantum Electronics and Laser Science Conference (CLEO / QELS) (2002–2003) Baltimore MD June 1–6 (2003)
- Reviewer for the National Research Council of report entitled “Partnerships for Solid-State Lighting: Report of a Workshop” authored by the Board on Science, Technology, and Economic Policy. This report is forwarded to the US Congress for the initiation of a national Solid-State Lighting Initiative. (2002)
- Program Committee Member “Lester Eastman conference on high performance devices” University of Delaware, Newark, Delaware, August 6 – 8 (2002)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose CA (2003)
- OIDA Next Generation Lighting (NGL) Consortium. Member of “Light-Emitting Diode” Committee (2003)
- Program Committee Member, International Semiconductor Device Research Symposium (ISDRS) Washington DC, Dec. 8 – 12 (2003)
- Program Committee Member of “Display and Solid-State Lighting Devices” conference for OSA/IEEE Conference on Lasers and Electro-Optics (CLEO) (2003 – 2004)
- Elected Member of the IEEE Electron Device Society Administration Committee (IEEE AdCom) (2003–2008)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose CA (2004)
- Program Committee Member “Fourth International Conference on Solid-State Lighting” August 2 – 6 Denver, CO (2004)
- Program Committee Member for the “Blue 2004: Advanced LEDs and Lasers Conference” Hsinchu, Taiwan, May 10–12 (2004)
- Conference Chair of SPIE Photonics West conference on “Light-emitting diodes: Research, Manufacturing, and Applications” San Jose CA (2005)
- Program Committee Member “International Semiconductor Device Research Symposium” December 7 – 9 Washington, DC (2005)
- Chair of “Display and Solid-State Lighting Devices” conference of OSA/IEEE Conference on Lasers and Electro-Optics (CLEO) (2005)
- Best Oral Presentation Award (Presenter: Hong Luo) at *Connecticut Microelectronics & Optoelectronics Consortium* (CMOC), 14th annual symposium, New Haven CT, March 17 (March 2005)
- Conference Chair of MRS Spring meeting “Symposium DD: Solid-State Lighting Materials and Devices” San Francisco, April 17–21 (April 2006)
- Member on the International Advisory Committee of *First International Conference on Display LEDs* (ICDL 2007), Seoul, Korea, January 31 to February 2 (2007)
- Member, Program Committee of *SPIE Photonics West* conference “Light-Emitting Diodes: Research, Manufacturing, and Applications XI” San Jose, CA, January 20 – 25 (2007)
- Program Chair of *SPIE Photonics West* conference “Semiconductor Lasers and LEDs” San Jose, CA, January 20 – 25 (2007)
- Member, Executive Organizing Committee *SPIE Photonics West* conference “LASE 2007” San Jose, CA, January

20–25 (2007)

- Opto Track Chair of *SPIE Photonics West* conference “Semiconductor Lasers and LEDs” San Jose, CA, January 21 –24 (January 2008)
- Member, Program Committee, Light-emitting diodes: Research, Manufacturing, and Applications, SPIE Photonics West 2008, San Jose, California, January 19 – 24 (January 2008)
- Program Committee Member of the 7th International Symposium on Semiconductor Light Emitting Devices (ISSLED-2008) held in Phoenix, Arizona (USA), April 27 – May 2 (April 2008)
- Member, Program Committee, China SSL 2008, Shenzhen Convention & Exhibition Center, China, July 24 – 26 (July 2008)
- Member, Program Committee, International Workshop on Nitride Semiconductors, IWN 2008, Montreux, Switzerland, October 6 – 10 (October 2008)
- Opto Track Chair of *SPIE Photonics West* conference “Semiconductor Lasers and LEDs” San Jose, CA, January 25 – 29 (January 2009)
- Guest Editor of Special Issue on *Solid-State Lighting* published in the *IEEE Journal of Selected Topic in Quantum Electronics*, July / August edition (August 2009)
- Honorable Conference Chair, 6th China International Forum on Solid-State Lighting (China SSL), Shenzhen Convention & Exhibition Center, China, October 14 – 16 (October 2009)
- Program Committee Member, International Conference on Nitride Semiconductors (ICNS), Jeju, South Korea, October 18 – 23 (October 2009)
- Program Committee Member, The Second International Conference on White LEDs and Solid-State Lighting, Taipei, Taiwan, December 13 – 16 (December 2009)
- Editor, *Compound Semiconductors and Energy Applications and Environmental Sustainability*, Materials Research Society (MRS) Symposium Proceedings Volume 1167 (MRS, Warrendale PA, 2009)
- Conference Chair, OPTO, *SPIE Photonics West 2010*, San Francisco, California, January 23 – 27 (January 2010)
- Guest Editor of Special Issue on *Light-Emitting Diodes* published in the *IEEE Transactions on Electron Devices* (January 2010)
- Program Committee Member, *8th International Symposium on Semiconductor Light Emitting Devices (ISSLED)*, Beijing, China, May 16 – 21 (May 2010)
- International Advisory Committee Member of the 16th *Microoptics Conference (MOC’10)* held in Hsinchu, Taiwan, sponsored and endorsed by OSA and IEEE/Photonics Society and organized by National Chiao Tung University, Oct. 31 to Nov. 3 (October 2010)
- Member of Academic Committee of *China Solid-State Lighting Conference (CHINA SSL 2010)* Shenzhen, China, October 14 – 16 (October 2010)
- Conference Co-Chair, OPTO, *SPIE Photonics West 2011*, San Francisco, California, January 22–27 (January 2011)
- Executive Organizing Committee OPTO, *SPIE Photonics West 2011*, San Francisco, California, January 22–27 (January 2011)
- Program Committee Member of conference entitled: “Light-Emitting Diodes: Materials, Devices, and Applications for Solid-State Lighting XV *SPIE Photonics West 2011*, San Francisco, California, January 22–27 (January 2011)
- Member of CLEO Subcommittee 15, entitled “LEDs, Photovoltaics and Energy-Efficient (“Green”) Photonics” for the 2011 Conference on Lasers and Electro-Optics (CLEO), Baltimore, Maryland May 1– 6 (May 2011)
- Member of the Academic Committee of the 8th China International Forum on Solid-State Lighting (CHINA-SSL-2011) Guangzhou November 8–10 (November 2011)
- Program Committee Member of conference entitled: “Light-Emitting Diodes: Materials, Devices, and Applications for Solid-State Lighting XV *SPIE Photonics West 2012*, San Francisco, California, January 21–26 (January 2012)
- Member of CLEO Subcommittee 15, entitled “LEDs, Photovoltaics and Energy-Efficient (“Green”) Photonics” for the 2012 Conference on Lasers and Electro-Optics (CLEO), San Jose, California, May 6–11 (May 2012)
- Member of Academic Committee of the 9th China International Forum on Solid-State Lighting (CHINA SSL 2012), Guangzhou, China, November 5–7, 2012 (November 2012)
- Program Committee Member of conference entitled: “Light-Emitting Diodes: Materials, Devices, and Applications for Solid-State Lighting XVI *SPIE Photonics West 2013*, San Francisco, California, 2–7 February 2013 (February 2013)
- Member of CLEO Subcommittee in the topic area: “Science & Innovation 15: LEDS, Photovoltaics and Energy-Efficient (“Green”) Photonics” for the CLEO 2013 conference, April 28–May 3, 2013 in Baltimore, Maryland (May 2013)
- Member, International Advisory Committee of the International Conference on Advanced Electromaterials (ICAE 2013) held on Jeju Island, Korea, from November 12–15, 2013 (November 2013)

- Program Committee Member, *Solid-State and Organic Lighting (SOLED)*, OSA Topical Meeting, 3–7 November 2013, Marriott Tucson Star Pass, Tucson, Arizona, USA (November 2013)
- Co-Chair, OPTIC International Conference, Chung Li, Taiwan, National Central University, December 5–7, 2013 (December 2013)
- Program Committee Member of conference entitled: “Light-Emitting Diodes: Materials, Devices, and Applications for Solid-State Lighting XVII” *SPIE Photonics West 2013*, San Francisco, California, 1 – 8 February (2014)
- Publication Committee Member, *5th International Conference on White LEDs and Solid-State Lighting* (White LEDs), Jeju Island, Korea, May 25–28, 2014 (May 2014)
- Sub-Committee Chair of Track 6: Displays, Solid-State Lighting, Photovoltaics, and Energy-Efficient Photonics of *Asia Communications and Photonics Conference 2014* (ACP 2014). ACP is the largest and the most influential conference in Asia and Pacific Rim for communications and photonics technologies. ACP 2014, Shanghai International Convention Center, Shanghai, China, November 11–14 (2014)
- International Consultant of technical seminar of the 11th China International Forum on Solid-State Lighting (SSL-China 2014) Guangzhou, China, November 6 – 8 (2014)
- Member of the International Advisory Committee of the 11th International Symposium on Semiconductor Light Emitting Devices (ISSLED 2017) held in Banff, Canada on October 8 – 13 (2017)
- Assisting the US Judicial Government Branch (various US District Courts), the USPTO (US Patent and Trademark Office) and the ITC (International Trade Commission) by serving as an independent Technical Expert Witness (1997 to present)

### Books

- ***Doping in III-V semiconductors*** (author) Hardback and paperback, 628 pages (Cambridge University Press, Cambridge, UK, 1993). The following excerpt is from a book review by D. L. Miller, *University of Pennsylvania*, University Park PA, which appeared in *Physics Today*, Oct. 1994, p. 71: “[...] Fred Schubert has written a book that very nicely fills two roles: It serves as a reference volume for those of us who use III-V materials, and it provides enlightening explanations of interesting and important problems in semiconductor physics. [...] Schubert, who is employed by AT&T Bell Laboratories, brings his extensive research involvement with III-V materials physics straight to this book. His lucid explanations of some of the important physics of doped semiconductors is a major strength. For example, the chapter on deep centers provides the clearest treatment of the DX center I can remember reading, and it uses the large lattice distortion model and configurational coordinates introduced for the DX center to describe the EL2 deep level. This book can also serve as an excellent reference volume, because it briefly describes epitaxial growth techniques and the doping methods used with them, catalogs dopant-related phenomena, describes characterization techniques and provides 45 pages of citations to published articles and books. [...] I will use it to help my graduate students in the physics of semiconductors. [...] It will certainly be available on my bookshelf, in part to remind me what the Burstein-Moss shift is and in part for the literally hundreds of references that it provides on nearly every topic related to III-V semiconductor doping. Because of its clarity in treating some interesting phenomena of modern semiconductor physics, you too might want to get a copy of this book, even if you believe that Ga and As are just poor alternatives for doping silicon”
- ***Delta doping in semiconductors*** (editor) Hardback and paperback, 616 pages (Cambridge University Press, Cambridge, U. K., 1996)
- ***Light-emitting diodes*** (author) Hardback and paperback, 328 pages (Cambridge University Press, Cambridge, UK, 2003). The following excerpt is from a book review by David Bour, *Agilent Laboratories*, Palo Alto CA, which appeared in *Physics Today*, Nov. 2004, p. 66: “[...] In “*Light-emitting diodes*”, E. Fred Schubert provides an excellent review of the physics and technology of semiconductor LEDs. [...] Interesting anecdotes like [the first demonstration of electroluminescence], clearly written by someone with a broad perspective and expertise, appear throughout the book, making it enjoyable to read. [...] Schubert provides an excellent description of the undesirable [non-radiative] recombination pathway. [...] Schubert has made pioneering contributions to those devices, and this variety of LEDs may become more widely used in the future. [...] Overall, “*Light-emitting diodes*” is an excellent examination of the physics and technology of semiconductor LEDs. The narration is simple and direct, and the book is well referenced for those seeking a deeper understanding of the topic. Written for the graduate level, the text will appeal to a broad audience; and for specialists who make semiconductor LEDs and laser diodes, it will serve as a useful connection to the scientific literature.”
- ***Light-emitting diodes, second edition*** (author) Hardback, 422 pages (Cambridge University Press, Cambridge, UK, 2006)
- ***Physical Foundations of Solid-State Devices*** (author) eBook, 275 pages, ISBN-13: 978-0-9863826-2-8 (Google Books, Mountain View CA, 2015)

- **Light-emitting diodes, 3rd edition** (author) eBook, 672 pages with hundreds of colored illustrations, ISBN: 978-0-9 863826-6-6 (Google Books, Mountain View CA, 2018) “The 1st edition of the book “Light-Emitting Diodes” was published in 2003. The 2nd edition was published in 2006. The current 3rd edition of the book is a substantial expansion of the second edition and has 37 chapters. The book includes a thorough discussion of white light-emitting diodes (LEDs), phosphor materials used in white LEDs, packaging technology, and the various efficiencies and efficacies encountered in the context of LEDs. The background of light, color science, and human vision is provided as well. The fully colored illustrations of the 3rd edition are undoubtedly beneficial given the prominent role of light and color in the field of LEDs. The book is a comprehensive discussion of the LED, particularly its semiconductor physics, electrical, optical, material science, thermal, mechanical, and chemical foundations. The 3rd edition is published in electronic format in order to make the book affordable and easily accessible to a wide readership.”

### ***Courses and laboratories developed at Boston University***

- Developed first laboratory for “Physics of semiconductor devices” (SC-471) Fall (1998)
- Developed course “Quantum mechanics applied to semiconductor devices” (SC-574) Fall (1999)
- Developed course “Semiconductor light emitters” (SC-760) Fall (2000)
- Developed distance-learning course and NTU course on “Light-emitting diodes – Device physics and applications” Fall (2000)

### ***Courses taught at Boston University***

- Undergraduate Course “Physics of semiconductor devices” (SC-471)
- Graduate course “Fiber optic communication systems” (SC-563)
- Graduate course “Quantum mechanics applied to semiconductor devices” (SC-574)
- Graduate course “Introduction to solid-state physics of devices” (SC-577)
- Graduate course “Quantum electronics” (SC-700)
- Graduate course “Integrated optoelectronics” (SC-770)
- Graduate course “Compound semiconductor devices” (SC-771)
- Graduate course “Light-emitting diodes” (SC-760)
- Graduate course “Research seminar” (SC-860, SC-892)
- Other courses “Research”, “Guided Study”, “Master Thesis”, and “Dissertation” (SC-900)

### ***Courses taught at Rensselaer Polytechnic Institute***

- Graduate Course “Semiconductor devices and models II” (ECSE-6290)
- Undergraduate course “Microelectronics technology” (ECSE-2210)
- Undergraduate course “Fields and Waves 1” (ECSE-2100)
- Graduate course “Quantum mechanics applied to semiconductor devices” (ECSE-6968)
- Graduate course “Physical foundations of solid-state devices” (SC-6960)
- Graduate course “Light-emitting diodes and solid-state lighting” (SC-6961)
- Undergraduate course “Introduction to Electronics” (ECSE-2050)
- Other courses “Research”, “Guided Study”, “Master Thesis”, and “Dissertation”

### ***Teaching evaluations and students’ comments***

**1997** – Students made the following comments: “Clear ... organized ... excellent explanations ... I’ve never had a professor like him – I wish all were like him ... very clear and concise presentations ... strong response to students’ questions and concerns ... Professor provided excellent notes ... laid out lectures in a clear and precise manner which worked out wonderfully ... well organized and confident ... responsive to students’ concerns ... excellent for students going into the semiconductor industry ... excellent hand-outs and course materials ... well prepared ... clear lectures ... I was strongly encouraged ... materials are very interesting ... hand-outs were excellent ... material is very important ... the presentation of materials was very clear ... hand-outs were excellent support to the class ... efforts made by Prof. Schubert in keeping everyone at the same pace was remarkable ...”

**1998** – Students made the following comments: “Professor was always well prepared ... excellent content ... very relevant for the field of solid-state devices ... excellent preparation for the class ... handouts were very good ... very well-organized teacher ... excellent knowledge of material ... provided a complete background of all material ... easy to talk to ... excellent overall teaching skills ... really enjoyed coming to class ... his choice of topics and homework helped me a lot ... enthusiastic in teaching and helpful during the office hours ... one of the best professors I have had at BU ... course gave a very good overview of the different solid-state physics principles ... the course was very well organized ... relevant examples and homework were given ... good explanations were

given ... presented clearly ... presentation was clear ... communicated effectively ... very knowledgeable ... good demonstrations in class ... gives clear descriptions ... asks questions of class ... grades homework fairly ... good at answering questions ... no weak points ... excellent instructor and scientist ... inspiring professor ... thorough ... the instructor is very precise and well prepared ... his knowledge of the material is exact ... very responsive to feedback ... encourages student questions, class participation and discussion ... the instructor cared about whether students understood material ... the instructor used applications immediately after showing theory ... handouts were excellent ... guest lecture and lab tour excellent idea ... excellent class notes ... presented topics neatly ... well prepared ... review of ongoing research topics was great ... Professor Schubert is undoubtedly an expert in his area ..."

**1999** – Students made the following comments: "He enjoyed teaching the material and was very clear ... the presentation of the material in class was excellent ... he helped me to understand a lot about semiconductors ... Prof. Schubert always tried to make sure that we would all have a clear understanding of the material ... manuscripts were very helpful ... encouraged lots of class participation and was always readily available for help ... presentation was excellent ... the instructor was always willing to help me ... very helpful ... Clearly, Prof. Schubert is *more* than just extremely knowledgeable about this material ... very thorough and exact communication of points ... excellent course packet written by the instructor ... he was very well prepared for class ... He is extremely fair and encourages participation ... he is also very accessible ... excellent instructor ... very approachable and easy to ask questions of ... handouts were very effective and helpful ... Prof. Schubert is very prepared and concepts are well explained ... materials will be very useful for my future ... very open to questions"

**2000** – Students made the following comments: "He did a lot of experiments which really helped ... the material is very interesting and cutting edge ... clear presentations ... good in-class demonstrations ... very clear lectures ... the material really does challenge you ... takes the time to answer your questions ... very interesting material ... relevant to today's world of communication ... the field trip was fun ... in-class demonstrations really added to class ... good understanding of course material ... excellent details, willing to help, good explanations ... in-depth details on quantum mechanics ... the instructor was extremely accessible to students ... he encouraged participation in class ... he gave intuitive arguments and explained concepts in a very physical way ... I very much enjoyed Professor Schubert and would like to take more classes with him ... material was very beautiful ... I *very much* enjoyed the papers that were discussed ... everything is well organized ... hand-out material is very complete and clear ... lectures are clear ... the professor prepared an excellent manuscript ... explained things very clearly ... he has strong enthusiasm to solve students' questions ... it's a very important course ... Professor follows the course notes exactly, so one can concentrate on material without having to focus on details ... clearly presented material ... the course is great preparation for future courses in solid-state physics ... I greatly admire Professor Schubert ..."

**2001** – Students made the following comments: "He has a thorough understanding of the subject ... I like the fact that he shows us examples in class demonstrations ... the manuscript was good ... instructor provides good notes ... materials are presented clearly ... in this course you learn a lot ... very illustrative and in depth ... very interesting course ... Professor presented the material well ... Professor seemed to have a strong grasp on what he was teaching ... the basics were presented correctly ... smooth transition into more complex materials ... presented basics well ... Professor's strong points are knowledge, organization and class materials ... clear conception ... very important and useful class ... Professor knew what was going on ... manuscript and his notes were very helpful ... responded to suggestions ... notes were comprehensive ... just fine ... manuscript was good ... knows the material very well ... notes handed out are good ... expert knowledge of material ... developed lectures logically and straightforward ... lecture notes were prepared for us - very nice touch ... Professor has deep knowledge of the materials ... Professor is always prepared for lectures ... he emphasizes principles and the concepts ... good preparation ... good stuff and clear presentation ... good research and industry experience ... excellent handout notes and materials ... excellent teaching skills ... inspires the interest of students ... great knowledge of material ... well organized course notes ... Professor Schubert gave very clear instructions ... listening to his presentation is a true enjoyment of an excellent art of lecture style ... the manuscript has the quality of an excellent book ... the manuscript was an excellent reference source book ... the instructor was very clear and well organized and encouraged participation ... text [written by Schubert] was extremely good ... expert knowledge of materials ... class demonstrations were very beneficial ... can clearly relate complex ideas – very good ... has a high amount of patience ... excellent understanding of material ... very enthusiastic in teaching ... always available for discussion ... very knowledgeable ... I don't see any weak points ... he explains the theory very clearly ..."

**2002** – Students made the following comments: "Always prepared ... presented difficult material in a manner that was easy to understand ... presented everything neatly ... very helpful and organized ... presents subjects in a very easy and friendly format ... very well qualified ... great experience ... very detailed notes ... well organized ... very useful ... very good diagrams and explanations ... he knows the material extremely well ... notes given to us

are extremely helpful ... professor was very knowledgeable ... was able to answer any of our questions ... very informative course ... very knowledgeable and a great teacher ... the instructor is enthusiastic to teach students ... the instructor can explain the theory very clearly ..."

**2003** – Students made the following comments: "Great overall knowledge ... good organization skills ... demonstrations were very interesting and useful ... effective instructor ... handouts were extremely useful and organized ... good course for completely understanding many points of fiber optics ..."

**2004** – SPIE short course: "Encouraged questions and handled them well ... excellent short course ... I really appreciated and enjoyed this course ... good course – covered very broad matters ... the instructor was very knowledgeable on the topic ... excellent! ..."; RPI Semiconductor devices and models II (ECSE 6290): Overall excellence of teacher: 4.8 out of 5.0. Student comments: "course was very well prepared ... [course] was very organized ... this is an excellent course ... I learned a lot from this course ... the course was very good ... thanks Prof. Schubert for a wonderful course ... it's been a great course ... thank you ..." RPI Microelectronics Technology (ECSE 2210): Overall excellence of teacher: 4.7 (average 4.2). Overall excellence of course: 4.3 (average 3.9). Student comments: "Understandable presentation ... great job [of] Prof. Schubert ... very nicely done class ... very helpful throughout the entire course ... provided timely explanations to complicated material ... very informative ... course was fun and interesting ... very interesting lecturer ... very down to earth and easy to ask for help ... [instructor] did a good job in presenting [material] ... good course ... fun course ... excellent instructor ... he is a great guy and very knowledgeable ... I would definitely take a class from him again" **Book review** by Neal Oldham (San Jose, CA, USA) on "Doping in III–V semiconductors" (E. F. Schubert, Cambridge University Press, Cambridge UK, 1993) on amazon.com (May 17, 2002): "[This is the] best book I've encountered in the semiconductor field. This is, no question, the best book that I've encountered in the entire field of semiconductor physics. It is expertly organized and indexed, easy to follow, complete in its treatment of electrical and materials-science aspects of III–V semiconductor production and measurement, well-written ... worth every penny if you even have the most remote interest in the subject." **Book review** by Debdeep Jena (Santa Barbara, CA, United States) on "Doping in III–V semiconductors" (E. F. Schubert, Cambridge University Press, Cambridge UK, 1993) on amazon.com (July 6, 2001): "Very useful text for semiconductor crystal growers. Doping is a big, big issue in semiconductors; this text does appreciable justice in its treatment of the issue. In addition, Schubert treats heterostructure physics appreciably well (in fact better than many textbooks on semiconductor physics!). Perusal of this book has proved very rewarding for me, and I expect it will do the same wonder for you too."

**2005** – SPIE Photonics West short course student comments: "Very good instructor! ... very knowledgeable ... clear on complex subjects ... good job fielding questions ... (numerical score 4.3 out of 5.0). Educational materials on the web: ... I have greatly enjoyed your LED slideshow. CLEO short course: ... very good and well-organized course!" ECSE 6968: "Class presentations were very helpful in learning ... very useful in learning *the details* of fundamental concepts ... the course is very good ... the course is excellent for engineers ... your [...] treatment brought about a much better understanding ... examples were great and helpful ... [discussion of] history and photons [...] helped increase interest ... After your course now, I can actually approach a quantum mechanics text book without fear ... overall, I just wanted to say – *thank you* ... excellent course ... the instructor made it interesting and taught very effectively ... the manuscript provided was also very well written ... class was excellently structured ... will benefit my studies in the future ... especially liked the term paper requirement ... Prof. Schubert is an excellent instructor, who is well prepared ..." (excellence of instructor: 4.8 out of 5.0). SPIE Photonics North short course: "Very good and clear in presentation ..." (numerical score 4.4 out of 5.0). ECSE 6960 mid-course and final feedback by students: "Professor has provided all course materials ... I really appreciate it ... well presented ... technical support was great ... my learning experience has been good ... responses to my homework questions have been very timely ... I have enjoyed the course and found it interesting and useful ... homework assignments have been extremely beneficial ... the set of notes is very comprehensive ... good class structure ..." (numerical scores of students' course and instructor evaluation: 5.0 out of 5.0). Comment on web educational materials: "Notes look very thorough and clear ..."

**2006** – SPIE Photonics West short course student feedback: "Excellent, knowledgeable ... excellent presentation ..." (numerical score 3.91 out of 5.0). ECSE 6961 (Light-emitting diodes and solid-state lighting): "excellent ... Informative, comprehensive and interesting ... the best part of this course, in terms of my learning experience, has been the course materials ... just an outstanding class ... so much is newly discovered and so much is current on-going research and commercially relevant ... Dr. Schubert is obviously a leading researcher and did a great job of conveying his experience and understanding to the class ... a highly technical topic that still makes a good general conversational topic ... I liked the course material ... I liked the fact that Prof. Schubert lectured directly from the textbook ... I liked the structure of the course ... I learned a lot about lasers and LEDs and other optical devices ... it is a basic and fundamental class ... the instructor gives ideas, concepts, and samples very clearly ... very good course ... students interested in LEDs and solid-state lighting are strongly recommended to take it ... liked the overall coverage ... the teaching pace was good ... he covered a lot of material that is

important for the subject, but it was clearly always related to the topic ... the manuscript that he let us use was excellent in my opinion ... the most important thing I liked about the course was the course material and the structure of the course ... right amount of homework and the two exams and the term paper presentation ... it was great to learn this course from someone who is a world leader in this field ... well-organized material ... liked the course format ... organization was good ... allowed me to know exactly what we were covering so I could look through the material prior to the lecture ... course content was good, starting with LED basics and covering materials through modern technologies, and then a look at solid-state lighting and sort of an intro to communication devices ... good fundamentals in LEDs ... GREAT Professor ... awesome course ... informative course ... ability to view course materials online was helpful ... very fruitful course ... covering a lot of materials ... very good and very important for graduate students to take this one ... for people in industry it's also useful ... for the instructor, this course is thought through very clearly ... the text book is also very good ... great course ... excellent instructor ... cute instructor ... course is very good ... I benefited a lot from it ..." (numerical scores: 4.7 out of 5.0). ECSE 2210 (Microelectronics Technology) student comments "Excellent teaching method ... I like that the Professor asks random questions at the end of class – it helped me understand the subject better ... I thought Prof. Schubert was fabulous ... his organization of the class encouraged learning ... I highly recommend this class to everyone ... a devoted and involved teacher ... displayed more enthusiasm in teaching than other Professors I had ... he also seemed to have a philosophy about teaching that was beyond helping students get good grades ... he emphasized real-world applications of material and had general advice about working in the real world after leaving academia ... helpful ... although he was harder in grading and exams, Prof. Schubert challenged us more and made the course more interesting ... the many class activities provide lots of practice of materials just learned ... provided good back-up information ... made sure students understand concepts ... thank you for asking students questions during class to reinforce concepts ... thank you for allowing open book exams ..." (numerical scores: excellence of teacher 4.4 out of 5.0; excellence of course 4.3 out of 5.0; overall average of ratings 4.4 out of 5.0)

**2007** – Book review by Steven J. Wojtczuk (Lexington, MA, USA) on "Light-Emitting Diodes" (E.F. Schubert, Cambridge University Press, Cambridge UK, 2003) on amazon.com (March 14, 2006): "Schubert (RPI) has written an excellent book on LEDs that manages to explain and derive simple quantitative models for many phenomena of current interest ... many monographs are a compendium of results in the field with hundreds of references ... in contrast, Schubert, while giving copious references, is the sole author, leading to a coherent presentation well suited to learning ... there are plentiful and good figures and drawings, as well as many exercises and solutions integrated into the text ..." SPIE photonics West Short Course: "Excellent talk ..." ECSE 2210 (Microelectronics Technology) "Thank you ... great course ... excellent instructor ... interesting course ... appreciated that you did not lecture completely from the slides and that you probed the class to ensure that we were understanding the key points ... course is fine ... good professor ... Professor Schubert is one of the best lecturers I had ... the pace at which he moves the topic, the way he explains things, and the manner in which he asks students questions all came together to help me learn much more from his lectures than I could on my own ... instructors are absolutely very intelligent ... Professor Schubert was a good professor ... I actually learned things when Professor Schubert taught ..." ECSE 6968 (Physical Foundations of Solid-State Devices) "The instructor explained every concept in a very simple and effective manner ... I really enjoyed taking this course ..." (numerical scores: 4.5 out of 5.0)

**2008** – SPIE Photonics West short course feedback: "Very good ... clear ... very nice ... answered questions readily ..." (numerical score 4.3 out of 5.0) ... ECSE 6961 (Light-emitting diodes and solid-state lighting) feedback: "It was great for me to have the opportunities to take two consecutive classes, *Physical Foundation* and *LEDs*, from you ... both these classes have taught me a lot ... they were very well organized ... thank you for all the help ... I have really enjoyed your classes ... relevant material ... very good professor ..." (numerical scores: 4.3 out of 5.0) ... Internet educational materials feedback: "I recently came across your course notes while trying to get a basic understanding about semiconductors and I wanted to thank you. Your notes for course "ECSE-2210 Microelectronics Technology" are the most useful and informative thing I have found on semiconductors on the Internet. I'm a chemist by trade and this is a great introduction for me ..." 2007 Chautauqua Short Course and High School Teacher Summer Course, held at RPI June 26 and July 12, 2007 (numerical average of scores: 9 out of 10) ... ECSE 6968 (Physical Foundations of Solid-State Devices) feedback: "Prof. Schubert is one of the best professors I've ever had ... his ability to explain difficult and complex materials in a clear and concise manner is unmatched ... the presentations, although time consuming, I felt were a great idea ... thanks for your efforts professor! ... I have really enjoyed taking this course ..." By email: "Thank you professor ... it has been a pleasure taking this course with you ..." (numerical scores: 4.4 out of 5.0)

**2009** – SPIE Photonics West short course feedback by students: "One of the best short courses I have taken ... it was very nice to hear about the history of LEDs ... very interesting but also very theoretical ..." (numerical score 4.1 out of 5.0). ECSE 2210 (Microelectronics Technology) "Great course ... instructors were excellent ... encourages students to stay up to date with the subject matter ... Thanks for this well-organized class ... [the instructor] tries

to get students to come out with the best grade possible ... this was a good class ...” ECSE 6968 (Physical Foundations of Solid-State Devices) feedback by students: “It is really an excellent course ... clear hand script ... great professor! ...” (numerical scores: 4.7 out of 5.0)

**2010** – SPIE Photonics West short course feedback by students: “Good to get the latest data and charts ... very good ... very broad course and well organized ... it was great ...” (numerical score 4.04 out of 5.0) ... ECSE 6961 (Light-emitting diodes and solid-state lighting) feedback by students: “A good course ... this was a wonderful course ... it has given me a lot of understanding ... the course has inspired me to take up LED research ... useful ... straight forward ... very good advisor ... good course ...” (numerical scores: 4.3 out of 5.0) ... ECSE 6220 (Physical Foundations of Solid-State Devices) feedback by students: “Overall excellent course ... Professor Schubert is a good teacher ... he can explain every discipline very clearly and relate them to practical applications ... I like his teaching style very much ... overall, it was a nice course ... material explained in a clear organized manner ...” (numerical scores: 4.7 out of 5.0)

**2011** – SPIE Photonics West short course feedback: “Very nice overview ... instructor was excellent! ... very good instructor ... I would recommend lengthening to 6 hours ... excellent presentation, materials and text ... thanks ... very clear and easy to follow ... to be recommended ... excellent presentation ... good compromise for a person with a busy schedule ...” (numerical score 4.45 out of 5.0); ... ECSE 2210 (Microelectronics Technology) “This was a great course ... I enjoyed Professor Schubert’s views ... I was successful ... this course was taught very well ... this subject I now find quite interesting and am no longer intimidated by it ... I liked the material of this course ... thank you ...” (numerical scores: 3.3 out of 5.0); Feedback on book *Light-Emitting Diodes*: “I am a graduate student from National Chiao Tung University, Taiwan ... your wonderful book *Light-Emitting Diodes*, both first- and second-edition, gave me a lot of information and help ... I would like to ask when can the third of the masterpiece be published? I wish I can get it as soon as possible and study more about the lighting devices; Feedback on Internet pages: I found your website and information [...] quite enlightening and provides a great start ... I simply wish to quickly express my thanks and gratitude.” Feedback on book *Physical Foundations of Solid-State Devices*: “Dear Prof. Schubert, I have read your book *Physical Foundations of Solid-State Devices* and I must say it is amazing the explanations are really good and I am most thankful that you have decided to put the book online thank you.” Itamar Jade Balla, The Israel Institute Of Technology. Feedback on book *Light-Emitting Diodes* by Trung Nguyen (San Jose, California): “It is a good book about Light Emitting Diodes (LEDs). It provides very good info and it is a good reference for engineers who work in the LED field”; ... ECSE 6220 (Physical Foundations of Solid-State Devices) feedback: “Amazing course ... great instructor ... very good course ... The text and lectures were very useful and informative ... I definitely learned a lot from taking this course ... I liked the course materials! ...” (numerical scores: 4.6 out of 5.0)

**2012** – Feedback on Internet-based materials: “I’m Cheng Liu [Wuhan National Laboratory for Optoelectronics, China], currently a graduate student major in Physical Electronics ... I deeply admire your profound knowledge on this field and your unselfish sharing of it ...”; ... SPIE Photonics West short course feedback: “Dr. Schubert was very clear and very patient with people who had questions ... the materials were comprehensive ...”; Feedback on Internet-based materials: “Supremely-rich course contents posted on your website. Thank you very much for showing such awesome materials for the world to see ...” (Prof. Natee Tangtrakarn, Thailand) ... ECSE 6962 (Light-Emitting Diodes and Solid-State Lighting) feedback: “... very interesting course ... Professor Schubert did a great job explaining the material ... his textbook is very clear and understandable ... nice course ... I learned a lot of new things by taking it ...” (numerical scores: 4.7 out of 5.0)

**2013** – *SPIE Photonics West short course* feedback (SC-052, Light-Emitting Diodes): “Great instructor with admirable combination of knowledge in academic and commercial knowledge ... I appreciated the depth of his knowledge and experience ... the length of the course was good ... Overall this was an excellent course ... Thank you ... course is very easy and I understand it easily ... Excellent course! ... Instructor was fantastic -- clear, explicit, took questions as we went and answered well ... One of the best SPIE courses I've taken (and I've taken lots)! ... Great course -- thanks! ... I was happy that the slides were updated with 2012 data”. **RPI course numerical scores (ECSE-6962, Light-Emitting Diodes and Solid-State Lighting)**: Numerical score of students’ evaluations: 4.67 out of 5.0; Verbatim comments: “The course is pretty good ... needs no improvement ... I can appreciate the more wide-angle approach from the course ... These areas are very important and previously I had no knowledge of them ... It was a pleasure attending your class ...” **RPI course numerical scores (ECSE-6968, Physical Foundations of Solid-State Devices)**; Verbatim comments: “It has been an awesome experience of learning for me in this course ... Thank you for everything ... Thank you for the great semester ... Have a good break ... Thank you for the great semester ... Have a good break ... Professor, thank you for an engaging and interesting class this semester ... I enjoyed the subject of my paper and learned quite a bit particularly about GaN, which I had not had a chance to really do any research into before ... Very good and interactive class ... I liked the style of the class ... I thought the topics covered were very interesting ... I think I got much more out of the class this way than if we would have followed the manuscript chapter by chapter ...” Numerical score of students’ evaluations: 4.83 out of 5.0

**2014 – SPIE Photonics West short course** verbatim feedback (SC-052, Light-Emitting Diodes): “Very knowledgeable instructor ... the course was packed with information ... handouts are excellent ... Excellent presentation and contents ... the color rendering section which was interesting and fun ...” Numerical score of students’ evaluations: 4.36 out of 5.0; **RPI Course ECSE-2210 Microelectronics Technology**; Verbatim comments: “Instructor is clearly very knowledgeable about the topics ... Very clear and comprehensive ... This is the best class ever ... I'm quite enjoying this course ... I don't really have any recommendations on things to change ... The homework and lectures being sent out at the beginning was very helpful ... Both the TA and the professor were able to explain things very well ... I think he is a good lecturer ... I think the homework each was very, very good at teaching me the material, and the exam was fairly graded and easy to understand ... I definitely like the professor and I would have him again ... A good class ... I enjoyed Prof. Schubert's style of teaching ... I would still recommend Prof. Schubert as a professor ... Microelectronics is a good class ... Prof. Schubert keeps it interesting though ... he's a great professor ... The two TAs are also great ...” Numerical score of students’ evaluations of instructor: 4.25 out of 5.0. **RPI Course ECSE-6220 Physical Foundations of Solid-State Devices**; Verbatim comments: “The book and lectures seem to be entirely in sync with one another ... it really enforces the material covered in the book ... the material is covered thoroughly and improves students' understanding of quantum physics ... The class was interesting with excellent learning materials ... I loved how the course was so well organized ... The lectures were very well put together ...” Numerical score of students’ evaluations of instructor: 4.75 out of 5.0.

**2015 – SPIE Photonics West Short Course SC-052 titled Light Emitting Diodes**, Verbatim comments: “I was very satisfied with this short course” Numerical score of students’ evaluations: 4.53 out of 5.0; **RPI Course ECSE-6960 Light-Emitting Diodes**; Verbatim comments: “the class has been excellent! ... I've learned a good amount about LEDs ... Also I'd like to thank you for a great semester and say that you've peaked my interest in the LED field! ... I would like to add that the course was an excellent experience for me and that I really enjoyed learning about LED technology! ... Thank you very much for teaching such a wonderful class ... It was a great learning course” Numerical score of students’ evaluations: 5.0 out of 5.0. **RPI Course ECSE-2100 Fields and Waves 1**; Verbatim comments: “This class is going perfectly and I love the way it's run ... The material is great and understandable ... the pace is perfect ... I like the pacing of the course and the fact that we spend time really developing an understanding of the theory and concepts that we will be using ... I like the Professor ... The lectures are great ... I really enjoy this professor and he is very understanding of the students’ levels of learning and focused on that ... Professor Schubert is clear and easy to understand ... Overall a very good professor ... very knowledgeable and helpful ... I thought the professor was very knowledgeable and was an excellent instructor ...” Numerical score of students’ evaluations of instructor: 4.17 out of 5.0.

**2016 – SPIE Photonics West Short Course SC-052 titled Light Emitting Diodes**, Verbatim comments: “This has been my favorite course (over 3 years) ... Well-structured presentation, and well given ... I was surprised by how much I didn't know. I learned a lot ... Explained difficult concepts in a clear and simple manner ... Able to go "off script" to clarify during questions.” Numerical score of students’ evaluations: 4.56 out of 5.0; **RPI Course ECSE-2100 Fields and Waves 1**; Verbatim comments: “This is cool material ... This class was one of the most well put together I have ever taken in terms of lecture pace, lecture clarity, TA support, and quality of teaching and communication ... The lectures never felt too long or too short, the pace was good, I never felt lost or without an option to turn for help ... The homework was neither too long nor too short, and was well balanced with conceptual and quantitative questions ... Prof. Schubert's lecture style was very clear, concise, and to the point, with many useful examples in real life scenarios which made the material more interesting ... Very well done ... Great class ... I liked the pace of the class ... it helps with understanding the material a lot ... The labs [...] were fun and very educational ... Overall, I learned a lot from this course ... The speed of the class is perfect ... I really got a chance to learn ... This professor is very good ... Also, [in] the lab section I was able to really break down what I learned in class ... Schubert has the neatest handwriting of any professor I've ever had in my 3 years here ... His diagrams are extremely neat and he is easy to understand verbally too ... Lots of conceptual knowledge covered ... Overall [...] it was an enjoyable class ...” Numerical score of students’ evaluations: 5.0 out of 5.0. **RPI Course ECSE-2210 Microelectronics Technology**; Verbatim comments: “So far, this has been one of my favorite courses at RPI ... I'm a huge fan of Prof. Schubert's ability to clearly describe concepts both conceptually and mathematically ... Class activities [...] were really helpful! ... Otherwise the class is great! ... Prof Schubert knows his stuff ... Best professor I have had ... This course was well taught ... Professor Schubert's explanations were very clear and understandable ... he took time to address student questions with in-depth answers ... I feel as though I gained a lot from this course, especially with regards to explanations of why certain things in ECSE-2050 (Intro to Electronics) occur the way they do like where the diode property comes from and how material properties of electronic components give rise to the very real circuit characteristics we see in ECSE-2050 labs ... In this sense, Microelectronics Tech is a very good companion class to Intro to Electronics, and I highly recommend future students take them at the same time ... this was a quite good class ... Best MET instructor ... I was so actively engaged during the lectures that it was kind of scary ... The lecture notes and lectures were mostly great ... The material covered in it was succinct and interesting,

yet still covered the knowledge needed to tackle engineering problems in semiconductors ...” Numerical score of students’ evaluations: 4.64 out of 5.0.

**2017 – RPI Course ECSE-2100 Fields and Waves 1;** Verbatim comments: “I thoroughly enjoy this class ... Schubert is awesome! ... Enjoyed the class ... He is a good teacher ... Most teachers talk really fast making it hard to follow ... Schubert talks slow and explains things really well ... Professor Schubert is an excellent professor, and has been one of my favorites at RPI so far ... He made a difficult topic approachable, interesting and understandable ... I hope I have him as a professor in the future ... Thank you ... I enjoyed this class, especially the labs ... Lectures were good too ... great class! ... The professor does a great job of engaging the students by asking questions and making students ask questions to make them think about the labs ... This course is overall excellent in that the professor does know the pace of class and gives feedback appropriately ...”; Numerical score of students’ evaluations: 4.63 out of 5.0. **SPIE Photonics West Short Course SC-052 titled Light Emitting Diodes,** Verbatim comments: “the course covered a wide variety of concepts ...” Numerical score of students’ evaluations: 4.03 out of 5.0.

**2018 – RPI Course ECSE-2100 Fields and Waves 1;** Verbatim comments: “Professor Schubert is great and very entertaining to listen to in the lab and in lecture ... Really appreciate how Prof. Schubert structures lectures ... Schubert is great! ... The professor is excellent at relaying concepts ... This course is very interesting and it goes at a good pace ... One of the better professors here at RPI ... He cares about his students and helps them to learn the most through lectures and labs ... Fantastic course that goes into great detail into not only knowing the material but also understanding the material ... [the course] has been clarified and allowed for a greater learning process.” Numerical score of students’ evaluations of instructor: 4.17 out of 5.0. **RPI Course ECSE-6220 Physical Foundations of Solid-State Devices;** Verbatim comments: “Perfect professor, no complaints.” Numerical score of students’ evaluations (median): 5.0 out of 5.0.

**2019 – RPI Course ECSE-2100 Fields and Waves 1;** Verbatim comments by students: “Schubert is excellent in relating information in a practical manner especially in the lab ... Overall, both the professor and TAs prioritize if students understand material over semantics in reports and homework, which is really helping me in the course, and feedback given is incredibly helpful in both ... Schubert is a mystery. He speaks very slowly and clearly, but you somehow learn everything at a very fast rate ... Class [...] being just the right amount focused and adequately paced ... Overall great class ... Labs were educational and we were allowed to have fun with it ... Otherwise great lectures, notes were available and understandable ... this was one of my favorite classes ... Very well run by Schubert ... lectures were informative and easy ... labs were fun ... The TA's were allowed to have personalities and interact with the students ... 10/10 would take again ... Schubert was okay ... The best parts about the course for me were everything was online and I could copy the notes at my leisure with my busy schedule ... I also liked that exams were open book and we had a lot of opportunities for practice ... I have nothing but good things to say about both TAs and Professor Schubert – this has been my favorite class this semester ... Though challenging, I have found the course material very interesting and all teachers have been excellent ... Course was good ... I like Professor Schubert's class notes online. They're super well written and helpful.” Numerical score of students’ evaluations of instructor: 4.63 out of 5.0 (average) and 5.0 out of 5.0 (median).

**2019 – RPI Course ECSE-6280 Light Emitting Diodes;** Verbatim comments by students: “This was a great course ... I learned a lot during the semester ... Great class ... Really enjoyed Professor Schubert's expertise on the subject ... Gives both in-depth technical knowledge as well as high level background to better understand the driving factors of the LED industry ... Would highly recommend it to anyone in ECSE.” Numerical score of students’ evaluations: 4.83 out of 5.0 (average) 5.0 out of 5.0 (median).

**2020 – RPI Course ECSE-2100 Fields and Waves 1;** Verbatim comments by students: “I really enjoyed this class ... the cool labs with good help and good lectures made me really enjoy this class and help the information stick in my head better ... The labs provided a great use to show theory in practice and how certain concepts are applied to real-life applications ... The laboratory session was also a great time to ask questions and have in-depth talks about the material ... I would have already commended this professor for class organization and material availability prior to online courses (course material easily available, organized well, and easy to understand; interactive lectures; interactive labs better than most other ECSE courses), Prof. Schubert handled the change to online coursework best of all of my professors and maintained the quality of lecture almost perfectly ... The 'live' online classes were interactive and courteous by students and the professor, organized, and just as in-depth as before, even including miniature homemade demonstrations and experiments ... The course was taught very fundamentally which allowed me to think and learn more ... Thank you, Professor Schubert ... I really missed your live lectures and labs! ... Professor Schubert made the best of the situation of online learning ... Great class ... I learn a lot from this class ... I enjoy lab sessions and try never to miss any class ... Prof. Schubert is really good!” Numerical score of students’ evaluations: 4.75 out of 5.0 (average) 5.0 out of 5.0 (median).

**2020 – RPI Course ECSE-2050 Introduction to Electronics;** Verbatim comments by students: “I really enjoyed how easy it was to follow along with the lecture ... I really enjoyed the content of this course, and I feel that the

applications of this content in the lab were extremely effective to help students understand the content ... the concepts in general were extremely interesting ... I liked how the lecture sessions for this class provided much more room for discussion and examples than nearly any other ECSE course I have taken at RPI so far ... Schubert was very aware of the students ability to fully comprehend the topic ... He was very patient with the students that needed extra explaining ... I learned a lot about the course material ... I liked the one-on-one attention we received in the in-person lab ... I enjoyed the in person laboratory sessions, they were a good place to get all my questions answered ... I really like the lecture notes and the detailed diagrams / graphs that help explain the concepts ... Professor Schubert does a great job of breaking down the material, he always tries to engage the students in every lecture ... Very clear notes, responded quickly, answered any confusing questions really well, and very nice and accommodating towards the current COVID situation everyone is going through ... He had very organized notes that helped especially with the difficulties of online learning ... I loved the explanation of diodes, it's never been so clear to me before! ... Examples were excellent ... The course was great! ... I learned a lot and this course stimulated my interest ... Very engaging ... stimulates participation ... Professor Schubert was a refreshing exception ... the professor was very knowledgeable in the subject area ... explanations were clear and easy to understand ... I really like the format of this class compared to my other classes ... I really enjoyed the format ... Very detailed lecture, very helpful with students, made very complex material easy to understand ... Prof is really understanding and cares about his students ... He is really willing to work with us which I found is really rare at RPI ... He is easily one of the best professors I have had ... He cares most about whether we are learning and understanding, rather than following his desired schedule perfectly ... Cannot say anything bad about Prof Schubert ... Class is great" Overall instructor rating: 4 out of 5. Overall course rating: 4 out of 5.

**2021 – RPI Course ECSE-2050 Introduction to Electronics;** Verbatim comments by students: "Class has been going smoothly ... Professor Schubert includes real world-examples of devices in his lectures, showing the importance of our course materials ... He is always very considerate of students, trying to adapt to what would help people most ... He engages students in lectures." Overall instructor rating: 4.8 out of 5.0. Overall course rating: 4.6 out of 5.0.

**2021 – RPI Course ECSE-2050 Introduction to Electronics;** Verbatim comments by students: "Professor is always able to conceptually answer our questions, and run through circuit analysis with us if the results we're measuring don't match up ... I tried taking this class once before, and I failed it. This time around, I feel like I know everything about everything. I had never imagined just what a difference teaching style could make in my ability to learn information, but this class is so much more welcoming to me this time around. It was with a different professor the first time. I much prefer Professor Schubert and the way he conveys information so effortlessly. He also seems like he's passionate about teaching the information and his handwritten notes are astonishingly detailed ... Great professor! I appreciate Professor Schubert taking the time to clarify different topics and always checking in with the students. He seems to genuinely care about our education. He is strict about deadlines, more so than other professors at least, but I think he has earned that ... Professor Schubert is very friendly to his students ... He was very helpful and one of the few professors who actually stays and talks to students all throughout the lab period. It was very helpful because often I would think that I fully understood a concept and then he would ask a question that would either stump me or reinforce information. Additionally he kept lectures short and to-the-point, which I appreciate." Overall instructor rating: 4.3 out of 5.0. Overall course rating: 4.3 out of 5.0.

**2022 – RPI Course ECSE-2050 Introduction to Electronics;** Verbatim comments by students: "Great professor! ... Handwriting is amazing ... His notes are flawless and easy to understand ... This course covers much more than most other EE courses I've taken, and yet I feel as though this has been the easiest EE course due to his teaching abilities ... Professor Schubert is a very knowledgeable professor ... It's clear that he wants his students to learn ..." Overall instructor rating: 4.3 out of 5.0. Overall course rating: 4.4 out of 5.0.

**2022 – RPI Course ECSE-2210 Microelectronics Technology;** Verbatim comments by students: "I think Schubert does a great job of teaching ... He makes the pn junctions as interesting as he can ... I also love the chalk-board! So great, every professor should be forced to use it, because you can follow the work so smoothly (not like powerpoints) ... I would not change the class ... I also like how Prof. Schubert asks for feedback from everyone after class ... Course was at a great pace and the level of difficulty ... Professor Fred Schubert is one of my most favorite professors at RPI ... I am sad to see in the course schedule for Spring 2023 that he is not teaching any 4000 level ECSE courses ... I think that the department and students are missing out by not having someone as knowledgeable as him teaching more conceptually hard topics because Professor Schubert does that exceptionally ... Best ever lecture experience, clear structure of lecture notes, comprehensive homework that helps to improve students' understandings, and always eager to solve students' questions ... Thanks for another great course Professor!"

**2024 – RPI Course ECSE-2050 Introduction to Electronics;** Verbatim comments by students: "... It's great to learn how a component works and learn "Iconic Circuits" that use those components ... I really appreciated the

Homeworks, they were well thought out and helped me understand the content ... I liked the open notes exams, they allowed me to use the notes I took in class and demonstrate how I can apply the concepts we learned in class to a different problem ... I appreciated [Professor Schubert] talking to everyone in [the] lab one-on-one ... I also liked that he showed interest in all the students and answered our questions promptly and thoroughly ... Very nice and understanding professor, one of the best in the ECSE department ... Professor Schubert seems to know what he is talking about ... Professor Schubert is very nice and during labs walks around and asks students questions making sure we understand the concepts ... He also introduced some applications not taught in the previous versions of the course and even added a lecture on class-D amplifiers to attempt to keep the course up with modern technology ... The last few lectures left a good impression though and were extremely engaging ...”

### ***Post-doctoral & visiting personnel for which I served as Major Research Advisor***

Dr. Li-Wei Tu	Post-Doctoral Fellow	1988–1990
Dr. Neil Hunt	Post-Doctoral Fellow	1991–1993
Dr. Matthias Passlack	Post-Doctoral Fellow	1993–1995
Dr. Wolf Grieshaber	Post-Doctoral Fellow	1995–1997
Dr. Thomas Gessmann	Post-Doctoral Fellow	2000–2002
Dr. Jong Kyu Kim	Post-Doctoral Fellow	2003–2005
Dr. Min Ho Kim, SEMCo	Visiting Engineer	2007–2008
Prof. Ji-Myon Lee, Sunchon Univ.	Visiting Professor	2007–2008
Dr. Jaehee Cho	Post-Doctoral Fellow	2008–2009
Dr. Yongjo Park, Samsung LED	Visiting Vice President	2010–2012
Dr. Yangang Andrew Xi	Visiting Scientist	2013–2014
Dr. Guan-Bo Lin	Post-Doctoral Fellow	2014–2015

### ***Graduate students for which I served as Major Research Advisor***

Dr. Dean A. Stocker	Ph.D. Dissertation	Ph. D. completed in 1999
Xiaoyun (Jane) Guo	Master Thesis	M.S.E.E. completed in 1999
John W. Graff	Master Thesis	M.S.E.E. completed in 1999
Dr. Ian D. Goepfert	Ph.D. Dissertation	Ph. D. completed in 2000
Yun-Li Li	Master Thesis	M.S.E.E. completed in 2000
Dr. Xiaoyun (Jane) Guo	Ph.D. Dissertation	Ph. D. completed in 2001
Dr. John W. Graff	Ph.D. Dissertation	Ph. D. completed in 2002
Dr. Erik L. Waldron	Ph.D. Dissertation	Ph. D. completed in 2002
Jay M. Shah	Master Thesis	M.S.E.E. completed in 2002
Dr. Yun-Li Li	Ph.D. Dissertation	Ph. D. completed in 2003
Jingqun (“JQ”) Xi	Master Thesis	M.S. completed in 2003
Yangang Andrew Xi	Master Thesis	M.S. completed in 2003
Ronald Jackson	Master Thesis	M.S. completed in 2004
Sameer Chhajed	Master Thesis	M.S. completed in 2004
Hong Luo	Master Thesis	M.S. completed in 2005
Xiaolu Li	Master Thesis	M.S. completed in 2005
Kaixuan Chen	Master Thesis	M.S. completed in 2005
Dr. Jay M. Shah	Ph.D. Dissertation	Ph. D. completed in 2006
Frank Mont	Master Thesis	M.S.E.E. completed in 2006
Dr. Hong Luo	Ph.D. Dissertation	Ph. D. completed in 2006
Dr. Jingqun (“JQ”) Xi	Ph.D. Dissertation	Ph. D. completed in 2006
Dr. Yangang Andrew Xi	Ph.D. Dissertation	Ph. D. completed in 2006
Won Seok Lee	Master Thesis	M.S. completed in 2007
Qi Dai	Master Thesis	M.S. completed in 2007
Di Zhu	Master Thesis	M.S. completed in 2007
Jiuru Xu	Master Thesis	M.S. completed in 2007
Ahmed Noemaun	Master Thesis	M.S. completed in 2007
Roya Mirhosseini	Master Thesis	M.S. completed in 2008

David Poxson	Master Thesis	M.S. completed in 2008
Qifeng Shan	Master Thesis	M.S. completed in 2009
Ming Ma	Master Thesis	M.S. completed in 2010
Xing Yan	Master Thesis	M.S. completed in 2010
Dr. Roya Mirhosseini	Ph.D. Dissertation	Ph. D. completed in 2010
Dr. Sameer Chhajer	Ph.D. Dissertation	Ph. D. completed in 2010
Dr. Jiuru Xu	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Frank Mont	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Wonseok Lee	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Di Zhu	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Qi Dai	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Ahmed Noemaun	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. David Poxson	Ph.D. Dissertation	Ph. D. completed in 2011
Dr. Qifeng Shan	Ph.D. Dissertation	Ph. D. completed in 2012
Dr. Ann Mao	Ph.D. Dissertation	Ph. D. completed in 2013
Dr. Xing Yan	Ph.D. Dissertation	Ph. D. completed in 2013
Dr. Ming Ma	Ph.D. Dissertation	Ph. D. completed in 2013
Dr. David Meynard	Ph.D. Dissertation	Ph. D. completed in 2013
Dr. Guan-Bo Lin	Ph.D. Dissertation	Ph. D. completed in 2013

## Expert Witness Consulting Service

- 1997**    **Case:** Hewlett-Packard Company versus CEO of United Epitaxy Company (Taiwan)  
**Nature:** Trade secret misappropriation  
**Venue:** U.S. District Court.  
**Law firm:** Morrison & Foerster LLP, Washington DC.  
**Role:** I served as technical expert witness on behalf of United Epitaxy (Defendant). I wrote one or more expert reports.
- 1998**    **Case:** Hewlett-Packard Company versus United Epitaxy Company (Taiwan)  
**Nature:** Patent infringement.  
**Venue:** U.S. District Court for the Northern District of California.  
**Law firm:** Quinn Emanuel Urquhart Oliver and Hedges LLP  
**Role:** I served as technical expert witness on behalf of United Epitaxy (Defendant). I wrote one or more expert reports.
- 2006**    **Case:** Kerr Company versus 3M and Dentsply International Company.  
**Nature:** Patent infringement.  
**Venue:** U.S. District Court for the Western District of Wisconsin.  
**Law Firm:** Woodcock Washburn LLP, Philadelphia, Pennsylvania.  
**Role:** I served as technical expert witness on behalf of Dentsply (Defendant). I wrote one or more expert reports.
- 2006**    **Case:** Nichia Corporation (Japan) versus Seoul Semiconductor Company (Korea).  
**Nature:** Design patent infringement.  
**Venue:** U.S. District Court for Northern District of California, San Francisco Division.  
**Law firm:** Foley & Lardner LLP Washington DC.  
**Role:** I served as technical expert witness on behalf of Nichia (Plaintiff). I wrote one or more expert reports; I was deposed.
- 2008**    **Case:** Seoul Semiconductor (SSC) Company LTD (Korea) versus Nichia Corporation (Japan).  
**Nature:** Patent infringement.  
**Venue:** U.S. District Court for the Eastern District of Texas, Beaumont Division.  
**Law firm:** Morrison & Foerster LLP, Palo Alto, California.  
**Role:** I served as technical expert witness on behalf of Nichia (Defendant). I wrote one or more expert reports; I testified in District Court during the claim construction / Markman hearing.
- 2008**    **Case:** Professor Gertrude Rothschild versus Toshiba Company (Japan).  
**Nature:** Patent infringement.  
**Venue:** U.S. International Trade Commission (ITC), Washington DC.  
**Law firm:** DLA Piper LLP, San Francisco California.  
**Role:** I served as technical expert witness on behalf of Toshiba (Defendant). I wrote one or more expert reports; I was deposed.
- 2008**    **Case:** Honeywell Company versus Cree Company and Lumileds Company.  
**Nature:** Patent infringement and Reexamination of patent.  
**Venue:** U.S. District Court for the Eastern District of Texas, Marshall Division. Reexamination before the USPTO's Patent Trial and Appeal Board.  
**Law firms:** Paul Hastings LLP, Washington DC and Ingrassia, Fisher & Lorenz PC, Washington DC.  
**Role:** I served as technical expert witness on behalf of Honeywell (Plaintiff). I wrote one or more expert reports. I testified at the USPTO during a re-examination hearing.

- 2010** *Case:* Landmark Screens Company versus MLB Company and Kohler.  
*Nature:* Mishandling of a patent application.  
*Venue:* U.S. District Court for the Northern District of California, San Jose Division.  
*Law firm:* Keker & Van Nest LLP, San Francisco, California.  
*Role:* I served as technical expert witness on behalf of MLB and Kohler (Defendant). Negligence in conjunction with a patent application; I wrote one or more expert reports.
- 2011** *Case:* Koninklijke Philips Electronics N.V. versus Seoul Semiconductor (SSC) Company LTD.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for the Central District of California Southern Division  
*Law firm:* Latham & Watkins LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of SSC (Defendant). I wrote one or more expert reports.
- 2011** *Case:* Jeou-Nan Tseng versus Home Depot USA Inc. and Guangde LEDup Enterprise Inc.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for the Western District of Washington at Seattle.  
*Law firm:* DLA Piper, Philadelphia, Pennsylvania.  
*Role:* I served as technical expert witness on behalf of Home Depot (Defendant). I wrote one or more expert reports.
- 2011** *Case:* Lightpanels Ltd. Company versus Fuzhou F&V Photographic Company.  
*Nature:* Patent infringement.  
*Venue:* U.S. International Trade Commission (ITC), Washington DC.  
*Law firm:* Locke Lord LLP, New York, New York.  
*Role:* I served as technical expert witness on behalf of Fuzhou F&V and Nanguang Photographic (Defendant). I wrote one or more expert reports; I was deposed.
- 2012** *Case:* Osram Company versus LG Company.  
*Nature:* Patent infringement.  
*Venue:* U.S. International Trade Commission (ITC), Washington DC.  
*Law firm:* Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of LG (Defendant). I wrote one or more expert reports; I was deposed; I testified at the ITC Hearing.
- 2012** *Case:* Osram Company versus LG Company and Samsung Company.  
*Nature:* Patent infringement.  
*Venue:* U.S. International Trade Commission (ITC), Washington DC.  
*Law firm:* Covington & Burling LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of LG and Samsung (Defendant). I wrote one or more expert reports; I was deposed; I testified at the ITC Hearing.
- 2013** *Case:* Chao Tai Electron Co. LTD. versus LEDup Enterprise Inc. and others.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for the Central District of California.  
*Law firm:* Hunton & Williams LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of LEDup Enterprise Inc. and others (Defendants). I wrote one or more expert reports.
- 2013** *Case:* Nichia Corporation versus Everlight Company and Emcore Company.  
*Nature:* Inter Partes Review (IPR).  
*Venue:* USPTO Patent Trial and Appeal Board.

**Law firm:** Foley & Lardner LLP, Washington DC.

**Role:** I served as technical expert witness on behalf of Nichia Corporation (Petitioner). I wrote one or more expert reports; I was deposed.

**2014 Case:** Everlight Electronics Co. LTD. versus Nichia Corporation.

**Nature:** Patent infringement.

**Venue:** U.S. District Court for the Eastern District of Michigan, Southern Division.

**Law firm:** Foley & Lardner LLP, Washington DC.

**Role:** I served as technical expert witness on behalf of Nichia Corporation (Defendant). I wrote one or more expert reports; I was deposed; I testified at Phase 1 of trial (jury trial) and I testified at Phase 2 of trial (bench trial).

**2014 Case:** LEDup Company versus Nicolas Holiday Company.

**Nature:** Patent infringement.

**Venue:** U.S. District Court for the Central District of California.

**Law firm:** Pendleton, Wilson, Hennessey, and Crow PC, Denver, Colorado.

**Role:** I served as technical expert witness on behalf of LEDup (Plaintiff). I wrote one or more expert reports.

**2014 Case:** Nichia Corporation versus Everlight Electronics Co. LTD.

**Nature:** Patent infringement.

**Venue:** U.S. District Court for the Eastern District of Texas, Marshall Division.

**Case number:** 02:13-cv-702-JRG (E.D. Texas).

**Law firm:** Rothwell, Figg, Ernst & Manbeck PC, Washington DC.

**Role:** I served as technical expert witness on behalf of Nichia (Plaintiff). I wrote one or more expert reports; I was deposed; I testified at trial (bench trial).

**2015 Case:** Cree Company versus Unity Opto, Unity Microelectronics, and Feit Electric Company

**Nature:** Patent infringement.

**Venue:** U.S. International Trade Commission (ITC), Washington DC.

**Law firm:** Alston & Bird LLP, Silicon Valley, East Palo Alto, California.

**Role:** I served as expert witness on behalf of Unity Opto Technology *et al.* (Defendants). I wrote one or more expert reports; I was deposed; I testified at trial (ITC Hearing).

**2015 Case:** Honeywell International Inc. versus Cree Inc.

**Nature:** Inter Partes Review (IPR).

**Venue:** USPTO Patent Trial and Appeal Board.

**Law firm:** Arnold & Porter LLP, San Francisco, California.

**Role:** I served as expert witness on behalf of Honeywell International Inc. (Plaintiff). I wrote one or more expert reports.

**2015 Case:** Honeywell International Inc. versus Cree Inc.

**Nature:** Patent infringement.

**Venue:** U.S. District Court for the District of New Jersey.

**Law firm:** Arnold & Porter LLP, San Francisco, California.

**Role:** I served as expert witness on behalf of Honeywell International Inc. (Plaintiff).

**2015 Case:** Cree Inc. versus Kingbright Electronic Co. LTD and SunLED Corporation.

**Nature:** Patent infringement.

**Venue:** U.S. District Court for the Western District of Wisconsin.

**Law firm:** Hansen Reynolds Dickinson Crueger LLC, Milwaukee, Wisconsin.

**Role:** I served as technical expert witness on behalf of Kingbright and SunLED (Defendants). I wrote one or more expert reports; I was deposed.

- 2016** *Case:* Acuity Brands Lighting Inc. versus Lynk Labs Inc.  
*Nature:* Inter Partes Review (IPR).  
*Venue:* USPTO Patent Trial and Appeal Board.  
*Law firm:* Haynes Boone LLP, Chicago, Illinois.  
*Role:* I served as technical expert witness on behalf of Lynk Labs (Plaintiff). I wrote one or more expert reports.
- 2016** *Case:* Godo Kaisha IP Bridge 1 Company versus Broadcom Company and others.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for the Eastern District of Texas, Marshall Division.  
*Law firm:* Ropes and Gray LLP, New York City, New York.  
*Role:* I served as technical expert witness on behalf of IP Bridge 1 (Plaintiff). I wrote one or more expert reports; I was deposed.
- 2016** *Case:* TSMC Company versus Godo Kaisha IP Bridge 1 Company.  
*Nature:* Inter Partes Review (IPR).  
*Venue:* USPTO Patent Trial and Appeal Board.  
*Law firm:* Greenblum & Bernstein, P.L.C., Reston, Virginia.  
*Role:* I served as technical expert witness on behalf of IP Bridge (Patent Owner). I wrote one or more expert reports; I was deposed.
- 2017** *Case:* Harvard University versus Micron Technology Company.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for MA, Boston; U.S. District Court for Delaware, Wilmington.  
*Law firm:* Weil Gotshal & Manges LLP, Redwood Shores, California.  
*Role:* I served as technical expert witness on behalf of Micron Technology Company (Defendant). I wrote one or more expert reports; I was deposed.
- 2017** *Case:* Seoul Viosys Company versus P3 Company.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court, Southern District of New York, New York City.  
*Law firm:* Holland & Knight LLP, New York City, New York.  
*Role:* I served as technical expert witness on behalf of Seoul Viosys (Plaintiff). I wrote one or more expert reports.
- 2017** *Case:* Nitride Semiconductor Company versus Rayvio Company.  
*Nature:* Patent infringement.  
*Venue:* US District Court for the Northern District of California.  
*Law firm:* Dentons LLP, Palo Alto, California.  
*Role:* I served as technical expert witness on behalf of Rayvio (Defendant).
- 2018** *Case:* CRX Tech LLC versus Samsung Electronics Co. LTD.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court for the Eastern District of Texas, Marshall Division.  
*Law firm:* Arnold & Porter LLP, Los Angeles, California.  
*Role:* I served as technical expert witness on behalf of Samsung (Defendant).
- 2018** *Case:* Macom Technology Solutions Holdings Inc. versus Infineon Technologies AG.  
*Nature:* Patent infringement.  
*Venue:* U.S. District Court Central District of California Western Division, Los Angeles.  
*Law firm:* Perkins Coie LLP, Denver, Colorado.

**Role:** I served as technical expert witness on behalf of Macom (Plaintiff). I wrote one or more expert reports; I was deposed.

- 2018**    **Case:** Vizio Inc. versus Nichia Corporation.  
**Nature:** Inter Partes Review (IPR).  
**Venue:** USPTO Patent Trial and Appeal Board.  
**Case number:** Case No. IPR-2017-01608 and IPR-2017-01623 (PTAB).  
**Law firm:** Rothwell, Figg, Ernst & Manbeck, P.C., Washington DC.  
**Role:** I served as technical expert witness on behalf of Nichia Corporation (Patent Owner). I wrote one or more expert declarations.
- 2018**    **Case:** Lowe's Companies Inc. versus Nichia Corporation.  
**Nature:** Inter Partes Review (IPR).  
**Venue:** USPTO Patent Trial and Appeal Board.  
**Case number:** Case No. IPR2017-02014 (PTAB).  
**Law firm:** Rothwell, Figg, Ernst & Manbeck, P.C., Washington DC.  
**Role:** I served as technical expert witness on behalf of Nichia Corporation (Patent Owner). I wrote one or more expert declarations.
- 2018**    **Case:** Ultravision Technologies LLC versus Prismaflex USA Inc.  
**Nature:** Patent infringement.  
**Venue:** US International Trade Commission (ITC), Washington DC.  
**Case number:** Investigation No. 337-TA-1114 (ITC)  
**Law firm:** Womble Bond Dickinson LLP, Winston-Salem, NC  
**Role:** I served as technical expert witness on behalf of Prismaflex USA (Defendant). I wrote one or more expert reports. I was deposed.
- 2019**    **Case:** Carl Zeiss AG versus Nikon USA Inc.  
**Nature:** Patent infringement.  
**Venue:** US International Trade Commission (ITC), Washington DC.  
**Case number:** Investigation No. 337-TA-1129 (US ITC)  
**Law firm:** Morrison & Foerster LLP, Los Angeles CA.  
**Role:** I served as technical expert witness on behalf of Nikon USA (Defendant). I wrote one or more expert reports. I was deposed.
- 2019**    **Case:** ASM IP Holding B.V. versus Hitachi Kokusai Electric Inc.  
**Nature:** Arbitration related to IP licensing dispute.  
**Venue:** ICDR (International Center for Dispute Resolution), Palo Alto CA.  
**Case number:** Case No. ICDR 01-17-0005-1963 (Palo Alto CA)  
**Law firm:** Quinn Emanuel Urquhart & Sullivan LLP, San Francisco CA.  
**Role:** I served as technical expert witness on behalf of ASM IP Holding B.V. (Complainant). I authored multiple witness statements. I testified at the Arbitration Hearing.
- 2019**    **Case:** Power Integrations Inc. versus C. W. Park.  
**Nature:** Breach of employment contract.  
**Venue:** US District Court, Northern District of California, San Jose Division.  
**Case number:** 5:16-cv-02366-BLF (Northern District of California)  
**Law firm:** Miclean Gleason LLP, San Mateo CA.  
**Role:** I served as technical expert witness on behalf of Power Integrations Inc. (Complainant). I performed analyses relating to switched-mode power supplies (SMPS) including flyback transformers. The matter ended in settlement.

- 2019** **Case:** Omni MedSci Inc. versus Apple Inc.  
**Nature:** Patent infringement.  
**Venue:** US District Court, Eastern District of Texas, Marshall Division.  
**Case number:** Civil Action No. 2:18-cv-134-RWS (E.D. Texas)  
**Law firm:** Sidley Austin LLP, Washington DC.  
**Role:** I served as technical expert witness on behalf of Apple Inc. (Defendant). I performed a non-infringement analysis relating to the heart rate monitor of the Apple Watch, authored an expert report, and testified at a deposition.
- 2019** **Case:** Fluxwerx Illumination Inc., versus OKT Lighting USA LLC  
**Nature:** Design patent infringement.  
**Venue:** US District Court, Southern District of Texas, Houston Division.  
**Case number:** Civil Action No. 4:19-CV-01113 (S.D. Texas)  
**Law firm:** Burns & Levinson LLP, Boston MA.  
**Role:** I served as technical expert witness on behalf of Fluxwerx Illumination, Inc. (Plaintiff). I performed an infringement analysis.
- 2020** **Case:** Lighting Science Group Corporation versus Nichia Corporation and others  
**Nature:** Patent infringement.  
**Venue:** US ITC, Office for Unfair Import Investigations, Washington DC  
**Case number:** Investigation No. 337-TA-1168  
**Law firm:** Shearman & Sterling LLP, New York, NY.  
**Role:** I served as technical expert witness on behalf of Nichia Corporation. I performed a non-infringement analysis, authored an expert report, was deposed, and testified at the ITC hearing as key technical witness on behalf of Nichia and Respondents (6 hours live testimony).
- 2020** **Case:** Regents of the University of California versus Amazon, Walmart, Ikea, Target, and others  
**Nature:** Patent infringement.  
**Venue:** US ITC, Office for Unfair Import Investigations, Washington DC  
**Case number:** Investigation No. 337-TA-1172  
**Law firm:** Nixon Peabody LLP, Los Angeles CA.  
**Role:** I served as technical expert witness on behalf of the Regents of the University of California. I performed an infringement analysis, authored an expert report, and was deposed.
- 2020** **Case:** Samsung Electronics Company versus Acorn Technologies Company.  
**Nature:** USPTO Inter Partes Review.  
**Venue:** USPTO, Patent Trial and Appeal Board, Alexandria VA.  
**Case numbers:** IPR-2020-01183 ('261), IPR-2020-01182 ('423), IPR-2020-01204 ('336), IPR-2020-01264 ('336), IPR-2020-01205 ('167), IPR-2020-01241 ('167), IPR-2020-01206 ('691), IPR-2020-01279 ('691), IPR-2020-01207 ('395), and IPR-2020-01282 ('395)  
**Law firm:** Desmarais LLP, New York NY.  
**Role:** I served as technical expert witness on behalf of Samsung Electronics Company. I authored several expert declarations and was deposed multiple times.
- 2020** **Case:** Satco Company versus The Regents of the University of California.  
**Nature:** USPTO Inter Partes Review.  
**Venue:** USPTO, Patent Trial and Appeal Board, Alexandria VA.  
**Case number:** IPR-2020-00579, IPR-2020-00695, IPR-2020-00780, and IPR-2020-00813.  
**Law firm:** Nixon Peabody LLP, Los Angeles CA.  
**Role:** I served as technical expert witness on behalf of The Regents of the University of California. I authored several expert declarations and was deposed.

- 2020** *Case:* Godo Kaisha IP Bridge 1 Company versus Micron Technology Company.  
*Nature:* Patent infringement.  
*Venue:* US District Court for the Western District of Texas, Waco Division.  
*Case number:* C.A. No. 6:20-cv-178-ADA.  
*Law firm:* Orrick Herrington & Sutcliffe LLP, Menlo Park CA.  
*Role:* I served as technical expert witness on behalf of Micron Technology Company. I authored multiple expert reports and was deposed.
- 2020** *Case:* Nichia Company versus Healtel Company and Lighting Science Group Company.  
*Nature:* Patent infringement.  
*Venue:* US District Court for the Middle District of Florida, Orlando Division.  
*Case number:* 6:19-cv-1332-RBD-EJK and 6:19-cv-1333-RBD-EJK.  
*Law firm:* Rothwell, Figg, Ernst & Manbeck, PC, Washington DC.  
*Role:* I served as technical expert witness on behalf of Nichia Company. I authored one or more expert reports.
- 2020** *Case:* Semiconductor Energy Laboratory (SEL) Co., Ltd. versus BOE Technology Group Co., Ltd.  
*Nature:* Patent infringement.  
*Venue:* US District Court for the Northern District of California.  
*Case number:* 3:20-cv-04297-EMC, N.D. Cal.  
*Law firm:* Fish and Richardson, P.C., Redwood City CA.  
*Role:* I served as technical expert witness on behalf of SEL.
- 2021** *Case:* The University of California versus General Electric, Ikea, Home Depot and others  
*Nature:* Patent infringement.  
*Venue:* US ITC, Office for Unfair Import Investigations, Washington DC  
*Case number:* Investigation No. 337-TA-1220  
*Law firm:* Nixon Peabody LLP, Los Angeles CA.  
*Role:* I served as technical expert witness on behalf of the University of California. I performed multiple analyses, authored several expert reports, was deposed multiple times, and testified at trial.
- 2021** *Case:* Tianma Microelectronics Co., Ltd. versus Japan Display Inc. (JDI)  
*Nature:* USPTO Inter Partes Review.  
*Venue:* USPTO, Patent Trial and Appeal Board, Alexandria VA  
*Case numbers:* IPR-2021-01029, IPR-2021-01057 and IPR-2021-01058  
*Law firm:* Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of Tianma. I performed multiple analyses and authored several declarations.
- 2021** *Case:* Japan Display Inc. (JDI) versus Tianma Microelectronics Co., Ltd.  
*Nature:* Patent infringement.  
*Venue:* US District Court for the Eastern District of Texas, Marshall Division.  
*Case numbers:* Civil Action No. 2:20-cv-00283-JRG; 2:20-cv-00284-JRG; and 2:20-cv-00285-JRG  
*Law firm:* Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, Washington DC.  
*Role:* I served as technical expert witness on behalf of Tianma. I performed multiple analyses, authored several expert reports, and was deposed multiple times.
- 2022** *Case:* Satco Products Inc. versus The Regents of the University of California.  
*Nature:* USPTO Inter Partes Review.  
*Venue:* USPTO, Patent Trial and Appeal Board, Alexandria VA.  
*Case number:* IPR-2021-00662.  
*Law firm:* Nixon Peabody LLP, Los Angeles CA.

**Role:** I served as technical expert witness on behalf of The Regents of the University of California, authored one expert declaration, and was deposed.

**2022 Case:** Samsung Electronics Co. Ltd. versus Bishop Display Tech LLC.

**Nature:** USPTO Inter Partes Review.

**Venue:** USPTO, Patent Trial and Appeal Board, Alexandria VA.

**Case numbers:** IPR-2022-00500 and IPR-2022-00502.

**Law firm:** Baker Botts LLP, New York City NY.

**Role:** I served as technical expert witness on behalf of Samsung Electronics and have authored two expert declarations.

**2022 Case:** Semiconductor Energy Laboratory (SEL) Co. Ltd. versus TCL China Star Optoelectronics Technology Co., Ltd.

**Nature:** Patent infringement.

**Venue:** US District Court for the Central District of California, Southern Division.

**Case number:** 8:21-cv-00554-JAK-ADS.

**Law firm:** Fish and Richardson, P.C., Redwood City CA.

**Role:** I served as technical expert witness on behalf of SEL, authored two expert reports, and was deposed.

**2022 Case:** Nvidia Corporation versus Ocean Semiconductors LLC.

**Nature:** USPTO Inter Partes Review.

**Venue:** USPTO, Patent Trial and Appeal Board, Alexandria VA.

**Case number:** IPR2022-01288.

**Law firm:** Sheppard Mullin LLP, Menlo Park CA.

**Role:** I served as technical expert witness on behalf of Nvidia and authored one expert declaration.

**2022 Case:** Nicor, Inc. versus SourceBlue LLC and InfiniLux Corporation.

**Nature:** Patent infringement.

**Venue:** US District Court for the Central District of California.

**Case number:** 2:21-cv-05876-AB(PDx) (C.D. Cal.).

**Law firm:** Loza & Loza IP LLP, Upland CA.

**Role:** I served as technical expert witness on behalf of Nicor, Inc., authored three expert reports, and was deposed.

**2023 Case:** Dr. Shimon Maimon versus Lockheed Martin Corporation.

**Nature:** Dispute relating to a License Agreement.

**Venue:** JAMS ADR (Alternative Dispute Resolution).

**Case number:** JAMS Ref. No. 1460005932.

**Law firm:** Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, Washington DC.

**Role:** I served as technical expert witness on behalf of Lockheed Martin Corporation, authored three expert reports, was deposed, and testified at the Hearing.

**2023 Case:** Samsung Electronics Co. Ltd. versus Daedalus Prime LLC.

**Nature:** USPTO Inter Partes Review.

**Venue:** USPTO, Patent Trial and Appeal Board, Alexandria VA.

**Case number:** IPR2023-00536 and IPR2023-00653.

**Law firm:** Fish & Richardson PC, Minneapolis MN.

**Role:** I served as technical expert witness on behalf of Samsung Electronics and authored two expert declarations.

- 2023** *Case:* Seoul Semiconductor Co. Ltd., et al. versus GE Healthcare Inc.  
*Nature:* Patent infringement.  
*Venue:* United States District Court for the District of Delaware.  
*Case number:* Civil Action No. 1:22-cv-01455.  
*Law firm:* Shearman & Sterling LLP, New York, NY.  
*Role:* I served as technical expert witness on behalf of GE Healthcare.
- 2023** *Case:* Efficient Power Conversion Corp. versus Innoscience (Zhuhai) Technology Company.  
*Nature:* Patent infringement.  
*Venue:* US International Trade Commission (ITC), Washington DC.  
*Case number:* Investigation No. 337-TA-1366.  
*Law firm:* Blank Rome LLP, Washington DC  
*Role:* I served as technical expert witness on behalf of EPC, authored multiple expert reports, was deposed, and testified at the ITC Hearing.
- 2023** *Case:* Xu Peicheng (Hong Kong) Optoelectronic Technol. Co. versus SemiSilicon Technol. Corp.  
*Nature:* USPTO Inter Partes Review.  
*Venue:* USPTO, Patent Trial and Appeal Board, Alexandria VA.  
*Case number:* IPR2024-00156 and IPR2024-00157 (US Patent 8,124,988 and US 8,884,546)  
*Law firm:* Rimon La PC, McLean VA.  
*Role:* I served as technical expert witness on behalf of Xu Peicheng and authored two expert declarations.
- 2024** *Case:* Seasonal Specialties, LLC versus LEDUP Manufacturing Group LTD.  
*Nature:* Patent infringement.  
*Venue:* US District Court, Central District of California, Western Division.  
*Case number:* 2:23-cv-06318-SB-AS.  
*Law firm:* Fairfield & Woods PC, Denver CO.  
*Role:* I served as technical expert witness on behalf of LEDUP Manufacturing Group and composed multiple Invalidity Claim Charts.
- 2024** *Case:* Wuxi Autowell Technology Co. Ltd. versus Teamtechnik Maschinen und Anlagen GmbH.  
*Nature:* USPTO Inter Partes Review.  
*Venue:* USPTO, Patent Trial and Appeal Board, Alexandria VA.  
*Case number:* US patent numbers 8,247,681 and 8,253,009.  
*Law firm:* Novick, Kim & Lee, PLLC, (NKL Law), Fairfax VA.  
*Role:* I served as technical expert witness on behalf of Wuxi Autowell Technology and composed one expert declaration.
- 2024** *Case:* Greenthread LLC versus Omnivision Technologies, Inc., and Texas Instruments, Inc.  
*Nature:* Patent infringement.  
*Venue:* US District Court, Eastern District of Texas, Marshall Division.  
*Case numbers:* 2:23-cv-00212-JRG and 2:23-cv-00157-JRG.  
*Law firms:* Benesch Friedlander Coplan & Aronoff LLP and Caldwell Cassady & Curry PC  
*Role:* I served as technical expert witness on behalf of Omnivision Technologies and Texas Instruments, composed one expert declaration, and was deposed.
- 2024** *Case:* Lian Li Industrial Co. Ltd. and CHEN, Chien-Hao versus Thermaltake Technology Co. Ltd.  
*Nature:* Patent infringement.  
*Venue:* US District Court, Central District of California.  
*Case numbers:* 2:23-cv-07470.  
*Law firm:* The Gikkas Law Firm, PC

**Role:** I served as technical expert witness on behalf of Thermaltake Technology, composed one expert declaration, and was deposed.

## United States Patents

1. A. Fischer, Y. Horikoshi, K. Ploog, and E. F. Schubert "Semiconductor devices with at least one monoatomic layer of doping atoms" European Patent No. 0183 146 A2; US Patent No. 4,882,609; issued on November 15 (1985)
2. J. E. Cunningham, E. F. Schubert, and W. T. Tsang "Delta doped ohmic metal to semiconductor contacts" US Patent No. 4,772,934; issued on September 20 (1988)
3. J. E. Cunningham, E. F. Schubert, and W. T. Tsang "Field-effect transistor having a delta-doped ohmic contact" US Patent No. 4,780,748; issued on October 25 (1988)
4. J. E. Cunningham, E. F. Schubert, and W. T. Tsang "Method for fabricating a field-effect transistor with a self-aligned gate" US Patent No. 4,784,967; issued on November 15 (1988)
5. E. Fred Schubert "Optical communications modulator device" US Patent No. 4,929,064; filed on July 21 (1988) issued on May 29 (1990)
6. J. E. Cunningham, A. M. Glass, and E. F. Schubert "Devices having asymmetric delta-doping" US Patent No. 4,974,044; issued on November 27 (1990)
7. J. E. Cunningham, A. M. Glass, and E. F. Schubert "Devices having asymmetric delta-doping" US Patent No. 5,031,012; issued on July 9 (1991)
8. J. E. Cunningham, T. D. Harris, E. F. Schubert, and J. P. van der Ziel "Optical system including wavelength tunable semiconductor laser" US Patent No. 4,980,892; issued on December 25 (1990)
9. R. F. Kopf, J. M. Kuo, H. S. Luftman, and E. F. Schubert "Doping procedures for semiconductor devices" US Patent No. 5,024,967; issued on June 18 (1991)
10. D. G. Deppe, R. D. Dupuis, and E. F. Schubert "Vertical cavity semiconductor lasers" US Patent No. 5,018,157; issued on May 21 (1991)
11. D. G. Deppe, L. C. Feldman, R. F. Kopf, E. F. Schubert, L.-W. Tu, and G. J. Zyzdik "Vertical cavity surface emitting lasers with electrically conducting mirrors" US Patent No. 5,068,868; issued on November 26 (1991)
12. D. G. Deppe, E. F. Schubert, L.-W. Tu, and G. D. Zyzdik "Optical devices with electron-beam evaporated multilayer mirror" US Patent No. 5,206,871; issued on April 27 (1993)
13. R. F. Kopf, E. F. Schubert, H. O'Brian, L.-W. Tu, Y. H. Wang, and G. J. Zyzdik "Vertical cavity surface emitting lasers with transparent electrodes" US Patent No. 5,115,441; issued on May 19 (1992)
14. E. F. Schubert, L.-W. Tu, and G. J. Zyzdik "Elimination of heterojunction band discontinuities" US Patent No. 5,170,407; issued on December 8 (1992)
15. S. W. Downey, A. B. Emerson, R. F. Kopf, and E. F. Schubert "Devices having repetitive layers" US Patent No. 5,226,055; issued on July 6 (1993)
16. A. Y. Cho, E. F. Schubert, L.-W. Tu, and G. J. Zyzdik "Resonant cavity light emitting diode" US Patent No. 5,226,053; issued on July 6 (1993)
17. L. C. Feldman, N. E. J. Hunt, D. C. Jacobson, J. M. Poate, E. F. Schubert, A. M. Vredenberg, Y. H. Wong, and G. J. Zyzdik "Erbium-doped optical devices" US Patent No. 5,249,195; issued on September 28 (1993)

18. R. F. Kopf and E. F. Schubert "PN junction devices with group IV element-doped group III-V compound semiconductors" US Patent No. 5,268,582; issued on December 7 (1993)
19. N. E. J. Hunt and E. F. Schubert "Single mirror light-emitting diodes with enhanced intensity" US Patent No. 5,362,977; issued on November 8 (1994)
20. N. E. J. Hunt, E. F. Schubert, and G. J. Zydzik "Photodetector with a resonant cavity" US Patent No. 5,315,128; issued on May 24 (1994)
21. A. M. Glass, N. E. J. Hunt, J. M. Poate, E. F. Schubert, and G. J. Zydzik "Absorption resonant rare-earth-doped microcavities" US Patent No. 5,363,398; issued on November 8 (1994)
22. N. E. J. Hunt, M. Passlack, E. F. Schubert, and G. J. Zydzik "Electron beam deposition of gallium oxide thin films using a single high purity crystal source" US Patent No. 5,451,548; issued on September 19 (1995)
23. N. K. Dutta, R. J. Fischer, N. E. J. Hunt, M. Passlack, E. F. Schubert, and G. J. Zydzik "Gallium oxide coatings for optoelectronic devices using electron beam evaporation of a high purity single crystal  $\text{Gd}_3\text{Ga}_5\text{O}_{12}$  source" US Patent No. 5,550,089; issued on August 27 (1996)
24. U. K. Chakrabarti, J. de Jong, E. F. Schubert, J. Wynn, and G. J. Zydzik "Mechanical fixture and procedure for in-vacuum coating of semiconductor laser facets" US Patent No. 5,719,077; issued on February 17 (1998)
25. E. F. Schubert "Enhanced p-type doping of wide-gap semiconductors" US Patent No. 5,932,899; issued on August 3 (1999)
26. J. D. Joannopoulos, S. Fan, P. R. Villeneuve, and E. F. Schubert "Light emitting device utilizing a periodic dielectric structure" US Patent No. 5,955,749; issued on September 21 (1999)
27. E. F. Schubert and D. A. Stocker "Crystallographic wet chemical etching on GaN" US Patent No. 6,294,475; issued on September 25 (2001)
28. E. F. Schubert "Light-emitting diode with omni-directional reflector" US Patent No. 6,784,462; issued on August 31 (2004)
29. Jaehee Cho, Hong Luo, Jong Kyu Kim, Yong Jo Park, Cheolsoo Sone, and E. Fred Schubert "Light emitting device having protection element and method of manufacturing the light emitting device" US Patent No. 7,411,221 B2; issued on August 12 (2008)
30. Jaehee Cho, Frank Wilhelm Mont, Cheolsoo Sone, Jong-kyu Kim, June-o Song, E. Fred Schubert "Optical thin film, semiconductor light emitting device having the same and methods of fabricating the same" US Patent No. 7,483,212; issued on January 27 (2009)
31. Jaehee Cho, Martin F. Schubert, E. Fred Schubert, Jong Kyu Kim, Cheolsoo Sone "Light emitting diodes and display apparatuses using the same" US Patent No. 7,560,746; issued on July 14 (2009)
32. Martin F. Schubert, Sameer Chhajed, Jong Kyu Kim, E. Fred Schubert, and Jaehee Cho "Reflector shapes for light-emitting diode-polarized light sources" US Patent No. 7,766,495; filed on June 24 (2008); issued on August 3 (2010)
33. Martin F. Schubert, Ahmed Noemaun, Sameer Chhajed, Jong Kyu Kim, E. F. Schubert, Cheolsoo Sone "Encapsulant shapes for light emitting devices lacking rotational symmetry designed to enhance extraction of light with a particular linear polarization" US Patent No. 7,819,557; filed on June 24 (2008); issued on October 6 (2010)

34. Jaehee Cho, Jong-Kyu Kim, Cheolsoo Sone, and E. F. Schubert “LED device having diffuse reflective surface” US Patent No. 7,816,855; filed on December 28 (2005); issued on October 19 (2010)
35. Jaehee Cho, E. Fred Schubert, and Xing Yan “Liquid crystal display with refractive index matched electrodes” US Patent No. 8,164,727; filed on April 28, 2010; issued on April 24 (2012)
36. Mary H. Crawford, Daniel Koleske, Jaehee Cho, Di Zhu, Ahmed Noemaun, Martin F. Schubert, and E. Fred Schubert “High efficiency III-Nitride light-emitting diodes” US Patent No. 8,451,877; filed on March 17, 2011; issued on May 28 (2013)
37. Min-ho Kim, Martin F. Schubert, Jong Kyu Kim, E. Fred Schubert, Yongjo Park, Cheolsoo Sone, and Sukho Yoon “Nitride semiconductor light-emitting device” US Patent No. 8,502,266; filed on September 8 (2010); issued on August 6 (2013)
38. David J. Poxson, Frank W. Mont, E. Fred Schubert, and Richard W. Siegel “Tunable nanoporous film on polymer substrates, and method for their manufacture” US Patent No. 9,732,427; filed on April 23 (2013); issued on August 15 (2017)
39. Sameer Chhajed, Jong Kyu Kim, Shawn-Yu Lin, Mei-Ling Kuo, Frank W Mont, David J Poxson, E Fred Schubert, Martin F Schubert “Ultra-low reflectance broadband omni-directional anti-reflection coating” US Patent No. 11,088,291; filed on July 22 (2016); issued on August 10 (2021)

**Patent Licensing:** Several patents listed above have been licensed to companies, including the Luminus Devices Company, Samsung Company, Epistar Company, Cree Company, Osram Company, and Lumileds Company.

## Journal Publications

### 1982

1. H. Künzel, H. Jung, E. F. Schubert, and K. Ploog "Influence of growth conditions and of alloy composition on electrical and optical properties of MBE AlGaAs" *Journal Physique Colloque C5*, **C5/175**, 42 (1982)

### 1984

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