

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MIANYANG BOE OPTOELECTRONICS TECHNOLOGY CO., LTD.;
WUHAN CHINA STAR OPTOELECTRONICS SEMICONDUCTOR DISPLAY
TECHNOLOGY CO., LTD.; TIANMA MICROELECTRONICS CO., LTD.;
AND VISIONOX TECHNOLOGY, INC.,
Petitioner,

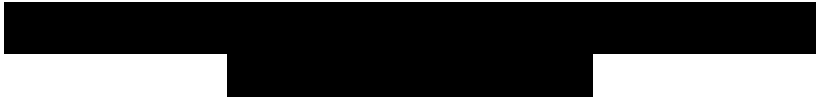
v.

SAMSUNG DISPLAY CO., LTD.
Patent Owner.

Case IPR2023-00941
U.S. Patent No. 7,414,599

DECLARATION OF ANDREW WOLFE, PH.D.

PUBLIC VERSION



[REDACTED]

I, Andrew Wolfe, Ph.D., declare and state, to the best of my knowledge, understanding, and belief, as follows:

1. I have been retained as a technical consultant on behalf of Samsung Display Co., Ltd. (“Samsung Display” or “Patent Owner”). I have been asked to consider whether U.S. Patent Publication No. 2003/0132931 (Ex. 1002, “Kimura”) in light of the knowledge of a person of ordinary skill in the art teaches or suggests the limitations recited in claims 1-18 of U.S. Patent No. 7,414,599 (Ex. 1001, the “’599 Patent”). I have also been asked to consider the state of the art and the prior art available before the time of the alleged invention of the ’599 Patent. I have also been asked to provide opinions on objective indicia of non-obviousness. My opinions are provided in this declaration.

2. To the best of my knowledge, I have no financial interest in Patent Owner. To the best of my knowledge, I have no financial interest in the Petitioners or any real party in interest. To the extent any mutual funds or other investments that I own have a financial interest in the Petitioner, the real parties in interest, the Patent Owner, or the ’599 Patent, I am not aware of, nor do I have control over, any financial interest that would affect or bias my judgment.

3. I am being compensated at my standard consulting rate for my time. My compensation is in no way contingent on the results of these or any other proceedings relating to the ’599 Patent.



I. BACKGROUND AND QUALIFICATIONS

4. My name is Andrew Wolfe. My complete qualifications and professional experience are described in my curriculum vitae, a copy of which is provided as Exhibit 2048. The following is a brief summary of my relevant qualifications and professional experience.

5. I am the founder and sole employee of Wolfe Consulting. Through Wolfe Consulting, I provide technical and business analysis to businesses on processor technology, computer systems, display technology, consumer electronics, software, design tools, data security, cryptography, and intellectual property issues. I have more than thirty years' experience developing products, researching, consulting, and teaching in those fields. In that time, I have worked as a computer architect, computer system designer, and as an executive in the PC and electronics business. I have also taught at some of the world's leading institutions in those fields, including Stanford University, Princeton University, Carnegie Mellon University, and Santa Clara University.

6. In 1985, I earned a B.S.E.E. degree in Electrical Engineering and Computer Science from the Johns Hopkins University. In 1987, I received a M.S. degree in Electrical and Computer Engineering from Carnegie Mellon University. In 1992, I received a Ph.D. degree in Computer Engineering from Carnegie Mellon University. My doctoral dissertation proposed a new approach for the architecture

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of a computer processor. My undergraduate Senior Project involved characterizing and filtering noise and interference in capacitive touchscreens.

7. In 1983, I began designing touch sensors, microprocessor-based computer systems, and I/O (input/output) cards for personal computers as a senior design engineer for Touch Technology, Inc. During the course of my design projects with Touch Technology, I designed I/O cards for PC-compatible computer systems, including the IBM PC-AT, to interface with interactive touch-based computer terminals that I designed for use in public information systems. I continued designing and developing related technology as a consultant to the Carroll Touch division of AMP, Inc., where in 1986 I designed one of the first custom touch-screen integrated circuits. I designed the touch/pen input system for the Linus WriteTop, which many believe to be the first commercial tablet computer.

8. From 1986 through 1987, I designed and built a high-performance computer system at Carnegie Mellon University. From 1986 through 1988, I also developed the curriculum and supervised the teaching lab for the processor design courses.

9. In 1989, I worked as a senior design engineer for ESL-TRW Advanced Technology Division. I designed and built a bus interface and memory controller for a workstation-based computer system and worked on the design of a multiprocessor system.

[REDACTED]

10. At the end of 1989, along with some partners, I reacquired the technology I had developed at Touch Technology and at AMP and founded The Graphics Technology Company. As an officer and a consultant, I managed engineering development activities at that company and personally developed dozens of interactive graphics and interactive video computer systems over the next seven years.

11. I have consulted, formally and informally, for a number of processor design companies. In particular, I have served on the technical advisory boards for two media processor design companies, BOPS, Inc., where I chaired the board, and Siroyan Ltd. I served in a similar role for three networking chip companies, Intellon, Inc., Comsilica, Inc., and Entridia, Inc. and one 3D game accelerator company, Ageia, Inc. I have also served as a technology advisor to Motorola and to several venture capital funds in the U.S. and Europe. Currently, I am a director of Turtle Beach Corporation, providing guidance in its development of premium audio peripheral devices and user-input devices for a variety of commercial electronic products.

12. From 1991 through 1997, I served on the Faculty of Princeton University as an Assistant Professor of Electrical Engineering. At Princeton, I taught undergraduate and graduate-level courses in Computer Architecture, Advanced Computer Architecture, Display Technology, and Microprocessor Systems courses

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as well as conducting sponsored research in the area of computer systems and related topics. I also was a principal investigator for DOD research in video technology and a principal investigator for the New Jersey Center for Multimedia Research. I worked on research proposals with Princeton's Center for Photonics and Optoelectronic Materials and taught classes on the use of thin-film transistors for active-matrix displays. From 1999 through 2002, I also taught the Computer Architecture course to both undergraduates and graduate students at Stanford University several times as a Consulting Professor. At Princeton, I received several teaching awards, both from students and from the School of Engineering. I have also taught advanced microprocessor architecture to industry professionals in IEEE and ACM sponsored seminars. I am currently a lecturer at Santa Clara University teaching courses on Microprocessor Systems, Real-time Embedded Systems, and Mechatronics.

13. From 1997 through 2002, I held a variety of executive positions at a publicly-held PC graphics company originally called S3, Inc. and later called Sonicblue Inc. These included Chief Technology Officer, Vice President of Systems Integration Products, Senior Vice President of Business Development, and Director of Technology. I also directed the display technology research group. At the time I joined S3, it supplied graphics accelerators for more than 50% of the PCs sold in the United States. As CTO, I led the development and introduction of more than 30 new

[REDACTED]

consumer electronics products. I was also part of a team that developed the Frontpath Progear tablet computer in 2000.

14. I have published more than 50 peer-reviewed papers in computer architecture and computer systems design. I have also chaired IEEE and ACM conferences in microarchitecture and integrated circuit design. I am a named inventor on at least fifty-seven U.S. patents and thirty-seven foreign patents including patents using TFT transistors and patents claiming OLED devices.

15. I have been the invited keynote speaker at the ACM/IEEE International Symposium on Microarchitecture and at the International Conference on Multimedia. I have also been an invited speaker on various aspects of technology or the PC industry at numerous industry events including the Intel Developer's Forum, Microsoft Windows Hardware Engineering Conference, Microprocessor Forum, Embedded Systems Conference, Comdex, and Consumer Electronics Show as well as at the Harvard Business School and the University of Illinois Law School. I have been interviewed on subjects related to computer graphics and video technology and the electronics industry by publications such as the Wall Street Journal, New York Times, LA Times, Time, Newsweek, Forbes, and Fortune as well as CNN, NPR, and the BBC. I have also spoken at dozens of universities including MIT, Stanford, University of Texas, Carnegie Mellon, UCLA, University of Michigan, Rice, and Duke.

[REDACTED]

16. Additional details of my education and work experience, awards and honors, and publications that may be relevant to the opinions I have formed are set forth in my CV (Exhibit 2048).

17. In summary, I have extensive familiarity with fields involving active-matrix displays and electroluminescence. I am familiar with what the state of this field was at the relevant time up to the time that the '599 Patent was filed.

II. MATERIALS REVIEWED

18. I am not an attorney and offer no legal opinions, but in my work, I have had experience studying and analyzing patents and patent claims from the perspective of a person skilled in the art.

19. In preparing this declaration, I reviewed the '599 Patent, including the claims of the patent in view of the specification, and I have reviewed the prosecution history of the '599 Patent and numerous prior art and technical references from the time of the alleged invention. More specifically, I have reviewed each of the following:

Exhibit	Description
Ex. 1001	U.S. Patent No. 7,414,599 (the "'599 Patent")
Ex. 1002	U.S. Patent Publication No. 2003/0132931 ("Kimura")
Ex. 1003	Declaration of Dr. Daniel Foty
Ex. 1004	U.S. Patent No. 6,362,798 ("Kimura '798")

Exhibit	Description
Ex. 1005	Certified File History for U.S. Patent No. 7,414,599
Ex. 1006	U.S. Patent Publication No. 2001/0022565 ("Kimura '565")
Ex. 1007	U.S. Patent Publication No. 2003/0030603 ("Shimoda")
Ex. 1008	Excerpts from <i>Analog Integrated Circuit Design</i> , David A Johns et al., John Wiley & Sons, Inc., 1997
Ex. 1009	<i>Modeling and Simulations of Insulated-Gate Field-Effect Transistor Switching Circuits</i> , Harold Shichman et al., IEEE Journal of Solid-State Circuits, Vol. SC-3, No. 3, September 1968
Ex. 1010	Excerpts from <i>Physics and Technology of Semiconductor Devices</i> , A. Grove, John Wiley & Sons, 1967
Ex. 1011	Excerpts from <i>CMOS Digital Integrated Circuits: Analysis and Design</i> , (third edition), S. Kang et al., McGraw-Hill, 2003
Ex. 1012	U.S. Patent No. 6,229,506
Ex. 1013	U.S. Patent No. 5,666,046
Ex. 1014	TFT AMOLED Pixel Circuits and Driving Methods, J. Stanford, SID 03 Digest, pp. 10–13 (2003)
Ex. 1015	A New Pixel Circuit for Active Matrix Organic Light Emitting Diodes, J Goh, IEEE Electron Device Letters vol. 23, pp 544–546 (2002)
Ex. 1016	A Novel Pixel Circuit for Active-Matrix Organic Light-Emitting Diodes, J. Goh et al., SID 03 Digest, pp. 494–497 (2003)
Ex. 1017	Current-Writing Active-Matrix Circuit for Organic Light-Emitting Diode Display Using a-Si:H Thin-Film

Exhibit	Description
	Transistors, R. Hattori et al., IEICE Transactions on Electronics vol. E83-C, pp. 797–782 (2000)
Ex. 1018	Declaration of T. Credelle
Ex. 2001	Certified File History for U.S. Patent No. 7,414,599
Ex. 2002	U.S. Patent Publication No. 2004/0041750 (“Abe”)
Ex. 2003	U.S. Patent Publication No. 2004/0145547 (“Oh”)
Ex. 2004	Digital Integrated Circuits, A Design Perspective 2 nd ed. (2003)
Ex. 2005	Claim Construction Order, Inv. No. 337-TA-1351
Ex. 2009	Replay the Display, <i>Mass Production of AMOLED – Samsung’s Dramatic Success That Changed the History of Displays</i> , Samsung Display Newsroom (Feb. 17, 2003) (https://global.samsungdisplay.com/31098)
Ex. 2010	SOCIETY OF INFORMATION DISPLAY, MOBILE DISPLAYS TECHNOLOGY AND APPLICATIONS (Achintya K. Bhowmik et al) (2008) (“Bhowmik”)
Ex. 2011	Dawson et al., <i>Design of an Improved Pixel for a Polysilicon Active-Matrix Organic LED Display</i> , Society of Information Display (1998) (“Dawson”)
Ex. 2012	Akimoto et al., <i>An Innovative Pixel-Driving Scheme for 64-Level Grey-Scale Full-Color Active Matrix OLED Displays</i> , Society of Information Display (2002)
Ex. 2013	Shirasaki et al., <i>Full Color Polymer OLED Display Driven by a-Si:H TFT Utilizing a New Current-Programmed Method</i> , International Display Workshop (2003)
Ex. 2014	Chih-Lung, Lin, <i>Pixel Circuit with High Immunity to the Degradation of TFTs and OLED for AMOLED Displays</i> , IMD/IDMC/ASIA Display Digest (2008)

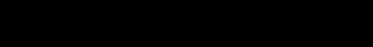
Exhibit	Description
Ex. 2015	Yoo et. Al., <i>302-ppi High-Resolution AMOLED using Laser-Induced Thermal Imaging</i> , Society of Information Display (2005) (“Yoo”)
Ex. 2016	Yoon Jeong-hyun, <i>Samsung Display Achieves the Highest Definition Quality With Tenacity. Full HD AMOLED “Revolution,”</i> BIZ Insight (2013) (including certified English translation)
Ex. 2017	Sung-eun Kim, <i>Climbing Mt. Fuji on Handstand?</i> (including certified English translation)
Ex. 2018	 Claim Chart 
Ex. 2019	
Ex. 2020	Teardown Photos of Samsung Galaxy S21 Product
Ex. 2021	Baek Byung-yuel, <i>Professor Kwon Wins Top Scientist Award of 2021</i> , The Korea Times (2021)
Ex. 2022	Jeon Ha-yeon, <i>Distinguished Professor Oh-Kyung Kwon, An Authority on Displays, Received the Korea’s Best Scientist and Technology Award</i> , Hanyang News Portal (2021)
Ex. 2023	Sung Kyun Kwan University, <i>2016 Karl Ferdinand Braun Prize for AMOLED</i> , Society for Information Display (2016)
Ex. 2024	U.S. Patent No. 9,666,132
Ex. 2025	U.S. Patent No. 8,941,309
Ex. 2026	Teardown Photos of MobileSentry Product

Exhibit	Description
Ex. 2027	Teardown Photos of Mengtor Product
Ex. 2028	Teardown Photos of Phone LCD Parts Product
Ex. 2029	Teardown Photos of Mobile Defenders Product
Ex. 2030	Teardown Photos of Injured Gadgets Product
Ex. 2031	Teardown Photos of Gadgetfix Product
Ex. 2032	Teardown Photos of Group Vertical Product
Ex. 2033	Teardown Photos of eTech Parts Plus Product
Ex. 2034	Teardown Photos of Parts4Cells Product
Ex. 2035	Teardown Photos of SEGMobile Product
Ex. 2036	Teardown Photos of Captain Mobile Parts Product
Ex. 2037	Teardown Photos of Repairs Universe Product
Ex. 2038	Teardown Photos of Sourcely Plus Product
Ex. 2039	Teardown Photos of Fixez Product
Ex. 2040	Teardown Photos of Wholesale Gadget Parts Product
Ex. 2041	Teardown Photos of Parts4LCD Product
Ex. 2042	Teardown Photos of DFW Product
Ex. 2043	Declaration of Aris Silzars, Ph.D.
Ex. 2046	Declaration of Kwangsae Lee
Ex. 2047	<i>Samsung Display Co., Ltd. v. BOE Tech. Co., Ltd. et al.</i> , Case No. 2-23-cv-00309, Compl. (E.D. Tex. Jun. 26, 2023)
Ex. 2049	Study of Leakage Current in n-channel and p-channel Polycrystalline Silicon Thin-film Transistors by

Exhibit	Description
	Conduction and Low Frequency Noise Measurements, C.T. Angelis, et. Al, J. Appl. Phys. 82, 4095-4101 (1997)
Ex. 2050	Transcript of February 23, 2024 Deposition of Daniel Foty

III. SUMMARY OF OPINIONS

20. As I explain below, it is my opinion that Kimura in view of the knowledge of a person of ordinary skill in the art (“POSITA”) does not render obvious the challenged claims. It is also my opinion that objective indicia of non-obviousness further support the non-obviousness of the challenged claims.

IV. RELEVANT LEGAL STANDARDS

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

22. I have been informed that each issued claim of an issued patent is presumed to be valid. I have been further informed that, to overcome the presumption of validity, the party challenging the claim’s validity must present clear and convincing evidence that the claim is invalid.

23. I have been informed that a patent claim is “obvious” in view of the prior art if the differences between the claim and the prior art are such that the subject matter as a whole would have been obvious to a POSITA at the time of the claimed invention.

[REDACTED]

24. I have been informed that the factors to be considered in analyzing whether a claim was obvious are: (i) the scope and content of the prior art; (ii) the differences between the prior art and the claims; (iii) the level of ordinary skill in the pertinent art; and (iv) any asserted objective indicia of non-obviousness.

25. I have been informed that objective indicia of non-obviousness (which I am informed are also referred to as secondary considerations of non-obviousness) refers to certain real-world facts that tend to show that a patent claim was not obvious at the time of the claimed invention. I have also been informed that this evidence may include, among other things, whether the claimed invention satisfied a long-felt but unmet need; whether other failed to develop a solution to the long-felt need; whether there was industry skepticism for the inventions; whether the claimed invention or a product having the attributes of the claimed invention was praised or recognized by others; and whether others copied the claimed invention.

26. I have been informed that this type of evidence demonstrates non-obviousness because it shows that others working in the field would have been motivated to create a product having the attributes of the claimed invention if they had had the necessary inventive skill to do so. I also understand that such objective indicia must be considered from the perspective of a POSITA.

27. I have been informed that it is appropriate to consider objective indicia if there is a nexus, or connection, between the claimed invention and the objective

[REDACTED]

indicia. I have also been informed that a nexus may be shown when the objective evidence is attributed to the specific product that embodies the invention disclosed and claimed in the patent.

28. I have been informed that where, as here, an obviousness defense is based on a combination of prior art references, a patent claim is not obvious unless a POSITA would have been motivated to combine or modify prior art elements to obtain the invention as set forth in the claim with a reasonable expectation of success. I understand that a motivation to combine prior art references can come from the references themselves or from the understanding of a POSITA.

29. I have been informed that references must be considered in their entirety from the view of a POSITA at the time of the invention, but that viewing the art through hindsight is impermissible.

30. I have been informed that in considering obviousness, it is relevant to consider whether the prior art includes references that “teach away” from the claimed invention. I understand that a reference teaches away from the claimed invention if a POSITA, reading the reference, would be discouraged from following the path of the claimed invention or would be led in a divergent direction.

V. TECHNOLOGY BACKGROUND

31. The type of technology used in displays for consumer electronics such as televisions, laptops, cellular phones, and tablets has evolved throughout the years

[REDACTED]

from older technologies, such as cathode ray tubes, to more modern day technologies like liquid crystal displays and organic light emitting devices. As the '599 Patent explains, “[n]ormally, an organic light emitting device may be classified into a passive matrix organic light emitting diode (OLED) and an active matrix OLED (AMOLED).” ’599 Patent at 1:23–29.

32. In a passive matrix organic light emitting diode display, rows and columns of the display are formed through a grid of overlapping cathode and anode lines. Individual pixels are formed at the intersections of each of the two types of lines. An organic EL layer is formed in between the overlapping lines, such that when a voltage is applied as between any one row and column, the corresponding pixel at the intersection of the two lines will emit light. Ordinarily, each row of the display will be written to individually, with the display cycling through every row once per frame. Given that passive matrix displays do not have active pixel driving circuitry, conventional passive matrix displays relied on high voltages being applied to each pixel to maintain the luminance of the pixel for a full frame. However, these high voltages lead to higher power consumption and to deterioration of the EL material used to form each pixel.

33. In contrast, active-matrix OLED displays, are “generally composed of a plurality of gate lines, a plurality of data lines, a plurality of power lines, and a plurality of pixels,” where “[e]ach pixel is normally composed of: an EL element;

[REDACTED]

two transistors, in which one is a switching transistor for transferring a data signal while the other is a driving transistor for driving the EL element depending on the data signal; and one capacitor for maintaining the data voltage.” ’599 Patent at 1:30–37. In modern displays, each pixel circuit may have more than two transistors (sometimes referred to as a “thin film transistor” or TFT), as well as additional capacitors. Because an AMOLED has pixel circuitry that maintains the data voltage throughout the frame, lower voltages can be used to turn on the EL element. Thus AMOLED “has an advantage in that power consumption is low,” and AMOLED displays have become the predominant form of display for commercial devices. ’599 Patent at 1:38-39.

34. A transistor controls a flow of current. Transistors can be made from different materials, e.g., amorphous silicon and polysilicon, and can have different polarities, e.g., NMOS and PMOS. The characteristics of NMOS and PMOS transistors differ. NMOS transistors have negative-type channels, with electrons serving as the majority carrier, whereas PMOS transistors have positive-type channels, with holes serving as the majority carrier. Historically, this has led to NMOS transistors being faster and PMOS transistors being built larger for a given current capacity (so as to match the speed of NMOS counterparts).

35. A thin film transistor generally has three terminals, a gate, a source, and a drain. A transistor is turned on or off based on the voltage applied between the gate

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and source of the transistor. Each transistor has a “threshold voltage,” which is the voltage level necessary to turn the transistor on. This voltage level will vary by the type of transistor. For example, in order to turn on an NMOS transistor, a more positive voltage than the threshold voltage must be applied between the gate and source of the transistors, whereas in a PMOS transistor a more negative voltage than the threshold voltage must be applied. Dr. Foty refers to this as “active-high” and “active low” signaling. *See, e.g.,* Ex. 1003 at ¶ 57.

36. As discussed above, an AMOLED pixel circuit normally comprises a driving transistor, which is sometimes also referred to as a “drive” transistor. The driving transistor drives the EL element by supplying it with a certain amount of current based on the data signal provided to the pixel circuit. The more current provided to the EL element (e.g., OLED), the brighter the EL element will become. By changing the brightness of each individual red, green, and blue pixel (sometimes referred to as subpixel) different images can be displayed.

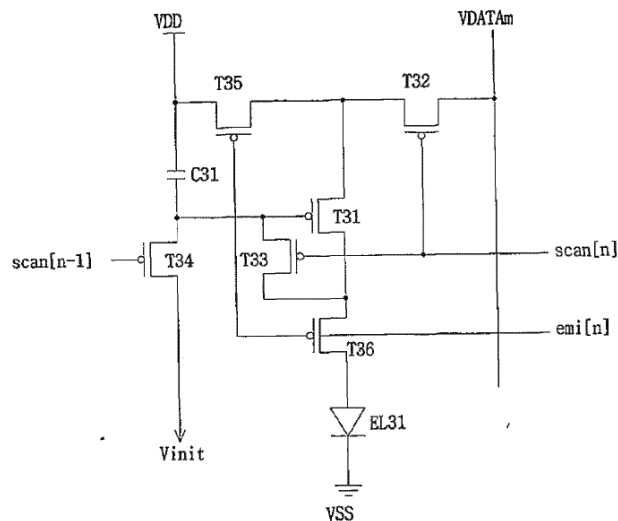
37. As the ’599 Patent explains, an organic light emitting device can further “be classified into a current driving OLED and a voltage driving OLED depending on the manner in which the EL element is driven.” ’599 Patent at 1:23–29. In a current driving (or current-programming) OLED, a specific current is used as the input data signal, whereas in a voltage driving (or voltage-programming) OLED the data signal that is provided to the pixel circuit is in the form of a specific voltage.



VI. OVERVIEW OF U.S. PATENT NO. 7,414,599

38. The '599 Patent is directed to the pixel circuits of an AMOLED display, such as those found in a cell phone or other mobile device. One of the problems identified by the '599 Patent is the issue of threshold voltage deviation that occurs between the drive transistors of the different pixel circuits of the display. While AMOLED displays have “an advantage in that power consumption is low, current intensity flowing through the EL element change[s] over time, causing display nonuniformity.” '599 Patent at 1:38–41. The change in current intensity is the result of threshold deviations in the drive transistors, which arise from both manufacturing variation and normal use over time. See '599 Patent at 1:38–50. Because of the threshold voltage deviations between the various driving transistors, the amount of current that passes through the OLED cannot reliably be controlled. For example, one cannot reliably set two or more transistors of different pixels of the display to deliver the same levels of current based on the same voltage levels.

39. The '599 Patent teaches a pixel circuit structure “capable of detecting and self-compensating threshold voltage deviations” in the drive transistor of the pixel circuit. *See, e.g.*, '599 Patent at 3:43–47. An embodiment of the invention of the '599 Patent is shown, for example, in Figure 3:

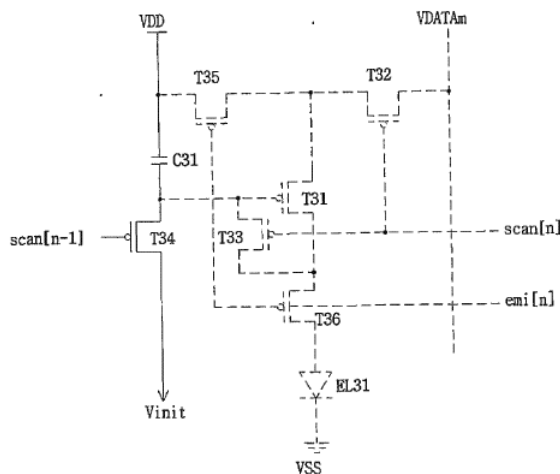


40. As shown in Figure 3, the circuit is designed such that multiple transistors can share the same control signal lines. For example, both transistors T32 and T33 are tied to the same scan line, scan[n]. Similarly, both transistors T35 and T36 are tied to the same emission line, emi[n]. Furthermore, transistor T34 is tied to the scan line of the previous row, scan[n-1]. By sharing lines, fewer lines can be used for each row of the display, reducing the overall cost and complexity.

41. The circuit of Figure 3 has three phases of operation, shown in Figures 5–7 of the '599 Patent.¹ The first phase, shown in Figure 5, is an initialization

¹ In the '599 Patent, Figures 6 and 7 both show the data program operation. Based on the specification, this appears to be an error. Figure 7 should depict the light emission operation. *See* '599 Patent at 7:59–55. However, the correct version of

operation. *See* '599 Patent at 7:15–26. As shown below, during the initialization operation, transistor T34 is the only transistor that is on, and an initialization path is formed. “[T]he data signal that ha[d] been stored in capacitor C31, namely, a gate voltage of driving transistor T31, is initialized.” '599 Patent at 7:24–26.

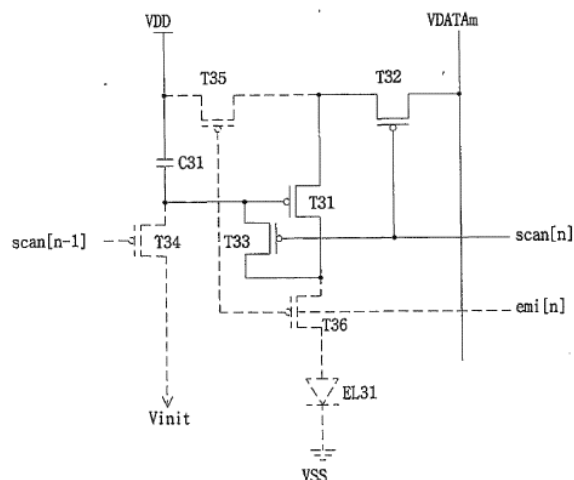


'599 Patent, Figure 5.

42. The second phase, shown in Figure 6, is a data programming operation. *See* '599 Patent at 7:27–48. As shown below, during the data programming operation, transistor T34 is turned off, while transistors T31, T32, and T33 are turned on. “Accordingly, data voltage VDATA_m applied to the associated data line is provided for the gate of driving transistor T31 through threshold voltage compensation transistor T33.” '599 Patent at 7:41–44. “Since driving transistor T31 is in the diode

Figure 7 can be found in the Foreign Application Priority document, KR 10-2003-0045610, which was provided during prosecution.

connection, $V_{DATAm} - V_{TH(31)}$ is applied to the gate of transistor T31 and the gate voltage is stored in capacitor C31.” ’599 Patent at 7:45–48.



’599 Patent, Figure 6.

43. The third phase, shown in corrected Figure 7, is a light emitting operation. *See* ’599 Patent at 7:49–65. As shown below, during the light emitting operation, transistors T32 and T33 are turned off, while transistor T31 is kept on, and transistors T35 and T36 are turned on. “Accordingly, a driving current generated in response to the data signal voltage applied to the gate of driving transistor T31 is provided through transistor T31 for organic EL element EL31.” ’599 Patent at 7:61–65.

[REDACTED]

46. Using these factors, in my opinion, a person of ordinary skill in the art (“POSITA”) with regard to the ’599 Patent would have had a relevant technical degree in Electrical Engineering, Computer Engineering, Materials Science, Physics, or the like, and experience in active matrix display design and electroluminescence.

47. I understand that the Petitioner has proposed that a POSITA in the field of the ’599 Patent would have had a Bachelor’s degree in electrical engineering or similar discipline, along with 2-3 years of circuit design/analysis experience,” and that “[l]ack of work experience can be remedied by additional education, and vice versa.” Petition at 13.

48. I do not agree with the Petitioner’s proposal, because it does not require any experience in active matrix display design or electroluminescence, which are the subject matter of the ’599 Patent. As explained above, the ’599 Patent is directed to AMOLED displays and solving problems specific to those displays, including their image quality and aperture ratio, i.e., the ratio of light-emitting to non-light emitting area. There are aspects of circuit design that are unique to the context of active matrix display design, and to the context of electroluminescent displays, as opposed to general circuit design. For example, the operation of the driving transistor in the pixel circuit to provide current to the OLED is specific to AMOLED displays. Additionally, the importance of compensating for deviations in threshold voltage to provide uniform light output across pixels is specific to AMOLED displays. These

[REDACTED]

impact the overall image quality of the display. As another example, how the pixel circuits are designed, including the number of signal lines and transistors that are used impacts the overall aperture ratio of the display. *See, e.g.*, Kimura at ¶ 429.

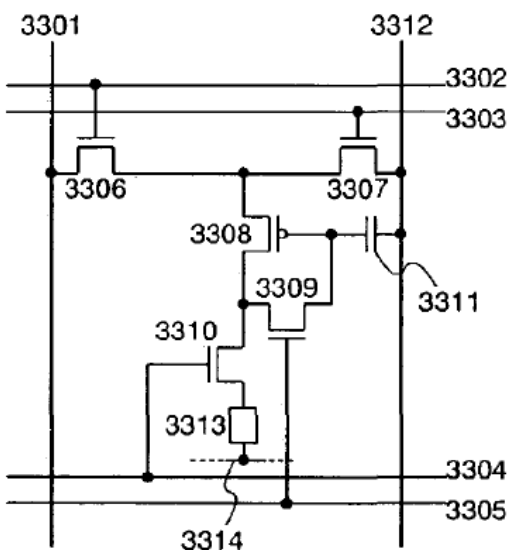
49. Petitioner’s definition, which relates only to general “circuit design” does not accurately reflect the unique aspects of, and design considerations that go into, active matrix displays, and as such it does not reflect the experience of those working in the field or the technology of the ’599 Patent. Indeed, this is evident even from the alleged prior art relied upon by Petitioner. For example, the disclosures from Kimura relating to “erasure” are specific to the display context. *See, e.g.*, Kimura at ¶ 405 (describing erasure in the context of a combined digital gray scale and time gray scale method). They describe how to “cut off” current from flowing to the OLED to prevent light from being output by the pixel. *See, e.g.*, Kimura at ¶ 410. Because Petitioner’s proposed definition fails to include any experience with active matrix display design and electroluminescence, in my opinion it fails to reflect the background and knowledge of a person of ordinary skill in the art.

VIII. CLAIM CONSTRUCTION

50. After reviewing the specification and the prosecution history, I do not believe that any constructions other than the plain and ordinary meaning of the claim terms of the ’599 Patent are necessary.

1003 at ¶ 129–30.

Fig.33A



² I understand that a Japanese document, JP 2003-202833, which includes the same figures from Kimura that Petitioner and Dr. Foty rely upon, was submitted during prosecution, and that the '599 Patent was still allowed. *See* '599 Patent “Foreign Patent Documents.”



52. Notably, Kimura identifies the embodiment of Figure 33A as having a significant problem: “there are cases in which electric current flows in the EL device to cause light emission . . . that is during a period that is not the normal light emitting period.” Kimura at ¶ [0665]. Kimura provides an express solution to this problem in Embodiment 11, depicted in Figure 36. Kimura at ¶¶ [0665] – [0666]. In light of this problem, it is unclear why Dr. Foty believes that a POSITA would be motivated to begin their analysis with the embodiment of Figure 33A (as opposed to, for example, the embodiment of Figure 36). In my opinion, they would not.

53. As illustrated above in Figure 33A, Kimura’s circuits often use both NMOS and PMOS transistors (CMOS). In Embodiments 4 and 5, shown in Figures 13-15, Kimura teaches optimized methods of manufacturing a CMOS driving circuit alongside its pixel circuits. Kimura at ¶¶ [0501]–[0615]; Kimura at ¶ [0547] (“By the above steps, as shown in FIG. 14D, the driver circuit portion including the CMOS circuit composed of the N-channel TFT and the P-channel TFT and the pixel part including the switching TFT and the drive TFT can be formed on the same substrate.”); see also Kimura at ¶ [0582]. Based on these methods of manufacture, Kimura teaches that “the number of photo masks required for manufacturing a semiconductor device can be reduced,” and “[a]s a result, the process is shortened and it can contribute to the reduction in manufacturing cost and the improvement of a yield.” Kimura at ¶ [0571].

X. KIMURA DOES NOT RENDER OBVIOUS THE CHALLENGED CLAIMS

54. Having reviewed the petition, Dr. Foty's declaration, and the cited references, as well as other relevant evidence described below, it is my opinion that the challenged claims of the '599 Patent would not have been obvious to a POSITA at the time of the invention.

55. As explained in further detail below, it is my opinion that Dr. Foty's opinions contain a number of flaws. For example, Dr. Foty's conclusory analysis of Kimura lacks evidence sufficient to explain why a POSITA would have selected different elements from the multiple embodiments Dr. Foty cites and combine them in the specific ways required by the challenged claims. In my opinion, Dr. Foty's proposed combinations are motivated primarily by hindsight.

56. Likewise, Dr. Foty fails to provide evidence showing that a POSITA would have a reasonable expectation of success or that the modifications he proposes would yield predictable results.

57. Dr. Foty has also explained that he did not consider evidence of objective indicia of non-obviousness. Ex. 2050 (Foty Tr.) at 44:14–45:5. I have examined such evidence, which I describe below, and which I believe confirms the non-obviousness of the claims.

[REDACTED]

[REDACTED]

A. A POSITA Would Not Have Been Motivated to Modify Kimura’s Design to an All-PMOS Design (All Claims)

58. Dr. Foty’s opinions all rely on modifications to Kimura’s disclosed circuits that are not taught by Kimura. In particular, Dr. Foty proposes alterations to Figures 33A and 34B to make all of the transistors PMOS. Dr. Foty refers to these modified circuits as his “All PMOS” designs. See, e.g., Ex. 1003 at ¶¶ 152–53. Dr. Foty appears to make these modifications because many of the challenged claims require certain transistors to be PMOS (e.g., claims 3, 5, and 13), or have limitations relating to connections between, for example, the drains and sources of certain transistors that would require PMOS transistors (e.g., claims 15 and 17).

59. It is worth noting at the outset that none of Kimura’s embodiments of its invention teach an all-PMOS (or any single-species) configuration. Instead, Kimura teaches CMOS circuits in which both NMOS and PMOS transistors are used. As I explain below, Kimura describes important benefits of its CMOS approach. I do not agree with Dr. Foty that a POSITA would have made the modifications he requires to arrive at the claims, or that such modifications would have been straightforward, particularly given Kimura’s focus on an improved CMOS approach.

60. The Petition and Dr. Foty present two theories as to why a POSITA would modify Kimura’s circuits to an all-PMOS approach. The first involves a “general interchangeability” theory, under which transistors that “function as simple switching devices” may have their polarities swapped (i.e., switch between NMOS

[REDACTED]

and PMOS). The second theory involves purported advantages of moving to a single-species (i.e., using all PMOS transistors) approach. I do not agree that either theory would allow for the significant modifications to Kimura's circuits Dr. Foty suggests.

61. Starting with the first theory of "general interchangeability," I do not agree that this theory supports Dr. Foty's opinions that a POSITA would make the numerous modifications to Kimura's circuits that Dr. Foty suggests. These modifications involve far more than simply changing the polarity of a particular switching transistor, and fail to take into account the significant structural and operational differences that a POSITA would have understood exist between NMOS and PMOS transistors.

62. Notably, Kimura discusses interchanging between NMOS and PMOS for simple switching transistors in the context of embodiments other than the embodiments on which Dr. Foty relies. Nowhere in Kimura does it describe that NMOS and PMOS transistors may be interchanged for every transistor in Figure 33, or any of the other embodiments Dr. Foty relies upon. This makes sense because, as I explain in greater detail below, Kimura is directed to an improved CMOS approach, in which both NMOS and PMOS transistors are used. In the Figure 33 embodiment Kimura describes using both NMOS and PMOS transistors, to take advantage of

[REDACTED]

benefits including a reduction in signal lines, which may lead to improved aperture ratio. See, e.g., Kimura at ¶ 458.

63. A POSITA would have similarly understood that there were other meaningful differences in NMOS and PMOS transistors. For example, in polysilicon thin-film transistors, such as those taught by Kimura, Kimura ¶ 357, NMOS transistors were known to be less susceptible to leakage current. For example, in Ex. 2049 (Study of Leakage Current in n-channel and p-channel Polycrystalline Silicon Thin-film Transistors by Conduction and Low Frequency Noise Measurements), the authors noted a “substantially lower leakage current” in polysilicon NMOS transistors as compared to PMOS transistors, and determined that “[t]he substantially lower leakage current observed in the n-channel polysilicon TFT is explained by the development of positive fixed charges at the interfaces near the drain junction which suppress the electric field.” C.T. Angelis, et. al, J. Appl. Phys. 82, 4095-4101 (1997). Dr. Foty also acknowledged during his deposition that it was known in the art that NMOS transistors were less susceptible to leakage current. Ex. 2050 at 92:20–93:20.

64. NMOS transistors were also known to generally be faster than PMOS transistors at the time of the invention of the '599 Patent. This was due to their higher electron mobility. Dr. Foty confirmed this during his deposition, in describing a roughly two to one higher electron mobility in NMOS transistors. Ex. 2050 at 92:20–

[REDACTED]

93:20. The improved speed of NMOS transistors is particularly important because timing in displays is critical. In particular, the speed at which the display is able to depict an image and refresh it impacts the perception of motion by the human eye and impacts the ability to implement high-resolution displays.

65. It was also understood that NMOS transistors could be made smaller than PMOS transistors. This again stemmed from the higher mobility of NMOS transistors. Dr. Foty also explained this during his deposition. Ex. 2050 at 92:20–94:18. An additional benefit of the smaller size of NMOS transistors was that the circuit area could be reduced, leading to the potential for a larger aperture ratio. See also Ex. 2050 at 39:6-18.

66. There are also other operational differences between NMOS and PMOS transistors that a POSITA would have recognized. For example, as Dr. Foty acknowledges, a high signal is used to turn on NMOS transistors, and a low signal is used to turn on PMOS transistors. See, e.g., Ex. 1003 at ¶ 57. This difference is important, as it implicates both the necessary control signals as well as their associated timings. For example, as discussed above, the beneficial reduction in signal lines that Kimura teaches leverages the inverted control signals used to control NMOS and PMOS transistors to obtain the reduction in signal lines. As Dr. Foty also acknowledges, “Kimura itself [teaches that] reducing the number of control lines improves aperture ratio.” Ex. 2003 at ¶ 258. Additionally, the use of a single

[REDACTED]

signal line in the CMOS approach allows for reduced power consumption in the drive circuit because it reduces the number of necessary signals.

67. Moving to the “all-PMOS” modification would remove these benefits. For example, an “all PMOS” circuit would preclude the reduction in gate lines for the alleged “first” and “fourth” transistors made possible by having them have opposite polarities and may thus require additional gate lines.

68. In sum, NMOS and PMOS transistors were not simply interchangeable in an analog display circuit such as the ones claimed. Detailed, circuit-level analysis is required whereby the impact of drive strength, leakage current, and V_{th} polarity can be evaluated.

69. I also note that while Dr. Foty points to a number of passages from Kimura that describe changing simple switching transistors from NMOS to PMOS in other embodiments, he points to no such disclosure suggesting that the “third” transistor in Figure 33 could similarly be modified. Ex. 2003 at ¶ 150. This is not surprising, when taking into account the location and function of the third transistor in Figure 33.

70. As shown in Figure 33, the “third” transistor is located within the pixel circuit such that it controls the flow of charge to the capacitor during programming and holds charge on the capacitor during emission. Kimura Fig. 33. The charge on the capacitor in turn determines the brightness of the pixel. In this context, ensuring



that the correct value is placed on, and held on, the capacitor is essential to the correct operation of the pixel circuit. Given the location of the third transistor and the role it plays in the circuit, a POSITA would have recognized that leakage current in the third transistor could alter the charge stored on the capacitor, thereby changing the brightness of the pixel from its intended value. It would thus be particularly important to mitigate any potential leakage current for this transistor, to ensure that the intended charge is placed on, and held on, the capacitor. Accordingly, it is unsurprising that Kimura never suggests that this transistor (or its counterpart in any other embodiment) may be switched from NMOS to PMOS, as this would lead to a higher susceptibility to leakage current.

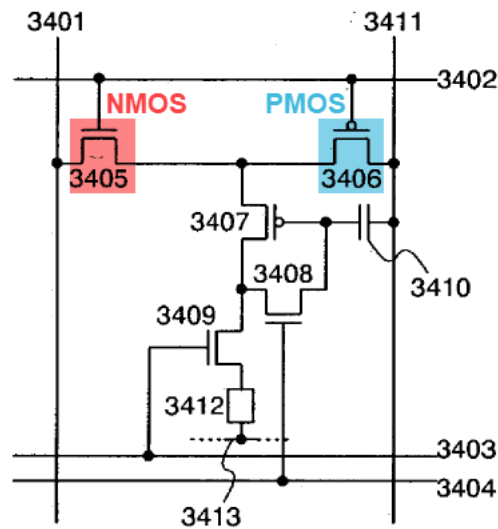
71. It also bears mention that the only discussion of Figure 33 that Dr. Foty cites in support of the all-PMOS modification does not support the changes he suggests. In particular, Dr. Foty points to Kimura ¶ 659 and Fig. 34A as purported support for replacing the first or fourth transistor in Figure 33 with a PMOS transistor. See, e.g., Ex. 1003 at ¶ 148. However, this portion of Kimura relates to changing the polarity of one of these transistors, in order to gain the benefit of reduced signal lines:

Furthermore, a gate signal line for controlling a TFT can be shared among a plurality of TFTs, as shown in FIGS. 34A and 34B. For example, the TFT 3306 and the TFT 3307 are controlled so as to turn on and off at mutually opposite timings, and therefore *the polarity of one of the TFTs may be made opposite to the polarity of the other*

TFT, and both of the TFTs can thus be controlled by the same gate signal line 3402, as shown in FIG. 34A.

Kimura at ¶ 659. As Kimura explains, it is the combination of both NMOS and PMOS transistors that enables this reduction in signal lines. Figure 34A shows this, as 3405 is an NMOS TFT and 3406 is a PMOS TFT, and both are controlled by gate line 3402:

Fig.34A



Kimura Fig. 34A
(with NMOS TFT 3405 and PMOS TFT 3406 highlighted)

72. This benefit would not be obtained under Dr. Foty's all-PMOS modifications, because an additional signal line would be necessary to control these two transistors to have inverted timings. Additionally, changes to the drive circuitry, signaling, and associated timings would be necessary to implement these changes,

[REDACTED]

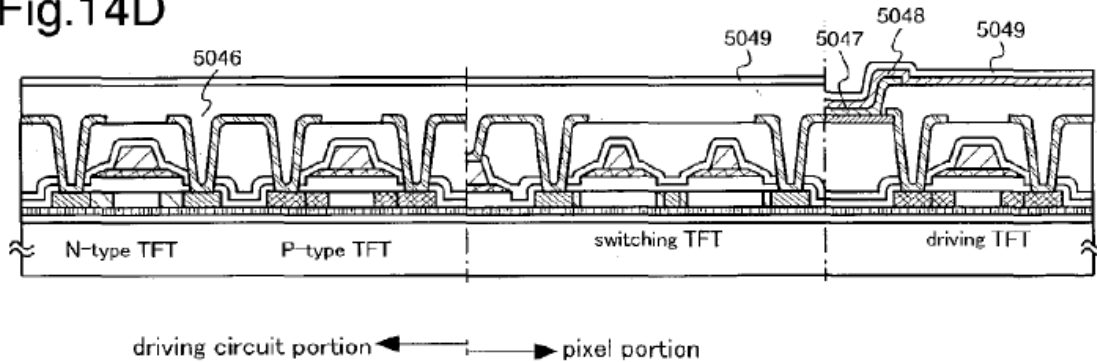
including for this additional signal line. A POSITA would have understood this, and would not have been motivated to discard the beneficial teachings of Kimura.

73. In addition, Dr. Foty has not explained why a POSITA, even if they were to determine to change to a single-species circuit, would modify the five transistors identified above to be PMOS. For example, changing just the transistor 3308 from PMOS to NMOS would result in a single-species circuit and require modifying the polarity of only one transistor. Additionally, even if in the abstract a POSITA may have thought there could be a potential benefit to having all transistors of the same polarity in a pixel circuit, a POSITA would not have been motivated to modify the circuits of Kimura in the manner Dr. Foty suggests, in light of Kimura's teachings, including as to Kimura's use of both NMOS and PMOS transistors and the associated benefits described above.

74. Additionally, and as noted previously, Kimura is directed to methods of manufacturing active-matrix devices that use both NMOS and PMOS transistors. Kimura at ¶¶ 0501–0615; Kimura at ¶ 0547 (“By the above steps, as shown in FIG. 14D, the driver circuit portion including the CMOS circuit composed of the N-channel TFT and the P-channel TFT and the pixel part including the switching TFT and the drive TFT can be formed on the same substrate.”); Kimura at ¶ 0582 (“By the above steps, the driver circuit portion including the CMOS circuit composed of the N-channel TFT and the P-channel TFT and the pixel part including the switching

TFT and the drive TFT can be formed on the same substrate.”). Figure 14D shows the resulting CMOS structure of Embodiment 4:

Fig.14D



75. Kimura describes specific manufacturing benefits associated with its CMOS manufacturing process, for example:

[A]ccording to the steps described in [Embodiment 4], the number of photo masks required for manufacturing a semiconductor device can be reduced. As a result, the process is shortened and it can contribute to the reduction in manufacturing cost and the improvement of a yield.

See, e.g., Kimura at ¶ 0571.

76. In my opinion, a POSITA would not start with Kimura, a reference directed to optimizing a CMOS manufacturing process, and look to modify the circuitry and associated manufacturing process to a single-species design. A POSITA would recognize that this would require altering the manufacturing process explicitly described in Kimura as advantageous. Such alterations would not be trivial. For example, Kimura’s process necessarily includes separate doping steps to create both NMOS and PMOS transistors, which would have to be materially changed. *See,*

[REDACTED]

e.g., Kimura at ¶¶ 0523–0529, 0574. Surrounding manufacturing steps would then need to be altered as well.

77. Dr. Foty states that a single-transistor-species circuit would be “simpler and less costly to manufacture.” Ex. 2003 ¶ 151. He cites a prior art reference U.S. Pat. 6,362,798 “Kimura ’798” in support of this opinion. I note that the inventor of this Kimura ’798 reference is not the same inventor of the Kimura reference on which Dr. Foty and Petitioner primarily rely. Moreover, this unrelated Kimura ’798 reference would not be applicable to the Kimura reference Dr. Foty and Petitioner rely upon, for the reasons I explain above relating to Kimura’s CMOS process. Specifically, a POSITA would recognize that the alleged benefits Dr. Foty describes in using only PMOS transistors would require changes to the peripheral drive circuitry (e.g., scan driver and emission driver) of the display in Kimura to be realized. For example, the inverter circuits disclosed in Kimura cannot be manufactured with only a single species of PMOS transistor. *See, e.g.,* Kimura Figures 25B, 28A, 42A, and ¶ 0417. In particular, because the display in Kimura is manufactured on a single substrate, with all of the TFTs being manufactured at the same time, if only the pixel circuit were designed to use a single species of transistor, the additional process steps necessary to make transistors of a different polarity (and the associated separate doping step) would still be necessary to form the drive circuitry.



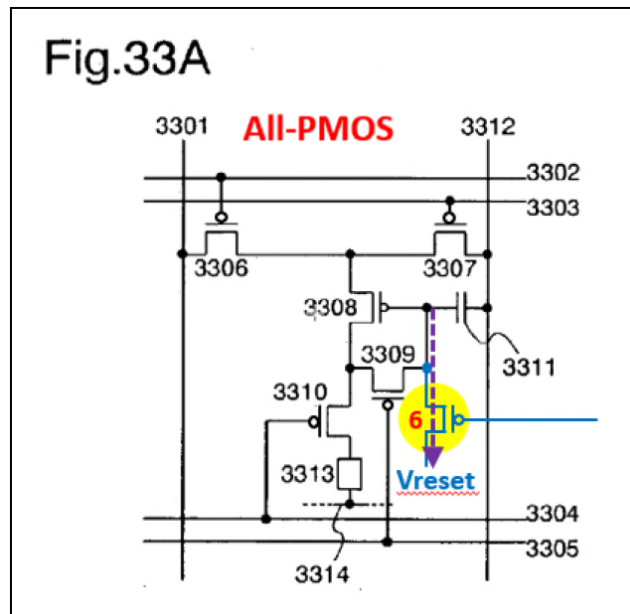
78. This means that even if a pixel circuit were designed to use only a single species of transistor, (i.e., PMOS or NMOS), the alleged benefits Dr. Foty describes, e.g., the ability to remove certain masking and doping steps, would not be realized if the other species of transistor were used in other parts of the display.

**B. Kimura Does Not Teach or Suggest the Claimed
“Initialization Transistor” (Claims 2, 8, 16, 18)**

79. Claims 2, 8, 16, and 18 of the '599 Patent require an initialization transistor that discharges the capacitor (which stores a data signal voltage) in response to a scan signal (scan[n-1]) just before the current scan signal (scan[n]). See '599 Patent claim 2 (“a fourth initialization transistor for discharging the data signal voltage stored in the capacitor in response to a scan signal just before the current scan signal”); claim 8 (“a sixth initialization transistor for discharging the data signal voltage stored in the capacitor in response to a scan signal just before the current scan signal upon initialization”); claim 16 (“a sixth transistor including a gate to which a scan signal just before the current scan signal is applied”); claim 18 (“a sixth transistor including a gate to which a scan signal to be applied to a scan line just before the associated scan line is applied”).

80. Kimura’s Figure 33, which Dr. Foty primarily relies upon, does not teach or suggest an initialization transistor. Nor do any of the all-PMOS modifications proposed by Dr. Foty teach or suggest an initialization transistor. Instead, Dr. Foty looks to the unrelated embodiment of Figures 16 and 17, which

teaches a distinct structure from the embodiment of Figure 33, and imports only the NMOS “initialization transistor” of Figures 16 and 17 into the all-PMOS modified version of Figure 33, after switching the polarity of the “initialization transistor” from NMOS to PMOS. Dr. Foty’s illustration of this proposed modification is reproduced below. See Ex. 1003 at ¶ 228.



Dr. Foty’s all-PMOS Figure 33A, with a sixth “initialization transistor” as a further modification

81. In transplanting the “initialization transistor” (TFT 1607) of Kimura’s Figures 16 and 17 into the embodiment of Figure 33 (after changing TFT 1607 from NMOS to PMOS), Dr. Foty conflates the concept of “erasure” in Kimura with “initialization.” I disagree with Dr. Foty that the concepts are the same.

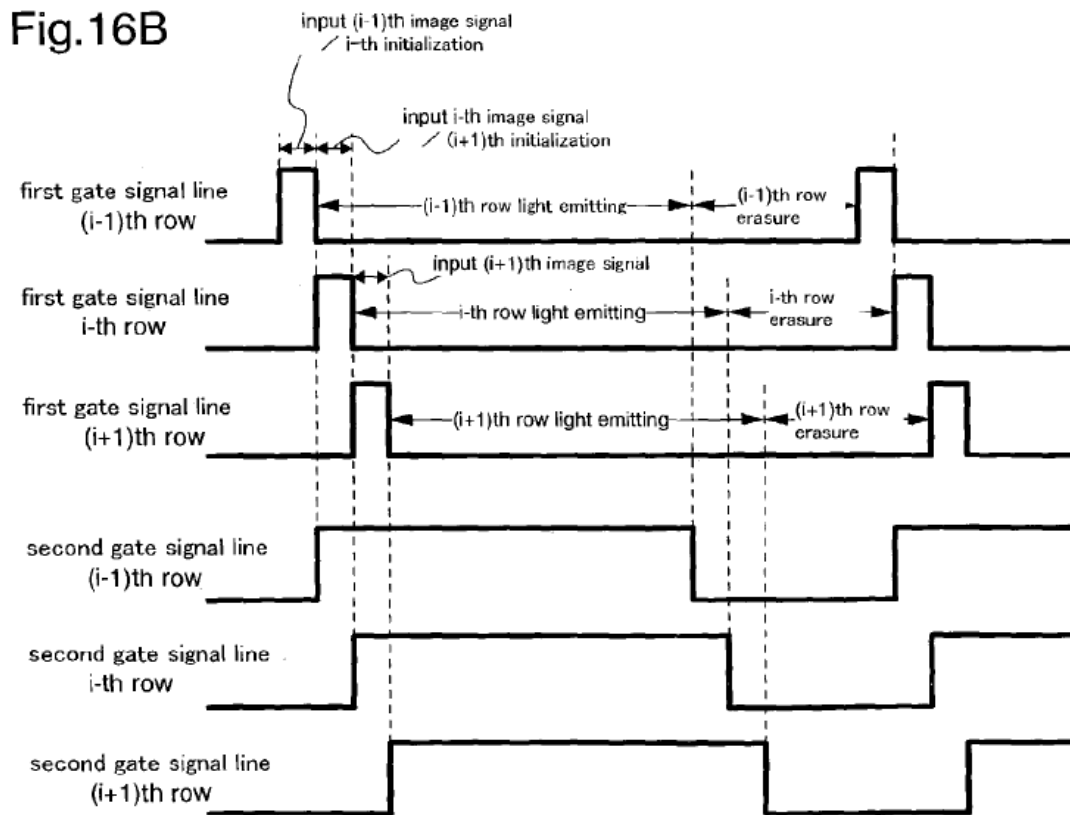
82. Kimura uses “initialization” and “erasure” to refer to two distinct operations. The “erasure” process in Kimura is not used to initialize a node to a

[REDACTED]

specific voltage. Instead, Kimura uses “erasure” to mean “forcibly plac[ing] [the EL device] in a non-light-emitting state.” Kimura at ¶ 410. Kimura discloses the use of an “erasure period” under some of its embodiments in which “electric current to the EL device [is] cutoff,” Kimura at ¶ 415 so as to address timing issues that can arise in certain embodiments. See, e.g., Kimura at ¶ 406 (“normal display becomes impossible . . . when the address (write in) periods of different subframe periods overlap . . . [t]he erasure period is formed in order to resolve these kinds of problems, and is formed so that two different address (write in) periods do not overlap after sustain (light emitting) periods”). Kimura then introduces its “erasure TFT” as a transistor that permits “electric current supplied to the EL device [to] be cut off at an arbitrary timing.” Kimura at ¶ 658; see also Kimura at ¶ 415 (“The erasure TFT 914 is off during . . . the erasure period, and electric current to the EL device 909 is thus cutoff.”). Dr. Foty acknowledged during his deposition that when Kimura states in paragraph 668 that turning off erasure TFT 3912 “cut[s] off” an “electric current path to the EL device 3916,” it means that erasure TFT 3912 “interrupt[s] the current path from the top to the bottom that goes down through the [O]LED . . . like turning a water faucet off . . . [s]o there’s no current flowing down that current path.” Ex. 2050 at 112:11–113:7.

83. While Kimura discusses an “initialization” operation when with respect to certain embodiments, for example, the embodiment shown in Figures 16 and 17,

it does not discuss initialization with respect to the Figure 33 embodiment relied upon by Dr. Foty and Petitioner. As is made clear in the Figure 16 embodiment, the terms “erasure” and “initialization” are not used interchangeably. This can be seen in the timing diagram of Figure 16B of Kimura (reproduced below), which identifies an “initialization” period that is distinct from the “erasure” period, i.e., the two periods are not co-extensive.



Kimura Fig. 16B (showing the distinction between “initialization” and “erasure”)

84. I note that the Board, in instituting this IPR proceeding, agreed with Samsung Display that Kimura uses “erasure” to mean “forcibly plac[ing] [the EL device] in a non-light-emitting state” (Kimura at ¶ 410) and that the erasure transistor

[REDACTED]

disclosed in Kimura “does not . . . discharge[] the capacitor to initialize the capacitor through the EL device . . . [i]nstead, the EL device is forcibly placed into a non-light emitting state in an erasure operation.” See ID at 47–48 (“The record evidence does not support Petitioner’s assertion that the fifth transistor, when used as an erasure transistor, resets the capacitor voltage to a default initialization value.”).

85. Dr. Foty asserts that “a POSITA would have been motivated to combine the initialization approach disclosed in Kimura at Figure 16 and Figure 17 with the [erasure transistor] approach disclosed by Kimura at Figure 33 – by adding a dedicated initialization transistor (i.e., the ‘sixth transistor’ of the ‘599 patent).” Ex. 1003 at ¶ 228. Dr. Foty goes on to state:

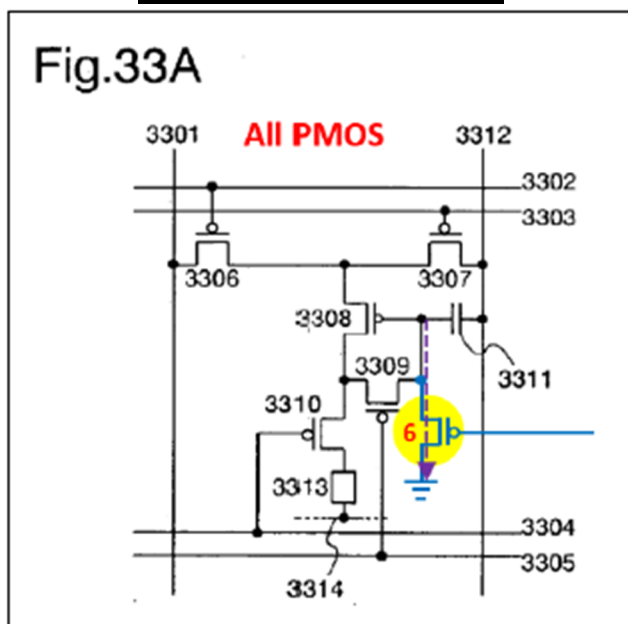
This is a simple insertion of an additional transistor into the circuitry of Figure 33 of Kimura, guided by Kimura’s disclosures as associated with Figure 16 and Figure 17; as noted earlier, when discussing Figure 33, Kimura expressly teaches that “the erasure [transistor] can be placed *in any location*, provided that it is a location at which electric current supplied to the EL device can be cut off at an arbitrary timing.” Kimura, [0658] (emphasis added) . . . Thus, a POSITA would have been motivated to place the initialization transistor discussed in Figure 16 and Figure 17 in the same location (i.e., directly connected to the node that is connected to the gate of the second transistor and the capacitor) in Figure 33.

Ex. 1003 at ¶¶ 228–29. I disagree with Dr. Foty, as this proposed modification is based on Petitioner’s incorrect conflation of an *erasure* TFT with an *initialization*

[REDACTED]

TFT, which the Board also expressed disagreement with. *See* ID at 47–48. I also note that Dr. Foty acknowledged during his deposition that he had not considered the embodiment of Figure 21, which describes erasure in detail, and makes clear that erasure is a wholly different concept than initialization in Kimura’s disclosures. Ex. 2050 at 86:6-11.

86. Moreover, Dr. Foty’s proposed modification—in which he would introduce an additional transistor “directly connected to the node that is connected to the gate of the second transistor and the capacitor” in Figure 33—as an “initialization” transistor, Ex. 1003 at ¶ 229, is inconsistent with Kimura’s requirement that the “erasure” transistor must be placed in a location where it can cut off the electric current supplied to the EL device. *See* Kimura at ¶ 658. As shown in Dr. Foty’s annotated version of Figure 33 below, the “initialization” transistor proposed by Dr. Foty would be placed in a spot that is *not* along the current path to the EL device and would therefore not be able to cut off the electric current supplied to the EL device.



Annotated Modified Figure 33A (Ex. 1003 at ¶ 228)

87. In fact, during his deposition, Dr. Foty admitted that the additional “initialization” transistor (labeled transistor “6” in the annotated Figure 33A above) he proposed to add to Figure 33 would not cut off current flow to the OLED.

Q. If we go back to the modified version of Figure 33A . . . there’s no current path through Transistor 6 that also leads through the EL element. Right?

A. Yes. That’s the point of the modification, to have that capacitor be drained without having it go through the electroluminescent element. And Kimura does actually, as I describe, describe that being a problem to do it that way.

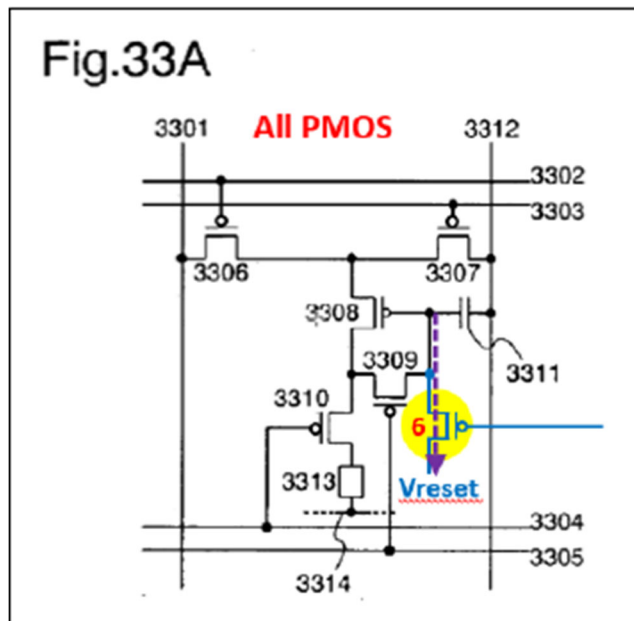
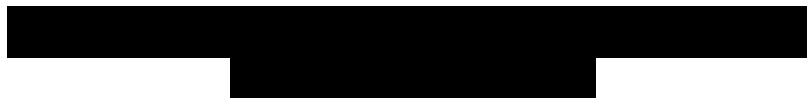
Ex. 2050 at 120:5-15.

88. In addition, Dr. Foty admitted during deposition that this proposed modification would require one (or multiple) additional signal line(s) connected to



the drain of his additional “initialization” transistor to allow charge to be “evacuated” through the transistor. See Ex. 2050 at 116:20-118:17. Dr. Foty fails to explain how this increase in signal lines squares with his stated motivation for other proposed modifications—which is to reduce signal lines. See Ex. 1003 at ¶ 225 (explaining the “convenience” of “using the prior scan line signal” such that “[t]he number of signal lines can be kept to a minimum”).

89. For example, as shown in Dr. Foty’s annotated modified Figure 33A above (from Ex. 1003 at ¶ 228), the drain of the additional “initialization” transistor (labeled transistor “6”) is tied to a ground symbol. See Ex. 2050 at 116:20–117:1. Dr. Foty explained that the ground symbol is there “to show[] the current flow going off the capacitor and down through the transistor” “[s]o it’s evacuated” and “[t]he ground symbol indicates there is some sort of a connection which provides a low signal out via which that charge can be evacuated.” Ex. 2050 at 117:9-20. Dr. Foty also testified that there could be multiple ground signal lines. See Ex. 2050 at 118:4-17 (“[I]t could be one line, ground line, it could be multiple ground lines. There just has to be something to provide the evacuation path . . . there has to be a sewer system there to evacuate the charge”); see also Ex. 2050 at 136:9–138:3.



Annotated Modified Figure 33A (Ex. 1003 at ¶ 321)

90. Likewise, when asked about the annotated modified Figure 33A in paragraph 321 of his declaration (reproduced above), which Dr. Foty used in connection with his opinions regarding claim 8 of the '599 Patent, Dr. Foty admitted that the drain of the “initialization” transistor (labeled as transistor “6”) is connected to Vreset:

Q. The voltage line would be necessary to bring that voltage to the drain of what you labeled here as the Transistor 6?

A. You would have to connect the Vreset . . . The lower side in the figure would have to be connected to something, which would serve as the what I keep calling the sewer pipe is the analogy that the charge is drained away and has to be somewhere.

[REDACTED]

Ex. 2050 at 137:9-20. Dr. Foty further explained that “Vreset” “can be many different things, but it has to serve the function of being able to pull the node connected to the gate of 3308 down.” Ex. 2050 at 136:18–137:4.

91. Based again on his mistaken conflation of “erasure” in Kimura with “initialization,” Dr. Foty argues that Figure 36 (for which Kimura discusses “erasure” but does not discuss any “initialization”) reflects the addition of an “initialization transistor” (TFT 3612) to Figure 33. See, e.g., Ex. 1003 at ¶ 223. I disagree. The embodiment of Figure 36 does not reference an “initialization transistor” and nowhere does Kimura discuss the concept of initialization with respect to Figure 36 embodiment.

92. According to Kimura, the purpose of the additional transistor, TFT 3612, is to prevent unwanted light emission by the EL device during unnecessary periods, such as the programming phase where the image signal is inputted:

A TFT 3612 is therefore added as shown in FIG. 36A. *Electric current* flowing in the TFT 3609 during input of the image signal *flows through the TFT 3612 and to an electric power source line 3617*. An electric current path to the EL device 3615 is cut off by a TFT 3611, and therefore the EL device 3615 does not emit light. *Light emission* by the EL device during unnecessary periods *can thus be prevented by using this type of structure*.

Kimura at ¶ 666 (emphasis added). Kimura does not describe TFT 3612 as performing initialization.

[REDACTED]

93. I also note that Petitioner argues that it would have been obvious to implement the initialization transistor “as a PMOS device,” “[g]iven that all other transistors in the All-PMOS implementation are PMOS devices.” Pet. at 53. I disagree with this, for the reasons provided above in IX.A.

94. I disagree with Dr. Foty’s proposal to modify Kimura’s Figure 33 to transplant an “initialization” transistor from the embodiment of Figures 16 and 17 for yet another reason, namely that the supposed “motivation” to solve Figure 33’s shortcoming was satisfied by a solution presented by Kimura itself. Dr. Foty’s modification is based on Kimura’s discussion that Figure 33’s approach of using an erasure transistor has the “downside[.]” “that . . . the transient discharge current flows through the light emitting element – causing a transient-but-undesirable emission of light from the light-emitting device.” See Ex. 1003 at ¶ 221; Kimura at ¶ 665 (“In the structures shown FIGS. 33 to 35, there are cases in which electric current flows in the EL device to cause light emission, before or after threshold voltage acquisition, that is during a period that is not the normal light emitting period.... [T]his therefore causes errors to develop between the actual brightness and the target brightness.” (emphases added)).

95. But Kimura actually provides a solution to this exact problem, in the embodiment of Figure 36, where TFT 3612 is added to prevent unwanted light emission:



A TFT 3612 is therefore added as shown in FIG. 36A. Electric current flowing in the TFT 3609 during input of the image signal flows through the TFT 3612 and to an electric power source line 3617. An electric current path to the EL device 3615 is cut off by a TFT 3611, and therefore the EL device 3615 does not emit light. *Light emission by the EL device during unnecessary periods can thus be prevented by using this type of structure.*

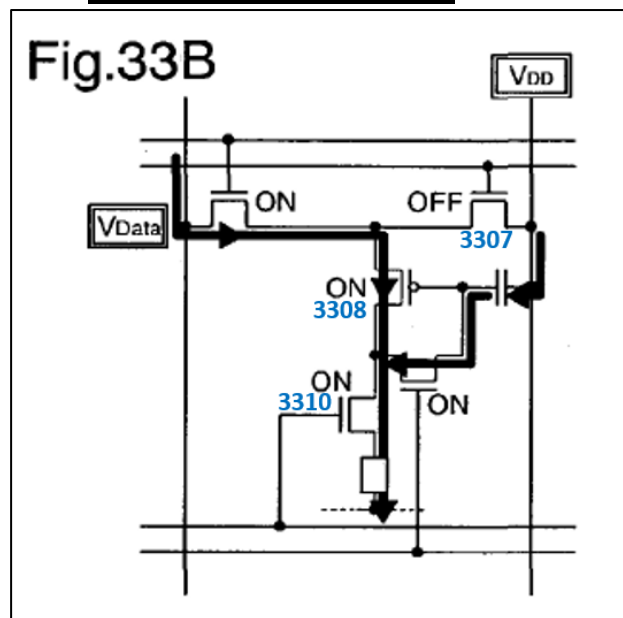
Kimura at ¶ 666 (emphasis added). The Petition itself acknowledges that “Kimura solves this problem . . . as shown in Figure 36B.” Pet. at 19. As discussed above, TFT 3612 is not an initialization transistor, and with the addition of TFT 3612, there would be no reason to add the additional transistor that Dr. Foty and Petitioner propose.

96. Moreover, while the initialization transistor claims (claims 2, 8, 16, and 18) require that the recited initialization transistor be controlled by “a scan signal just before the current [or associated] scan signal” (i.e., controlled by the previous scan line), neither TFT 3612, nor any other transistor in the circuit of Figure 36 is controlled by the previous scan line. Kimura’s TFT 3612 is controlled by line 3606, which Kimura does not teach or suggest as being the previous scan signal line for the circuit. Thus, even if TFT 3612 could be viewed as an “initialization transistor,” Figure 36 would not render obvious the claims.

C. Kimura Does Not Teach or Suggest that the “Current Light-Emitting Signal” Controls the Fourth and Fifth Transistors (Claims 13–18) or Fifth and Sixth Transistors (claims 1–6)

97. Certain challenged claims require two transistors that are controlled by the same light emitting signal. For example, claim 1 requires that a fifth transistor and a sixth transistor each operate in response to the same current light emitting signal. Kimura does not disclose these limitations and Kimura in view of the knowledge of a POSITA does not render obvious these limitations. Dr. Foty proposes to modify the Figure 33 circuit of Kimura to control the gates of transistors 3307 and 3310 with the same current light emitting signal. I do not agree with Dr. Foty that a POSITA would make that modification to Kimura’s Figure 33, because it would result in an inoperable circuit. In particular, and as I explain in detail below, if transistors 3307 and 3310 were controlled by the same signal, the circuit would not operate as Kimura teaches.

98. As shown below, Figure 33B of Kimura shows a stage in the operation of the circuit in which transistor 3307 is OFF, while transistor 3310 is ON.



Kimura Fig. 33B (annotated)

99. During this stage, the driving transistor 3308 is turned ON so that it is ready for the subsequent operations shown in Figure 33. Kimura at ¶¶ 655-656. Dr. Foty confirmed this during his deposition. Ex. 2050 (Foty Tr.) at 72:9–18 (“So in 33B, this is the initialization step. And all you’re doing here is draining the charge off the capacitor. This will pull the node connected to the gate of transistor 3308 low, which will turn the transistor on. You’re preparing it for the programming step which is coming in 33C.”).

100. The stage shown in Figure 33B is necessary to the operation of the circuit, as Kimura explains. Kimura at ¶¶ 655-656. In particular, the subsequent operations shown in Figure 33 cannot be performed if the Figure 33B step is not first performed. Kimura at ¶¶ 655-656. Dr. Foty acknowledged that the Figure 33B step

[REDACTED]

is necessary during his deposition. Ex. 2050 (Foty Tr.) at 72:21–73:7 (“And you can’t do the programming step unless 3308 is on and can function as is shown in 33B.”).

101. As shown in Figure 33B, transistor 3307 is OFF and transistor 3310 is ON during this stage of operation. Under Dr. Foty’s modification to Figure 33, however, transistors 3307 and 3310 could not be in different states (i.e., ON or OFF) at the same time. This is because Dr. Foty’s modification involves controlling transistors 3307 and 3310 (which are PMOS transistors under Dr. Foty’s proposed all-PMOS modification) with the same emission control signal. This means that transistors 3307 and 3310 would always have the same state (i.e., would either both be ON or both be OFF).

102. Because transistors 3307 and 3310 would both either be ON or OFF at any given time, there are accordingly two possibilities for how these transistors would be controlled at the Figure 33B step. First, both transistors could be controlled to be OFF. This would effectively eliminate the Figure 33B step, and merge it in with the Figure 33C step. In particular, and as shown in Fig. 33B, transistor 3310 must be ON in order for the transistor 3308 to turn ON. *See, e.g.,* Kimura at ¶ 655 (“In addition, the TFT 3309 and a TFT 3310 turn on, and the TFT 3308 thus behaves as a diode connected TFT.”); *see also* Ex. 1003 (Foty Dec) at ¶ 133 (“As can be seen in the figure – and for reasons that will be explained below – with transistors 3309



and 3310 turned on, the voltage on the node that connects to the gate of transistor 3308 will be drained away, pulling the node low; this causes transistor 3308 to turn on.”).

103. This means that if both transistors 3307 and 3310 were controlled to be OFF, the stage shown in Fig. 33B would collapse into Fig. 33C (in which both transistors 3307 and 3310 are OFF). This would mean that the driving transistor would not be turned back ON prior to the Figure 33C stage, which Dr. Foty has acknowledged is necessary for the programming step to be performed correctly. Thus, the circuit would not operate correctly, nor operate consistently with Kimura’s teachings, if both transistors were controlled to be OFF under Dr. Foty’s proposed modification.

104. If, on the other hand, transistors 3307 and 3310 were controlled to be ON, the circuit would also not function correctly. As shown above, if transistor 3307 were ON during the Figure 33B stage, transistor 3308 would be connected to VDD in addition to Vdata. Providing both of these signals during this stage would disrupt the operation of the circuit and cause a number of problems.

105. For one thing, this would allow additional current to flow to the OLED, leading to additional light emission. This would only exacerbate the problem with unwanted light emission I previously described that Kimura acknowledges is an issue with the Figure 33 embodiment. Dr. Foty’s proposed modification of

[REDACTED]

controlling transistors 3307 and 3310 with the same signal would only make this unwanted light emission worse, as it would allow additional current to flow through the OLED during this stage. Connecting transistor 3308 to both VDD and Vdata during this stage would also lead to potential compensation issues *Id.* I understand that Dr. Foty acknowledged in deposition that providing both VDD and Vdata to the circuit during this operation stage “would make no sense” and “would be a bad idea.” Ex. 2050 (Foty Tr.) at 76:12–77:5. I agree that a POSITA would not want to provide both VDD and Vdata to the pixel circuit during this operation stage, and that doing so would render the circuit unsuited for its intended operation, and contrary to Kimura’s teachings.

106. It also bears mention that Dr. Foty’s opinions as to certain claims require multiple of the modifications I described above in Sections X.A through X.C. In particular, Dr. Foty relies on the all-PMOS and shared current light emitting signal modifications for claims 1, 3-6, 13-15, and 17; the all-PMOS and initialization transistor modifications for claim 8; and the all-PMOS, initialization transistor, and shared current light emitting signal for claims 2, 16, and 18. Dr. Foty does not explain how a POSITA would make these multiple modifications within the same circuit, or address how these modifications would purportedly interoperate. Dr. Foty also does not explain why a POSITA would be motivated to make these

[REDACTED]

modifications, or have a reasonable expectation of success in making them. In my opinion a POSITA would not have done so.

107. As one example, as explained above, Dr. Foty states that a POSITA would modify Kimura's Figure 33 to control transistors 3307 and 3310 with the same signal to arrive at claim 16's requirement of a shared "current light-emitting signal." Dr. Foty identifies reducing the number of necessary signal lines as a motivation to make this modification. However, with respect to claim 16's separate requirement of an "initialization transistor," Dr. Foty proposes a modification to add an additional transistor that he has also acknowledged would increase the number of required signal lines. Dr. Foty does not explain why a POSITA would make these separate modifications within the same circuit, when the motivation identified for one modification would be frustrated by making the other modification.

D. Objective Indicia of Non-obviousness for the '599 Patent

108. Samsung Display's counsel has asked me to provide an opinion as to whether the non-obviousness of the challenged claims of the '599 Patent is supported by objective indicia of non-obviousness.

109. It is my opinion, based on my review of the evidence discussed in this declaration, that the non-obviousness of the challenged claims of the '599 Patent is supported by extensive real-world objective evidence including failures of others,

[REDACTED]

longstanding technical needs, skepticism, industry praise, and widespread adoption and copying of the '599 Patent's pixel circuits.

1. Failure of Others

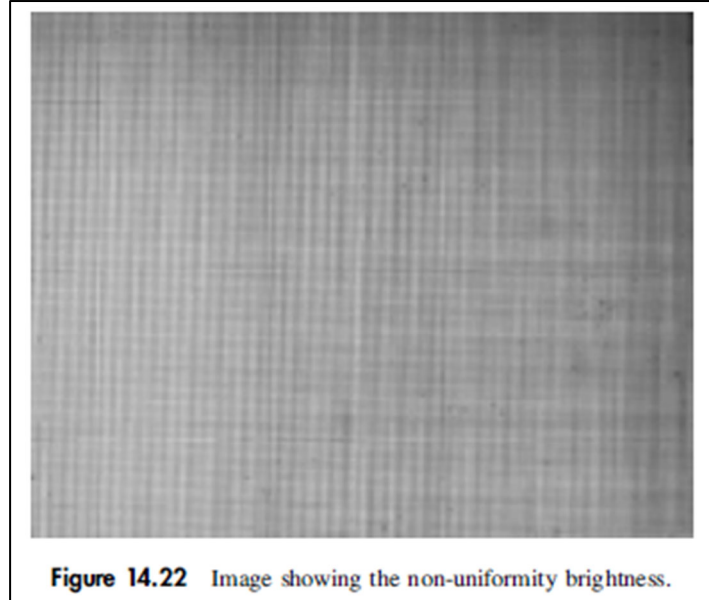
110. By the early 2000s, AMOLED displays were understood to hold great potential to become a disruptive technology to the existing dominant display technology, TFT-LCD. Many industry players, including research organizations and display companies, had been expending significant resources to commercialize AMOLED displays. There was, however, a significant roadblock in the path to successful commercialization, namely the need for ensuring that the AMOLED display is visibly uniform throughout.

111. The problem of display non-uniformity (widely referred to as “mura,” a Japanese word to describe the same) was understood to be due, at least in part, to variations in the electrical characteristics of TFTs used in AMOLED pixel circuits. Commonly used TFTs are manufactured using polycrystalline silicon that is fabricated by a low-temperature process. As explained in a 2008 book chapter titled “Advances in AMOLED Technologies” in the “Mobile Display Technology Applications” textbook which provides a historical overview of AMOLED display technologies, low-temperature polycrystalline silicon TFTs (or LTPS-TFTs) “ha[d] proved to be the only technology able to drive OLED and give rise to good reliability.” Ex. 2010 (SOCIETY OF INFORMATION DISPLAY, MOBILE DISPLAYS

TECHNOLOGY AND APPLICATIONS (Achintya K. Bhowmik et al) (2008) (“Bhowmik”)) at 27. However, “LTPS does have issues of its own,” mainly “luminance ‘non-uniformity’” which is a “general concern that needs a better solution.” Ex. 2010 (Bhowmik) at 27. The “Advances in AMOLED Technologies” book chapter explains how the LTPS process leads to variances in the electrical properties of TFTs that lead to display non-uniformity:

Polycrystalline silicon film, which is formed from amorphous silicon by excimer laser annealing crystallization or furnace annealing crystallization, has many defects at grain boundaries and within grains. In addition to the poly-Si defects, LTPS TFT characteristics are also very sensitive to the interface defects between the poly-Si film and the gate insulator where the carriers transfer in the channel of the transistor . . . The greatest concern about LTPS TFTs for AMOLED applications is the ELA mura (a well-known and extensively used word from Japanese to describe the luminance non-uniformity, so-called ‘MURA’). Variations from pulse-to-pulse laser energy and laser beam profile are the main causes of variation in the localized TFT characteristics. Subsequently, light emits differently in these areas.

Ex. 2010 (Bhowmik) at 31. An example of an AMOLED display that suffers from display non-uniformity (mura) is shown below.

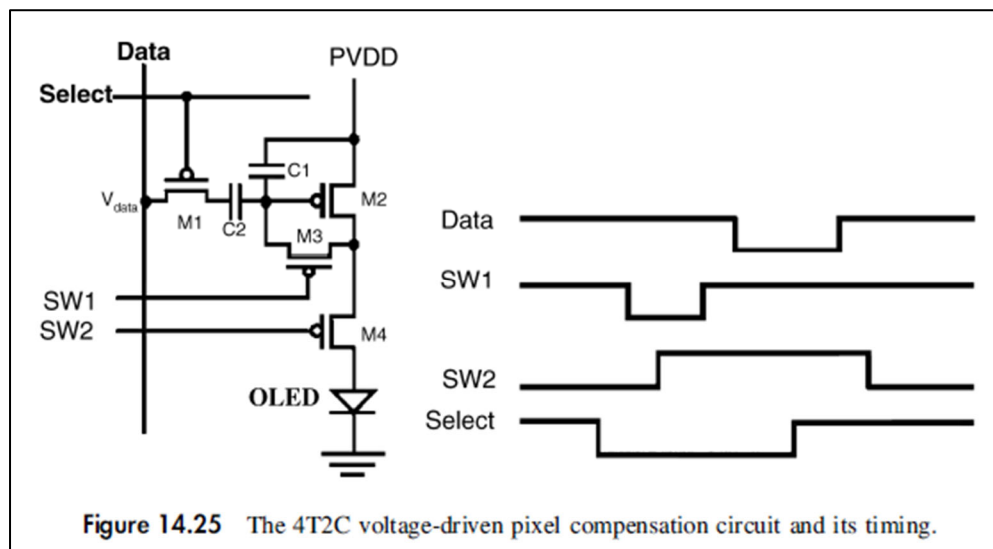


Ex. 2010 (Bhowmik) at 36.

112. To overcome the non-uniformity problem caused by LTPS-TFTs in AMOLED displays, companies and research groups invested heavily in developing approaches to use pixel circuits to “compensate” for the non-uniformity problem. “Compensation means that the driving TFT in a pixel has to be compensated for parameters such as threshold voltage and/or mobility, so that the output current becomes independent of the parameters.” Ex. 2010 (Bhowmik) at 37.

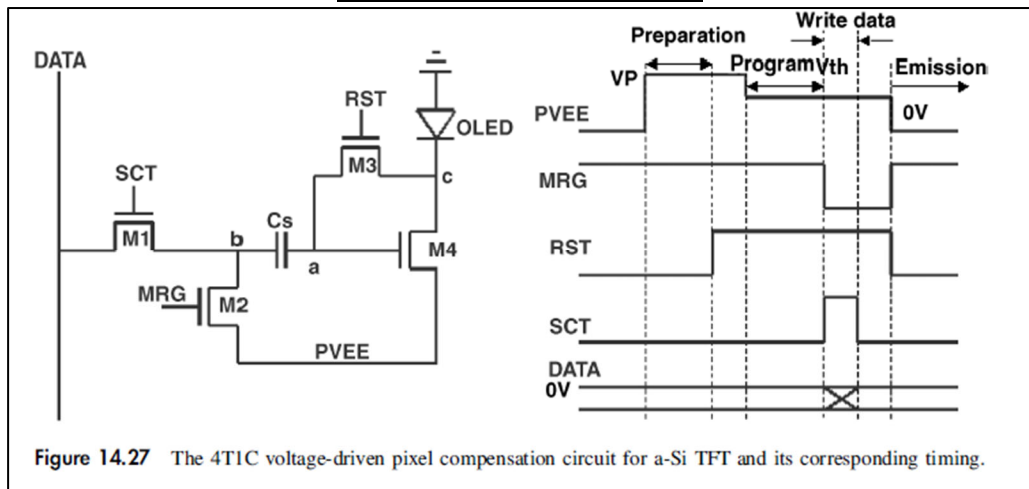
113. The “Advances in AMOLED Technologies” book chapter describes the efforts by many research groups and electronics companies to develop AMOLED pixel circuits that would solve the problem of providing a uniform display. At a high level, two categories of compensation pixel circuits were proposed over the years—voltage-programmed circuits and current-programmed circuits.

114. Voltage-programming pixel circuits are distinct from current-programmed circuits in that the data signal that is inputted to the pixel circuit is provided in the form of a specific voltage. See Ex. 2010 (Bhowmik) at 37. For example, as shown below, Dawson *et al.* from the Sarnoff Corporation proposed a voltage-driven pixel compensation circuit containing four transistors and two capacitors.



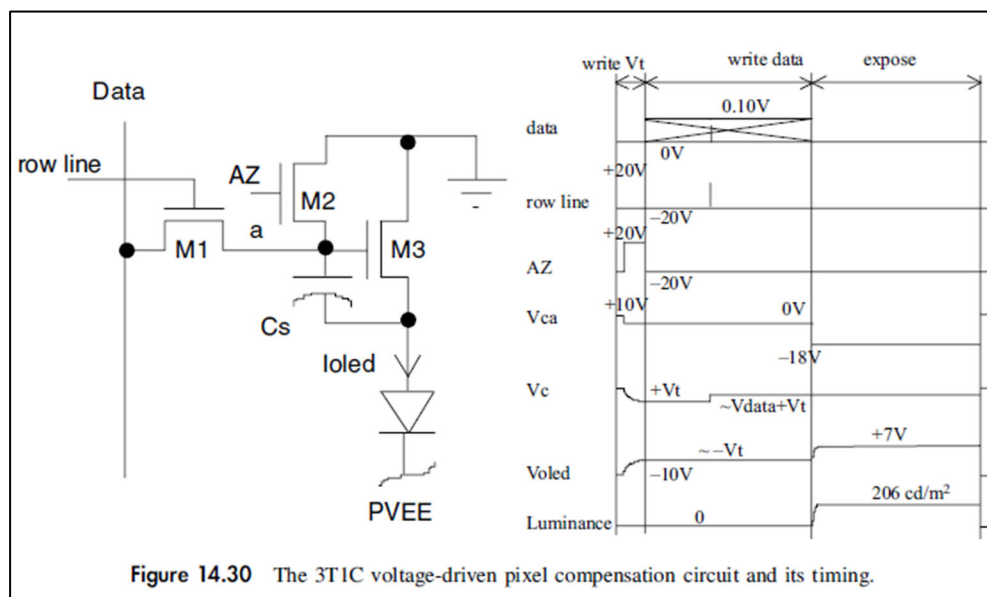
Ex. 2010 (Bhowmik) at 38.

115. Ono *et al* from IDT proposed a voltage-controlled pixel circuit using 4 transistors and 1 capacitor, as shown below.



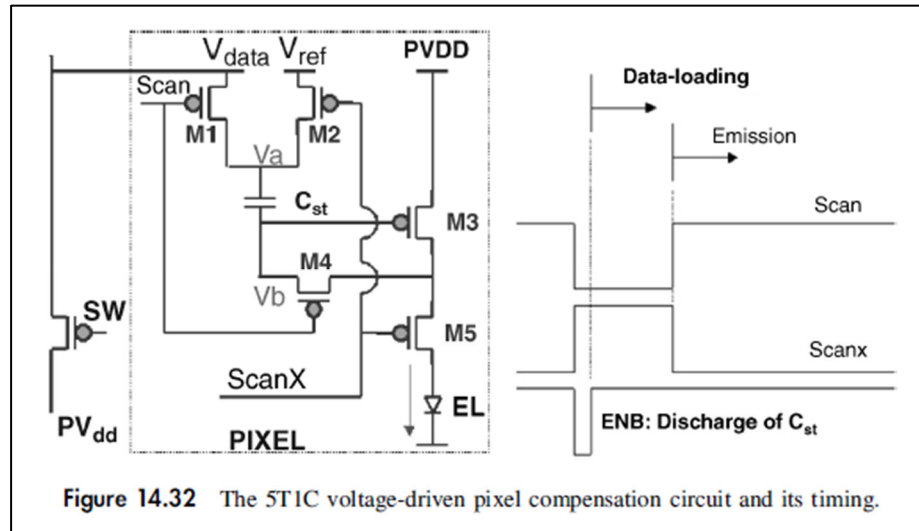
Ex. 2010 (Bhowmik) at 39.

116. Sanford and Libsch from IBM's T.J. Watson Research Center, proposed a three-transistor, 1-capacitor compensation circuit using voltage-programming, as shown below.



Ex. 2010 (Bhowmik) at 41.

117. Du-Zen Peng *et al.* from Toppoly Optoelectronics Corporation proposed a five-transistor and one-capacitor compensation pixel circuit using voltage-programming.

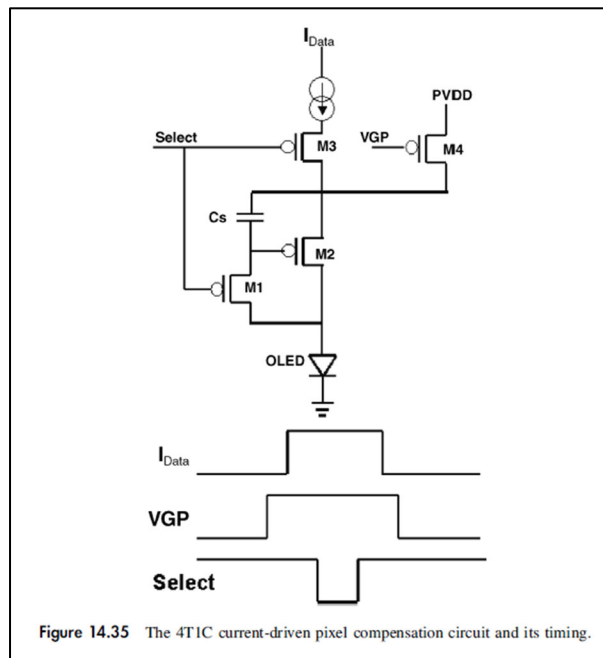


Ex. 2010 (Bhowmik) at 42–43.

118. Current-programmed pixel circuits, which use specific currents as input data signals, have also been proposed and studied. The '599 Patent explains, however that prior art current-programmed pixel circuits had shortcomings, including data instability and prolonged data line charge times. *See* '599 Patent at 1:51–2:10 (“However, the organic light emitting device as described above employs a current driving approach for driving the EL element which depends on a data signal current level applied from the current source and has difficulty in charging a data line. Because a parasitic capacitance of the data line is relatively larger while the current level of the data signal provided from the current source is relatively smaller,

the data becomes unstable as well as considerably long time is required to charge the data line.”).

119. As an example, Dawson *et al.* from the Sarnoff Corporation proposed a current-programmed pixel circuit with four transistors and one capacitor as shown below.



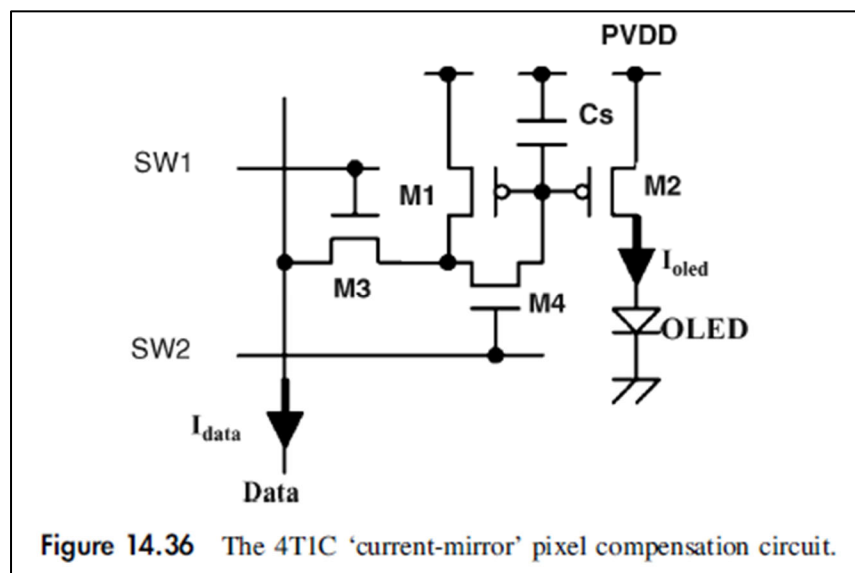
Ex. 2010 (Bhowmik) at 44.

120. The “Advances in AMOLED Technologies” book chapter identifies a significant shortcoming that made Dawson’s current-programmed pixel circuit unsuitable for use in commercial AMOLED displays:

Yet another issue arises for the quick-test procedure of the panel. This procedure means that before IC bonding, every panel is examined with a simple plain or monochrome image to check the panel uniformity and functionality. This normal procedure, however, is not suitable for

Ex. 2010 (Bhowmik) at 45 (emphasis added).

121. Moreover, as shown below, Sasaoka *et al.* from Sony Corporation developed a current-programmed circuit with four transistors and one capacitor known as the “current-mirror type” pixel circuit.



Ex. 2010 (Bhowmik) at 45.

122. The '599 Patent likewise discusses the display non-uniformity problem which stems from the uneven electrical characteristics (e.g., threshold voltages) of TFTs. In particular, the '599 Patent explains that although AMOLED displays have “an advantage in that power consumption is low, current intensity flowing through

[REDACTED]

the EL element change[s] over time, causing display nonuniformity, can be a problem.” ’599 Patent at 1:38-40. The change in current flowing through the EL element is the result of threshold deviations in the drive transistors of the individual pixels. ’599 Patent at 1:38-50, 3:19-26. The value of the threshold voltage for a particular transistor is initially determined during manufacturing. The ’599 Patent explains that variations occurring during the manufacturing process may cause the threshold voltage value to vary between driving transistors in the display. ’599 Patent at 1:38-50, 3:19-26. In addition to variations in threshold voltage due to manufacturing, the ’599 Patent explains that the threshold voltage of a particular transistor may change over time based on use. ’599 Patent at 1:38-50. Because of these threshold voltage deviations, the amount of current that passes through an EL element will differ from the intended value, and the light output for the pixel will therefore differ from the intended intensity, degrading the image quality. *See also* ’599 Patent at 3:22-26 (“[I]t is very difficult to obtain the same threshold voltage due to the manufacturing process parameters of TFT. Therefore, there is a problem that it is difficult to obtain a uniform driving current due to deviation of the threshold voltage of TFT, resulting in degraded image quality.”).

123. In addition to the display uniformity problem in AMOLED displays, there was also the difficulty of achieving adequate pixel aperture ratios, *i.e.*, the portion of each pixel that emits light. It was well understood that securing adequate

[REDACTED]

pixel aperture ratios is important in improving the “lifetime” and “luminance” of displays. Ex. Ex. 2010 (Bhowmik) at 28. An increased aperture ratio was understood to have many benefits, such as improving the brightness, quality, and energy efficiency of a display.

124. But the efforts of companies and research groups to propose increasingly complicated pixel circuits involving “more TFTs and capacitors” to compensate for display non-uniformity came at the expense of pixel aperture ratios. *See id.* at 17–18. For example, in a 2003 International Display Workshop paper by researchers at Casio Computer and Kyushu University, pixel circuits “need[ing] more than four TFTs . . . for each pixel” were viewed as “too complicated” and “too busy in pixel ar[e]a to achieve the high reliability and large aperture ratio.” Ex. 2013 (Shirasaki et al., *Full Color Polymer OLED Display Driven by a-Si:H TFT Utilizing a New Current-Programmed Method*, International Display Workshop (2003)) at 1. Similarly, in referencing a proposal for a pixel circuit with 5 transistors and 1 capacitor, researchers at the National Cheng Kung University in Taiwan explained that “[t]he presented circuit uses an excess of components . . . , reducing the aperture ratio of the display.” Ex. 2015 (Yoo et. Al., *302-ppi High-Resolution AMOLED using Laser-Induced Thermal Imaging*, Society of Information Display (2005) (“Yoo”)).

[REDACTED]

125. I have not seen any indication that the many alternative pixel circuits described above (including both voltage-programmed pixel circuits and current-programmed pixel circuits) were successfully implemented in mass-produced AMOLED displays, despite the extensive amount of research and development work concerning alternative AMOLED pixel circuits. Instead, every product I have considered, including AMOLED displays used in mobile devices such as the Galaxy series products, uses the '599 Patent's pixel circuits.

126. In the next section concerning "longstanding technical needs," I discuss how the pixel circuits of the '599 Patent succeeded in combining display uniformity and adequate aperture ratio in an inventive pixel circuit that proved to be suitable for use in mass-produced AMOLED displays for mobile devices. As I will go onto discuss, the '599 Patent's pixel circuits were key in allowing Samsung Display to successfully commercialize AMOLED displays for mobile devices.

2. Longstanding Technical Needs

127. By the time of the inventions of the '599 Patent, there was a longstanding technical need for pixel circuits for AMOLED displays for mobile devices that would provide adequate threshold voltage compensation to ensure uniform display characteristics while providing adequate aperture ratios in the display.

[REDACTED]

128. This need is discussed in the '599 Patent. The Background of the Invention section discusses, among other things, “display nonuniformity . . . problem[s],” “image quality degradation” issues, “difficult[ies] [in] manufactur[ing] transistors in the AMOLED,” and “difficult[ies] to obtain a uniform driving current due to deviation of the threshold voltage of TFT”). This longstanding need is also evident from the years-long attempts by numerous companies and research groups to develop pixel circuits suitable for use in mass-producible AMOLED displays for mobile devices, as discussed above in connection with “failure of others.” It is my opinion that this longstanding need of combining good display uniformity with adequate aperture ratio serves as an important objective indicia of non-obviousness of Samsung Display’s patented AMOLED pixel circuits, which satisfied this need.

129. The industry recognized this longstanding need. For example, in 1998, Sarnoff, Planar, Eastman Kodak, and Princeton University researchers explained that the ““thin film transistors” used in AMOLED displays “suffer[ed] from significant initial output characteristic non-uniformity . . . mak[ing] it difficult to create a uniform current source at each pixel” in a Society of Information Display (“SID”). Ex. 2011 (Dawson et al., *Design of an Improved Pixel for a Polysilicon Active-Matrix Organic LED Display*, Society of Information Display (1998) (“Dawson”)). In 2002, Hitachi researchers wrote in a SID paper that “[s]everal pixel-driving methods have been proposed for suppressing inter-pixel non-uniformity . . .

[REDACTED]

caused by a deviation in poly-Si TFTs performance,” and that despite these efforts, “challenges remain[ed] with active matrix OLED displays,” with “inter-pixel uniformity [being] one of the most important for a [sic] picture quality.” Ex. (Akimoto et al., *An Innovative Pixel-Driving Scheme for 64-Level Grey-Scale Full-Color Active Matrix OLED Displays*, Society of Information Display (2002)). In 2008, TPO Displays researchers recounted in a book chapter titled “Advances in AMOLED Technologies,” that the problem of “TFT non-uniformity” had caused a “major bottleneck[]” in the commercialization of AMOLED displays in the early 2000s. Ex. 2010 (Bhowmik) at 52.

130. At the same time, it was understood that AMOLED displays prior to the '599 Patent's inventions were prone to inadequate aperture ratios as a result of the complexity of the pixel circuits and the excessive space taken up by their components. For example, the “Advances in AMOLED Technologies” book chapter explains that while “[s]everal pixel compensation circuits for AMOLED applications have been proposed” over the years, “complicated pixel circuits require[d] more TFTs and capacitors” such that “the sub-pixel aperture ratio [wa]s reduced.” Ex. 2010 (Bhowmik) at 30–31. As another example, National Cheng Kung University in Taiwan researches explained that explained that “[t]he presented circuit uses an excess of components . . . , reducing the aperture ratio of the display” when referencing a prior art pixel circuit with 5 transistors and 1 capacitor.

[REDACTED]

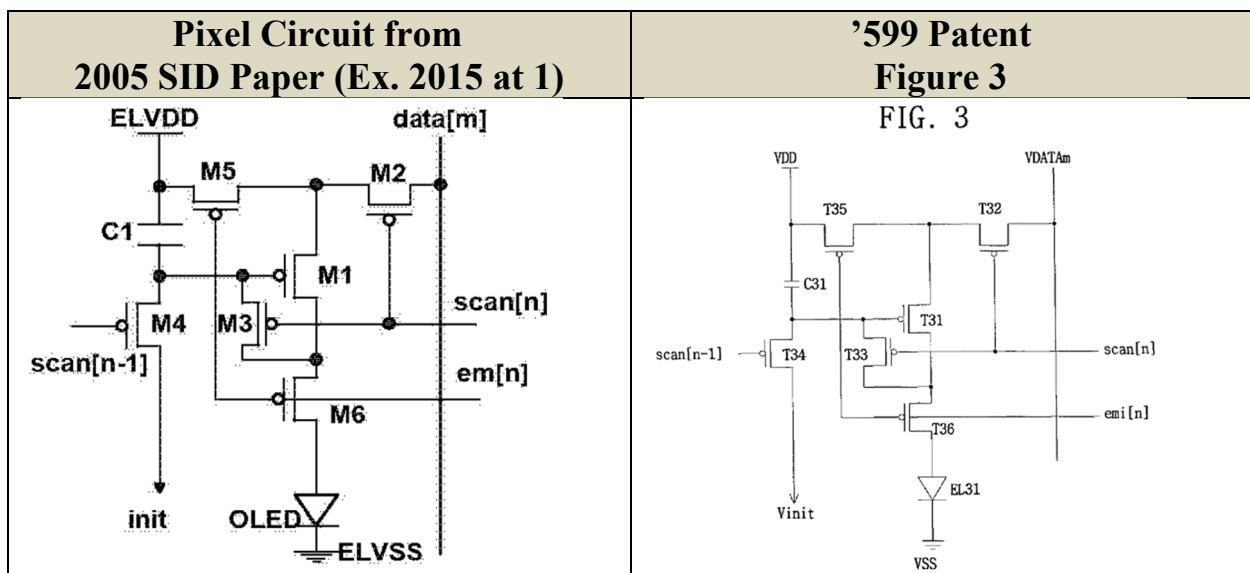
Ex. (Chih-Lung, Lin, *Pixel Circuit with High Immunity to the Degradation of TFTs and OLED for AMOLED Displays*, IMD/IDMC/ASIA Display Digest (2008)) at 1.

131. The '599 Patent's inventions satisfied these long-felt needs by creating pixel circuits suitable for mass-produced mobile device displays. The '599 Patent explains at 3:44–48 that “[t]he present invention, therefore, addresses the aforementioned problem of the prior art, and provides a pixel circuit in an organic light emitting device capable of detecting and self-compensating threshold voltage deviations, and a method for driving the same.” Both display uniformity and adequate aperture ratios were achieved by the '599 Patent's pixel circuits. Display uniformity was achieved by incorporating a threshold voltage compensation transistor that connects the gate and drain of the driving transistor such that the driving transistor is connected in the form of a diode, which allowed the driving transistor's specific threshold voltage (V_{th}) to be stored in the storage capacitor. Based on the voltage stored on the capacitor, a specific current would flow through the driving transistor to the OLED during the light-emitting phase, allowing for the detection and compensation of the threshold voltage deviation of the driving transistor. *See* '599 Patent, 3:43–4:27, 7:28–8:32. Adequate aperture ratio was achieved by requiring the use of fewer scan or control lines for each row of pixels. In particular, the emission transistors (e.g., T35 and T36 of '599 Patent's Figure 3) share a single emission control line and the switching transistor and threshold

voltage compensation transistor (e.g., T32 and T33 in '599 Patent's Figure 3) share a single scan line. Moreover, the initialization transistor, which is T34 in Figure 3, is turned ON and OFF by the scan signal of the previous pixel row, which allows further reduction in the number of scan lines.

132. In a 2005 paper submitted to the Society of Information Display, Samsung SDI (which I am informed is a predecessor to Samsung Display) researchers described that the '599 Patent's pixel circuit's "6 TFTs and 1 capacitor structure" was "suitable to realize a high image quality and high resolution for AMOLED panel[s]" and "compensate[s] the V_{th} variation of the driving TFT in the pixels." Ex. 2015 (Yoo) at 1.

133. As shown below in the side-by-side comparison chart, the "6TFTs and 1 capacitor structure" pixel circuit referred to in the 2005 SID paper is the same pixel circuit as the one shown in Figure 3 of the '599 Patent.



[REDACTED]

134. The 2005 SID paper also explained that “[a]lthough many groups [had been] developing compensation circuits,” it was “difficult to integrate such circuits in . . . higher pixel density display[s] due to restricted pixel area[s].” Ex. Ex. 2015 (Yoo) at 1. The ’599 Patent’s pixel circuit allowed the Samsung SDI researchers to develop a “full color VGA AMOLED display with the highest resolution to date” with “40% aperture ratio, making it the world’s highest density AMOLED display reported to date,” and a “Vth compensating pixel circuit to improve image quality.” Ex. Ex. 2015 (Yoo) at 3.

135. With the pixel circuits of the ’599 Patent, Samsung Display successfully mass-produced AMOLED displays for mobile devices, with work beginning in as early as 2005 (shortly after the ’599 Patent’s inventions) and first successful commercial production in 2007. *See* Ex. 2009 (Replay the Display, *Mass Production of AMOLED – Samsung’s Dramatic Success That Changed the History of Displays*, Historic Moments of Samsung Display, Vol. 21 (Feb. 17, 2023)) (“Samsung began its attempt at producing [AMOLEDs] in 2005 . . . [and] became the world’s first company to successfully mass-produce AMOLED in September 2007.”); Ex. Ex. 2016 (Yoon Jeong-hyun, *Samsung Display Achieves the Highest Definition Quality With Tenacity. Full HD AMOLED “Revolution,”* BIZ Insight (2013)) at 6 (“Nevertheless, the company persevered to uphold the principle of “Samsung smartphone is AMOLED itself” and it finally overcame all the barriers.”);

[REDACTED]

Ex. 2017 (Sung-eun Kim, *Climbing Mt. Fuji on Handstand?*) at 5 (“Samsung Display has emerged as an unparalleled powerhouse in the current small and medium-sized OLED display market thanks to its endeavors to walk down the uncharted path that no other competitors had taken before.”).

136. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

137. I have prepared a claim chart mapping all challenged claims of the '599 Patent to an exemplary Samsung Display AMOLED display used in the Samsung Galaxy S21 product. *See* Ex. 2018 (Samsung Galaxy S21 AMOLED Display Claim Chart). This claim chart is based on [REDACTED]

[REDACTED] *See* Ex. 2046 (Declaration of Kwangsae Lee); [REDACTED]

138. As demonstrated in the claim chart, Samsung Display's AMOLED display in the Galaxy S21 product practices the claims of the '599 Patent and has the advantage of having adequate aperture ratios while ensuring display uniformity.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

139. I was informed by Patent Owner's counsel that Petitioner Mianyang BOE alleged in a separate ongoing ITC dispute between Samsung Display and Mianyang BOE (*In re Certain Active Matrix Organic Light-Emitting Diode Display Panels & Modules for Mobile Devices, & Components Thereof*, ITC Inv. No. 337-TA-1351) that [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] I disagree with that allegation.

140. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

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142.

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[REDACTED]

[REDACTED]

[REDACTED]

144. Accordingly, it is my opinion that extensive real-world evidence establishes that—despite failures of others—long-felt needs were satisfied by the '599 Patent's pixel circuits, which allowed for the successful commercialization and adoption of AMOLED displays for mobile devices.

3. Skepticism

145. It is my opinion that Samsung Display overcame industry skepticism, which supports the non-obviousness of the claims of the '599 Patent.

146. At the time of the inventions of the '599 Patent, there was a concern that pixel circuits using an excessive number of components (e.g., transistors, capacitors, scan/signal lines) would not be suitable for mass-producible AMOLED displays. This is because the space taken up by the components would negatively reduce pixel aperture ratios, i.e., the portion of the display area that emits light.

[REDACTED]

147. As recounted in the 2008 “Advances in AMOLED Technologies” book chapter (Ex. 2010 (Bhowmik)), companies and research groups before the inventions of the ’599 Patent were proposing increasingly complicated pixel circuits, including a 4-transistor and 2-capacitor circuit proposed in 1998 by researchers at the Sarnoff; a 4-transistor and 1-capacitor circuit proposed in 2003 by engineers at IDT; a 3-transistor and 1-capacitor circuit proposed in 2003 by researchers at IBM; a 5-transistor and 1-capacitor circuit proposed in 2005 by engineers at Toppoly Optoelectronics. These pixel circuits, which incorporated multiple TFTs and/or capacitors, sacrificed pixel aperture ratio—which are important to display lifetime and luminance—in an effort to resolve the display non-uniformity problem. See Ex. 2010 at 30–31 (“[C]omplicated pixel circuits require more TFTs and capacitors. Subsequently, the sub-pixel aperture ratio is reduced.”).

148. It was also understood at the time of the inventions of the ’599 Patent that NMOS transistors could be made smaller than PMOS transistors due to their higher relative electron mobility. Dr. Foty explained this during his deposition. Ex. 2050 at 92:20–94:18. Thus, it was understood that it would be advantageous to use NMOS transistors, which are smaller than PMOS transistors, to develop pixel circuits, since they would take up a smaller footprint, leading to the potential for a larger aperture ratio. Ex. 2050 at 39:6-18. The industry’s skepticism for the use of numerous transistors, and particularly PMOS transistors, is well documented.

[REDACTED]

149. Researchers at Casio Computer and Kyushu University expressed skepticism with compensation pixel circuits in a 2003 International Display Workshop paper:

There are two ways to compensate the TFT threshold voltage variation, current program . . . and voltage-program . . . Both of them needed more than four TFTs and four bus-lines for each pixel in general, which is too complicated in driving scheme and too busy in pixel area to achieve the high reliability and large aperture ratio. Simpler circuit design and driving scheme are expected in a-Si TFT driving AM-OLED.

Ex. 2013 at 1. As shown above, the Casio/Kyushu researchers were critical of compensation pixel circuits because of the excess number of components, including multiple TFTs and lines, that would negatively affect pixel aperture ratio. Similarly, in referencing a proposal for a pixel circuit with 5 transistors and 1 capacitor, researchers at the National Cheng Kung University in Taiwan explained that “[t]he presented circuit uses an excess of components . . . , reducing the aperture ratio of the display.” Ex. 2014.

150. It was therefore surprising when Samsung Display overcame industry skepticism to introduce the novel pixel circuit of the '599 Patent using six PMOS transistors and one capacitor, and was successful in mass-producing AMOLED displays using those circuits. As noted in the 2005 SID paper (Ex. 2015 (Yoo)), the '599 Patent's pixel circuit allowed the Samsung SDI researchers to develop a

[REDACTED]

“full color VGA AMOLED display with the highest resolution to date” with “40% aperture ratio, making it the world’s highest density AMOLED display reported to date” Ex. 2015 (Yoo) at 3. This fact that Samsung Display overcame industry skepticism further confirms the non-obviousness of the challenged claims of the ’599 Patent.

4. Industry Praise

151. It is my opinion that industry praise supports the non-obviousness of the claims of the ’599 Patent.

152. In particular, I reviewed evidence of significant recognition and praise for the named inventors of the ’599 Patent. For example, the President of South Korea awarded Dr. Oh-Kyong Kwon the Korea Best Scientist and Engineer Award for “develop[ing] pixel circuits . . . for AMOLED displays that can be accurately controlled to very low current levels, which were considered practically impossible, enabling the mass production of AMOLEDs for mobile devices.” Ex. 2021 (Baek Byung-yuel, *Professor Kwon Wins Top Scientist Award of 2021*, The Korea Times (2021)) at 1. As noted in this article, the industry recognized that Dr. Kwon’s inventive pixel circuits claimed in the ’599 Patent enabled the mass-production of AMOLED displays for mobile devices.

153. As described in one news article that I reviewed:

Pixel circuit research is also one of Professor Kwon’s major achievements. The existing pixel circuit structure had uneven

[REDACTED]

luminance and low yield. Professor Kwon talked about the development process, saying, “We solved the problem by . . . *[developing a] pixel circuit that can compensate for the deviation in the characteristics of the TFT for current control.*” He then replied, “Through research on pixel circuit structure, we have been able to increase the resolution of displays even with low current levels. I also remember that this technology was mass-produced at Samsung Mobile Display.”

Ex. 2022 (Jeon Ha-yeon, *Distinguished Professor Oh-Kyung Kwon, An Authority on Displays, Received the Korea’s Best Scientist and Technology Award*, Hanyang News Portal (2021)) at 2 (emphasis added). I understand from counsel that Samsung Mobile Display is a predecessor to Samsung Display.

154. Dr. Ho Kyoon Chung, another named inventor, received a number of awards. This includes the Order of Science and Technology Merit and the Order of Industrial Service Merit by the President of South Korea and Karl Ferdinand Braun Prize by the Society for Information Display—for, among other things, “for his contributions to the large-scale commercialization and technical development of AMOLED displays.” Ex. 2023 (Sung Kyun Kwan University, *2016 Karl Ferdinand Braun Prize for AMOLED*, Society for Information Display (2016)).

155. It is my opinion that industry recognition for the named inventors of the ’599 Patent, and in particular their achievement of developing an innovative pixel circuit that allowed for display uniformity in a mass-producible AMOLED

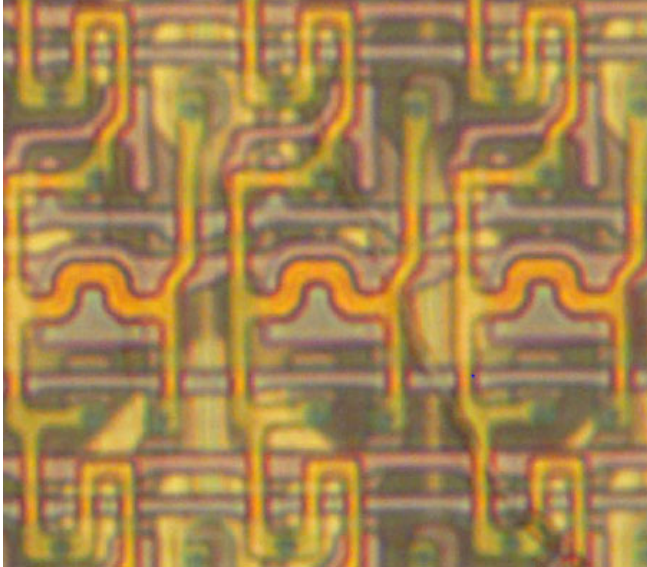
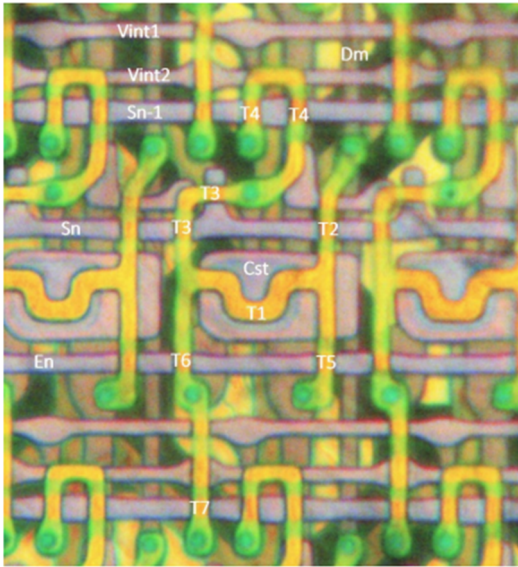
[REDACTED]

display with adequate aperture ratios, demonstrates the non-obviousness of the claimed inventions.

5. Copying

156. I have reviewed evidence indicating that numerous display manufacturers—including Petitioner Mianyang BOE—copied Samsung Display’s patented pixel circuits and replicated Samsung Display’s AMOLED displays.

157. For example, Petitioner Mianyang BOE Mianyang BOE’s copying is particularly clear from the below side-by-side annotated comparison of teardown images of pixel circuits in a Samsung Display AMOLED display (Galaxy S21) and a Mianyang BOE AMOLED display (iPhone 12). The teardown image of the pixel circuit of Mianyang BOE’s AMOLED display (used in the iPhone 12) comes from complaint filed by Samsung Display against Mianyang BOE in the Eastern District of Texas. *See* Ex. 2047 (*Samsung Display Co., Ltd. v. BOE Tech. Co., Ltd. et al.*, Case No. 2-23-cv-00309, Compl. (E.D. Tex. Jun. 26, 2023)).

Samsung Display AMOLED (Galaxy S21)	Mianyang BOE AMOLED (iPhone 12)
 Ex. 2020 at 5	 Pixel Circuit from Mianyang BOE's AMOLED Display (iPhone 12) (Ex. 2047 at 12)

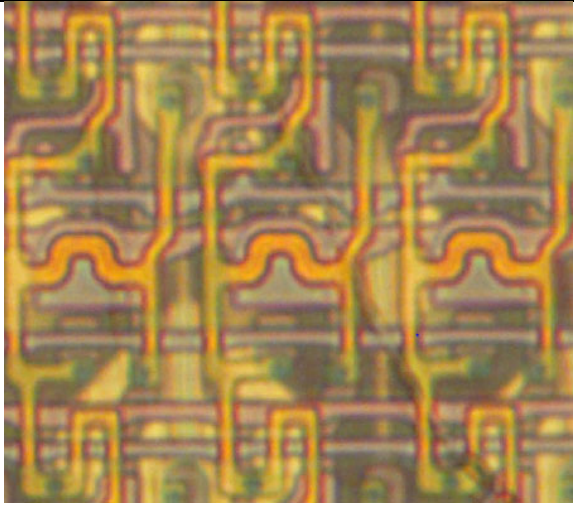
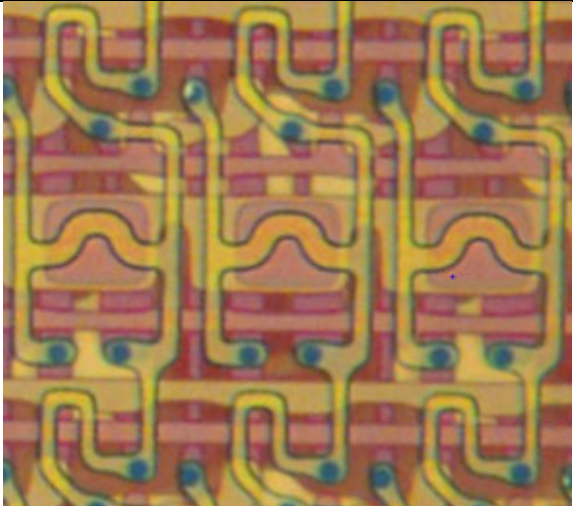
158. In fact, public patent documents show that Mianyang BOE had previously proposed alternative pixel circuits, including circuits using 5 transistors and 1 capacitor (described in U.S. Patent No. 9,666,132; Ex. 2024 (U.S. Patent No. 9,666,132)) and a different pixel circuit using 4 transistors and 1 capacitor (described in U.S. Patent No. 8,941,309; Ex. 2025 (U.S. Patent No. 8,941,309)). Despite its attempt at independent pixel circuit design, Mianyang BOE adopted—apparently through copying—Samsung Display’s patented pixel circuits in order to mass-produce AMOLED displays for mobile devices.

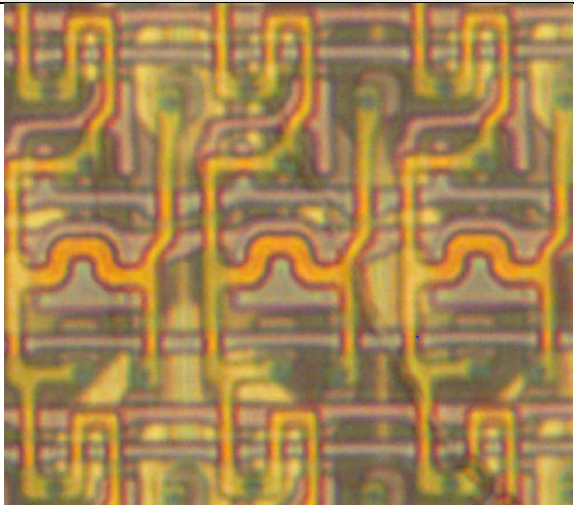
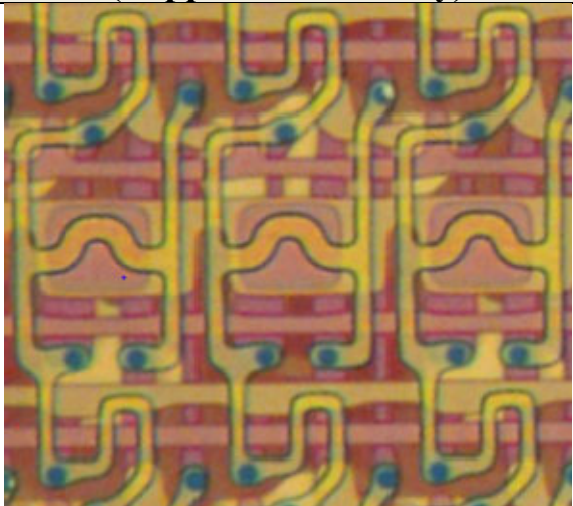
159. I also reviewed teardown photographs obtained from a number of AMOLED displays sold by MobileSentry (Ex. 2026); Mobile Defenders, LLC (Ex. 2029); Injured Gadgets, LLC (Ex. 2030); Group Vertical, LLC (Ex. 2032);

[REDACTED]

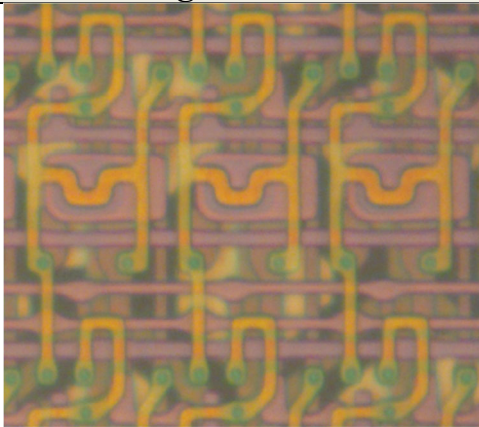
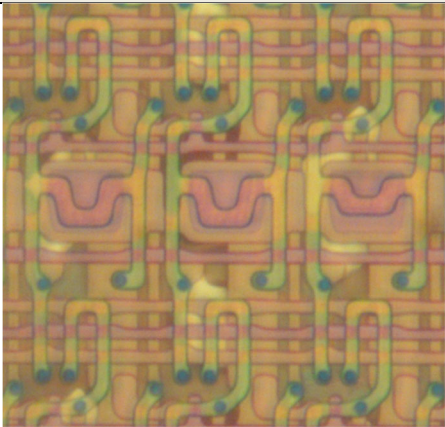
Fixez.com (Ex. 2039); Repairs Universe, LLC (Ex. 2037); SEGMobile.com (Ex. 2035); Sourcely Plus LLC (Ex. 2038); eTech Parts, LLC (Ex. 2033); Parts4Cells, Inc. (Ex. 2034); Wholesale Gadget Parts, Inc. (Ex. 2040); Captain Mobile Parts, Inc. (Ex. 2036); DFW Cellphone and Parts (Ex. 2042); Phone LCD Parts LLC (Ex. 2028); Parts4LCD (Ex. 2041); Mengtor Inc. (Ex. 2027); and Gadgetfix Corp (Ex. 2031). See Ex. 2043 (Declaration of Aris Silzars, Ph.D.).

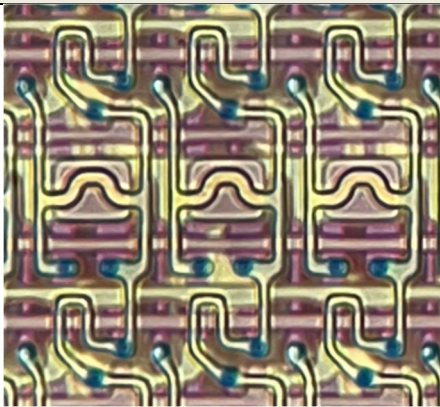
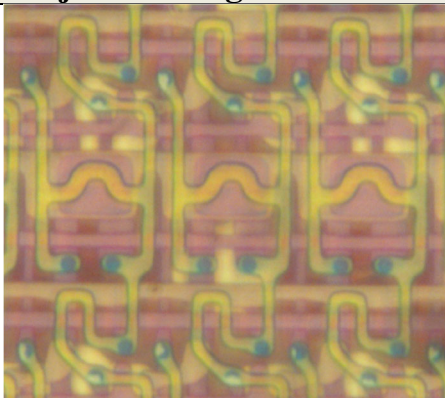
160. As shown in the side-by-side comparison of teardown images of the pixel circuits from the Galaxy S21 AMOLED display (containing a Samsung Display AMOLED display) and the MobileSentry product, the MobileSentry's pixel circuit is strikingly similar to that of Samsung Display, even down to the physical layouts. These pixel circuit teardown photographs are so similar, including for example in the physical layout topology and geometry of the metal wirings, that the only reasonable inference one could draw is that someone with access to Samsung Display's AMOLED display products or other confidential technical information determined to replicate Samsung Display's pixel circuits in the MobileSentry product.

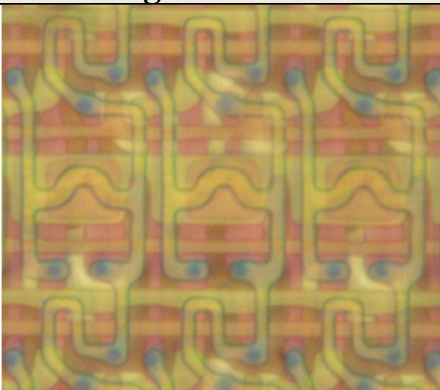
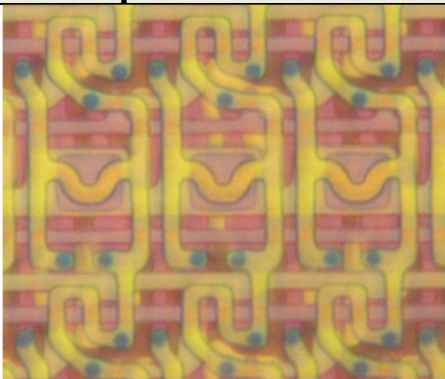
Galaxy S21 Pixel Circuit	MobileSentry Product
	
Ex. 2020 at 5	Ex. 2026 at 5

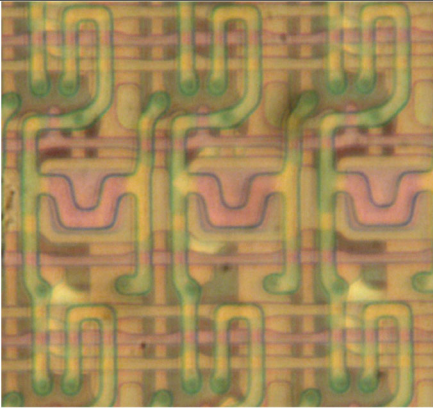
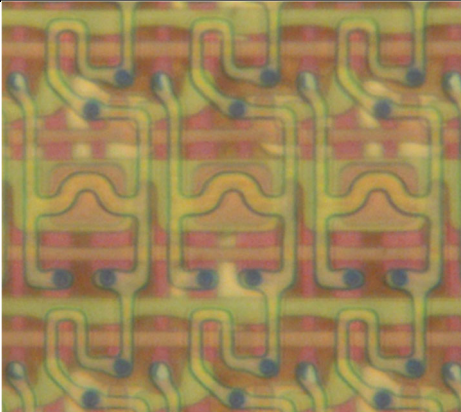
Galaxy S21 Pixel Circuit	MobileSentry Product (Flipped Horizontally)
	
Ex. 2020 at 5	Ex. 2026 at 5

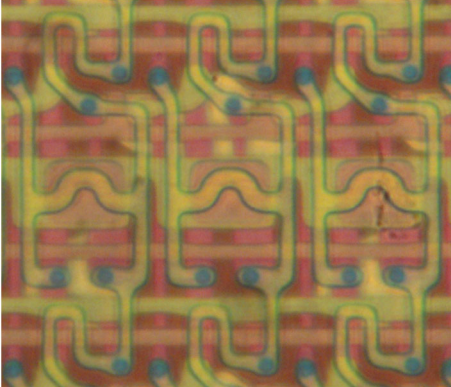
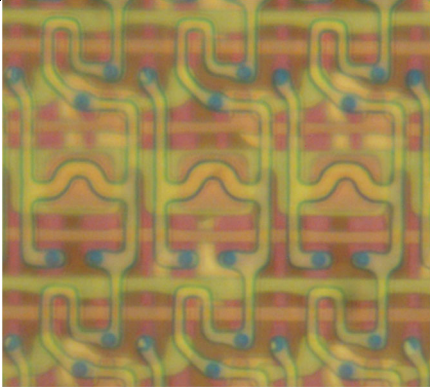
161. Additional teardown images of pixel circuits used in other replacement display products are shown below.

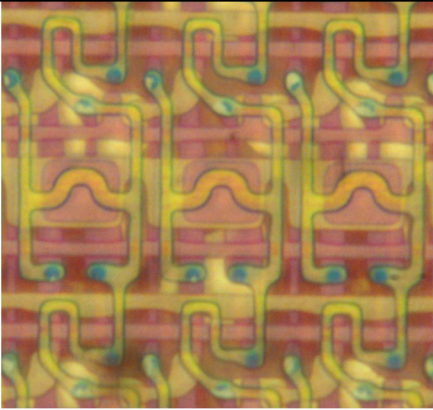
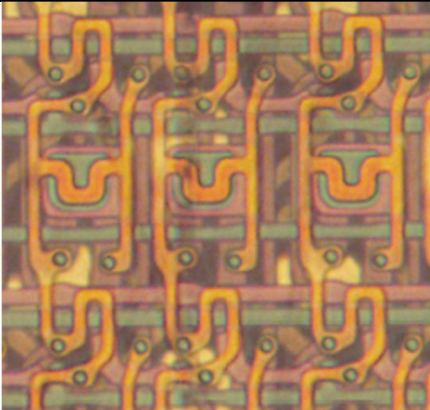
Mengtor Product	Phone LCD Parts Product
	
Ex. 2027 at 4	Ex. 2028 at 4

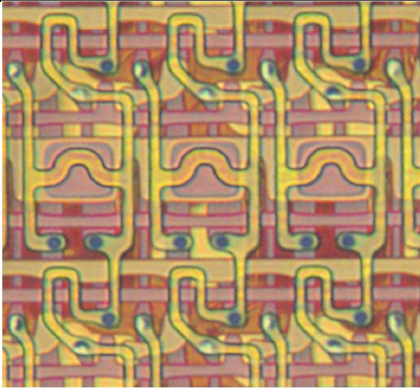
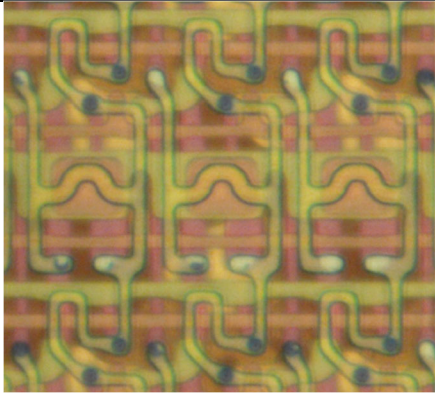
Mobile Defenders Product	Injured Gadgets Product
	
Ex. 2029 at 5	Ex. 2030 at 5

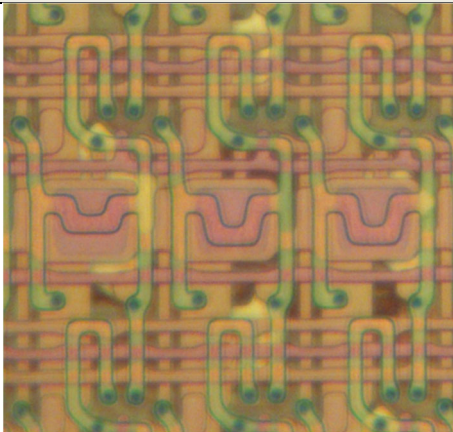
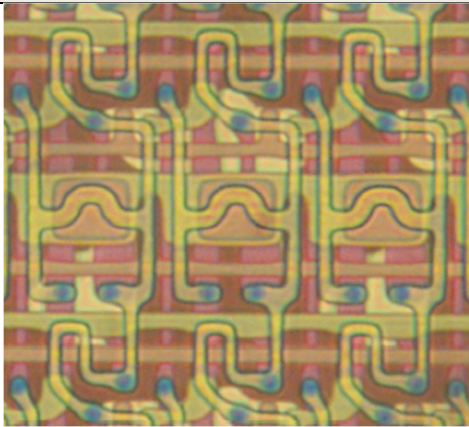
Gadgetfix Product	Group Vertical Product
	
Ex. 2031 at 4	Ex. 2032 at 3

eTech Parts Plus Product	Parts4Cells Product
	
Ex. 2033 at 5	Ex. 2034 at 5

SEGMobile Product	Captain Mobile Parts Product
	
Ex. 2035 at 5	Ex. 2036 at 4

Repairs Universe Product	Sourcely Plus Product
	
Ex. 2037 at 5	Ex. 2038 at 5

Fixez Product	Wholesale Gadget Parts Product
 Ex. 2039 at 4	 Ex. 2040 at 4

Parts4LCD Product	DFW Product
 Ex. 2041 at 4	 Ex. 2042 at 4

6. Nexus

162. In my opinion, the evidence of objective indicia that I have reviewed is adequately connected to the claimed inventions of the '599 Patent.

163. The '599 Patent's inventions enabled Samsung Display to successfully commercialize AMOLED displays for mobile devices. The '599 Patent allowed for this by solving the long-existing technical challenge of providing a new pixel circuit that ensures both high display uniformity and adequate pixel aperture ratio for an

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AMOLED display. While many companies and research groups attempted to satisfy the longstanding need, including through the introduction of different types of pixel circuits that would provide both display uniformity and aperture ratio, none of the alternative pixel circuits made their way into mass-produced commercial AMOLED displays for mobile devices. As noted before, I am not aware of any commercial AMOLED display for a mobile device that has adopted the alternative pixel circuits proposed over the years.

164. The inventive pixel circuit structures of the '599 Patent achieves display uniformity, including by requiring a threshold voltage compensation transistor that connects the gate and drain of the driving transistor such that the driving transistor is connected in the form of a diode. *See* '599 Patent at 4:24-27 (“The third transistor connects the second transistor in the form of a diode in response to the current scan signal, so that the second transistor detects and compensates its threshold voltage deviation in itself.”).

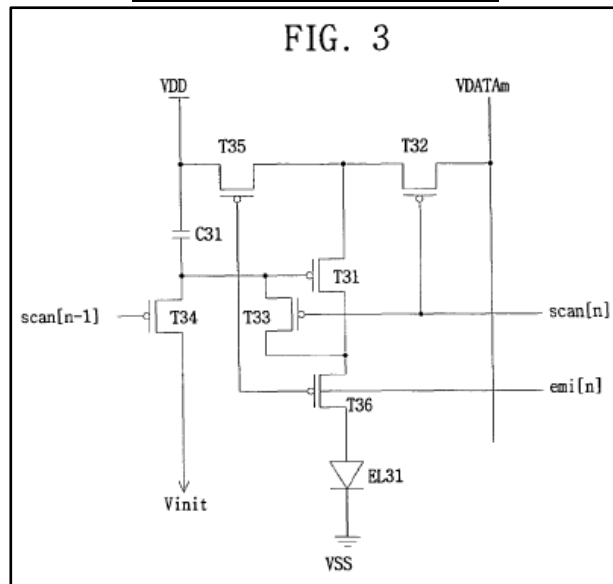
165. The specification goes onto explain that by connecting the gate and drain of the driving transistor in the form of a diode, the circuit structure allows a voltage to be stored on the capacitor that reflects the threshold voltage of the particular driving transistor during the data-writing phase. *See* '599 Patent at 3:43–4:27 (“A third transistor detects and self compensates threshold Voltage deviations in the second transistor. A capacitor for stor[ing] the data signal Voltage delivered

[REDACTED]

to the second transistor. An electroluminescent element emits light corresponding to the driving current generated through the second transistor.”).

166. During the light-emission phase (i.e. when the OLED element is being activated), the current flows through the same driving transistor to the OLED element based on the voltage stored on the capacitor during the data-writing phase, which allows for the detection and self-compensation for the threshold voltage deviation in that particular driving transistor. *See* ’599 Patent at 7:28–8:32 (“[T]he driving current flows through EL element EL31, corresponding to the data signal voltage applied to the data line regardless of the threshold voltage of current driving transistor T31. That is, because the present invention detects and self-compensates the threshold voltage deviation in current driving transistor T31 through transistor T33, it is possible to finely control the current flowing into the organic EL element, thereby”).

167. In addition to achieving good display uniformity, the pixel circuits of the ’599 Patent allow high aperture ratios to be achieved in AMOLED displays by requiring fewer control or scan lines for each pixel row. This simplification reduces complexity and allows for a smaller footprint and a greater aperture ratio, which are significant to AMOLED displays for mobile devices. There are a number of ways in which the inventions of the ’599 Patent achieve space-saving to maximize the aperture ratio for each pixel.



168. For example, the emission transistors, which are transistors T35 and T36 in Figure 3 of the '599 Patent (reproduced above), share a single emission control line ("emi[n]"), as opposed to having separate emission lines. *See* '599 Patent at 6:52–7:1 ("Further, each pixel comprises second switching transistor T35 for providing power supply voltage VDD for driving transistor T31 in response to current light-emitting signal EMI[n], and third switching transistor T36 for providing a driving current, generated through driving transistor T31, for EL element EL31 in response to current light-emitting signal EMI[n]."), claim 1 ("current light-emitting signal" turns on or off "a fifth transistor" and "a sixth transistor"), claim 14 ("current light-emitting signal" turns on or off "a fourth transistor" and "a fifth transistor"), claim 15 ("a fourth transistor including a gate to which a current light-emitting signal is applied" and "a fifth transistor including a gate to which the current light-emitting signal is applied").



169. As another example, the switching transistor and threshold voltage compensation transistor, which are transistors T32 and T33 in Figure 3, share a single scan line. *See* '599 Patent at 6:19–51 (“First switching transistor T32 is composed of a P-type thin film transistor in which current scan signal SCAN[n], applied to the associated scan line, is applied to its gate . . . Threshold voltage compensation transistor T33 is composed of a P-type thin film transistor in which its drain and source are connected to the gate and drain of driving transistor T31, respectively, and a current scan signal scan [n] is applied to the gate of transistor T33.”), Fig. 3, claim 7 (“current scan signal” turns on or off “a third transistor” and “a first transistor”), claim 17 (“a first transistor including a gate to which a current scan signal to be applied to the associated scan line is applied” and “a fourth emitting transistor including a gate to which a current light-emitting signal is applied”).

170. As a further example, the initialization transistor, which is T34 in Figure 3, is turned ON and OFF by the scan signal of the previous pixel row, which allows further reduction in the number of scan lines. *See* '599 Patent at 7:3-11 (“Moreover, each pixel includes initialization transistor T34 for initializing the data signal stored in capacitor C31 in response to a previous scan signal SCAN[n-1] applied to a scan line just before the associated scan line. Transistor T34 is composed of a P-type thin film transistor in which previous scan signal SCAN[n-1] is applied to its gate, its source is coupled to the one terminal of capacitor C31, and

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initialization voltage Vinti is applied to its drain.”), Fig. 3, claim 2 (“a fourth initialization transistor for discharging the data signal voltage stored in the capacitor in response to a scan signal just before the current scan signal”), claim 16 (“a sixth transistor including a gate to which a scan signal just before the current scan signal is applied; . . . a drain to which an initialization voltage is applied”).

XI. AVAILABILITY FOR CROSS-EXAMINATION

171. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during a time as mutually agreed between the parties.

XII. RIGHT TO SUPPLEMENT

172. I reserve the right to supplement my opinions in the future to respond to any arguments that the Petitioners raise. This declaration represents only those opinions that I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information that becomes available to me and on my continuing analysis of the materials already provided.

* * *

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I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on: 3/8/2024
Date

By: 
Andrew Wolfe, Ph.D.