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 IPR2023-01075
U.S. Patent No. 11,594,578

DECLARATION OF IOANNIS KYMISSIS, PH.D.

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I, Ioannis Kymissis, 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"), who I understand is the owner of U.S. Patent No. 11,594,578 (Ex. 1001) ("'578 Patent"). I understand that Mianyang BOE Optoelectronics Technology Co., Ltd. ("BOE"), Wuhan China Star Optoelectronics Semiconductor Display Technology Co., Ltd. ("CSOT"), Tianma Microelectronics Co., Ltd. ("Tianma"), and Visionox Technology, Inc. ("Visionox") (collectively, "Petitioner") have filed a petition for *Inter Partes* Review of the '578 Patent (Paper No. 1) ("Petition") and a declaration by Dr. P. Morgan Pattison (Ex. 1003) ("Pattison Declaration").

2. I have been asked by counsel for Samsung Display to provide my expert opinions concerning the validity of claims 1–6, 1,0 12, 17–19, 21–23, 40–47, and 51–52 of the '578 Patent ("Challenged Claims"). In particular, I have been asked to consider certain arguments presented in the Petition and Dr. Pattison's opinions provided in the Pattison Declaration. I have also been asked to consider the state of the art and various references on which Petitioner and Dr. Pattison rely.

3. I submit this Declaration in support of Samsung Display's Response to the Petition. My opinions are based on my review of certain materials (described

below) and my knowledge, education, experience, and training. My opinions are subject to supplementation or change if new information becomes available.

4. I am being compensated at my standard consulting rate for my time. My compensation is in no way contingent on the result of this or any other proceeding relating to the ’578 Patent, or on the substance of any opinion I provide.

I. EXPERIENCE AND QUALIFICATIONS

5. I am the Kenneth Brayer Professor of Electrical Engineering at Columbia University in New York City. I also serve as the Chair of the Department of Electrical Engineering. I have been a faculty member in the Department of Electrical Engineering at Columbia University since 2006. I typically teach courses in solid state electronics, including undergraduate and graduate device physics, thin film electronics, and displays. In my course on displays, which I have taught for nearly twenty years, we cover a broad range of topics, including organic light-emitting diode (“OLED”) displays, liquid crystal displays (“LCD”), visual perception, color science, wave optics, emissive displays and their mechanisms, display panel backplanes, and 3D displays. Over the course of my career, I have supervised twenty Ph.D. candidates and fourteen post-doctoral associates.

6. I received my bachelor’s degree (S.B.) in electrical engineering from the Massachusetts Institute of Technology (“MIT”) in 1998. I received my master’s degree in engineering (M.Eng.) in 1999, and a doctoral degree (Ph.D.) in 2003, both

from MIT. My Ph.D. thesis was on field emission displays. I also completed a post-doc at MIT working on OLED technologies, organic semiconductors, and quantum dot-based materials.

7. I have published over 150 peer-reviewed journal papers and have delivered more than 100 invited, plenary, and keynote presentations on display technology and thin film electronics.

8. I am a fellow of the Society for Information Display (and currently president elect of that society), a fellow of Optica, and a fellow of the IEEE. I previously served as the Editor-in-Chief of the Journal of the Society for Information Display, where my role included reading and assessing each paper. I am an associate editor of the IEEE Open Journal on Immersive Displays, the Journal of the Society for Information Display, and Advanced Science. I am a distinguished lecturer of the IEEE Electron Device Society, and have served on more than 40 program committees for international conferences in the past 10 years including positions in SID (Society for Information Display), DRC (Device Research Conference), EMC (Electronic Materials Conference), SIGGRAPH (The Association for Computing Machinery's Special Interest Group on Computer Graphics and Interactive Techniques), IEDM (International Electron Devices Meeting), MRS (Materials Research Society), SPIE (Society of Photo-Optical Instrumentation Engineers), and LOPEC (Large-area, Organic & Printed Electronics Convention). I served as the

general chair for the Device Research Conference, one of the leading conferences in device electronics, in 2014. From 2009 to 2011, I was on the executive committee for the Organic Electronics Workshop sponsored jointly by IEEE, MRS, and ACS (American Chemical Society).

9. I am the recipient of more than thirty technical awards listed on my CV, including the IEEE EDS Paul Rappaport Award, and am a fellow of the Society for Information Display, Optica, and the IEEE for my work on displays and thin film electronics.

10. I am the named inventor on several dozen patents, including many patents relating to electronic displays, organic materials, and fabrication of semiconductor devices.

11. I have been involved in a number of display development programs. My interest in displays began as a student. I worked at IBM in New York and Tokyo for a total of about 18 months while I was a student. My master's degree research was conducted at IBM Research in Yorktown Heights, New York on organic semiconductor electronics for display technologies. I also worked at the IBM Tokyo Research Laboratory as a doctoral student, working on liquid crystal displays. My Ph.D. thesis was on field emission displays, and I completed a post-doc at MIT working on OLED technologies, organic semiconductors, and quantum dot-based materials.

12. In addition to my research work, I have further worked at a number of companies on the development of display technologies. I was the first employee of QDVision, a small company based in Watertown, Massachusetts from 2005-2006, and designed the display demonstrators and prototypes used by that company. My work at QDVision included making and testing OLED display devices. I am also a co-founder of Lumiode, a company that specializes in the development of advanced backplanes for microLED displays, and continue as a co-inventor and lead designer for the display demonstrators developed by the company.

13. I also serve as a consultant and board member for Chromation, Lumiode, Lelantos, and Kelvin (formerly Radiator Labs). I have also served as a consultant for Corning and Applied Materials in connection with microLED display technologies. In addition, I have had a number of sponsored research projects with other companies and government agencies, including Magic Leap, RDS, IBM, Samsung Electronics, the U.S. Air Force, and the National Science Foundation ("NSF"). For example, I performed a research project with Magic Leap concerning microLED technologies, a project from approximately 2018 to 2019 with Samsung Electronics to measure the degradation and lifetime of OLED displays with RGBW pixel arrangements, and projects from approximately 2006 to 2009 with the U.S. Air Force and from approximately 2013 to 2017 with the NSF involving OLED technologies.

14. My work at QDVision and Lumiode involved designing every aspect of the display, including the pixel arrangement structures to be used. At QDVision, I was the first employee and designed the test vehicles used for all internally fabricated displays over the life of the company. At Lumiode, I serve as a technical advisor and continue to be involved in the design and reviews for all layouts and pixel formats.

15. A copy of my curriculum vitae further detailing my education, experience, awards and honors, and publications that may be relevant to my opinions is attached to this declaration as Exhibit 2010.

16. In sum, I have extensive expertise in OLEDs, displays, and pixel arrangements. I am familiar with the state of the art at the relevant time up to the time of the invention of the ’578 Patent.

II. MATERIALS REVIEWED

17. In preparing this declaration, I have reviewed the ’578 Patent, including the claims of the patent in view of the specification, and the prosecution history of the ’578 Patent. I have reviewed the petition for *inter partes* review and the declaration of Dr. Pattison, as well as numerous prior art and technical references from the time of the invention of the ’578 Patent. Specifically, I have reviewed each of the following:

Exhibit	Description
1001	U.S. Patent No. 11,594,578
1002	Excerpts of File History of U.S. Patent No. 11,594,578
1003	Declaration of P. Morgan Pattison, Ph.D.
1004	U.S. Patent No. 6,897,855 B1 to Matthies et al.
1005	U.S. Patent No. 6,366,025 B1 to Yamada
1006	U.S. Pub. 2009/0302331 A1 to Smith et al.
1007	U.S. Patent No. 3,971,065 to Bayer
1008	U.S. Patent No. 7,250,722 to Cok et al.
1009	U.S. Patent No. 9,818,803 to Lee
1010	Excerpt from Complainant's Opening Claim Construction Brief in ITC Inv. No. 337-TA-1351
1011	U.S. Pub. 2011/0234550 A1 to Hong et al.
2001	Claim Construction Order, Inv. No. 337-TA-1351
2002	Joint Submission of Agreed Upon and Disputed Claim Terms, Inv. No. 337-TA-1351
2003	U.S. Patent No. 5,644,327
2004	U.S. Patent No. 6,867,549 to Cok et al.
2011	U.S. Patent No. 6,747,618 ("Arnold")
2012	U.S. Patent No. 8,716,929 ("Yoo")
2013	Korea Industry Post, *Popularity of Galaxy S4 to Kickstart Demand for AMOLED Market*, (2013)
2014	Dr. Raymond M. Soneria, *Galaxy S4 Display Technology Shoot-Out*, DisplayMate

Exhibit	Description
2015	U.S. Patent No. 9,697,760 ("Wang")
2016	Jiin-Joi Lih et al., *The Challenge of High Resolution to Active-Matrix OLED*, Society for Information Display (2006)
2017	Ho-Kyoon Chung et al., *AMOLED Technology for Mobile Displays*, Society for Information Display (2006)
2018	U.S. Patent Publication No. 2007/0278933 ("Chao")
2019	Society of Information Display, *Mobile Display Technology and Applications* (Achintya K. Bhowmik et al.) (2008)
2020	Journal of Display Technology, *New Pixel Design on Emitting Area for High Resolution Active-Matrix Organic Light-Emitting Diode Displays* (Soon-Kwang Hong et al.) (2010)
2021	U.S. Patent Publication No. 2008/001525 ("Chao")
2022	Bogdan Petrovan, *Diamond Pixels: Galaxy S4's Unique Subpixel Arrangement Gets a Close Up* (2013)
2023	Hyunjung Jung, *History of Advancement of 'AMOLED', Core Competitiveness of Galaxy* (2014)
2024	Nell Hughes, *Apple Won't Adapt AMOLED Displays in iPhones Until 2019 at the Earliest, Insider Says* (2015)
2025	Dr. Raymond M. Soneira, *Smartphone "Super" LCD-OLED Display Technology Shoot-Out*
2026	Jin-Gyu Meyong, *Sharper Galaxy S4, the Secret Weapon is the 'Diamond*' (2013)
2027	Dr. Raymond M. Soneira, *Samsung Diamond Pixels*
2029	Teardown Photos of Samsung Galaxy S22 Ultra Product
2030	INTENTIONALLY LEFT BLANK

Exhibit	Description
2031	INTENTIONALLY LEFT BLANK
2032	INTENTIONALLY LEFT BLANK
2033	Chung-Chia Chen et al., *Low Power Consumption and Wide Color Gamut AMOLED Display with Four Primary Colors*, Society for Information Display (2015)
2034	*Detailed Explanation: Why Zhou Dongyu's BOE Screen is Not as Good as Samsung Screen*
2035	Xiaojian, *What Exactly was the Scolded "Dongyu Zhou" Screen Like? Is it Really Unusable?* (2020)
2036	Li-Qin Shao et al., *The Development of 403ppi Real RGB Printing AMOLED*, Society of Information Display (2019)
2037	*Secret to the Face of Galaxy S4, Reason for Striking Resolution* (2013)
2038	Chris Davies, *The iPhone X has the Best Smartphone Display Around* (2017)
2039	Dr. Raymond M. Soneira, *iPhone X Display Technology Shoot-Out*
2040	Bryan Jones, *iPhone X Pixels* (2017)
2041	*Samsung Display Co., Ltd. v. BOE Tech. Co. Ltd. et al.*, Case No. 2-23-cv-00309, Compl. (E.D. Tex. Jun. 26, 2023)
2044	Teardown Photos of Group Vertical Product
2045	Teardown Photos of Phone LCD Parts Product
2046	Teardown Photos of Sourcely Plus Product
2047	Teardown Photos of eTech Parts Product
2048	Teardown Photos of Parts4LCD Product

Exhibit	Description
2049	Teardown Photos of MobileSentrix Product
2050	Teardown Photos of Mobile Defenders Product
2051	Teardown Photos of Injured Gadgets Product
2052	Teardown Photos of Fixez Product
2053	Teardown Photos of Repairs Universe Product
2054	Teardown Photos of SEGMobile Product
2055	Teardown Photos of Parts4Cells Product
2056	Teardown Photos of Wholesale Gadget Parts Product
2057	Teardown Photos of Captain Mobile Parts Product
2058	Teardown Photos of DFW Products
2059	Teardown Photos of Mengtor Product
2060	Teardown Photos of Gadgetfix Product
2061	Declaration of Aris Silzars, Ph.D.
2062	Transcript of March 20, 2024 Deposition of Dr. Morgan Pattison
2063	Declaration of Adam Fontecchio, Ph.D.
2064	Sung-eun Kim, *Climbing Mt. Fuji on Handstand?* (including certified English translation)
2065	Yoon Jeong-hyun, *Samsung Display Achieves the Highest Definition Quality With Tenacity, Full HD AMOLED "Revolution,"* BIZ Insight (2013) (including certified English translation)
2066	*Public-Private Commitment to Ceaseless Effort for Display Super Gap*, Ministry of Trade, Industry, and Energy (2023)

Exhibit	Description
Ex. 2067	Dr. Raymond M. Soneira, *About Display Mate Technologies*
Ex. 2068	Dr. Raymond M. Soneira, *iPhone XS Max Diamond Sub-Pixels*
Ex. 2069	Dr. Raymond M. Soneira, *iPhone X Diamond Sub-Pixels*
Ex. 2070	Dr. Raymond M. Soneira, *iPhone 14 Pro Max Diamond Pixels*
Ex. 2071	Dr. Raymond M. Soneira, *iPhone 13 Pro Max Diamond Pixels*
Ex. 2072	Dr. Raymond M. Soneira, *iPhone 12 Pro Max Diamond Sub-Pixels*
Ex. 2073	Amal Ghosh et al., *Short Course S-1: Fundamentals of OLEDs*, Society for Information Display
Ex. 2074	G. Gu et al., *Design of Flat-Panel Displays Based on Organic Light-Emitting Devices*, IEEE Journal on Selected Topics in Quantum Electronics, Vol. 4, No. 1, (1998)
Ex. 2075	DE Patent No. 10 2011 053 000 B4 (and including certified English translation)
Ex. 2076	D. Braun, *Crosstalk in Passive Matrix Polymer LED Displays*
Ex. 2077	Jong In Park et al., *Direct Prediction Methods on Lifetime Distribution*, IEEE Transactions on Reliability 59 (2010)
Ex. 2078	Priyanka Tyagi et al., *Degradation of Organic Light Emitting Diode: Heat Related Issues and Solutions*, Synthetic Metals 216 (2016)
Ex. 2079	M.M. Azrain et al., *Analysis of Mechanisms Responsible for the Formation of Dark Spots in Organic Light Emitting Diodes (OLEDs): A Review*, Synthetic Metals 235 (2018)
Ex. 2080	Jiun-Haw Lee et al., *Introduction to flat panel displays* (2008)

III. LEGAL STANDARDS

18. I am not a lawyer or an expert in patent law, and I am not offering opinions about the relevant law. For purposes of this declaration, I have been informed by counsel for Samsung Display of the relevant legal standards that apply to my analysis, and I have applied these legal standards in forming my opinions.

19. I have been informed that each issued claim of a patent is presumed to be valid. I understand that in this proceeding, to overcome the presumption of validity, Petitioner bears the burden of proving unpatentability by a preponderance of the evidence. I understand that a "preponderance" means "more likely than not." I understand that general and conclusory assertions without underlying factual evidence may not support a conclusion that something is more likely than not.

20. I understand that a patent claim is obvious in view of the prior art if the differences between the patented claims and the prior art are such that the subject matter as a whole would have been obvious to a person of ordinary skill in the art ("POSITA") at the time of the claimed invention. I understand 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 claim; (iii) the level of ordinary skill in the art; and (iv) any objective indicia of nonobviousness, such as copying.

21. I further understand that obviousness may be based on one reference or a combination of prior art references. I understand that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I have been informed that, if obviousness is based on the combination of multiple prior art references, then there must have been some reason or motivation for a POSITA to combine the references so as to arrive at the claimed invention, with a reasonable expectation of success. I understand that a patent claim composed of several limitations is not proven obvious merely by demonstrating that each limitation was independently known in the prior art.

22. I am informed that it is improper to analyze obviousness by working backwards from the claimed invention with the aid of hindsight. Thus, the prior art cannot be combined with the specific problem solved by the invention in mind. Thus, when considering what a POSITA would have been motivated to do, and what that person would find obvious, one cannot proceed with the asserted patent in mind. It is improper to pick and choose prior art teachings so as to reconstruct the claimed invention.

23. I understand that the scope and content of the prior art should be examined as a whole to determine what it would have taught a POSITA at the time of the claimed invention.

24. I have also been informed that it is relevant to consider whether the prior art includes references that "teach away" from the claimed invention. A reference teaches away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken in the claim.

25. I am informed that obviousness grounds must rely on analogous art and that art is considered analogous if it is: (1) from the same field of endeavor as the claimed invention (even if it addresses a different problem); or (2) reasonably pertinent to the problem faced by the inventor (even if not in the same field of endeavor as the invention). I also understand that a reference is reasonably pertinent only when it logically would have commended itself to an inventor's attention in considering his problem. I understand that if a prior art reference is not in the same field of endeavor as the challenged patent, or not reasonably pertinent to solving the problem the inventor aimed to solve, it is not analogous art and should not be considered as part of an obviousness analysis.

26. I understand that objective indicia of non-obviousness refer to real-world considerations and facts that show that a patent claim would not have been obvious to a POSITA at the time of the invention. I understand that objective indicia of nonobviousness include long-felt but unmet need, failure of others, copying, unexpected results, commercial success, skepticism, and industry praise and

acceptance. I also understand that such objective indicia must be considered from the perspective of a POSITA.

27. I also understand that objective indicia 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 the necessary inventive skill to do so. 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 indicia.

IV. CLAIM CONSTRUCTION

28. I have been informed that, unless a term has been construed to have a particular meaning, every term of a patent claim is to be given its plain and ordinary meaning as would be understood by a POSITA at the time of the invention. I further understand that neither Petitioner nor Patent Owner has argued that any claim term requires construction. Therefore, in forming my opinions, I have applied the plain and ordinary meaning to every claim term.

V. BACKGROUND OF THE TECHNOLOGY

29. The ’578 Patent relates to a pixel arrangement structure of an organic light emitting diode (“OLED”) display. In this section I provide a brief overview relevant to understanding this technology, and the differences between it and the prior art.

A. Electronic Display Basics

30. Electronic displays provide an interface through which various types of information, such as text, images, or video, can be transmitted electronically and presented to a viewer. There have been many different types of electronic display devices developed over the years. For many decades, cathode ray tube ("CRT") technology was the predominant display technology, and CRT televisions and computer monitors were in widespread use. Starting in the 1980s and 1990s, liquid crystal displays ("LCDs") and plasma displays started being commercialized, with LCDs becoming more widespread in the 1990s and 2000s with the introduction of TFT-LCDs, which used thin-film-transistor ("TFT") technology to drive the LCDs. The first practical OLED display device is credited to Eastman Kodak in 1987. It is described in what is sometimes referred to as "the first OLED paper." But even by the 2000s, commercial OLED display devices remained elusive. This was, in part, due to challenges that were difficult to overcome in mass-producing OLED displays.

31. Typically, an electronic display is configured to display images using a two-dimensional array of picture elements, commonly called pixels. Pixels output light that can be viewed by a user, and the intensity of the light output by each pixel can be controlled to display different images. For color displays, individual pixels can be configured to output light of different colors at different intensities. When

users view different color pixels together from a sufficient distance, they will perceive a color that is the combination of the colors output by each individual pixel.

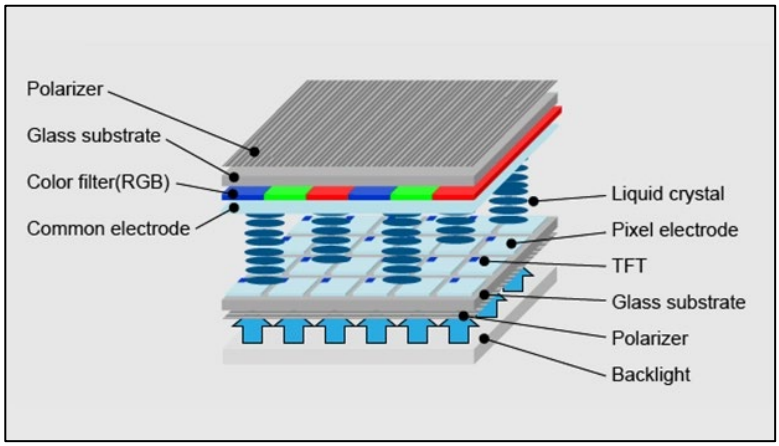
32. As a point of nomenclature, the combination of color elements in a display can be referred to as the single pixel, with the smaller units containing individual colors being referred to as the sub-pixels. Or each of the smaller units containing individual colors can be referred to as a pixel. Either way, a pixel in a display generally refers to the basic unit that constitutes the images on the screen. Pixels of various colors have been used in OLED displays, such as red (R), green (G), blue (B), white (W), and yellow (Y). An array of a large number of pixels together can form images to be displayed. A pixel arrangement refers to the shape, sizing, and positioning of these pixels.

B. Principles of Operation – LCDs vs OLED Displays

33. Today, both liquid crystal displays ("LCD") and OLED displays are found in a variety of applications such as TVs, computer monitors, laptops, and smartphones. But LCDs and OLED displays have significant structural, manufacturing, and operational differences.

34. LCDs display images using a two-dimensional array of picture elements, commonly known as pixels. To display color images, individual pixels can be configured to allow light of different colors to pass through. Typically, these

colors are: red, green, and blue. By turning on and off each of these pixels, and by controlling their corresponding brightness, different images can be displayed.



[1]

35. In an LCD, a backlight (shown above) is required to provide light to the entire display. Each pixel of the LCD includes a layer of material called liquid crystals, as well as a pair of electrodes. When a voltage is applied to the electrodes, an electric field is formed between the electrodes. Liquid crystals are sensitive to electric fields, and twist and turn in response to the electric field. Depending on the orientation of the liquid crystals, a different amount of light is allowed to pass through the pixel.

36. Liquid crystal materials occur in several varieties, but as an example, some liquid crystals are organic molecules in a rod-like shape with an electrical polarizability that is different in the long direction versus the other two directions.

[1] From https://www.j-display.com/images/product/displaybasic/img_04_en.webp.

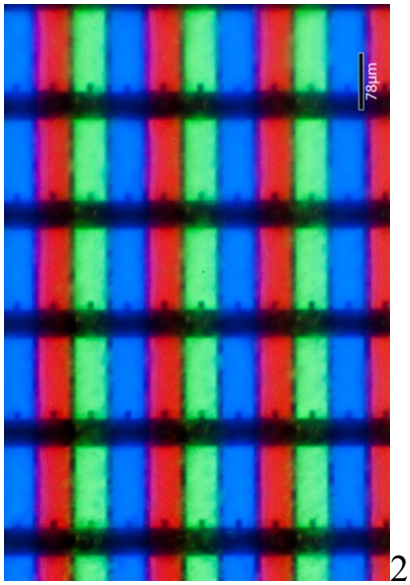
This allows for two important functionalities—the material can be manipulated through the application of an electric field (the molecule will orient itself to align the higher dielectric constant direction along the field) and the index of refraction is also anisotropic (and higher in the direction with the higher dielectric constant). These two effects are used in a variety of modes to create structures that can, under electrical control, manipulate the polarization of light and create controllable shutters for displays.

37. Because LCDs operate as spatial light modulators, each pixel either passes or blocks light, and the individual pixels do not themselves generate light. As illustrated in the figure above, a color filter (which is an array of patterned dyes) filters the light from a backlight to create the color in these displays. Light passes through all of the layers of the display, and the fill factor is especially important in evaluating the efficiency and visual quality of such a display.

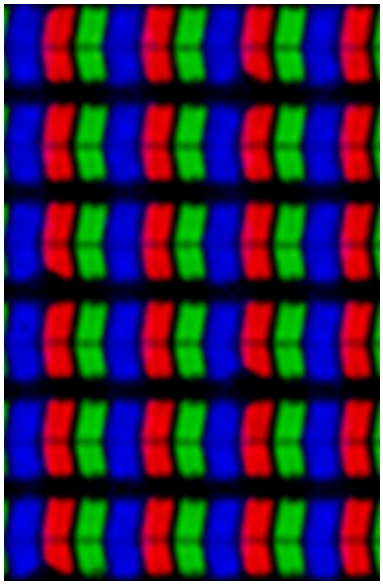
38. LCD displays have a single layer of liquid crystal shared by multiple pixels, with pixel boundaries being defined by the locations of pixel electrodes and color filters. Adjacent pixels in an LCD thus run right up against each other, bounded only by thin black masks that demark boundaries of pixels by virtue of simply blocking the light from being seen by the user in that part of the display. The aperture ratio of LCD displays is thus very high, with non-emission areas generally limited to the black masks between adjacent pixels (the black masks may also extend into

the pixel region over the locations of pixel driving circuitry, which can help shield the TFTs from being affected by external or reflected light).

39. In LCD displays, pixels are typically arranged in simple rows and columns, with a triplet of red, green, and blue pixels in three adjacent columns forming a unit that is repeated multiple times to form a single row, with the same color pattern repeated for each row. Variations of shapes and sizes were available for different applications. For example, chevron-shaped pixels were introduced to improve the viewing angle of the display using advanced LCD modes.



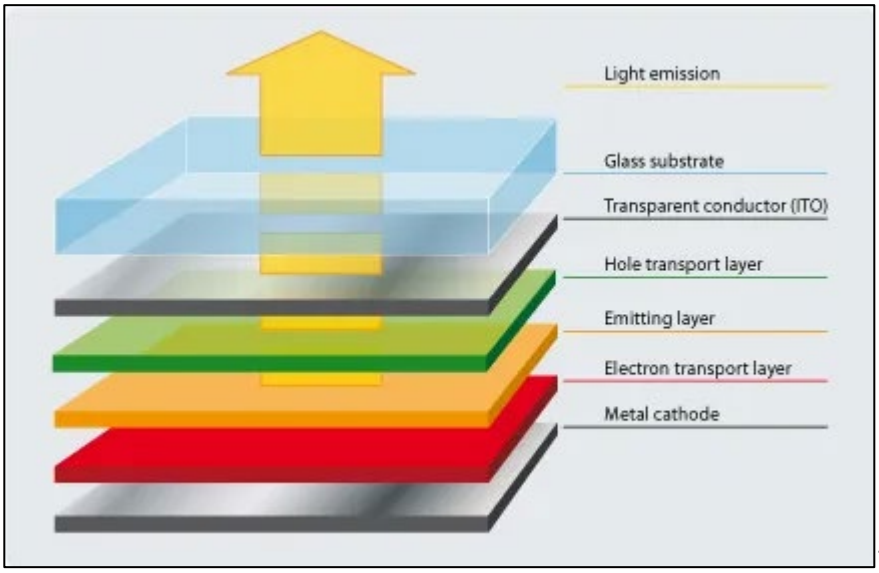
[2]


[3]

[2] From https://prometheus.med.utah.edu/~bwjones/wp-content/uploads/2010/06/iPhone-3G-Display_.jpg.

[3] From https://prometheus.med.utah.edu/~bwjones/wp-content/uploads/2014/10/iPhone6.jpg.

40. OLEDs display images using a two-dimensional array of pixels of different colors, again typically red, green, and blue. Unlike LCDs, OLEDs do not require a separate light source. Instead, the organic materials that form each pixel emit light. And unlike LCDs, where the red, green, and blue pixels appear to be directly adjacent to each other, OLED pixels have larger gaps between pixels due to the characteristics of organic materials and limitations of the manufacturing process.



[4]

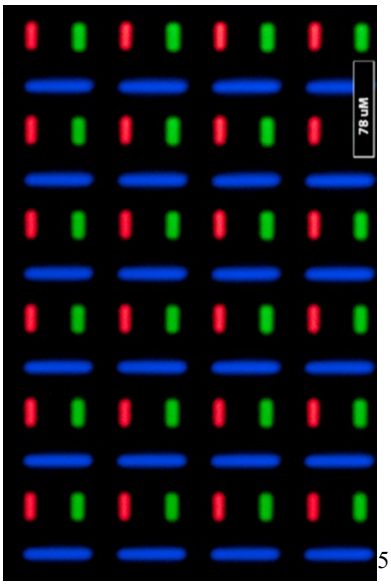
41. A typical OLED device is fabricated using a stack including a substrate, an anode, a hole transport layer, an emissive electroluminescent layer formed of an organic material, an electron transport layer, and a cathode. In such a device, holes are injected in the anode, electrons are injected from the cathode, and these form an

[4] From https://i0.wp.com/semiengineering.com/wp-content/uploads/2016/10/21c8niq.jpg.

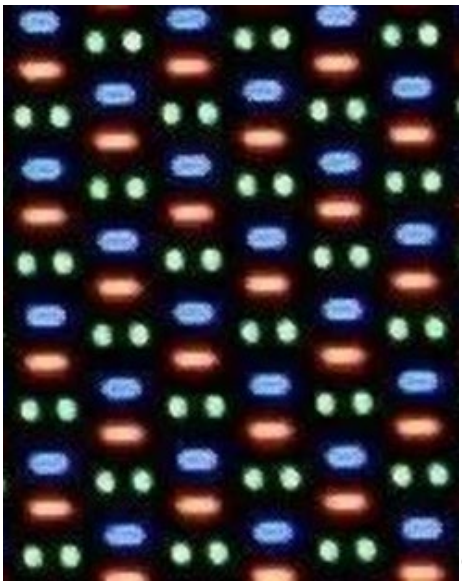
excited state which recombines, emitting light. The OLED stack may include other additional layers, such as a hole injection layer between the hole transport layer and the anode, an electron injection layer between the electron transport layer and the cathode, or blocking layers to help confine charge carriers to the emissive layer.

42. Manufacturing high-resolution OLED displays for small/medium sized display applications proved difficult, with low production yield rates. One significant source of the difficulty lay in the difference in methods of manufacturing the individual pixel elements for LCDs and OLEDs.

43. In LCDs, a single layer of liquid crystal material could be deposited on the entire display, with red, green, and blue color filters made of insulating material simply formed placed on top of each pixel region. But in OLEDs, the organic emissive materials that form each pixel conduct electricity, so the organic material must be sufficiently separated from each other to prevent defects. Further, when organic materials for emitting different colors are deposited too close to each other, overlap of the material can result in color mixing, compromising the color of the display. Thus, in contrast to LCDs, OLED displays have large gaps between pixels. Examples of OLED displays are shown below. Other examples can also be seen in Exs. 2023, 2034, 2035.



[5]


[6]

44. Manufacturing OLED displays, and particularly the emissive layers that are responsible for forming visible images on the display screen, requires deposition processes that are challenging from both design and manufacturing standpoints. In the case of OLED displays for mobile devices, the manufacturing process is especially complicated because the pixels are extremely small and must fit very close to one another. Further complicating the process is that the different colored pixels use different organic materials, each of which have unique characteristics, such as life span.

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[5] From https://prometheus.med.utah.edu/~bwjones/wp-content/uploads/2015/07/Apple-Watch-Pixels.jpg.

[6] From https://p1-tt.byteimg.com/origin/tos-cn-i-qvj2lq49k0/3ff6413f9f054ff7b3e2f88fed3f27a9.jpg.

45. The most common deposition method has been thermal evaporation under high vacuum using a fine metal mask. The fine metal mask ("FMM") is essentially a layer of metal with openings that define the positions, sizes, and shapes of individual OLED pixels. The FMM is placed near the surface of a display substrate, and organic materials are deposited onto the substrate such that the individual OLED pixels are formed within the opening of the FMM.

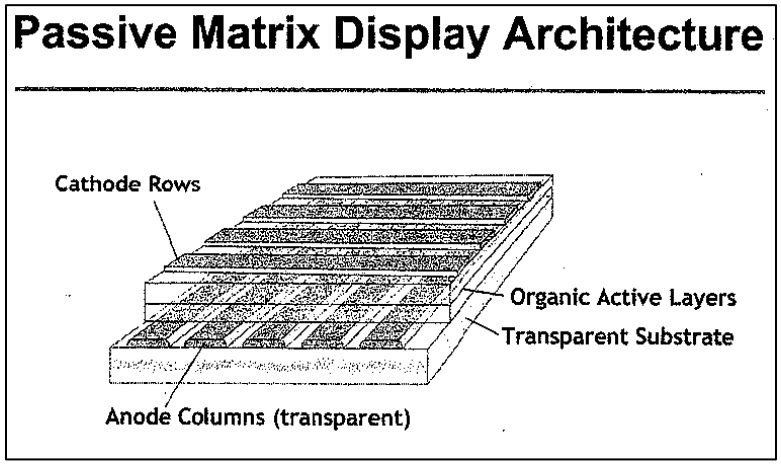
46. The locations, shapes, and sizes of the FMM mask openings correspond to the locations, shapes, and sizes of the red, blue, and green organic light-emitting materials deposited on the display substrate. Accordingly, FMM design and evaporation process considerations are closely related to the design for the red, green, and blue pixels of an OLED. Thus, the choice of OLED pixel arrangements has a significant impact on the manufacturability of the OLED display.

C. Display Architectures – Passive Matrix vs Active Matrix

47. There are two different ways to operate flat panel displays—active-matrix driving and passive-matrix driving. At a high level, active-matrix and passive-matrix driving refers to different ways in how the individual display elements are addressed for controlling the operation of each pixel (*i.e.*, how the light emitting material is controlled to change the brightness of each pixel). The two different approaches require fundamental differences in the physical structure of the

display as well. As a result, the technologies and design methods used for one are not readily transferable to the other.

48. Passive-matrix displays have row and column electrodes that have varying voltages applied in a particular time sequence to address the cells. There is no common electrode and the row and column electrodes are integral with the pixel electrodes. The basic structure of a passive-matrix display is illustrated below:



Ex. 2073 (Ghosh) at 13.

49. In a passive-matrix display, pixels are formed where column electrodes and row electrodes overlap. Ex. 2074 (Gu) at 6. Thus, the intersection of column electrodes and row electrodes defines the OLED pixel size. An individual pixel is illuminated when appropriate voltages are applied to the row and column electrodes that overlap at the location of that pixel. Note that in this configuration, a row of pixels shares one row electrode and a column of pixels shares one column electrode. When operating the display, one row of pixels is illuminated at a time by applying a

scan signal to that row, and applying data signals to each of the columns in that row. By scanning through all the rows successively within one time frame, a complete image can be output on the display in each frame.

50. Because one row of pixels emits light at a time, and an image is generated by sequentially scanning each row of pixels for a very short time while other rows are not emitting light (often called "flashing," or "pulsing"), each pixel must output a large amount of light in the sub-frame in which it is illuminated so that the average luminance for that pixel in the total duration of the frame corresponds to the desired brightness of the pixel in that frame. The light pulses must be extremely bright because of the short time within which each row is addressed, and this requires the pixels to be driven with high voltage and current density. Ex. 2074 (Gu) at 6; Ex. 2073 (Ghosh) at 12-15. The "high-instantaneous luminance requirement" was known to "lower[] the OLED power conversion efficiency" Ex. 2074 (Gu) at 6. It was also known to "shorten[] the device lifetime." Ex. 2080 (Lee) at 7-8.

51. The high voltages required for driving pixels in a passive matrix display also promotes more rapid degradation of the OLED pixels. There are several mechanisms that result in this type of degradation, but one significant mechanism is heat generation. When an OLED is biased, heat is generated because there is a potential drop at the interfaces and because the organic layer has a high resistance.

Ex. 2078 (Tyagi) at 1. Heat generation in an OLED can result in crystallization of the organic material, which reduces the luminance and efficiency of the OLED. Ex. 2078 (Tyagi) at 1-4. This effect will be more pronounced at higher voltages and current densities.

52. Voltage drop through the column and row electrodes, crosstalk, and leakage current through non-selected pixels, also present significant issues. Ex. 2074 (Gu) at 6-8. Further, with an increase in the resolution (*i.e.*, the number of rows and columns in the passive matrix display), the problems of crosstalk and leakage current—both of which can result in stray light emission—can become more pronounced. Ex. 2076 (Braun) at 1-2. Passive matrix displays were thus understood to be unsuitable for high-resolution applications, and to be limited to small, low-resolution displays. Ex. 2080 (Lee) at 5.

53. Unlike PMOLEDs, AMOLEDs do not rely on the intersection of row- and column-electrodes to drive the organic EL element. Instead, AMOLEDs comprise pixel drive circuits made up of thin-film transistors ("TFTs") and capacitors that drive each EL element while actively maintaining the state of the pixels. The capacitors allow the voltages on particular EL elements to be held constant for the duration of a frame, even when the row(s) associated with those particular EL elements are not selected. In other words, pixels can remain on while other rows of pixels are on. This allows the OLEDs to be driven at a significantly

lower voltage and driving current as compared to PMOLED. Ex. 2073 (Ghosh) at 12-15. As a result, OLEDs in active-matrix displays undergo lower rates of degradation, and different primary modes of degradation, than OLEDs in passive-matrix display. AMOLED displays thus have increased lifetime and decreased power consumption compared to PMOLED displays. Ex. 2080 (Lee) at 10-11.

54. The basic structure of an active-matrix display is illustrated in Figures 5 and 6 of Yamada, which show a basic pixel circuit with two transistors and one capacitor (called "2T1C" for short). In this example, the pixel circuit includes "a first TFT 30 for receiving a data signal," "a holding capacitor SC for holding the data signal," and a "second TFT 40 for supplying current via the power source line 53 to the organic EL element 160." Yamada, 7:19-36. Additionally, each pixel circuit is connected to a patterned electrode, usually the anode, of an OLED. It is the overlap of this electrode (as well as the counter-electrode) and the EL material that defines the light emitting region.

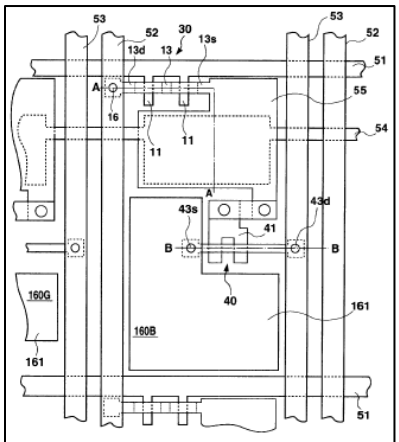


Fig. 5

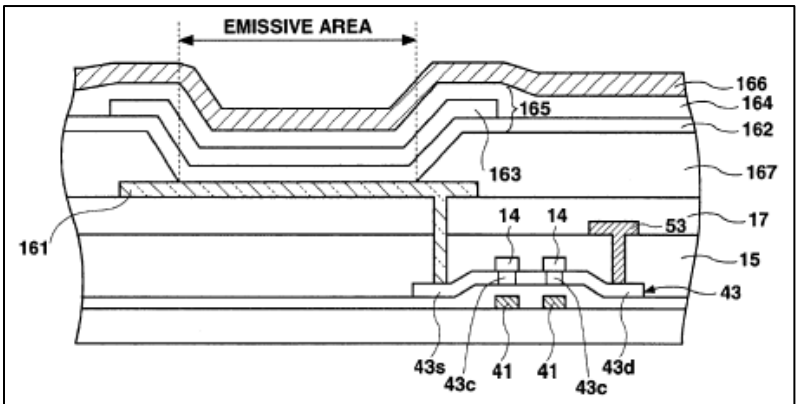


Fig. 6B

55. The additional pixel driving circuitry associated with each pixel in an active-matrix OLED, in conjunction with the power and signal lines necessary to control this circuitry, also impose different constraints on the size and locations of pixels. Ex. 2073 (Ghosh) at 12-15. For example, in Yamada's bottom-emission type AMOLED, the available lateral space is shared between the light emission area and the driving circuitry area, resulting in an irregular L-shaped pixel. Similar considerations for routing the driving circuits and signal lines also apply for top-emission type AMOLEDs. In top-emission displays, while lateral space does not have to be shared between the pixel emissive area and the driving circuitry and signal lines, the placement of the anode and emissive material directly above the driving circuitry and signal lines can lead to unwanted electrical effects, including crosstalk (both optical and electrical). This can result in poor display quality; for example, color shifting effects and other nonlinearities, such as ghost images (due to crosstalk) and distortion of the output image (due to stimulation of the TFTs in the driving circuitry due to the OLED optical output, because some TFTs are photosensitive).

56. In practice, the pixel circuits are often significantly more complicated than the 2T1C circuit shown in Yamada. For example, by the time of the invention of the '578 Patent, pixel circuit designs with as many as 6 transistors and 2 capacitors were developed to improve various device characteristics (for example, to compensate for non-uniformities in the backplane processes for manufacturing the

transistors). Thus, while these displays are more efficient and can be made for larger and higher-resolution applications, they are also more complicated to make. Ex. 2080 (Lee) at 10-11.

VI. OVERVIEW OF THE ’578 PATENT

57. The ’578 Patent is directed to novel pixel arrangement structures for OLED displays. As the patent explains, such displays have numerous advantages, including being small and low in power consumption, as well as having high luminance and high response speed. ’578 Patent, 1:27-35. This makes them useful in mobile devices, such as mobile phones.

58. The pixel arrangement structure affects important characteristics of OLED displays, such as aperture ratio (which is the fraction of the display area that is lit up), luminance, resolution, lifetime, as well as readability and visual perception. The layout of the pixels affects all of these; the size of the pixels, for example, determines the space available in between the pixels (which affects the fill factor) and the pixel pitch (which impacts the quality of reproduction of images in the display).

59. The ’578 Patent extensively discusses FMM manufacturing and its challenges. For example, the specification explains that “[a]n organic emission layer included in the pixel of an OLED display may be deposited and formed by using a mask such as a fine metal mask” and that “[w]hen reducing a gap between the

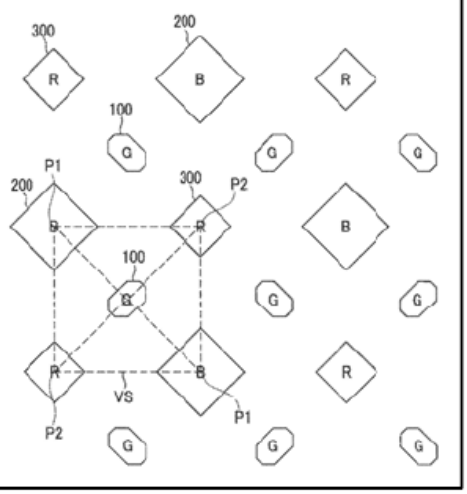
neighboring pixels to obtain a high aperture ratio of the pixel, deposition reliability may be deteriorated." '578 Patent, 1:46-50. Conversely, the specification explains that "when increasing the gap between the pixels to improve the deposition reliability, the aperture ratio of the pixel may be deteriorated." '578 Patent, 1:51-53. The '578 Patent also explains that the organic materials used to emit red, green, and blue lights have differing life spans and are prone to deterioration at different rates. '578 Patent, 7:35-42.

60. The specification discusses the importance of maintaining a high aperture ratio, which is a measure of the proportion of the display, or pixel, that emits light, as compared to the total area. An increased aperture ratio can have many benefits, such as improving the brightness, quality, and energy efficiency of a display. Reducing the gap between pixels will create a higher aperture ratio. However, doing so has trade-offs, because smaller gaps can lead to short-circuits and other issues that reduce manufacturability and yield. '578 Patent, 1:46-53. These tradeoffs present particular concerns when dealing with small screens such as those used in mobile devices, which are the focus of the '578 Patent.

61. Figures 1 through 5 in the specification show certain examples of the inventions of the '578 Patent, which teaches arrangements of red, green, and blue pixels in an OLED display. For example, Figure 5 (reproduced below) shows an exemplary embodiment in which there are green "first pixels" labeled 100, blue

"second pixels" labeled 200, and red "third pixels" labeled 300. As can be seen in Figure 5, the blue pixels are larger than the red pixels, which in turn are larger than the green pixels, and the pixels are arranged in a special pattern specified in the claims of the '578 Patent.

FIG.5



62. This pixel arrangement structure overcame the manufacturing and design challenges associated with the emissive layers of the OLED display. By arranging the red, green, and blue pixels in a RGBG format, as opposed to the traditional RGB format used in older devices such as LCDs, and by sizing and shaping the subpixels in particular ways, the '578 Patent struck the surprising and unexpected balance of improving the aperture ratio of the OLED display (by enlarging the emissive areas) while allowing for a more reliable deposition of the organic material (by ensuring sufficient gaps between pixels) during FMM manufacturing. This achievement allowed for "the manufacturing time and the

manufacturing cost of the OLED display" to be "reduced and the display quality of the image of the OLED display [to] be improved." '578 Patent, 6:50-52.

63. Moreover, the '578 Patent led to significant benefits in terms of display characteristics. Before the invention of the '578 Patent, the "established theory" in the display industry had been that "it would be difficult for AMOLED[s] to exceed the resolution of LCD[s] due to their light emitting diode and patterning limits." Ex. 2037 at 3. But "Samsung Display succeeded in innovating resolution by changing the existing rectangular patterning structure to a diamond structure." Ex. 2037 at 3.

VII. LEVEL OF ORDINARY SKILL IN THE ART

64. I understand that in a related ITC Investigation involving the '578 Patent, the ALJ has issued a claim construction order finding that a POSITA for the '578 Patent would have had a relevant degree in Electrical Engineering, Computer Engineering, Materials Science, Physics, or the like, and experience in electroluminescence and the design of active matrix displays or pixel arrangements for such displays. Ex. 2001 at 15.

65. I understand Dr. Pattison has instead proposed that a POSITA "would have had a degree in electrical engineering, materials science, physics, or a similar discipline, along with 2 years of professional experience working with display design, including OLED displays, or an equivalent level of skill, knowledge, and experience," and that such a POSITA "would have been aware of and generally

knowledgeable about OLED materials, and display pixel design, layout, and operation." Ex. 1003, ¶39.

66. Under either definition of a POSITA, Dr. Pattison fails to show that the challenged claims of the '578 Patent are unpatentable.

VIII. OVERVIEW OF THE ASSERTED PRIOR ART

A. Matthies (Ex. 1004)

67. Matthies refers to U.S. Patent No. 6,897,855, which issued on May 24, 2005.

68. The patent is directed to "large-area display devices," which could be the size of a room, or even larger. The displays "are formed as an array of tiled display devices." Matthies, 1:8-10. As shown below in Figure 1, Matthies describes a "tiled display in which emissive or reflective elements, on which the image pixels are formed, are built as . . . small arrays on tiles 120 and assembled into a frame to produce the large-area display having a large number of pixel forming elements." Matthies, 5:35-42.

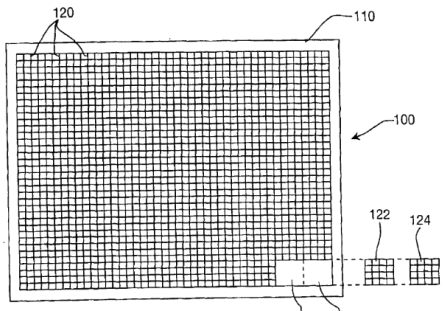


FIG. 1

69. Matthies uses a couple of different types of display, including cathode ray tubes. Matthies includes some OLED embodiments, which are passive matrix displays, also called PMOLEDs. For instance, Matthies explains that the "tiles" that form the large-area display "use a block-wise passive addressing technique," Matthies, 3:4-5, and that "the invention employs a passive addressing technique within a block in which only one row of pixels is illuminated at any time." Matthies, 10:31-33. Unlike active matrix OLEDs or AMOLEDs which use thin-film transistors as switching elements to drive the electroluminescent element, Yamada, 1:15-17, PMOLEDs like those used in Matthies involve depositing the red, green, and blue OLED materials between a column electrode and row electrode, whereby "[c]urrent flowing from one electrode to the other electrode causes the organic polymer to emit light." Matthies, 6:22-23.

70. Matthies depicts its PMOLED configuration in Figure 3 (reproduced below). As shown below, organic materials (e.g., 324 and 326) are deposited in between row electrodes 328 and column electrodes 322. The emission areas (i.e., the areas of the display that actually emit light) are limited to the areas where the pairs of column and row electrodes overlap. Matthies, 16:38-40 ("[I]n . . . monochrome displays[,] [t]he pixels have a single emissive area which is controlled by a single row and column electrode pair."), 10:21-27 ("The amount of light emitted by a pixel

when it is turned on is controlled by controlling the level of current applied to the pixel in the on state.”).

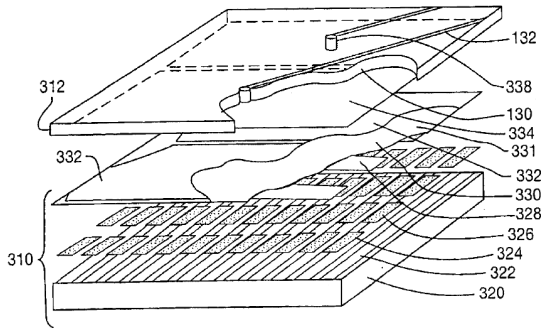


FIG. 3

71. Matthies describes a color pixel structure with a single red sub-pixel, a single blue sub-pixel, and a single green sub-pixel placed side-by-side. Matthies, 16:40-43. This is shown below in Figure 8A of Matthies. The “three sub-pixels 820 [red], 822 [green], and 824 [blue] each have a respective column electrode” and “a single row electrode . . . is used by all three of the sub pixels.” Matthies, 16:40-48.

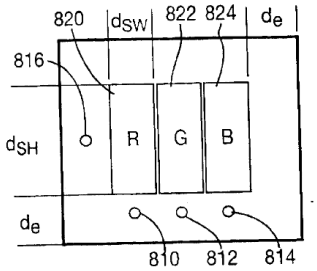


FIG. 8A

72. Matthies alternatively describes “an alternative color pixel structure” which includes “four sub-pixel elements” as shown below in Figure 8B. Matthies, 16:62-63. Sub-pixel elements 830 and 836 “emit green light when stimulated while the other two pixel elements, 832, and 834 emit red and blue light, respectively.”

Matthies, 16:64-66. Matthies calls this the "quad sub-pixel structure." Matthies, 16:67.

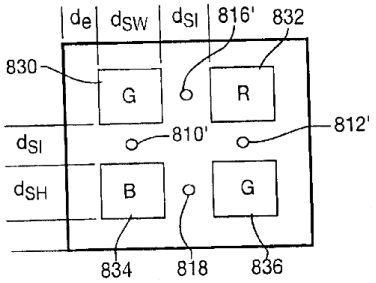
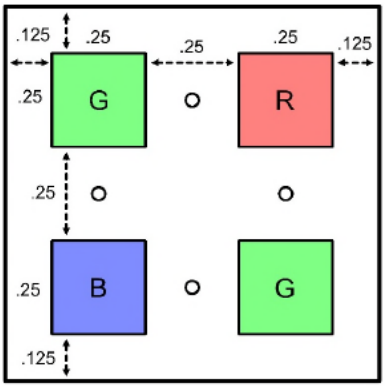


FIG. 8B

73. Matthies explains that in some cases, using two green sub-pixels could result in a brighter display. Matthies, 17:3-4. This could be the case, for example, in display technologies such as LCD or CRT. When different color pixels have different efficiencies (such as in the case of OLEDs), Matthies suggests alternative quad sub-pixel structures: "In some display technologies, the amount of light emitted by the red or blue pixel material may be less than the amount of light emitted by the green pixels. In this instance, making the pixels 830 and 836 both be red or blue pixels would improve the overall brightness of the display." Matthies, 17:6-8. Thus, if the blue pixels are least efficient in OLED displays, Matthies recommends that the quad sub-pixel structure have two blue pixels.

74. One of Matthies' stated concerns is to "eliminat[e] the visibility of the seams between tiles," Matthies, 2:7-10, given that Matthies is directed to a large-area display made up of many smaller tiles. To address this concern, Matthies explains that "[t]he tiles are constructed with pixel forming elements evenly spaced

up to the edges of the tiles." Matthies, 5:47-48. As shown in the annotated version of Figure 8B in Dr. Pattison's declaration, reproduced below, Matthies teaches having even spaces between the rows of pixels and between the columns of pixels. Adjacent pixels are separated by 0.25 times the pitch. This would be the case whether the pixels are adjacent within a quad pixel or adjacent across two quad pixels that are separated by a seam in between.



B. Yamada (Ex. 1005)

75. Yamada is U.S. Patent No. 6,366,025, which issued on April 2, 2002.

76. Yamada is cited on the face of each of the Diamond Pixel patents and was thus considered by the Examiner during prosecution of each of the Diamond Pixel patents. I understand that Yamada did not lead the Examiner to conclude that the asserted claims of the Diamond Pixel patents were anticipated, obvious, or otherwise invalid. I agree with the Examiner that Yamada does not anticipate or render obvious the asserted claims, either alone or in combination with other references.

77. Yamada is directed to active-matrix OLEDs (AMOLEDs) that use thin-film transistors (TFTs) as switching elements to drive an organic electroluminescence (EL) element. Yamada, 1:6-9 ("The present invention relates to an electroluminescence display apparatus comprising an electroluminescence (hereinafter also referred to as EL) element and a thin film transistor (hereinafter referred to as TFT) element."); Yamada, 1:18-3:8.

78. Yamada describes "a color display device, in which a display pixel having an emissive element is provided for every color, wherein the emissive area of the display pixel of any one color, among the display pixels of the various colors, is different in size from the emissive area of the display pixel of another color." Yamada, 3:16-23. Yamada further explains that "the element emissive areas in the display pixels for R, G, and B are designed to take into consideration not only the emission efficiency of the emissive elements of the display pixels but also the luminance ratio of red to green to blue in accordance with the chromaticity of the target display white of the display device and with the chromaticity of each red, green, and blue color emitted by the emissive elements of the respective display pixels." Yamada, Abstract.

79. Figure 4, which Yamada describes as a "conceptual diagram" of an embodiment, depicts pixels that are arranged in a matrix of stripes. Yamada, Fig. 4; 6:24-26 ("conceptual diagram showing emissive region areas of the EL display

apparatus"); Yamada, 12:37-39 ("[T]he arrangement of the display pixels of various colors in the embodiment [i]s shown in a stripe layout."). As shown below, Yamada arranges one red pixel (1R), one blue pixel (1B), and one green pixel (1G) in a stripe layout.

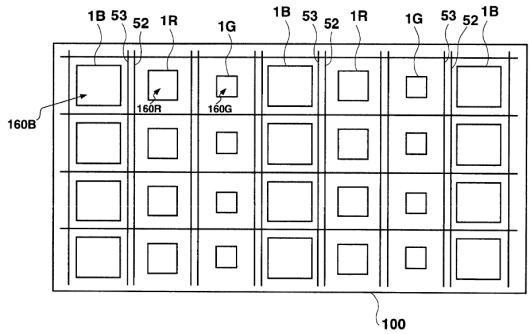


Fig. 4

80. Yamada is a bottom-emission device, as indicated by the ITO anodes and magnesium indium alloy cathodes. Yamada, 7:19-8:18. Bottom-emission means that the direction of light emission is towards the transparent ITO anode. So in the cross-sectional view of a pixel shown in Figure 6B below, light would be emitted in the downward direction. In bottom emission devices, the driving circuitry is also in the direction of the anode, which limits the area for the pixels.

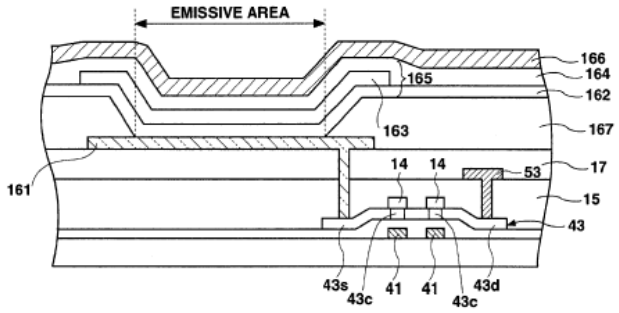


Fig. 6B

81. Yamada explains that the display pixels have "a rectangular shape or an 'L' shape." Yamada, 12:33-35. Figure 5, which Yamada describes as "a schematic top plan view of one display pixel," shows, for example, an L-shaped blue pixel (160B) that is surrounded by, for example, source lines (53), thin film transistors (30, 40), gate signal lines (51), and drain signal lines (52). Yamada, 6:28-30. The cross-section (Figure 6A) clearly shows a bottom emitting OLED device; with a transparent ITO anode (161) and a reflective metal cathode (166), MgIn. This configuration requires the transistor to be separated from the emissive area of the pixel. Because of the space occupied by thin film transistor 40, blue pixel 160B takes on an irregular L-shape.

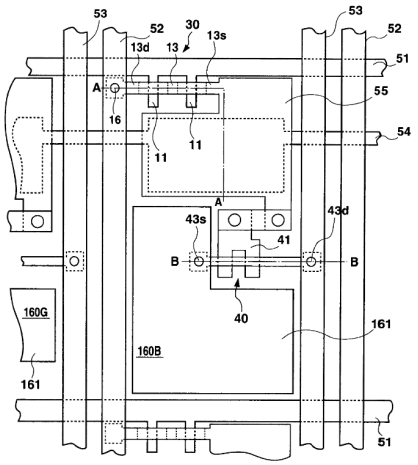


Fig. 5

82. Yamada explains that for the blue EL elements, "which have the lowest emission efficiency among the R, G, and B EL elements," Yamada, 8:47-53, "a current larger than that supplied to the other display pixels having a high emission

efficiency must be supplied," causing "the life of those display pixels having a low emission efficiency, in particular, to shorten." Yamada, 2:60-67. Yamada addresses the relatively lower emission efficiency of blue pixels in an RGB structure by increasing the size of the blue pixel. The current density in the blue pixel can be decreased by increasing the light-emission area of the blue pixel, which can contribute to increased life span.

C. Hong (Ex. 1011)

83. Hong is U.S. Patent Application Publication No. 2011/0234550, which was published on September 29, 2011.

84. Hong is cited on the face of the '578 patent and was considered by the Examiner during prosecution of the '578 patent. I understand that Hong did not lead the Examiner to conclude that the asserted claims of the '578 patent were anticipated, obvious, or otherwise invalid. I agree with the Examiner that Hong does not anticipate or render obvious the asserted claims of the '578 patent, either alone or in combination with other references.

85. Hong is directed to an OLED display device that uses a particular arrangement of organic patterns in sub-pixel regions. Hong, ¶[0003]. Specifically, Hong is directed to a specific variant of the RGB stripe-type structure, where the red, green, and blue pixels are arranged in a "zigzag" pattern, instead of being arranged in a regular rectilinear grid. Hong, Abstract, ¶¶[0015]-[0016], [0043], [0052], [0067],

Figures 4, 6, 9. The zigzag pattern is an important aspect of Hong's invention because it is what allows for greater separation between adjacent pixels of different colors to result in improved aperture ratio and resolution while reducing the shadowing effect. Hong, ¶¶[0036], [0043]-[0044], [0048]-[0049], [0052].

86. Hong describes "an organic electroluminescent device" with "first, second and third organic patterns . . . [that] may correspond to red (R), green (G), and blue (B) organic patterns, respectively." Hong, ¶[0040]. As shown below in Figure 4, Hong describes a display in which "[t]he first, second and third organic patterns 200a, 200b and 200c are disposed in the first, second and third sub-pixel regions SP1, SP2 and SP3 to have a zigzag shape along the first direction with respect to a virtual line VL," the virtual line VL being "parallel to the gate line GL." Hong, ¶[0043].

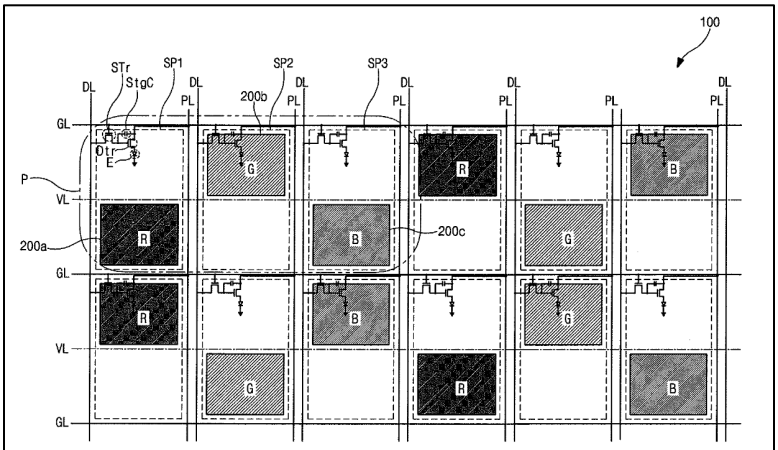
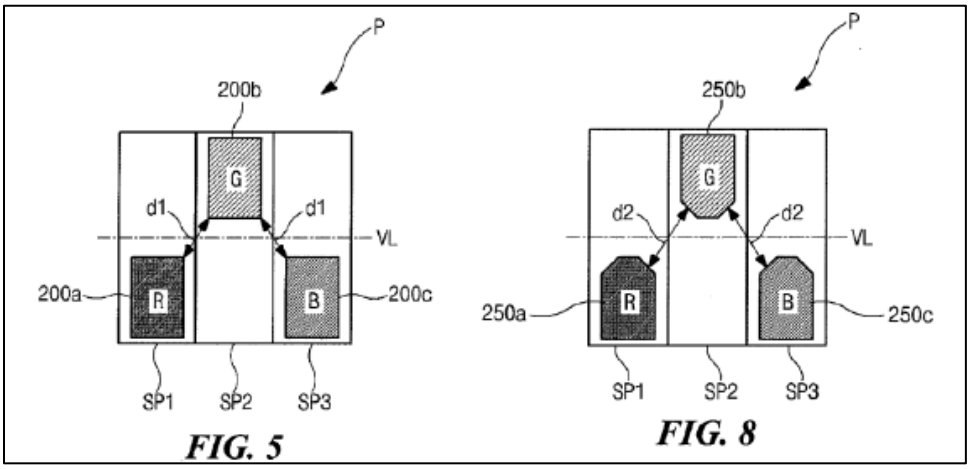


FIG. 4

87. As shown below in Figures 5 and 8 of Hong, the shortest distance between adjacent organic patterns in the zigzag arrangement is in the diagonal

direction (d1). Hong seeks to increase the aperture ratio by using this zigzag pattern to avoid a "shadowing effect" that the proximity of organic patterns in such an arrangement can cause. Hong, ¶¶[0011], [0044]. Hong explains that the arrangement in Figure 8 further addresses the potential shadowing effect by truncating the corners of the organic patterns to increase the shortest distance from d1 to d2. Hong, ¶¶[0047]-[0048], [0060]-[0061]. This allows the patterns 250a, 250b, and 250c to have "a further enlarged area" and results in an increase in the total light-emitting area. Hong, ¶¶[0057], [0061]. This is consistent with Hong's teaching that pixel areas in RGB designs should be enlarged to increase the aperture ratio.



IX. OVERVIEW OF DR. PATTISON'S OPINIONS

88. In his declaration, Petitioner's expert Dr. Pattison opined as follows:

- Ground 1: Claims 1–6, 10, 12, 17–19, 21–23, 41–42, 44–47, and 52 are rendered obvious by Matthies and Yamada
- Ground 2: Claims 40, 43, 45–47, and 51 are rendered obvious by Matthies, Yamada, and Hong

89. I disagree with Dr. Pattison's opinions for the reasons below.

X. GROUND 1: MATTHIES AND YAMADA

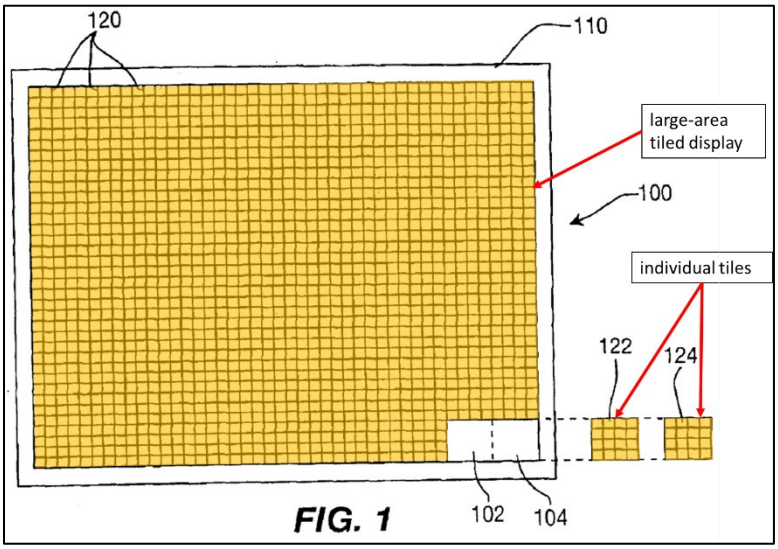
90. For the reasons explained below, it is my opinion that the combination of Matthies and Yamada fails to render obvious claims 1–6, 10, 12, 17–19, 21–23, 41–42, 44–47, and 52 of the ’578 Patent.

A. A POSITA would not have been motivated to combine Matthies and Yamada because they involve fundamentally different technologies and are incompatible with each other

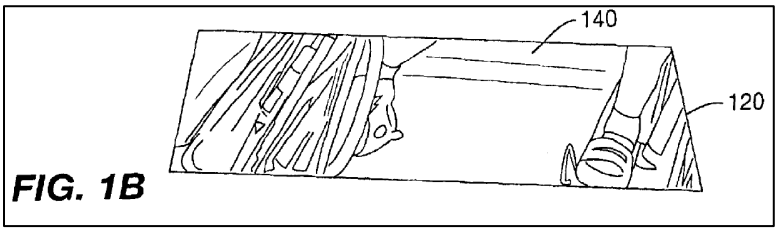
1. Matthies is directed to a passive-matrix display built as a tiled structure

91. Matthies is directed to “large-area display devices,” Matthies, 1:8-9, which would commonly be the size of an entire room, or even larger. It is difficult and expensive to build a single display that large. Matthies therefore assembles the display out of a large number of “tiles.” Matthies describes a “tiled display in which emissive or reflective elements, on which the image pixels are formed, are built as . . . small arrays on tiles 120 and assembled into a frame to produce the large-area display having a large number of pixel forming elements.” Matthies, 5:35-42. Matthies states that such large-area displays can be applied to “[h]ome theater applications,” “[a]pplications that require multiple viewers,” “[a]pplications in which the user needs to move about in an area,” and “[a]pplications where simulation of the real world is needed for training.” Matthies, 1:20-25. Matthies is even titled “***Tiled*** Electronic Display Structure.” Matthies, Cover.

92. Matthies shows how individual tiles can be used together to create a large area display, as I've illustrated in an annotated version of Figure 1 below:



Each individual display tile shows a small section of a complete image as shown below in Figure 1B, with the large-area tiled display combining tiles to show the full image:



93. Matthies is primarily focused on difficulties that are encountered when trying to make displays larger. As Matthies explains, "[t]here are fundamental technical issues that impose scaling-laws and limit the size of displays that can be manufactured. These fundamental limitations are one reason why a technical solution that meets the need for large-area displays has not been achieved." Matthies,

1:34-38. As Matthies explains, "[n]o practical tiled display system has yet been developed." Matthies, at 1:66-2:2. "What has been missing is a fabrication technology that allows a display to be constructed so that pixels can be brought up to the very edge (actually, with in [sic] ½ pixel spacing period of the edge), while at the same time allowing for electronics to address each tile, even [with] those tiles completely surrounded by other tiles." Matthies, at 2:2-7. Matthies also explains that the distance between the edges of pixels on a tile and the edge of the tile is important to allow for electronics and connections between tiles, and to avoid the seams between tiles being visible. Matthies, 8:37-39, 9:23-26, 15:61-63, 16:5-9. Thus, Matthies is addressed to overcoming what it identifies as "[t]wo barriers to implementing the tiled approach": "1) eliminating the visibility of the seams between tiles, and 2) providing electrical access to the pixels." Matthies, 2:8-10. Matthies thus focuses on solutions to design issues that are unique to tiled displays.

94. Matthies also highlights the distinction between its tiled displays and monolithic (*i.e.*, single-substrate) displays, noting that "[t]iled displays have relatively few pixels so that the number of interconnects per tile is relatively small," which confers "a significant advantage of tiled displays when compared to fabrication of large displays from single substrates." Matthies, 9:34-38.

95. Matthies' tiled displays—including the specific embodiment of the tiled display shown in Figure 8B that Dr. Pattison relies on—are PMOLED displays. Matthies, 10:31-33.

96. In Matthies' display, the basic light emitting unit consists of a red, green, or blue organic light-emitting material layer sandwiched between two electrodes: a row electrode and a column electrode, as shown in an annotated version of Figure 3, below. Matthies, 12:61-13:16, 6:19-21.

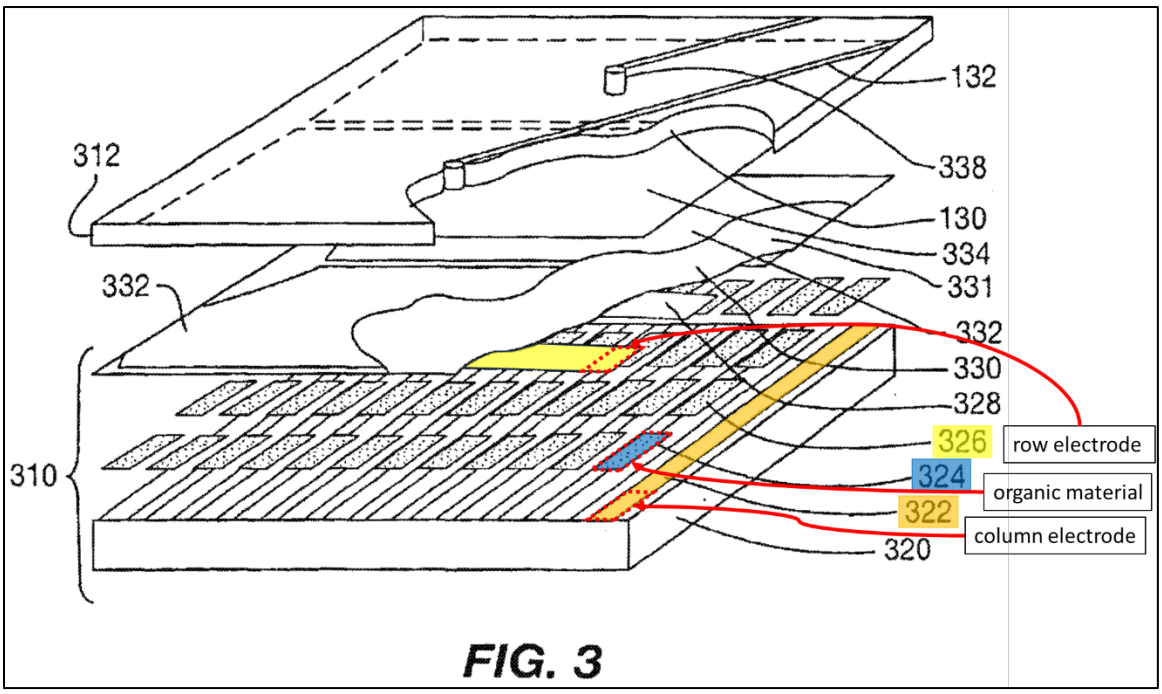
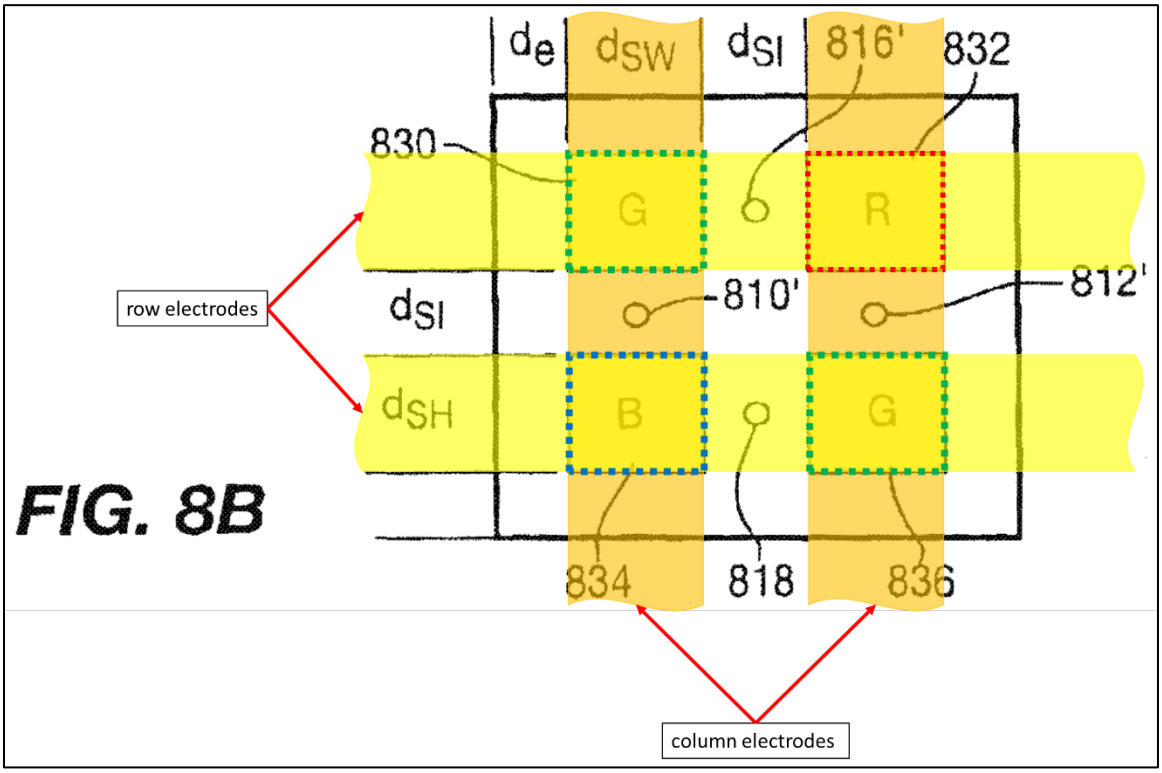


FIG. 3

97. As Matthies explains, "[c]urrent flowing from one electrode to the other electrode" causes the organic material to emit light. Matthies, 6:22-23. Consequently, the emissive area of a pixel is defined by the area where a column electrode and a row electrode cross (*i.e.*, the region of overlap of the vertical and horizontal

electrodes), with the organic emissive material sandwiched in between. Matthies, 13: 1-5. Thus, Matthies describes a passive-matrix display.

98. The quad sub-pixel structure of Figure 8B that Dr. Pattison relies on is similarly a passive-matrix structure, and has "two row electrodes … and two column electrodes" creating the four sub-pixel regions where the electrodes cross as shown below in an annotated version of Figure 8B. Matthies, 17:10-12.



99. In this embodiment of Matthies, consistent with a PMOLED structure, "[t]he geometry of the quad sub-pixel structure is defined by the dimensions d_{SH} the height of the sub-pixel, d_{SW}, the width of the sub-pixel, d_e, the distance from the active sub-pixel areas to the edge of the pixel area, and d_{SI}, the distance between adjacent sub-pixels." Matthies, 17:16-20. So in the quad sub-pixel structure, the

width of the row electrode and the width of the column electrode define the pixel areas. The result is that in the quad sub-pixel structure of Matthies, each of the green, blue, and red subpixels would have the same area: $d_{SH}*d_{SW}$.

2. Yamada is directed to an active-matrix display built on a single substrate

100. On the other hand, Yamada is directed to active-matrix OLEDs ("AMOLEDs"). Yamada, 1:6-9, 1:18-3:8. And Yamada is directed to what are called monolithic displays—unitary OLED displays having many pixels built on a single substrate. Yamada, 1:45-53.

101. As explained above in Section V, Figures 5 and 6 of Yamada illustrate the basic structure of an AMOLED with a 2T1C pixel circuit. In Yamada, the pixel circuit includes "a first TFT 30 for receiving a data signal," "a holding capacitor SC for holding the data signal," and a "second TFT 40 for supplying current via the power source line 53 to the organic EL element 160." Yamada, 7:19-36.

102. As Yamada explains, "the region actually emitting light, namely, the emissive area," is the area "in contact with the emissive element layer 165 and the anode 161." Yamada, 10:39-44. This pixel structure is shown in Yamada's Figure 6B. In Yamada's devices, each pixel's driving circuitry limits the light-emitting area of the pixel. Yamada, 7:19-8:18. This can be seen in the following annotated versions of Figures 5 and 6B of Yamada, which highlight the emissive areas in both a plan view and a cross-sectional view:

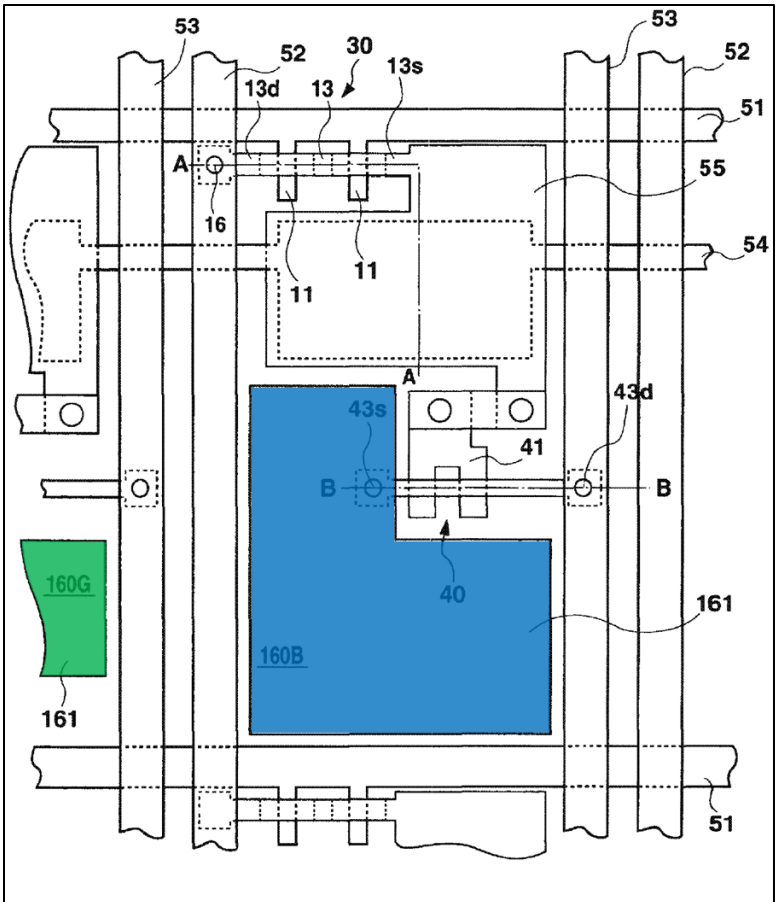

53
52
30
13s
13d
13
53
52
51
A
55
16
54
11
11
A
43s
43d
41
B
B
40
160G
161
160B
161
51

Fig. 5

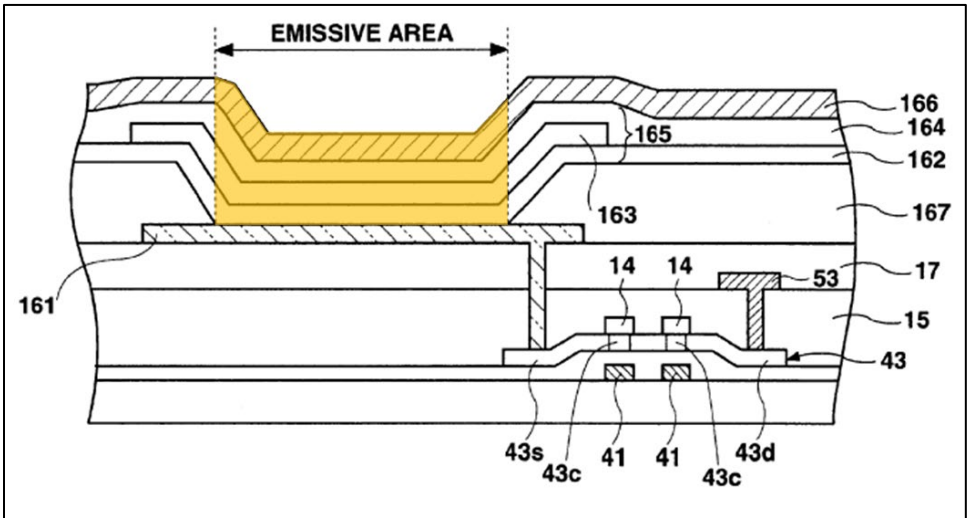

EMISSIVE AREA
166
164
165
162
163
167
161
14
14
53
17
15
43
43s
43c
41
41
43c
43d

Fig. 6B

103. Thus, Yamada's AMOLED display does not use row and column electrodes, and Yamada's pixel shapes and sizes are not dictated by the dimensions of row or column electrodes. But as shown above, and as discussed in the technical background section, Yamada's pixels are still constrained by the pixel driving circuit (including transistors and a capacitor) and power and signal lines.

3. Due to their fundamental differences, a POSITA would not have looked to Yamada to modify Matthies

104. In view of these differences, a POSITA would not have looked to Yamada's teachings regarding lifetime of OLED pixels in monolithic AMOLED displays to modify the OLED pixels in Matthies' tiled PMOLED displays.

105. As I explained above in Section V, a POSITA would have understood that passive matrix OLEDs and active matrix OLEDs drive the OLED pixels in fundamentally different ways. The different driving methods result in differences in the degradation profile of the OLED pixels that make up the display.

106. To recap, in passive-matrix OLEDs, the rows of OLED pixels are selected sequentially, one row at a time for only a small fraction of a frame. The light pulses must be extremely bright because of the short time within which each row is addressed, and this requires the pixels to be driven with very high voltage and current density. This "high-instantaneous luminance requirement" was known to "lower[] the OLED power conversion efficiency" Ex. 2074 (Gu) at 6. Further, the high voltages required for driving pixels in a passive matrix display also promotes

more rapid degradation of the OLED pixels due to several different mechanisms. Heat generation is one major mechanism. When an OLED is biased, heat is generated due to potential drops at the interfaces between the different layers of the OLED device stack. The electrical resistances at the different interfaces of the stack, as well as the high resistance of the organic layer, all contribute to heating. Heat generation in an OLED can result in crystallization of the organic material, which reduces the luminance and efficiency of the OLED. Ex. 2078 (Tyagi) at 1-4. This effect will be more pronounced at the higher voltages and current densities required to drive a PMOLED display.

107. On the other hand, in active-matrix OLED displays, the capacitors allow the voltages on particular OLED pixels to be held constant for the duration of a frame, even when the row(s) associated with those particular OLED pixels are not selected. Thus, pixels can remain on while other rows of pixels are selected. This allows the OLEDs to be driven at a significantly lower voltage and driving current as compared to the OLEDs in passive-matrix OLED displays. Ex. 2073 (Ghosh) at 12-15. As a result, OLEDs in active-matrix displays undergo lower rates of degradation, and different primary modes of degradation, than OLEDs in passive-matrix displays.

108. Further, there were well-recognized shortcomings with PMOLED displays, and well before the time of the invention of the ’578 Patent, the industry

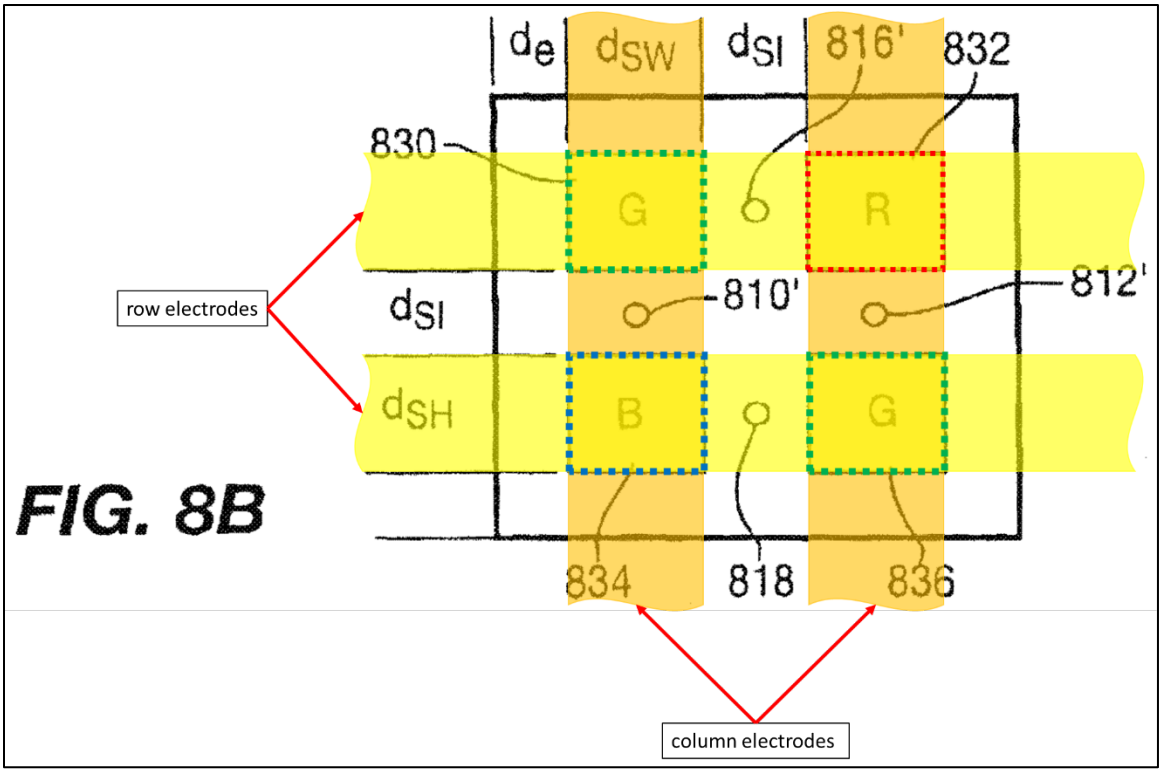
was shifting away from PMOLED displays to AMOLED displays. PMOLED displays have limited resolution. As discussed above, PMOLED displays require significantly higher voltages than AMOLED displays, and the voltages required to drive PMOLED displays scales with the resolution of the display. The more rows, the higher the voltage necessary, so this imposes a constraint on the resolution of a PMOLED display. By the time of the ’578 Patent, display resolution had increased to a point where PMOLED displays would no longer be practical for most applications. Thus, a POSITA by the time of the invention would have had no reason to look to implement a color PMOLED display shown in Matthies, let alone modify it based on the disclosures of Yamada’s teachings focused on AMOLED displays.

109. Thus, a POSITA would not have expected that proposed solutions to OLED pixel degradation and aging in the context of active-matrix OLED displays would have been directly applicable to OLED pixels used in passive-matrix OLED displays, and would not have considered Matthies and Yamada together.

110. Even if a POSITA were to consider these two references together, a POSITA would not have been motivated to modify Matthies’ passive matrix display by varying pixel sizes based on Yamada’s disclosures, given the significant structural differences between active matrix and passive matrix displays.

111. As I explained above in Section V, passive-matrix OLED displays and active-matrix OLED displays require fundamentally different structures that implicate different design considerations and constraints.

112. And as I just explained, in the PMOLED of Matthies, the light-emitting area is defined by the overlap of the row and column electrodes. As a result, as shown in Matthies' Figure 8B (shown below with annotations), the pixels in the same row (for example, green pixel 830 and red pixel 832 in the top row) have the same height (d_{SH}), and pixels in the same column (for example, green pixel 830 and blue pixel 834 in the left column) have the same width (d_{SW}). If a POSITA were to try to change the size of a pixel in the PMOLED shown in Figure 8B, that would require changing the size of a row and/or column electrode, but doing so would also change the size of all of the other pixels defined by that row and/or column electrode. Dr. Pattison does not give any explanation of how the pixel sizes could be individually arbitrarily changed into the proportions that he suggests should be used, and it is not clear how such a display could be made.



113. It is not a simple matter to resize the row and/or column electrodes to be irregular. An engineer would have to somehow design and develop a mask to pattern each of the row and column electrodes to be shaped to accommodate the alternatingly large and small pixel shapes required by Dr. Pattison's combination. Patterning the electrodes would further add a process step, increasing manufacturing costs and reducing yield. Additionally, if a POSITA were to try to make such irregularly sized electrodes, that would have an effect on the IR voltage drop, which would need to be compensated differently than in a typical PMOLED display with uniformly sized electrodes, thus adding additional complexity to the design. This would necessitate changes not only to the structure of the electrodes, but also to the

display driver circuitry for applying the appropriate voltages to the row and column electrodes to allow the OLED to display images.

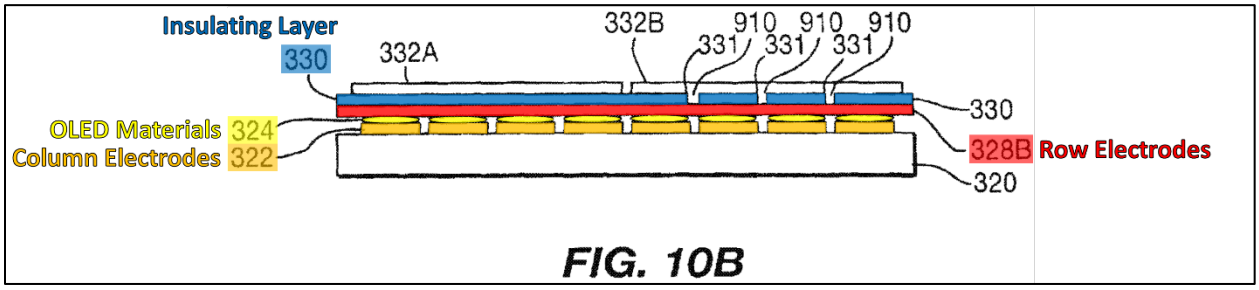
114. Further, irregularly patterning the ITO material that forms the column electrodes can increase the risk of catastrophic failure of the OLED display. Catastrophic failure (also sometimes called "sudden death") refers to large luminance drops due to electrical shorts that develop as a result of defects in the interfaces of the OLED stack, such as non-uniform organic layers, or defects in the ITO layer. To take one example, one way these defects can occur is through morphological defects in the ITO—called ITO spikes. The organic layer in an OLED is thin. Roughness in the ITO layer can result in a topographic change in the organic layer that overlays the ITO, so the organic layer above an ITO spike will become even thinner. When a large electric field is applied, or if the OLED is operated for a long time, the electric field will be enhanced at the location of the ITO spike. This can result in a collapse at the defect position, causing an electrical short between the ITO and the cathode metal. When the two metal layers touch, they will either locally burn each other out in the best case, or short the whole display in the worst case. Localized electrical shorts at the locations of these ITO spikes can also grow over time. The result is significantly decreased luminance; and if the driving voltage and current density is increased to maintain the desired luminance, even faster degradation of the OLED pixel.

115. The defects and surface roughness at the interfaces of the OLED stack can also result in dark spot formation. Dark spots refer to non-emissive areas of the OLED. Dark spots are typically associated with moisture or other impurities, or supply of high electric current. Ex. 2079 (Azrain) at 2. When a high electric field is applied to the OLED (which can be further enhanced by surface roughness of ITO or other layers), a chemical reaction (electromigration) pulls in metal from the cathode of the OLED stack, and this migrated metal can form grain clusters at the ITO, forming dark spots and deteriorating the charge carrier injection path. The dark spot can also grow larger over time. The result is similarly significantly decreased luminance and faster degradation of the OLED pixel. Ex. 2079 (Azrain) at 6-10.

116. These effects would be particularly pronounced in a PMOLED display, given the high operating voltages necessary, as discussed previously.

117. A POSITA would also not have attempted to re-size pixels by adding additional layers. If instead of resizing the electrodes a POSITA were to try to add a blocking or isolation layer between the row and column electrodes to change the size of the overlap between the anode and organic material (and thus the emissive area of the pixels), this would require additional process steps, increasing manufacturing costs and reducing yield. This would also increase the overall thickness of the display. Further, this design would result in electrical charge accumulation in the regions of the overlapping electrode areas that are not overlapping the organic

emissive material and not contributing to the driving of the OLED, resulting in increased energy consumption. As shown in the cross-section of Matthies' display shown in Figure 10B (annotated version below), Matthies does not use any layer between the row and column electrodes for shaping the organic material, because there is no need for such a layer in the PMOLED where the electrode overlap regions define the emissive area. *See also* Matthies, 12:58-13:26.



118. A POSITA would further not have been motivated to modify Matthies' display by varying pixel sizes based on Yamada's disclosures, because they would conflict with constraints on pixel arrangements imposed by Matthies' tiled display design.

119. Matthies itself highlights the distinction between tiled and monolithic displays, noting that "[t]iled displays have relatively few pixels so that the number of interconnects per tile is relatively small," which confers "a significant advantage of tiled displays when compared to fabrication of large displays from single substrates." Matthies, 9:34-38. In fact, Matthies turns to tiled displays specifically to avoid the complexities and costs involved in manufacturing a "monolithic multi-

pixel display." Matthies, 1:60-65. The problems encountered in trying to manufacture a tiled display are distinct from those encountered in trying to manufacture a monolithic display, resulting in differences in what a POSITA would consider to the key constraints for designing the pixel arrangement structure for the display.

120. Matthies repeatedly stresses the importance of ensuring that pixels are spaced such that the distance from each pixel to the edge of the tile is the same, and the distance between pixels within a tile is the same as the distance between pixels across adjacent tile. *See, e.g.*, Matthies, 5:47-53, 8:37-41, 15:59-63, 16:5-9. As I've explained further below in Section X.D.3, this is important to Matthies' tiled display to avoid optical effects at the tile edges. *See, e.g.*, Matthies, 8:37-41, 21:22-27, 22:53-56. Matthies also places constraints on its pixel arrangements to accommodate vias and connectors. *See, e.g.*, Matthies, 15:61-63, 16:5-9, 16:22-26, 24:39-42. These constraints important to Matthies' tiled display would be incompatible with Dr. Pattison's proposed resizing of Matthies' pixels based on Yamada.

121. Thus, a POSITA at the time of the invention of the '578 Patent would not have looked to Yamada, which proposes a solution in the context of monolithic active-matrix OLED displays with significantly different electrical considerations and pixel layout constraints, to modify Matthies' passive matrix OLED tiles. And a

POSITA would not have had a reasonable expectation of success in making Dr. Pattison's proposed combination given these incompatibilities.

B. Dr. Pattison's proposed motivations to combine fail

1. Dr. Pattison's proposed combination would reduce the lifetime of the display

122. Dr. Pattison argues that a POSITA would have been motivated to make a combination of Matthies' quad-pixel tile structure with Yamada's teachings by (1) keeping the blue sub-pixels the same size; (2) reducing the size of the red sub-pixels to be smaller than the blue sub-pixels; and (3) reducing the size of the green sub-pixels to be smaller than the red sub-pixels. Ex. 1003, ¶246. According to Dr. Pattison, modifying Matthies' display in this manner would extend the lifetime of the display. Ex. 1003, ¶410. This is incorrect.

123. Predicting the lifetime of OLED pixels is complicated, and there are many different mechanisms for OLED degradation. OLED degradation can be characterized into three categories: dark spot formation, catastrophic failure, and intrinsic degradation. Of these, Dr. Pattison's discussion of OLED lifetime is focused on the intrinsic degradation mechanism, which refers to the following phenomenon: even when an OLED is driven with constant current, over time the luminance of the OLED decreases.

124. According to Dr. Pattison, applying a "lower current density for the blue pixels" would have the effect of "prolonging the life of the blue pixels." Ex.

1003, ¶410. According to Yamada, blue OLED materials had lower emission efficiency, requiring blue pixels to be driven at a higher current density (current applied per unit area) to emit a given intensity of light than equally-sized red- or green-pixels. Yamada, 2:60-67; 10:61–11:3, 11:11-15. The lifetime of OLED pixels is indeed a function of current density—the amount of current applied to the pixel divided by the area of the pixel (though the relationship is not as simple as Dr. Pattison and Yamada assume, given the other degradation modes and differences in degradation profiles between passive matrix and active matrix structures). But generally speaking, if the same current is applied to two OLED pixels with different sizes, then all else being equal, the smaller OLED pixel will tend to have a shorter life than a larger OLED pixel. So absent any countervailing considerations, the preference for an OLED display designer is to have larger pixel areas when possible, to extend the lifetime of the display.

125. But Dr. Pattison's proposed combination of Matthies and Yamada would not extend the life of the display under his own theory of OLED lifetime. By keeping the blue pixels the same size, the life of the blue pixels would not be extended. And by reducing the sizes of the red and green pixels, the life of the red and green pixels would be ***reduced***. In a color display, where (for example) the red, green, and blue pixels are configured to be driven together to express the full color gamut, the failure of any one of the color pixels would shorten the useful lifetime of

the display. Thus, a POSITA, particularly a POSITA concerned with the lifetime of the display, would not have sought to reduce the sizes of any of the pixels, as Dr. Pattison suggests, because doing so would decrease the lifetime of the display.

126. Additionally, Dr. Pattison's proposed combination would increase the risk of the catastrophic failure and dark spot modes of degradation. As I've explained above in Section X.A.3, when a large electric field is applied, or if the OLED is operated for a long time, the electric field will be enhanced at the location of irregularities in the interfaces of the OLED stack (*e.g.*, at locations of ITO spikes or non-uniform organic layers), which can result in a collapse at the defect position and catastrophic failure of the OLED. Similarly, a large electric field can result in electromigration of cathode metal to the ITO and formation of dark spots. Both phenomena can result in significantly decreased luminance. And if the driving voltage and current density is increased to maintain the desired luminance, even faster degradation of the OLED would occur. By reducing the sizes of the red and green pixels, Dr. Pattison's proposed modification would require a significantly higher current density to be supplied to the red and green pixels to maintain the same brightness as before. This would increase the risks of catastrophic failure of the OLEDs and dark spot formation, and thus reduce the useful life of the display.

127. If anything, a POSITA seeking to extend the life of the display would have sought to *increase* the size of the blue pixels. But increasing the size of the blue

sub-pixels in Matthies would have frustrated Matthies' goal of eliminating the visibility of seams between tiles. For example, in Figure 19 of Matthies, if the size of the pixels (1910) increases, the light from the pixels will be blocked by the black lines (2010), making the seam appear more visible. *See* Matthies, 22:53-56, 24:5-47. And due to the differences in relative sizes of the different color pixels, it will also have the same shadowing effect and color shift issues, which I discuss in Section X.D.3. Further, making the blue pixels larger could reduce the space necessary for vias and other circuitry in Matthies' tile display. *See, e.g.*, Matthies, 15:59-16:9, 2:35-41.

128. As I've explained above in Sections V and X.A.3, since PMOLED displays like Matthies were already known to suffer from shorter lifetimes, a POSITA would not have had a reason to make Dr. Pattison's proposed combination that would reduce the life of Matthies' display. Nor would a POSITA have had a reasonable expectation of success in making Dr. Pattison's proposed combination.

2. Dr. Pattison's proposed modification to Matthies' display would eliminate necessary circuitry and reduce display quality

129. Matthies discloses circuitry that "compensates for luminance chromaticity non-uniformities in the tile and among the tiles of the display," including over time. Matthies, 2:63-3:3. Acknowledging that Matthies provided a circuitry-based solution to the differential aging problem, Dr. Pattison argues that a

POSITA could have eliminated that circuitry and thus "simplified" Matthies' display, if his proposed combination were made. Ex. 1003, ¶¶411-417. That is incorrect. The circuitry Dr. Pattison proposes eliminating is ***necessary*** for Matthies' display to function because it both provides display data to each pixel, Matthies, 10:1-5, and ensures uniformity in brightness and color across different pixels and across different tiles—a critical requirement for Matthies' tiled display, Matthies, 10:6-9.

130. The "non-volatile memory 214" and "programmable current sources 216" are necessary to send the image data to the display because the memory stores the value for the pixel cell corresponding to the image data to be displayed, and the current source provides the electrical current to the pixel cell to cause it to emit the light corresponding to the image data to be displayed. Matthies, 10:58-11:21. It is unclear how Dr. Pattison's display would display any images without them. And Matthies explicitly acknowledges that each OLED pixel can have different characteristics due to manufacturing variations, and thus contemplates that individual OLEDs would be tuned during the manufacturing process, with necessary adjustments saved in the "non-volatile memory 214." Matthies, 11:36-46. Eliminating this memory as Dr. Pattison proposes would result in a non-uniform display (if the display could operate at all) with poor image quality that cannot be fixed by just re-sizing the pixels.

131. Removing the additional compensation circuitry such as Matthies' optional "light sensor" or "circuitry 134" as Dr. Pattison suggests would also eliminate another key functionality. Matthies' circuitry "continually adjusts" the brightness of individual pixels to compensate for aging throughout the life of the display as it is used—something Yamada's static re-sized pixels cannot do. Matthies, 11:61-12:41. Further, POSITAs in the field understood that the decay slope for each color pixel is different (owing to differences in the light-emitting materials) and non-linear, and Yamada's static re-sizing of pixels would fail to account for the resulting differential aging of the OLED pixels as they are used over time, resulting in color shift through the life of the display, and some pixels dying off faster than others. Ex. 2077 (Park) at 8-10, Figs. 4-6; Ex. 2011 (Arnold) at Fig. 10.

132. Thus, without Matthies' circuitry, the display's color would shift over time, rendering the display defective.

133. Dr. Pattison also claims that shrinking pixel sizes would provide "greater design flexibility" because it "would create additional space for Matthies' vias and other circuitry." Ex. 1003, ¶¶423-426. But that is not a benefit at all. Taking away this "additional space" from the pixels would lower the aperture ratio of the display. To maintain the same brightness with smaller emissive area, the OLEDs would have to be driven harder at a higher current density to maintain the same brightness as before, resulting in lower lifetime; alternatively, if the OLEDs were

driven at the same current density with a reduced area, the display would be dimmer than before. Dr. Pattison's modification would remove light-emitting area, thus lowering the aperture ratio and resulting in either worse lifetime or reduced brightness, when Matthies sought to improve the overall brightness of the display. *See, e.g.*, Matthies, 17:3-4, 17:8-10.

134. A POSITA would have sought to *increase* the aperture ratio of the display because OLED displays traditionally had (and indeed, continue to have) relatively low aperture ratios, due to the manufacturing difficulties I described above in the background of the technology. *See* Section V. Other prior art emphasized the need to improve aperture ratio. Ex. 2081 (Hong), ¶¶[0013], [0036], [0044]. Matthies' display prior to Dr. Pattison's proposed modification already has enough space for the vias, so Dr. Pattison's proposed combination would reduce the aperture ratio for no reason.

135. At the same time, Dr. Pattison's proposed modifications would introduce asymmetries in pixel size and spacing that Matthies seeks to avoid. These modifications would be inconsistent with Matthies' PMOLED structure, and would be in conflict with Matthies' design rules intended to avoid optical effects at tile edges, as I discuss in Sections X.A.3, X.D.3, X.D.4.

C. A POSITA would not have been motivated to modify Matthies' quad sub-pixel structure based on Yamada's teachings directed to triple-pixel structures

136. Even if a POSITA would have had a reason to modify Matthies based on Yamada, a POSITA would have had no motivation to try to apply Yamada's teachings to Matthies' quad sub-pixel structure shown in Figure 8B, because Yamada does not disclose or suggest a quad-pixel structure.

137. Matthies describes different displays, some of which use a quad sub-pixel structure and others which use an RGB stripe. An example of such an RGB stripe is shown in Figure 8A of Matthies, shown below with annotations.

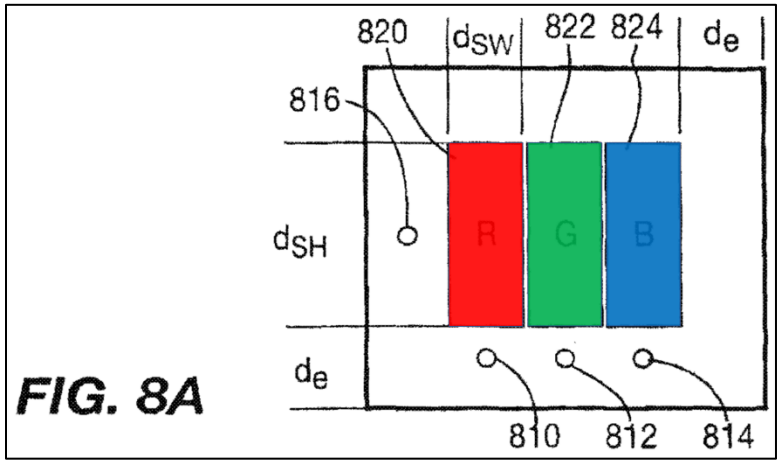
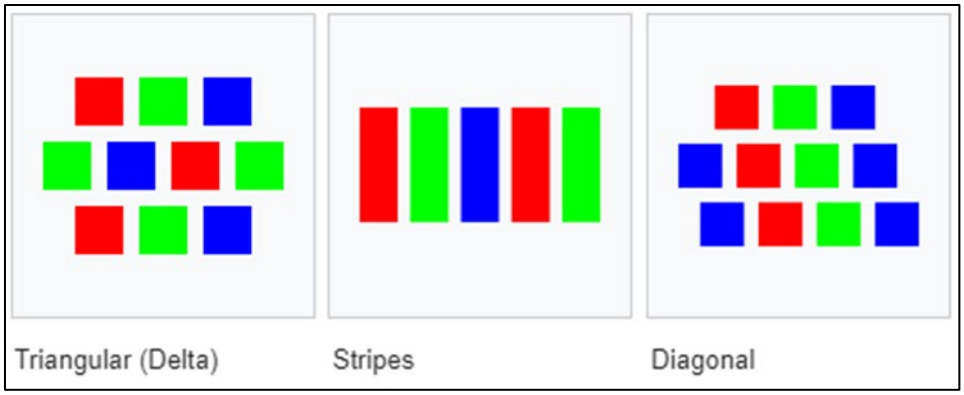


FIG. 8A

138. Yamada only contemplates R/G/B triplet structures, as evidenced by its reference to only "stripe," "delta," and "diagonal" layouts. Yamada, 12:37-43. These pixel structures are illustrated below:



[7]

139. Yamada does not discuss or contemplate using quad-pixel structures, or resizing pixels in a quad-pixel structure. Yamada's approach of re-sizing pixels is tied to pixel arrangements with equal numbers of red, green, and blue pixels, and in the context of AMOLED displays.

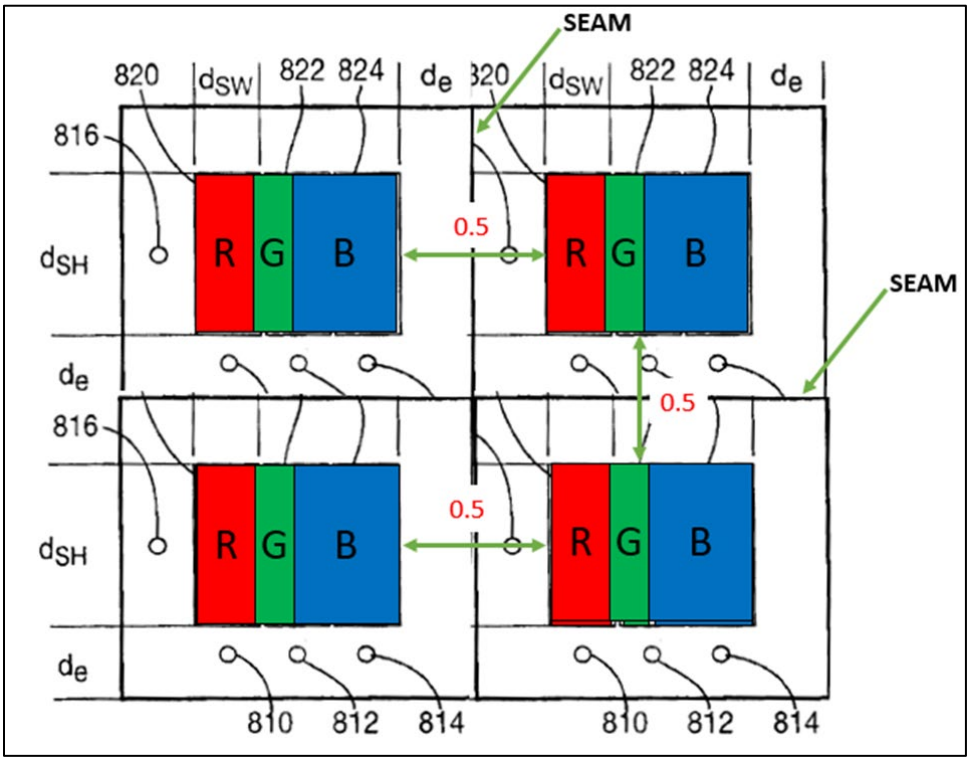
140. Dr. Pattison provides no explanation of why a POSITA would have been motivated to combine two fundamentally different pixel structures (i.e., Matthies' quad sub-pixel structure and Yamada's RGB stripe structure), and why a POSITA would have had a reasonable expectation of success in arriving at the pixel arrangement structure claimed in the '578 Patents.

141. A POSITA would not have had any reason to do so. If a POSITA were to try to change the relative sizes of pixels in Matthies, then Matthies' triple-pixel structure of Figure 8A would have been a more suitable starting point. In that structure, each column electrode contains only one color, such that changing the

[7] From https://en.wikipedia.org/wiki/Pixel_geometry.

relative width of each column electrode would allow re-sizing pixels of each color.

Shown below is this alternative potential modification of Matthies:



142. This arrangement would allow the spacing between adjacent pixels separated by tile seams to remain the same, even after resizing the width of the red, green, and blue sub-pixels, which is what Matthies teaches. This arrangement also increases the size of the blue pixels which, unlike Dr. Pattison's proposed combination, would actually increase the life of the display. This approach would also avoid the need to pattern the electrodes or add additional layers to re-size the pixel areas, thus avoiding all of the electrical and manufacturing problems that would create, which I explained in Section X.A.3 above.

143. In contrast, attempting to adjust the width of any electrodes in Matthies' quad sub-pixel structure of Figure 8B would result in two different colors being resized in the same way, which would not be consistent with Dr. Pattison's purported goal of re-sizing pixels according to emission efficiencies, purportedly based on Yamada's teachings.

144. Additionally, a POSITA would have understood that, generally speaking, RGB stripe pixel arrangements can result in greater light emission area (i.e. aperture ratio) than quad-pixel arrangements. With a greater light emission area, a display can achieve the same level of brightness at a lower current density. This in turn results in a longer lifetime for the display. This would have been particularly important for Matthies' PMOLED display, because the higher voltages necessary to drive PMOLED displays result in lower lifetimes. Thus, a POSITA would have understood that it would have been much more desirable to start with Matthies' RGB stripe pixel arrangement in making a combination with Yamada, particularly under Dr. Pattison's own theory that the reason for such a POSITA to make the combination is to extend the lifetime of Matthies' display.

145. Thus, even if a POSITA would have had a reason to modify Matthies based on Yamada, a POSITA would not have been motivated to modify Matthies' quad-pixel structure as Dr. Pattison proposes, when making the combination with

Matthies' RGB stripe pixel structure would have resulted in more advantages and fewer incompatibilities and technical difficulties.

146. If a POSITA were to make any combination, a POSITA would have modified Matthies' RGB stripe structure. Such a combination, however, when tiled, would result in a structure that fails to meet any of the challenged claims of the '578 Patent. Specifically, this structure fails to meet at least the following limitations:

- "wherein the first pixels are arranged in first sets extending along a first direction to form respective first lines," (claim 1, limitation [1-4]; claim 42, limitation [42-4])
- "wherein the second pixels and the third pixels are alternately arranged in second sets extending along the first direction to form respective second lines parallel to the first lines," (claim 1, limitation [1-5]; claim 42, limitation [42-5])
- "wherein one of the second lines passes through centers of the second pixels and the third pixels in a corresponding one of the second sets and passes between the first pixels in corresponding adjacent ones of the first sets," (claim 1, limitation [1-6])
- "wherein the first pixels are also arranged in third sets extending along a second direction that is perpendicular to the first direction to form

respective third lines," (claim 1, limitation [1-8]; claim 42, limitation [42-7])

- "wherein the second pixels and the third pixels are also alternately arranged in fourth sets extending along the second direction to form respective fourth lines that are parallel to the third lines," (claim 1, limitation," (claim 1, limitation [1-9]; claim 42, limitation [42-8])
- "wherein a region having a width in the second direction that is equal to a width of the first pixels in the second direction, extending parallel to the first direction, and completely overlapping a row of the first pixels extending in the first direction, is entirely offset in the second direction from at least one of the second pixels or the third pixels in at least one of rows of the second pixels and the third pixels adjacent to the row of the first pixels," (claim 1, limitation [1-12])
- "wherein a shortest distance between two nearest ones of the first pixels in one of the first sets is greater than a shortest distance between one of the second pixels and one of the third pixels that are nearest each other in one of the second sets." (claim 1, limitation [1-13]; claim 42, limitation [42-15])
- "wherein only one of the second pixels and the third pixels is included in a virtual quadrangle containing outer edges comprising some of the

edges of a group of four neighboring ones of the plurality of first pixels, all portions of all others of the second pixels and the third pixels being outside of the virtual quadrangle, and" (claim 45, limitation [45-4])

- "wherein a shortest distance between any two of the group of four neighboring ones of the plurality of first pixels is greater than a shortest distance between the only one of the second pixels and the third pixels included in the virtual quadrangle and a nearest one of the second pixels or the third pixels in a direction perpendicular to any side of the virtual quadrangle." (claim 45, limitation [45-5])

D. Even if a POSITA tried to modify Matthies' quad sub-pixel structure based on Yamada' teachings, the modification would not meet the challenged claims

1. Matthies teaches a POSITA to use two blue pixels in its quad sub-pixel design if blue-emitting material is less efficient

147. Even a POSITA had tried to modify Matthies' quad sub-pixel structure based on Yamada, the POSITA would not have had any reason to use the quad sub-pixel structure with two green subpixels (an RGBG arrangement). The references that address the different efficiencies of materials for emitting different colors would actually have led a POSITA away from a quad sub-pixel structure having two green subpixels.

148. Yamada teaches that "blue EL elements" can have "the lowest efficiency" and that "green EL elements" can have "the highest emission efficiency." Yamada, 8:47-52. Yamada's motivation for creating a display with different sizes of emissive areas for different colors is its observation that, if all the pixels of various colors have the same emissive areas, then "in order to obtain the same luminance at the display pixels having a low emission efficiency, a current larger than that supplied to the other display pixels having a high emission efficiency must be supplied." Yamada, 2:55-64. But doing so would cause "the life of those display pixels having a low emission efficiency, in particular, to shorten." Yamada, 2:64-67.

149. But Matthies already contemplates a solution for this situation where different light emitting materials have different emission efficiencies for its quad sub-pixel arrangement: when a pixel of one color has lower efficiency, double up on pixels of that lower efficiency color: "In some display technologies, the amount of light emitted by the red or blue pixel material may be less than the amount of light emitted by the green pixels. In this instance, making the pixels 830 and 836 both be red or blue pixels would improve the overall brightness of the display." Matthies, 17:6-10. Examples of these quad sub-pixel arrangements are illustrated in annotated versions of Figure 8B shown below:

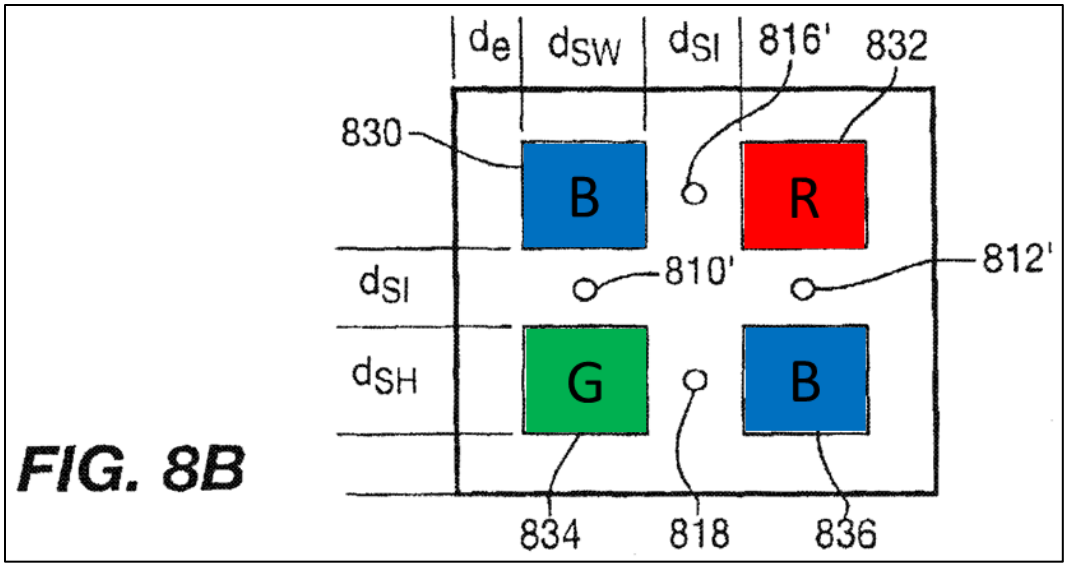


FIG. 8B

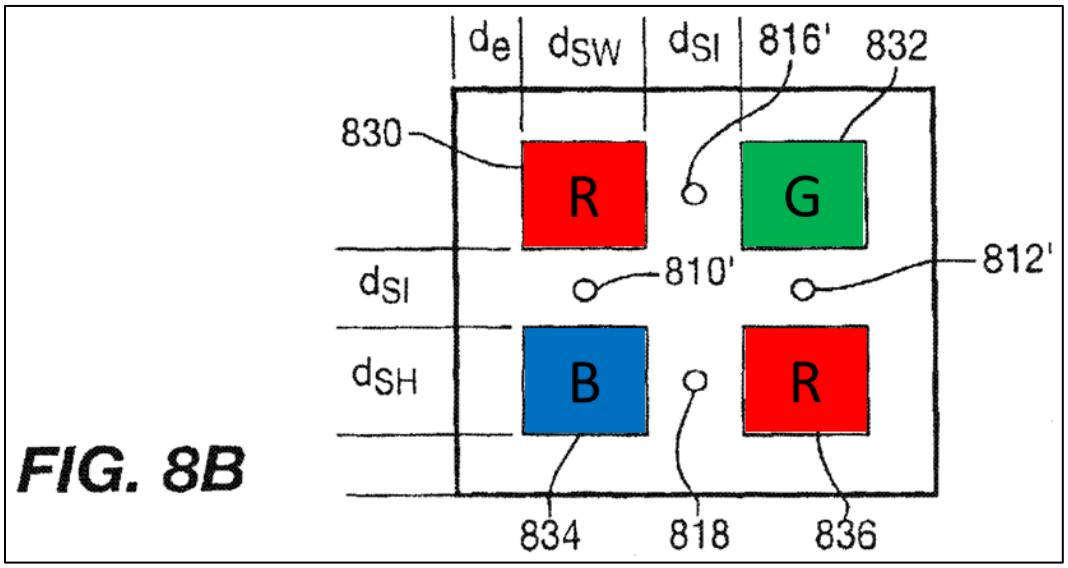


FIG. 8B

150. Thus, if the emissive material for the blue pixel had the lowest emission efficiency as stated in Yamada, then Matthies directed a POSITA to use a quad sub-pixel structure in which the pixels 830 and 836 are both *blue* pixels (an RBGB arrangement), thus increasing the total emissive area of the least efficient color, rather than decrease the size of the red and green pixels as Dr. Pattison suggests. Matthies' solution to double up on the emission area of the least efficient blue pixels

is also consistent with Yamada's teaching of increasing the size of the blue light-emitting area relative. It also improves the overall brightness of the display without requiring more current to be supplied to the blue pixels, thus extending the life of the display. Following Dr. Pattison's solution would do nothing to improve the display lifetime of the display, and instead reduce the display lifetime.

151. This RBGB structure would both (1) increase the blue-light-emitting-area, both in absolute terms and relative to green, and (2) increase the display lifetime, consistent with Yamada's objective. The RBGB pixel structure would thus be the natural result of applying Yamada's teachings about emission efficiency to Matthies' quad sub-pixel structure.

152. This RBGB pixel structure, when tiled, would result in a structure that fails to meet any of the challenged claims of the '578 Patent. There are no "first sets," "second sets," "third sets," or "fourth sets" of pixels. Additionally, the pixel structure would not have the recited region "overlapping a row of the first pixels" and "entirely offset" from the second or third pixels. Specifically, this structure fails to meet at least the following limitations:

- "wherein the first pixels are arranged in first sets extending along a first direction to form respective first lines," (claim 1, limitation [1-4]; claim 42, limitation [42-4])

- "wherein the second pixels and the third pixels are alternately arranged in second sets extending along the first direction to form respective second lines parallel to the first lines," (claim 1, limitation [1-5]; claim 42, limitation [42-5])
- "wherein one of the second lines passes through centers of the second pixels and the third pixels in a corresponding one of the second sets and passes between the first pixels in corresponding adjacent ones of the first sets," (claim 1, limitation [1-6])
- "wherein the first pixels are also arranged in third sets extending along a second direction that is perpendicular to the first direction to form respective third lines," (claim 1, limitation [1-8]; claim 42, limitation [42-7])
- "wherein the second pixels and the third pixels are also alternately arranged in fourth sets extending along the second direction to form respective fourth lines that are parallel to the third lines," (claim 1, limitation," (claim 1, limitation [1-9]; claim 42, limitation [42-8])
- "wherein a region having a width in the second direction that is equal to a width of the first pixels in the second direction, extending parallel to the first direction, and completely overlapping a row of the first pixels extending in the first direction, is entirely offset in the second

direction from at least one of the second pixels or the third pixels in at least one of rows of the second pixels and the third pixels adjacent to the row of the first pixels," (claim 1, limitation [1-12])

- "wherein a shortest distance between two nearest ones of the first pixels in one of the first sets is greater than a shortest distance between one of the second pixels and one of the third pixels that are nearest each other in one of the second sets." (claim 1, limitation [1-13]; claim 42, limitation [42-15])
- "wherein a shortest distance between any two of the group of four neighboring ones of the plurality of first pixels is greater than a shortest distance between the only one of the second pixels and the third pixels included in the virtual quadrangle and a nearest one of the second pixels or the third pixels in a direction perpendicular to any side of the virtual quadrangle." (claim 45, limitation [45-5])

2. Dr. Pattison oversimplifies Yamada and disregards that the prior art was critical of, and did not follow, Yamada's teachings

153. Dr. Pattison also misapplies Yamada's teachings. Dr. Pattison oversimplifies Yamada by asserting that it "teaches that the pixels should be re-sized" only based on "emission efficiency," such that "the 'emissive element of a color with

the lowest emission efficiency' (for instance, blue) is made 'larger.'" Ex. 1003, ¶¶119-120; *see also* Ex. 1003, ¶¶236-237, 397.

154. Yamada does not propose only looking at the relative emission efficiencies of the different colors. Yamada teaches that the "the element emissive areas in the display pixels for R, G, and B are designed to take into consideration ***not only the emission efficiency*** of the emissive elements of the display pixels ***but also the luminance ratio*** of red to green to blue in accordance with the ***chromaticity of the target display white*** of the display device and with the ***chromaticity of each red, green, and blue color*** emitted by the emissive elements of the respective display pixels." Yamada, Abstract; *see also* Yamada, 4:29-37, 4:57-67.

155. While certain embodiments of Yamada result in the blue pixel being the largest, *see, e.g.*, Yamada, 11:4-39, a POSITA would have understood that the relative sizes of the pixels would have depended on the specific emission efficiency and chromaticity values for the selected organic materials for a display. In fact, Yamada explicitly states that different emissive efficiency and chromaticity values could result in different pixel sizes. Yamada, 10:52-60, 11:56-62.

156. As an example, Arnold, which issued in 2004, teaches that if different materials and chromaticity values are applied, then applying Yamada's teachings would result in a display with blue pixels having 2.8 times the size of blue pixels, despite the lower emissive efficiency of blue OLED materials. Ex. 2011, 15:58-

16:36. Thus, contrary to Dr. Pattison's claim, Yamada does not teach that "the pixels with lower emission efficiencies (like the blue pixels) should be made larger than pixels with higher emission efficiencies (like the green pixels)." Ex. 1003, ¶397.

157. Dr. Pattison does not identify what organic emissive materials he proposes using in his proposed combination. He provides no analysis of the specific emissive efficiencies or chromaticity values in his proposed modification of Matthies' display. He does not perform any calculations to determine what the appropriate pixel size ratios for Matthies' display would be when applying Yamada's teachings. Without any data or analysis, Dr. Pattison's assertion that the combination of Matthies and Yamada necessarily results in the blue pixels being largest is nothing but speculation.

158. While Dr. Pattison claims that "[a]ccording to Yamada, in a typical OLED display, the 'green pixel' has the highest efficiency and is thus made smallest, while the 'blue pixel' has the lowest efficiency and is made largest," Ex. 1003, ¶238, Yamada says nothing about the "typical" OLED display or "typical" efficiencies. The portions of Yamada that Dr. Pattison cites for this assertion make clear that Yamada concludes that green has the lowest efficiency and blue has the largest efficiency based on its specific embodiment with its set of specific materials selected as the emissive elements. *See* Yamada, 8:19-22, 10:52-56.

159. A POSITA would also have had no reason to apply Yamada's teachings because they had been criticized by others in the field for failing to account for key factors in designing pixel arrangements for displays, and because they rely on flawed assumptions.

160. Dr. Pattison does not take into account the prior art's criticisms of Yamada's failure to account for these other design considerations.

161. Cok is a U.S. Patent issued in 2005 that explains that, "[w]hile Yamada discloses light emitting elements having different sizes for optimizing the lifetime of the display, ***the display is not optimized with respect to the response of the human visual system***." Ex. 2004, 2:5-8.

162. Arnold is a U.S. Patent issued in 2004 that explains that "***Yamada fails to discuss other important characteristics of OLED materials that will affect device lifetime***, such as the differences in the inherent luminance stability over time of different materials. ***Yamada further does not consider important optical characteristics of the target display design, each of which will influence the overall lifetime of OLED materials***." Ex. 2011, 2:34-41.

163. Additionally, a POSITA would have understood that Yamada relies on an incorrect assumption about the lifetime of OLED devices.

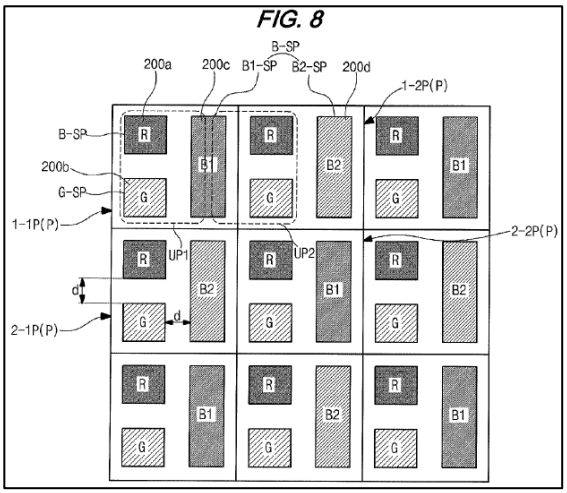
164. Yamada assumes that the organic materials for emitting each color would decay (1) linearly, and (2) at the same rate. Both are incorrect. First, the

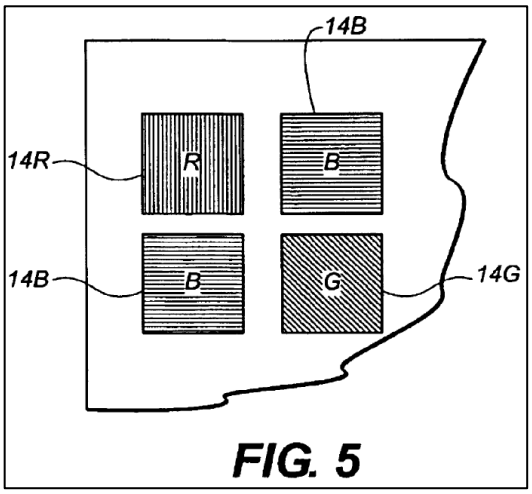
lifetime of any given OLED material decays non-linearly over time at constant current density. Ex. 2077 (Park) at 8-10, Figs. 4-6. Second, the lifetime and rate of decay of different materials varies. Ex. 2011 (Arnold) at Fig. 10. Thus, adjusting the pixel sizes for different colors according to the emission efficiency of each material as Yamada suggests would fail to maintain the same ratio of red, green, and blue light in the display over an extended period of operation. This ratio, which is also known as white balance, needs to be carefully managed in a display—consistency and predictability in the white balance is a requirement for both faithful reproduction of the source media and consistency in display operation. Additionally, because the lifetime curve of OLED materials is non-linear, the display must necessarily have secondary compensation in order to maintain the white balance over time. Re-sizing pixels according to the ratio of emissive efficiency is neither necessary nor sufficient to achieve uniform white balance or increased life time of the display.

165. In light of these shortcomings and criticisms, a POSITA would not have sought to apply Yamada's teachings to any display, much less so the passive matrix display of Matthies, where the repercussions of shrinking pixel sizes has a particularly negative effect on the quality of the display, as discussed above.

166. Further, many other prior art references also illustrate that a POSITA would not have combined Matthies and Yamada in the manner proposed by Dr. Pattison. Several references authored by other workers in the field, including those

who explicitly considered Yamada's teachings, show pixel arrangement structures that deviate from the arrangement proposed by Dr. Pattison. For example, Yoo (below, left) arrived at a triple-pixel (RGB) structure. *See* Ex. 2012, Fig. 8. And Arnold (below, right) arrived at a quad-pixel structure with two *blue* pixels, in a similar way as done by Matthies as described above. *See* Ex. 2011, Fig. 5.





3. Dr. Pattison's proposed combination conflicts with Matthies' goal of avoiding visible differences at the seams between tiles

167. Further, a POSITA would not have made Dr. Pattison's proposed combination because doing so would introduce uneven spacing between pixels and between the pixel edges and tile edges, contrary to Matthies' goal of eliminating the visibility of seams between tiles. A POSITA would thus not have had a reasonable expectation of success.

168. One of Matthies' main concerns is to "eliminat[e] the visibility of the seams between tiles" in its tiled displays. Matthies, 2:7-10; *see* Mattheis, 22:17-22.

To ensure that the seams are not visible, and to allow space for materials that join adjacent tiles while ensuring that no useful light emission is blocked, Matthies teaches that the edges of pixels should be evenly spaced from the edges of the tile.

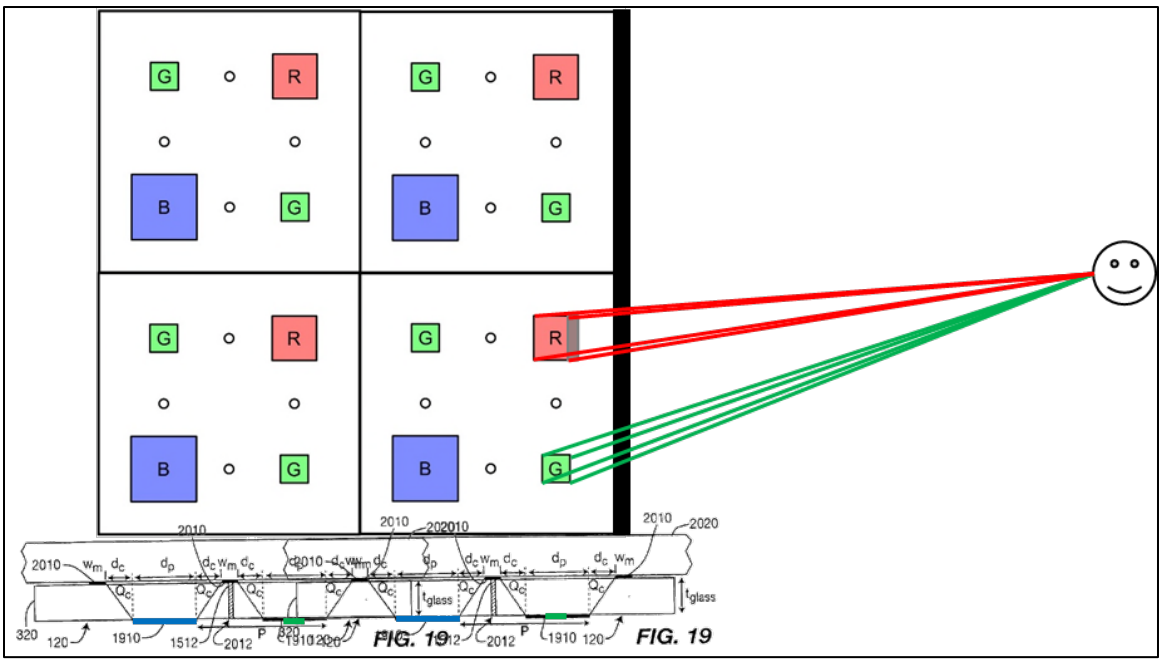
169. As Matthies explains, in tiled displays, if light scatters at the edge of a tile such that the light refracts differently than at the center, the edge may appear visibly different, for example as "a band of reduced brightness in the displayed image." Matthies, 22:53-56. Thus, for example, for tiled displays using mullions, this problem could arise due to a difference in the index of refraction of the mullion and the glass display substrate, edges in the structure, or due to the bottom stem of the mullion not being light-colored or transparent. Matthies, 22:47-53. The same problem of scattering could arise due to differences in the light-emitting sources themselves. Pixels that are smaller or larger, and pixels that are closer or farther from the tile edge, will result in their emitted light scattering differently at the tile edges than away from the edges, and for the reasons discussed below, differently relative to each other. Matthies explains that, to ensure the edge is not visible to a viewer, "[t]he tiles are constructed with pixel forming elements ***evenly spaced up to the edges of the tiles***." Matthies, 5:47-48. Matthies also defines a value "d_e" to represent the distance between the edges of the outermost row or column of sub-pixels on a tile and the edge of the tile. *See* Matthies, 17:16-20, 16:49-52, Figs. 8A, 8B. Thus, in Matthies, having equal spacing between the edges of the pixels and the edges of

the tiles, and allowing black stripes or mullions to be placed between adjoining tiles while blocking the gaps, is crucial to ensuring that the tile seams are not visible. Matthies, 8:37-46; 21:21-34; 22:17-25; 22:53-56.

170. Dr. Pattison's proposed modification of Matthies would eliminate this key feature of Matthies' tiled display by making the seams more apparent, because the modification would introduce *uneven* pixel size and spacing from the edge. In particular, the larger pixels would have more of their light emission blocked by the black stripes or mullions (called "shadowing") than the smaller pixels. The different degree of shadowing for different colors would also cause the display to exhibit an undesirable color shift, contrary to the goals of both Matthies and Yamada. Further, the degree of shadowing and color shift would vary by viewing angle, resulting in an inconsistent white balance throughout the viewing space. This is particularly problematic because Matthies is directed to large displays for, for example, "[a]pplications that require multiple viewers," and "[a]pplications in which the user needs to move about in an area," in which the display must have a wide viewing angle. *See* Matthies, 1:14-25.

171. Below is an illustration of the shadowing effect, which I have created based on Dr. Pattison's modified version of Matthies' Figure 8B. A modified version of Figure 19 immediately below Dr. Pattison's figure shows what a cross-section taken along a row of blue and green pixels would look like. Because of the different

sizes of the red and green pixels and their different distances to the black stripe/mullion at the right edge of the tile, a user may see the entirety of the light emission from the green pixel, but a portion of the light emission from the red pixel would be blocked (shown in a gray box below). This would result in a perceived shift in the color of the display to appear more green or cyan-ish, compared to the unmodified version of Matthies' Figure 8B implementation with equally sized red and green pixels up to the edge.



172. Further, because the amount of the color shift will vary depending on the viewing angle, no amount of adjusting the pixel sizes would be able to alleviate this issue, further negating Yamada's goal of achieving "easy" control of the white balance based on re-sizing pixel emissive areas. *See* Yamada, Abstract, 4:67-5:3.

4. Dr. Pattison's proposed combination conflicts with Matthies' other design rules for quad sub-pixel arrangements

173. Further, a POSITA would not have made Dr. Pattison's proposed combination because doing so would require an overhaul of fundamental aspects of Matthies' display.

174. Matthies' requirement for the design of its quad sub-pixel structure is that it be formed of equally-sized pixels that have equal spacing from the edge of the pixel to the edge of the tile. Matthies, 17:16-20 ("***The*** geometry ***of the quad sub-pixel structure is defined by the dimensions*** d_{SH} the height of the sub-pixel, d_{SW}, the width of the sub-pixel, d_e, the distance from the active sub-pixel areas to the edge of the pixel area, and d_{SI}, the distance between adjacent sub-pixels."). By defining the shape of all four pixels in the quad sub-pixel structure through the two values d_{sh} and d_{sw}, Matthies reinforces that each pixel must have the same area.

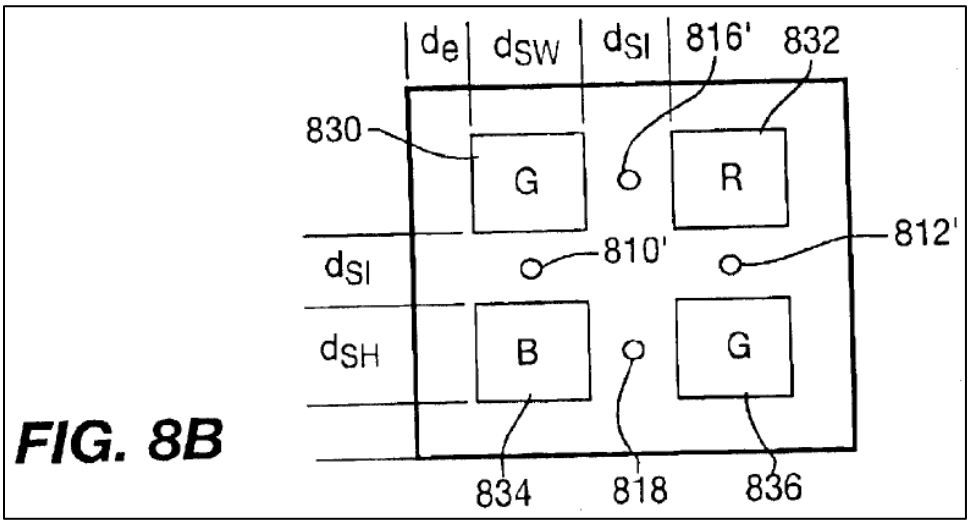
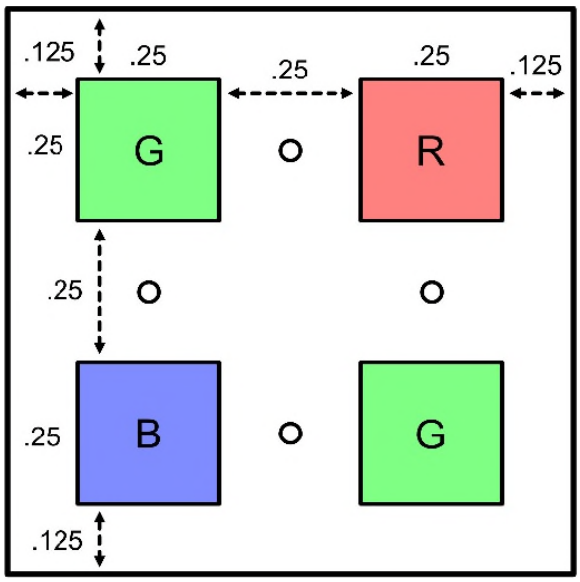


FIG. 8B

175. This design requirement naturally follows from the passive matrix OLED structure of Matthies' display, where each pixel is defined by the overlap of column and row electrodes. And because Matthies locates two different colors of pixels on each row electrode and column electrode, Matthies' design does not allow for arbitrarily varying the dimensions of any or all one of the different color sub-pixels. Instead, Matthies specifies the two dimensions it allows to be varied—"the distances d_e and d_{SI}" may be different "in the horizontal and vertical directions," Matthies, 17:31-33. And these constraints also maintain the equal sizing of the pixels and equal distances between the edge of a row or column of pixels and the tile edge that is key to ensuring that the seams in Matthies' tiled display are not visible.

176. Further, Matthies teaches having the same spacing between the pixels, both within each tile and across adjacent tiles, as illustrated by Dr. Pattison's "scale drawing" of Matthies' quad sub-pixel structure shown in Figure 8B using the example values listed in Table 2, reproduced below. *See* Ex. 1003, ¶198.



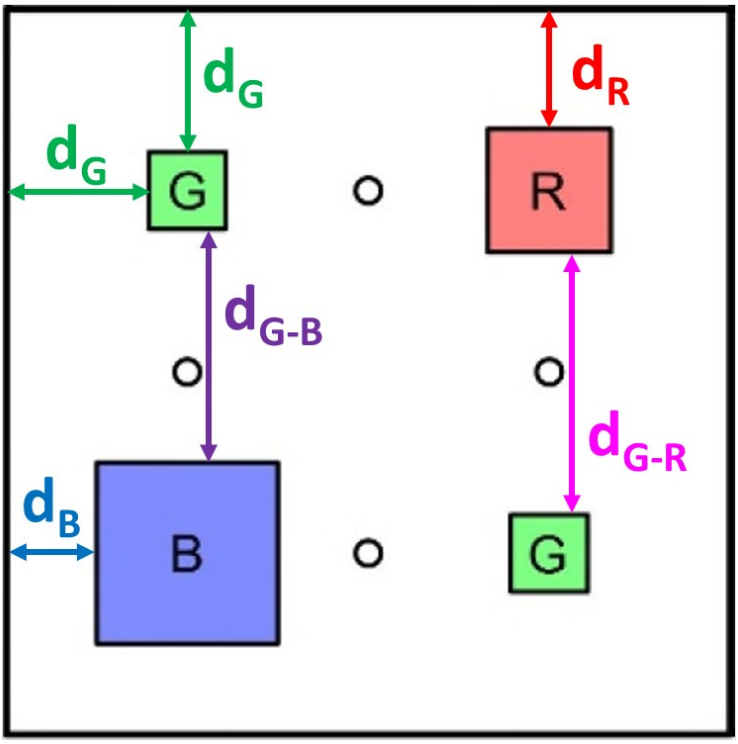
Here, each pixel is 0.125P from the edge of the tile, and adjacent pixels are separated by a distance of 0.25P both within the tile and between tiles. (As Matthies explains, P is the pixel pitch. Pixel pitch a term of art referring to the distance between the center of a sub-pixel and the center of the same sub-pixel in an adjacent pixel. In Dr. Pattison's combination, where a tile is one quad sub-pixel unit, the pixel pitch is also equal to the side length of a single tile.)

177. More generally, Matthies explains that "[t]he tiles are constructed with pixel forming elements evenly spaced up to the edges of the tiles" Matthies, 5:47-48 and "[o]ne criterion for the tiles is that the spacing between the pixels separated by the tile seam is the same as the spacing of pixels on the tile," Matthies, 8:39-41; *see* Matthies, 9:23-26.

178. Nothing in Matthies suggests that any of the pixels that share a row electrode (or a column electrode) may have (1) different sizes, or (2) different

distances to the edge of the tile. That would be fundamentally inconsistent with the design requirement for Matthies' quad sub-pixel tiles composed of uniformly sized pixels arranged to ensure the gap between adjacent pixels is consistent throughout the display and the edges of pixels are equally spaced from the edges of the tiles.

179. Dr. Pattison's proposed combination with Yamada would require a POSITA to disregard Matthies' teachings and violate its design requirements for its quad sub-pixel structures. For red, green, and blue pixels to all have different sizes with respect to each other as proposed by Dr. Pattison, the distance between adjacent pixels cannot be constant, and the distance between pixels and the edges of the tile would need to be different for each color pixel. As illustrated below in an annotation of one of Dr. Pattison's annotated figures depicting his proposed combination where the red pixels are smaller than the blue pixels and the green pixels are smaller than the red pixels (Ex. 1003, ¶248), the space between a green pixel and an adjacent red pixel would be ***greater*** than the space between a green pixel and an adjacent blue pixel. Similarly, there would be ***different*** distances between the edges of each adjacent color pixel and the edge of the tile:



180. Further, as I've explained above, Dr. Pattison's proposed modifications would also be incompatible with Matthies' passive-matrix OLED design and the fabrication of the device, and would also contradict Matthies' design goal of preventing optical differences at tile edges that result in visible seams.

181. Dr. Pattison also states that Figures 3 and 4 of Yamada show that "the same pixel arrangement, spacing, and geography has been employed (thus the pixel centers [do] not move), but the pixels have been re-sized in accordance with their emission efficiencies." Ex. 1003, ¶239. This is an incorrect reading of Yamada. Yamada's specification does not support making these inferences from conceptual Figure 4. Yamada explicitly describes Figures 3 and 4 as just "conceptual diagrams." Yamada, 6:21-26. Figure 3 conceptually illustrates the "layout" of emissive regions

in prior displays (showing the standard triplet RGB "stripe" layout, *see, e.g.*, Yamada, 12:37-39), and Figure 4 conceptually illustrates different-sized emissive regions for different colors, *see, e.g.*, Yamada, 7:3-12. But Yamada's depictions of how pixels would actually be implemented to account for its other circuitry in the "schematic" diagrams shown in Figures 5, 6A, and 6B show that the pixel shape is more complex, and incompatible with the display of Matthies' Figure 8B. Dr. Pattison also ignores the fact that Yamada is directed to active matrix OLED displays, which as discussed above have different constraints on pixel size, shape, and arrangement than the passive matrix OLED of Matthies' Figure 8B.

182. Dr. Pattison has not explained how the PMOLED display of Matthies' Figure 8B could be made with differently sized red, green, and blue sub-pixels as required in his proposed combination. Dr. Pattison has not explained how it would be possible to make a display that results in the pixel arrangement Dr. Pattison states would result from the combination while staying consistent with Matthies' disclosure. Yamada, being directed to a fundamentally different AMOLED display architecture, also does not help. Even if a POSITA were willing to ignore the key features of Matthies' displays, the types of modifications required to form Dr. Pattison's combination would have presented complicated design and manufacturing hurdles that a POSITA would not have been motivated to make or had a reasonable expectation of success in making. For instance, as discussed above

in Section X.A.3, creating electrodes with non-uniform width would introduce complex electrical effects that would impact the operation and quality of the display and would require adding process steps that would reduce yield and increase manufacturing costs. Matthies does not use (or require) a blocking or isolation layer between the row and column electrodes for defining the pixel area of the organic material. *See* Matthies, 12:58-13:25; Fig. 10B. That is of course expected, because there is no need for such a layer in the PMOLED display where the electrode overlap regions define the emissive areas. A POSITA would not have attempted to add such an additional layer, which would undesirably increase thickness and require additional process steps of deposition and patterning that would increase cost and reduce yield, and result in increased power consumption due to charge accumulation that does not contribute to the operation of the OLED, as discussed above in Section X.A.3.

183. Dr. Pattison asserts that "Matthies itself already contemplates that the sizes of and space between its pixels can [be] adjusted." Ex. 1003, ¶439 (relying on Matthies, 17:31-37, 12:9). Dr. Pattison fails to appreciate that Matthies only contemplates changes to sizing that maintain the uniform spacing of pixels in a row or column, including their uniform distance from the edge of the tile, as discussed above. The cited portion only contemplates d_e and d_{SI} being different for the horizontal and vertical directions; it does not contemplate those values being

different for every sub-pixel in the tile as Dr. Pattison's combination would require. Matthies does not contemplate having the kind of arbitrary *nonuniform* spacing of pixels along a row or column in its quad-pixel structure or having differently sized pixels, let alone uneven spacing to the edge of the tile would make the seams between tiles visible.

184. Dr. Pattison claims that Matthies invites changing the "geometry of the pixels" to address OLED pixel aging and decay. Ex. 1003, ¶¶421-422. Dr. Pattison overreads Matthies. Matthies merely observes that pixel geometry and materials relate to pixel aging. Matthies, 12:3-10. And Matthies does teach several different geometries of pixel structures, including an RGB stripe structure, Matthies, 16:40-61, Fig. 8A, and quad sub-pixel structures doubling up on pixels for colors that have less emissive efficiency, Matthies, 17:5-10. Matthies teaches that the solution to differential aging of blue pixels in a quad sub-pixel structure is to use a quad sub-pixel structure with two blue pixels. Matthies also contemplates that geometries can change by adjusting the pixel dimensions of the sub-pixels structures. Matthies, 16:49-52, 17:16-20. But nothing in Matthies suggests the type of wholesale modification of the geometries contemplated by Dr. Pattison. Matthies clearly shows that each of the sub-pixels have the same size, providing only one set of pixel height (d_{SH}) and pixel width (d_{SW}) values in each embodiment. Matthies, Fig. 8A, Table 1; Matthies, Fig. 8B, Table 2. Nothing in Matthies invites or suggests the type of

modifications Dr. Pattison proposes, which as discussed would be incompatible with passive matrix OLED display architecture, violate Matthies' design rules, and further accelerate the aging of the red and green pixels.

185. Thus, a POSITA would not have been motivated to make or had a reasonable expectation of success in making Dr. Pattison's proposed combination.

E. Dr. Pattison's proposed combination of Matthies and Yamada fails to satisfy all of the limitations of any claim of the '578 Patent.

1. Matthies does not teach a "pixel defining layer"

186. Each of the challenged claims require that the OLED display comprise a "pixel defining layer." *See* '578 Patent, cl. 1 ("wherein the OLED display comprises a ***pixel defining layer*** defining areas of the first pixels, the second pixels, and the third pixels"); cl. 42 ("wherein the OLED display comprises a ***pixel defining layer*** defining areas of the first pixels, the second pixels, and the third pixels"); cl. 45 ("wherein the OLED display comprises a ***pixel defining layer*** defining areas of the first pixels, the second pixels, and the third pixels"). The '578 Patent states that "there may be an insulation layer such as a pixel definition layer to define an area and a shape of each pixel." '578 Patent, 1:42-44. The '578 Patent uses the term consistent with how it is used in the industry. In particular, a POSITA would have understood that a "pixel defining layer" is an actual layer that is physically present in an OLED display.

187. There is no teaching or suggestion in Matthies relating to a "pixel defining layer." Matthies' specification and figures do not ever teach or suggest the presence of a pixel defining layer in Matthies' display nor do they teach or suggest any manufacturing steps that would lead to the deposition of a pixel defining layer. Dr. Pattison's declaration includes the following annotated version of Figure 10B and labels a portion highlighted blue as the "pixel defining layer." But Dr. Pattison acknowledges in his declaration that a pixel defining layer is "not labeled or shown in [original] Figure 10B." Ex. 1003, ¶171. Instead, Dr. Pattison simply asserts that Matthies' display would "obviously" include a pixel defining layer. Ex. 1003, ¶178. I disagree.

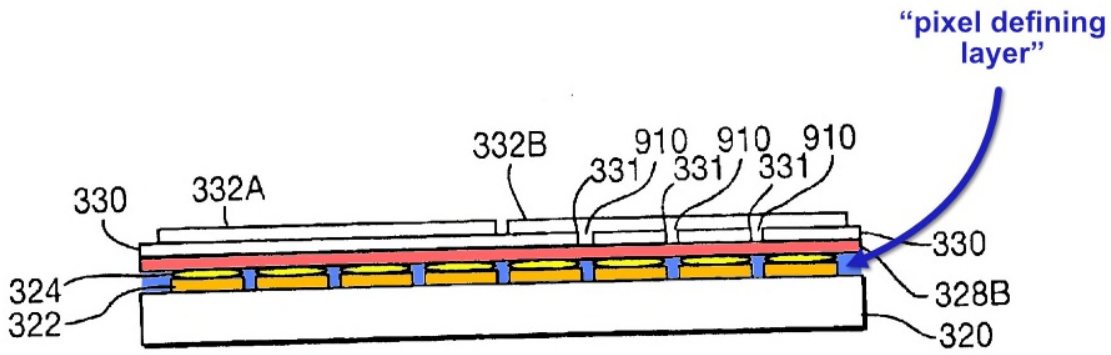


FIG. 10B

188. A POSITA would not have understood Matthies to "obviously" include a pixel defining layer in its display. Matthies does not identify any benefits or advantages to including a pixel defining layer in its display. Matthies does not

explain that the lack of a pixel defining layer would pose any problems with its display. A POSITA would instead have understood that adding a pixel defining layer would introduce additional manufacturing steps, which would add costs.

189. Dr. Pattison points to *Yamada's* discussion of a "planarization insulating film 167" to suggest that "a POSITA would understand that *Matthies* obviously includes an analogous insulating film that surrounds its OLED active areas" as a pixel defining layer. Ex. 1003, ¶¶173-174. I disagree with Dr. Pattison for all of the reasons I previously provided as to why a POSITA would not have looked to Yamada's active-matrix OLED display structures to make any proposed modifications to Matthies' passive-matrix display structures. A POSITA would understand that the design considerations required for Yamada's active-matrix display would be completely different from those required for Matthies' passive-matrix display. Given fundamental technical incompatibilities between Yamada and Matthies, a POSITA would not have been motivated to modify Matthies by taking select features from Yamada and inserting it into Matthies' display with any reasonable expectation of success. Dr. Pattison offers no explanation as to what function would be served by adding a planarization layer to Matthies or why a POSITA would be motivated to try to do so. In fact, while Dr. Pattison points to Yamada's figure 6B, which shows a "planarization insulating film 167," Yamada's figure 6A does *not* include the same layer, suggesting that a planarization insulating

film is not a key feature of Yamada's display that a POSITA would have been motivated to implement into Matthies (assuming a POSITA would have been motivated to combine Yamada and Matthies in the first place).

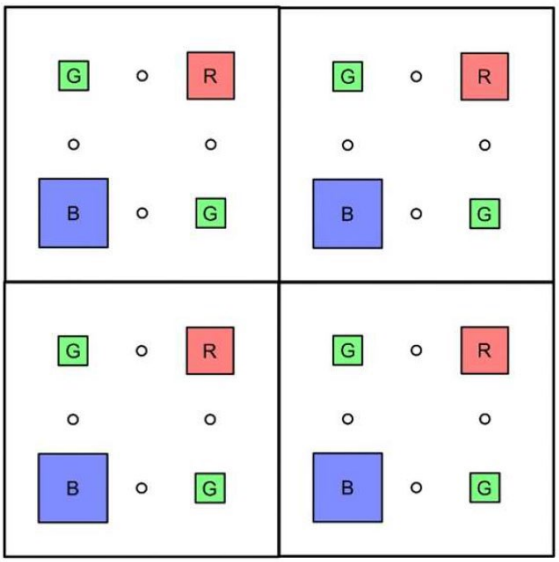
2. Dr. Pattison's arguments for claim 5 are inconsistent with his arguments for the other challenged claims

190. Claim 5 depends on claim 1. Dr. Pattison fails to show that the combination of Matthies and Yamada would satisfy all of the limitations of claim 5, including the limitations inherited from claim 1.

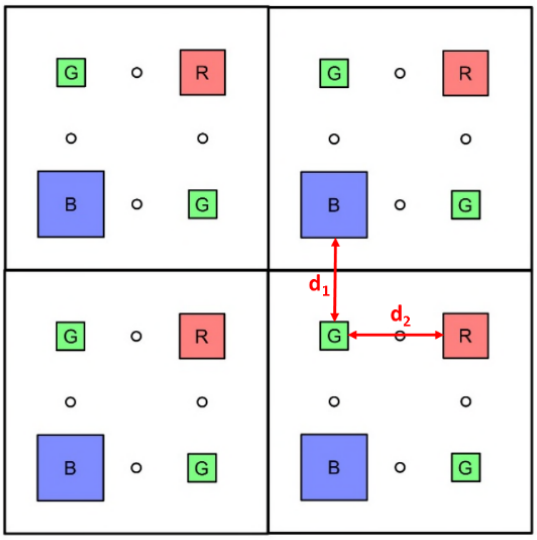
191. Claim 5 adds the limitation that "a shortest distance between the first pixels and the second pixels, and a shortest distance between the first pixels and the third pixels, are a same first length." According to Dr. Pattison, the "first pixels" are the green pixels, the "second pixels" are the blue pixels, and the "third pixels" are the red pixels. Ex. 1003, ¶267. Thus, for Dr. Pattison's proposed combination to satisfy this limitation of claim 5, a shortest distance between green and blue pixels must be equal to a shortest distance between green and red pixels in Dr. Pattison's proposed combination.

192. Therefore, Dr. Pattison must show that it would have been obvious to create a pixel arrangement structure that simultaneously meets all of the requirements of claim 1 and has the green-blue distance equal to the green-red distance. He has not done so.

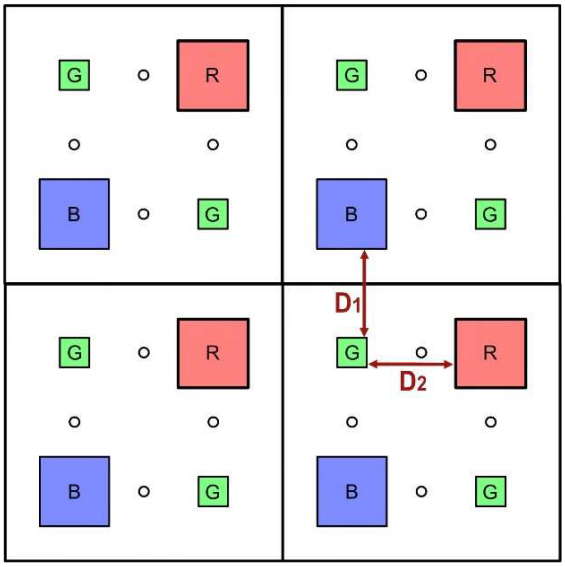
193. When discussing claim 1, Dr. Pattison proposed to combine Matthies and Yamada in such a way that the blue pixels were bigger than the red pixels which were, in turn, bigger than the green pixels. Dr. Pattison illustrated his combination in an annotated illustration, reproduced below:



194. But this combination does *not* satisfy the additional limitation of claim 5. In particular, because the pixels all have different sizes, the green-blue distance is *smaller* than the green-red distance (instead of being equal). This is illustrated in the annotated figure below. Under Dr. Pattison's theory, the shortest distance between the first (green) pixels and the second (blue) pixels (labeled d_1) is *shorter* than the shortest distance between the first (green) pixels and the third (red) pixels (labeled d_2).



195. Acknowledging that his proposed combination fails to render obvious claim 5, Dr. Pattison pivots to a different combination, which he applies only to the additional limitations of claim 5. In this new combination, shown below, the red pixels have the same size as the blue pixels. Dr. Pattison states that "a POSITA would have considered it obvious to keep the green-to-blue and green-to-red distance the same" by making "the red and blue pixels equally sized." Ex. 1003, ¶¶270-271.



196. But Dr. Pattison has also not shown that this new combination would satisfy all of the limitations of claim 5. And Dr. Pattison has failed to show that a POSITA would have been motivated to combine Matthies and Yamada in this new way.

197. Elsewhere in his declaration, Dr. Pattison repeatedly and consistently argued that a POSITA combining Matthies and Yamada would have been motivated to specifically make a combination where the green pixels would be smaller than the red pixels and the red pixels would be smaller than the blue pixels, in order to extend the life of the display. For example, Dr. Pattison stated that "Yamada teaches that to improve the life of an OLED display, the blue sub-pixels should be made largest, the red sub-pixels intermediately sized, and the green subpixels smallest." Ex. 1003, ¶306. Dr. Pattison also stated that "[b]ecause OLED displays were routinely designed with larger blue pixels, intermediately sized red pixels, and smaller green

pixels, a POSITA would not only have been aware of this design, but would have been motivated to employ it with Matthies to obtain the benefits of this relative pixel sizing known and discussed in the prior art." Ex. 1003, ¶436. And Dr. Pattison stated that in his original combination of Matthies and Yamada, "Matthies' sub-pixels have been re-sized in accordance with their emission efficiencies such that the "first pixels" (the green sub-pixels) are smallest, the "second pixels" (the blue sub-pixels) are largest, and the "third pixels" (the red sub-pixels) have an intermediate size." Ex. 1003, ¶249.

198. Dr. Pattison's assertion that Matthies' sub-pixels, when re-sized according to their emission efficiencies following Yamada, results in red pixels smaller than blue pixels is directly contradictory to his assertion for claim 5 that "a POSITA would have considered it obvious to keep the green-to-blue and green-to-red distance the same" by making "the red and blue pixels equally sized." Ex. 1003, ¶¶270-271. Dr. Pattison fails to explain how a POSITA would have arrived at these two disparate conclusions from the same references, let alone why a POSITA would have been motivated to make both of Dr. Pattison's proposed combinations.

199. Dr. Pattison's only explanation is that the red pixel and blue pixel being the same size is a "permissible pixel sizing arrangement contemplated by Yamada" that is "deemed acceptable by Yamada," and that a POSITA would have considered the use of either red pixels being smaller than blue pixels, or red pixels being the

same size as blue pixels, as "nothing more than a routine, obvious design choice." But the mere fact that two choices exist does not provide a reason *why* a POSITA would have selected both to make two different combinations with the same references. Further, Dr. Pattison has specifically argued that the Matthies emission efficiencies are such that a POSITA would specifically have selected one of these options—the red pixels being smaller than the blue pixel—when addressing claim 1 because that would result in improved lifetime. He fails to justify why, if that is true, a POSITA would have chosen another option—the red pixels being equal in size to the blue pixel—when addressing claim 5.

200. Claim 5 depends from and incorporates all of the limitations of independent claim 1. Dr. Pattison argues that his first combination of Matthies and Yamada (where blue pixels are larger than red pixels) meets all limitations of claim 1, but as noted above, this combination fails to meet the additional limitations of claim 5. Dr. Pattison argues that his second combination of Matthies and Yamada (where blue pixels are the same size as red pixels) meets all limitations of claim 5, but does not show how this combination meets all limitations of claim 1.

3. A POSITA would not have found it obvious to modify Dr. Pattison's proposed combination of Matthies and Yamada to use pixels with elongated sides, as required by claims 41, 44, and 52

201. Claims 41, 44, and 52 require the first pixel to have "elongated" sides or edges. Dr. Pattison asserts that Matthies and Yamada teach pixels "with this

shape," and that pixels with elongated sides were known in the art as shown by Matthies and Yamada, and that a POSITA would have considered their use a "routine, obvious design choice." Ex. 1003, ¶¶335-339.

202. However, Dr. Pattison overlooks that Matthies only shows rectangular shaped pixels in its RGB stripe pixel arrangement structure. Matthies, 16:49-61, 25:46-54, Fig. 8A. Matthies does not describe or depict using rectangular shaped sub-pixels in its quad sub-pixel structure. Matthies, 17:16-29, 25:46-54, Fig. 8B. Similarly, as I noted above, Yamada only discusses triplet structures with one red, one green, and one pixel, and thus does not teach using rectangular shapes or L-shapes in the context of a quad pixel structure. Yamada, 12:37-43.

203. Dr. Pattison offers no reason why a POSITA would have chosen to further modify his proposed combination of Matthies and Yamada based on square sub-pixels in a square quad sub-pixel tile and used rectangular sub-pixels instead. Dr. Pattison simply asserts that elongated pixels were known and interchangeable, and thus that using one was a matter of routine, obvious design choice. But he does not even attempt to show how non-square pixels could even be used in his modified proposed combination, or why a POSITA would have chosen to do so. Indeed, Dr. Pattison's statement that the green pixel is "particularly amenable to being formed in different shapes" because it is smaller than the other pixels "and thus has a larger amount of surrounding space to accommodate such a different shape" belies his

conclusion that any elongated pixel shapes could have been interchangeably used in his proposed combination. Ex. 1003, ¶339. As I've explained above in Section V, real displays impose constraints on locations, shapes, and sizes of pixels that a POSITA would have had to consider in selecting a pixel shape and arrangement. Moreover, modifying Matthies' display tile to include "elongated" pixels would have exacerbated the problem warned by Matthies, namely the sub-pixels being unevenly spaced from the edges of the tiles, leading to unwanted visual effects in both vertical and horizontal directions. Thus a POSITA would have lacked a reasonable expectation of success in attempting to modify Matthies' display with Dr. Pattison's proposed "elongated" pixels (which, as explained above, Dr. Pattison does not even show how they look like or how they would be used in Matthies' display).

204. Dr. Pattison fails to provide any analysis of how a modified display tile having pixels with elongated sides meets all of the limitations of claim 41. Claim 41 depends on independent claim 1, yet Dr. Pattison fails to explain how such a modified tile would satisfy the limitations of claim 1. For example, claim 1 requires that "a region having a width in the second direction that is equal to a width of the first pixels in the second direction . . . and completely overlapping a row of the first pixels extending in the first direction, is entirely offset in the second direction from at least one of the second pixels or the third pixels." But Dr. Pattison does not explain how, if the shape of the pixels were changed to have elongated sides, Matthies'

modified tile would meet this limitation. Dr. Pattison also has not explained how his modified Matthies tile would satisfy the limitation that the "shortest distance between two nearest ones of the first pixels in one of the first sets is greater than a shortest distance between one of the second pixels and one of the third pixels that are nearest each other in one of the second sets."

205. Dr. Pattison's arguments for dependent claims 44 and 52 are defective for the same reasons. For both of these claims, he simply points back to his flawed analysis of claim 41, and fails to show how the structure he proposes for these claims would meet the limitations of the independent claims from which they depend. Ex. 1003, ¶¶367-369, 392-394. Dr. Pattison fails to show how his proposed modified structure would meet all of the limitations of independent claim 42 (from which claim 44 depends) or independent claim 45 (from which claim 52 depends).

XI. GROUND 2: MATTHIES, YAMADA AND HONG

206. For the reasons explained below, it is my opinion that the combination of Matthies, Yamada, and Hong fails to render obvious claims 40, 43, 45–47, and 51 of the '578 Patent.

A. A POSITA would not have been motivated to combine Matthies with Yamada and Hong

207. As I have already explained in Section X above, a POSITA would not have been motivated to combine Matthies with Yamada. Shrinking the size of the

red and the green pixels as Dr. Pattison proposes would have shortened the lifetime of Matthies' display. Further, Matthies' tiled, passive-matrix display and Yamada's monolithic, active-matrix display are fundamentally different in structure and operation, such that a POSITA would not have had any reason to combine the teachings of those references, and a POSITA would not have had a reasonable expectation of success in making the combination. Still further, Dr. Pattison's proposed combination would contradict the express teachings of Matthies that are important to its tiled, passive-matrix display architecture, including (1) reducing the visibilities of seams between tiles by having pixels evenly spaced up to the edges of the tiles, and (2) doubling up on the number of pixels of the color (*e.g.*, blue) that has lower efficiency. All of my opinions apply with equal, if not greater force, to the three-way combination of Matthies, Yamada, and Hong. Since a POSITA would not be motivated to combine Matthies and Yamada, and would not have had a reasonable expectation of success in doing so, then they would be even less motivated to make—and would have even less of an expectation of success with—the three-way combination.

208. Adding Hong to the combination does not cure any of the deficiencies discussed above regarding the combination of Matthies and Yamada. Dr. Pattison does not offer any reason why a POSITA would be motivated to further modify the

combination of Matthies and Yamada based on Hong to change the shape of the pixels in Matthies' tiled display.

209. Dr. Pattison claims that choosing one pixel shape over another is "nothing more than a routine, obvious design choice." Ex. 1003, ¶483. This conclusory assertion is simply incorrect. Pixel shape design has long been a subject of study in electronic displays, and the characteristics of the underlying display technology influences the range of pixel geometries that can or should be used in a particular type of display. For example, as I explained at length above in Sections V and X.A, pixel shapes in passive-matrix displays are defined by the overlap in row and column electrodes, and it would have been very difficult if possible at all, and in any case inadvisable, to try to use arbitrary pixel shapes. For another example, in LCDs using the typical RGB stripe arrangement, using chevron pixel shapes were found to result in improved viewing angles compared to using rectangular pixel shapes. In LED displays, the shapes of the pixels may be constrained by the packaging of the individual LED diodes.

210. Still further, the choice of pixel shapes can have an impact on visual perception. Examples can be found in the references that Dr. Pattison himself chose to rely on in related proceedings involving patents related to the '578 Patent (IPR2023-00987; IPR2023-00988). For example, Murai (Ex. 1007 in IPR2023-00987, ¶¶[0005]-[0014]) taught that in densely-packed LCD displays, a "streaking"

effect among the green pixels can be reduced by cutting the corners of the rectangular green pixels.

211. It is not a trivial matter to choose pixel shapes, and the design decision is necessarily heavily influenced by the nature of the underlying technology, manufacturing limitations, visual perception and color science, and the applications of the resulting display. Pixel shape design is a multi-faceted technical problem, and is not a matter of being able to use any two-dimensional shapes that can be drawn for any display. As such, I disagree that using octagonal pixel shapes in Matthies' tiled display would have been "nothing more than a routine, obvious design choice."

212. Dr. Pattison does not identify any problems with Matthies' square pixels that would lead a POSITA to consider a change to a different pixel shape. But Dr. Pattison nevertheless claims that it would have been obvious to use an elongated, octagonal pixel, because Matthies and Yamada contemplate elongated pixels, and because using octagonal pixels with truncated corners would have been "particularly desirable" because they (1) were known to provide good aperture ratio, (2) were easier to manufacture than square pixels, and (3) would improve resolution by minimizing the "shadowing effect." Ex. 1003, ¶¶479-489. I disagree on all points.

213. Regarding Dr. Pattison's claims about Matthies and Yamada contemplating different pixel shapes, despite these alleged teachings, Dr. Pattison's proposed combination of Matthies and Yamada uses square pixels, and Dr. Pattison

does not provide any reason why a POSITA would now further seek to deviate from that combination to use elongated pixels. Nothing in Matthies or Yamada contemplates using elongated pixels in Matthies' quad pixel structure or the modified quad pixel structure proposed by Dr. Pattison.

214. Matthies contemplates using elongated pixels only in the RGB stripe pixel structure, not in the quad pixel structure. Matthies, 16:41-60, Fig. 8A. This holds true even for the alternative embodiment of Matthies directed not to an OLED display, but instead a cathodoluminescent display. Matthies, 25:46-54. The other cited portions of Matthies do not relate to pixel shapes, and none of them suggest using elongated pixels in a quad pixel structure. *See* Ex. 1003, ¶480. Specifically, Dr. Pattison points to one section discussing the shapes of ***tiles***, not shapes of ***pixels***, Matthies, 8:47-52, and two figures that simply illustrate the structure of a tile and how electrical connections may be made, Matthies, Figures 3, 9.

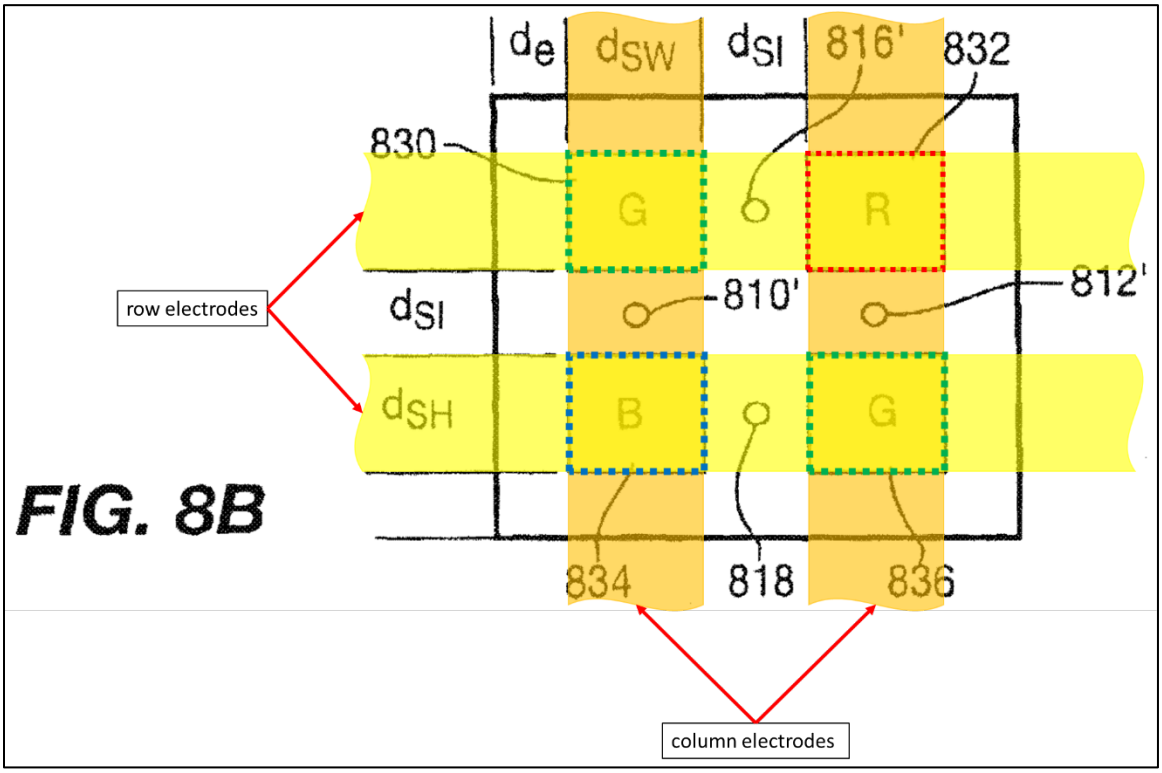
215. Similarly, as discussed above, Yamada only contemplates R/G/B triplet structures, as evidenced by its reference to only "stripe," "delta," and "diagonal" layouts. Yamada, 12:37-43.

216. Dr. Pattison's suggestion that a POSITA would have simply chosen to use elongated pixels as a matter of mere design choice is also at odds with his theory that a POSITA would have first chosen to use the square pixels in a quad pixel structure as shown in Figure 8B and using the dimensions exactly as provided in

Table 2 of Matthies and that a POSITA would further have been motivated to keep the square pixels even when modifying Matthies to use different pixel sizes in view of Yamada, which are both necessary predicates for his theory for why the combination of Matthies and Yamada renders claim 1 obvious.

217. As to Dr. Pattison's opinions that "many different types of pixel shapes were known, in routine use, and were considered largely interchangeable," and that "all pixel shapes capable of accommodating the inter-pixel electrical connections would have been considered," I disagree with Dr. Pattison's conclusory assertions. Ex. 1003, ¶¶482, 484. Dr. Pattison says these things without any support, and he is incorrect. Again Dr. Pattison oversimplifies the design of pixels that can operate as part of actual, functioning displays. As I just explained above, the choices of pixel shapes are not arbitrary. In the real world, the designer of pixel shapes for displays must take into account myriad considerations, such as manufacturability, aperture ratio, and image quality. Further, pixel shapes may be further constrained by the area necessary for power and signal lines, and driving circuitry, as I have already explained in relation to Hong and Yamada. A POSITA thus would not have considered it a matter of "mere design choice" or otherwise obvious to use any pixel shapes, let alone elongated octagonal pixel shapes. Dr. Pattison points to no evidence that octagonal pixels were widely used or that the choice of octagonal pixels or other pixel shapes was a matter of routine design choice.

218. In fact, Dr. Pattison's argument fails because the octagonal pixel shapes in his proposed combination would ***not*** be "capable of accommodating the inter-pixel electrical connections." As I explained above, Matthies is directed to a passive-matrix display. *See* Section VIII.A. And in a passive-matrix display, the pixels are defined by the overlap of the row and column electrodes, as shown in the annotated version of Figure 8B of Matthies below:



Dr. Pattison does not explain how a POSITA would have created irregularly-shaped, octagonal pixels in Matthies' passive-matrix display with any reasonable expectation of success. As I've explained above, attempting to change the shapes of the pixels in a passive-matrix display would introduce several complex electrical effects that would negatively impact the operation and quality of the display and

would require adding process steps that would reduce yield and increase manufacturing costs. *See* Section V. What's more, even if Dr. Pattison is correct that a POSITA would have "considered" other non-rectangular shaped pixels for use in Matthies' passive-matrix display, he has not offered any explanation at all why a POSITA would have chosen the particular octagonal shape that he relies on.

219. As to Dr. Pattison's opinions that "truncated pixels" offer certain advantages, I disagree. Dr. Pattison cites to Hong as supporting these assertions, but he misreads Hong.

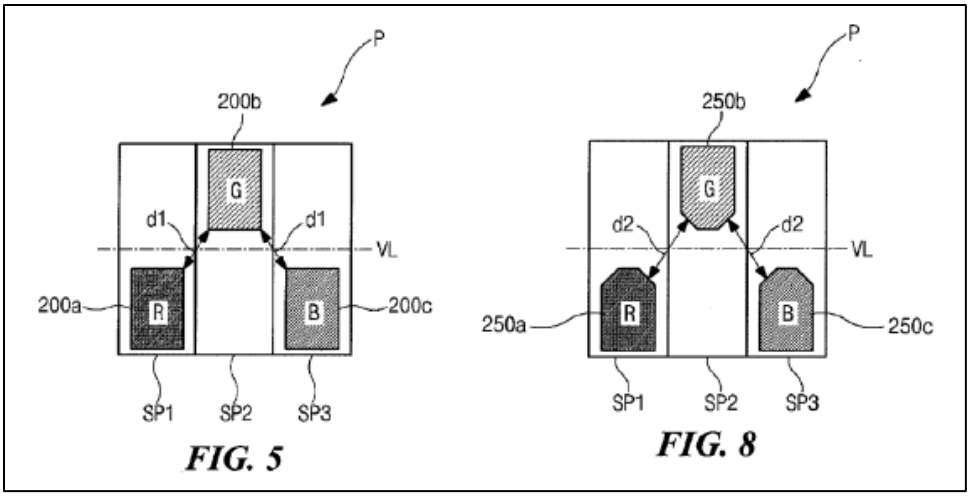
220. Hong does not attribute the benefits identified by Dr. Pattison to the truncated corners of pixels. Hong is instead very clear that the higher aperture ratio is due to its zigzag pattern, which allows for the organic patterns to be larger in size and to be deposited using Hong's manufacturing method. Hong, ¶¶[0003] ("aperture ratio and resolution are improved due to an arrangement of organic patterns in sub-pixel regions and a method of fabricating the organic ELD device"), [0075]-[0076] ("since the organic patterns are disposed to have a zigzag shape along the first direction and the two adjacent organic patterns are spaced apart from each other by the predetermined distance for preventing a shadowing effect along the diagonal direction, each organic pattern has an enlarged area. Accordingly, an aperture ratio of the organic ELD is improved . . . ."); *see also*, Hong, ¶¶[0036], [0044], [0048]-[0049], [0061]-[0062]. Hong does state that aperture ratio is improved in the

embodiment where corners of organic patterns are cut off or truncated, but this is not because the corners were cut off, but because the cut-off corners result in a greater distance between pixels, which can then be taken advantage of by "further enlarg[ing]" the area of the organic patterns for each pixel. Hong, ¶¶¶[0061]-[0062]. Thus, it is enlarging the pixel, not cutting off its corners, that results in the increased aperture ratio. Of course, this makes perfect sense; merely cutting the corners of the pixels without more would decrease the aperture ratio, not increase it. And such a modification would go against Hong's teachings to increase the aperture ratio by enlarging pixel size.

221. Dr. Pattison also cites to Smith (Ex. 1006) to assert that "non-square pixel[s] with diagonally arranged [sic] w[ere] known to 'provide[] a good aperture ratio' and were easier to manufacture than square pixels." Ex. 1003, ¶486. But Smith (and in particular the embodiment that Dr. Pattison points to) is directed to the use of nonconventional emissive layer manufacturing methods such as inkjet printing (Ex. 1006 at ¶¶¶[0063]-[0064]) that are not prone to the same types of manufacturing and structural challenges that exist with conventional emissive layer deposition methods, including the shadow masks used in Hong and Yamada. And while display manufacturers have considered inkjet printing as an alternative to conventional deposition methods such as shadow masks or FMM, I am not aware of any display manufacturer who has successfully mass-produced high resolution mobile

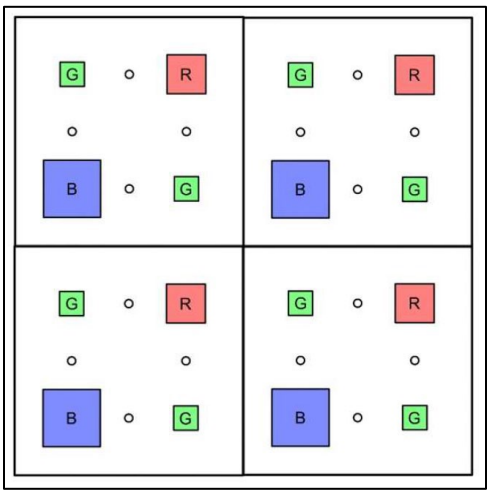
AMOLED displays using inkjet printing. A POSITA would therefore have had no reason (and Dr. Pattison identifies none) to look to Smith's teachings regarding pixel shapes or arrangements. Dr. Pattison is wrong to assert that Smith would have motivated a POSITA to use "non-square pixel[s]" to achieve a "good aperture ratio" and "easier . . . manufactur[ability]." Ex. 1003, ¶¶486. Smith is merely describing how one embodiment of its disclosure is better than another embodiment of its disclosure, and does not support a generalized understanding that any OLED pixel would be easier to manufacture in an octagonal shape. Further, Smith's discussion of these benefits of one of its embodiments is clearly limited to its particular manufacturing method, which is inkjet printing. There is no generalized understanding that octagonal OLED pixels are easier to manufacture than square pixels, or provide a "good aperture ratio" (whatever "good" is even supposed to mean, given no basis for comparison).

222. Dr. Pattison also claims that combining Matthies and Yamada with Hong would help minimize the "shadowing effect." I disagree. Dr. Pattison again misreads Hong. In Hong, the shortest distance between adjacent pixels is in the diagonal direction. Hong explains that truncating the corners of the pixels addresses the potential shadowing effect because it increases the distance between the pixels. Hong, ¶¶¶[0047]-[0048], [0060]- [0061]. This is shown in Hong's Figures 5 and 8, reproduced below.

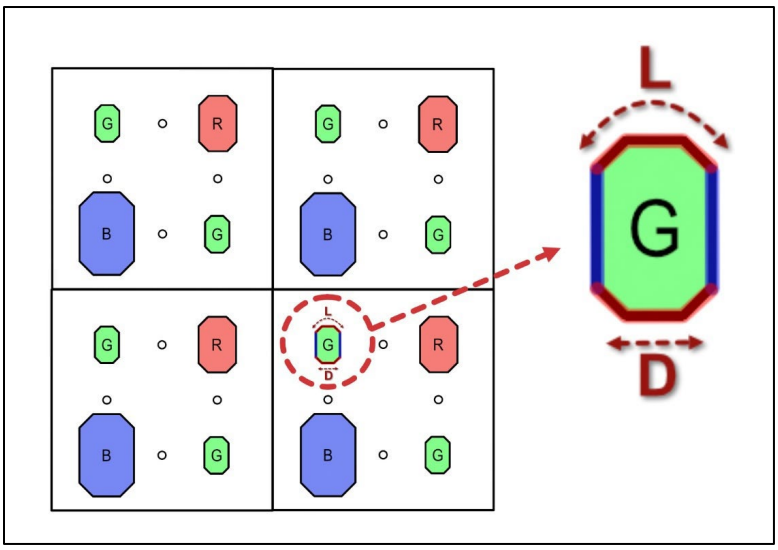


By chamfering the corners, the distance between pixels increases from d1 (in Figure 5) to d2 (in Figure 8). Thus, the benefit comes from the increased distance between pixels, not inherently from the hexagonal shape of the pixels.

223. But in Dr. Pattison's proposed combination of Matthies and Yamada, the shortest distance between pixels is not in the diagonal direction. As shown in Dr. Pattison's demonstrative, the shortest distances are in the horizontal and vertical directions. Thus, cutting off the corners would not change the distances between pixels.

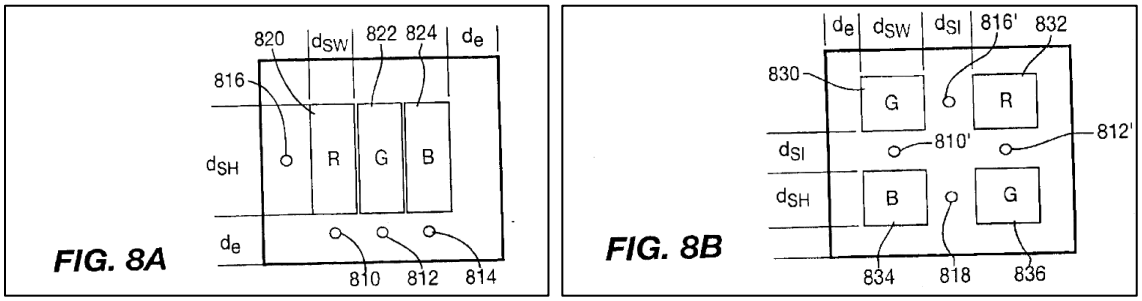


224. Thus, Dr. Pattison's proposed further addition of Hong would not do anything to minimize the shadowing effect. As shown below in Dr. Pattison's demonstrative, by replacing the square pixels with "elongated" octagonal pixels, the blue and green pixels are actually closer together than they were in Dr. Pattison's proposed combination of Matthies and Yamada. Dr. Pattison's combination is therefore contrary to the teachings of Hong. There is no reason to believe that his modification would have any impact on any shadowing effect.



225. Additionally, a POSITA would not have been motivated to combine Matthies with Yamada and Hong because they all use different pixel arrangements, and Hong's teachings are predicated on such a different pixel arrangement structure that a POSITA would understand that Hong's teachings are not applicable. As discussed above, Matthies discloses two alternative pixel arrangement structures: an

RGB stripe arrangement, shown in Figure 8A, and a quad sub-pixel arrangement, shown in Figure 8B.



226. On the other hand, Yamada discloses only triplet structures. Yamada, 12:37-43. As I've explained above, a POSITA would not have expected that Yamada's teachings are applicable directly to Matthies' quad sub-pixel structure without modification. *See* Section X.C.

227. Hong introduces yet another pixel arrangement that is different from each of the pixel arrangement structures disclosed by Matthies or Yamada. Hong is directed to one specific variant of the RGB stripe-type structure, where the red, green, and blue pixels are arranged in a "zigzag" pattern, instead of being arranged in a regular rectilinear grid. Hong, Abstract, ¶¶[0015]-[0016], [0043], [0052], [0067]; Figures 4, 6, 9. The zig-zag structure is illustrated in an annotated version of Figure 4 below.

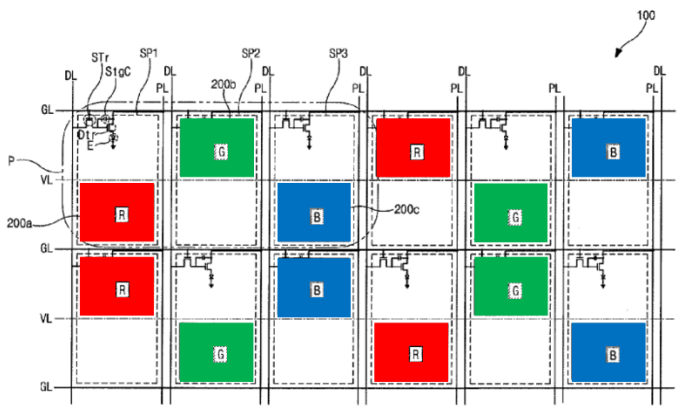


FIG. 4

228. Hong's zigzag structure is similar to an RGB stripe arrangement in that it is a triplet structure with equal numbers of red, green, and blue pixels. But unlike either the RGB stripe arrangement or the quad sub-pixel structure, in Hong's zigzag arrangement, the organic patterns for two pixels of the same color are adjacent to each other in the column direction, with large gaps between every pair of such adjacent organic patterns in the column direction. Also unlike either the RGB stripe arrangement or the quad sub-pixel structure, in Hong's zigzag arrangement, the organic patterns for pixels are alternatingly placed at an upper half portion or a lower half portion of each pixel region along the row direction. Hong's arrangement also differs from the arrangements in both Matthies and Yamada because the shortest distances between different colored pixels are along the diagonal directions. Thus, Hong's teachings relating to truncating corners of pixels to create more spacing between adjacent pixels of different colors are simply inapplicable to any of the pixel

structures taught in Matthies, Yamada, or Dr. Pattison's proposed combination of the two.

229. Further, Hong also teaches away from the pixel structures contemplated by Matthies and Yamada. Hong is directed to one specific variant of the RGB stripe-type structure, where the red, green, and blue pixels are arranged in a "zigzag" pattern, instead of being arranged in a regular rectilinear grid. Hong, Abstract, ¶¶[0015]-[0016], [0043], [0052], [0067]; Figures 4, 6, 9. The zig-zag structure is illustrated in an annotated version of Figure 9, below.

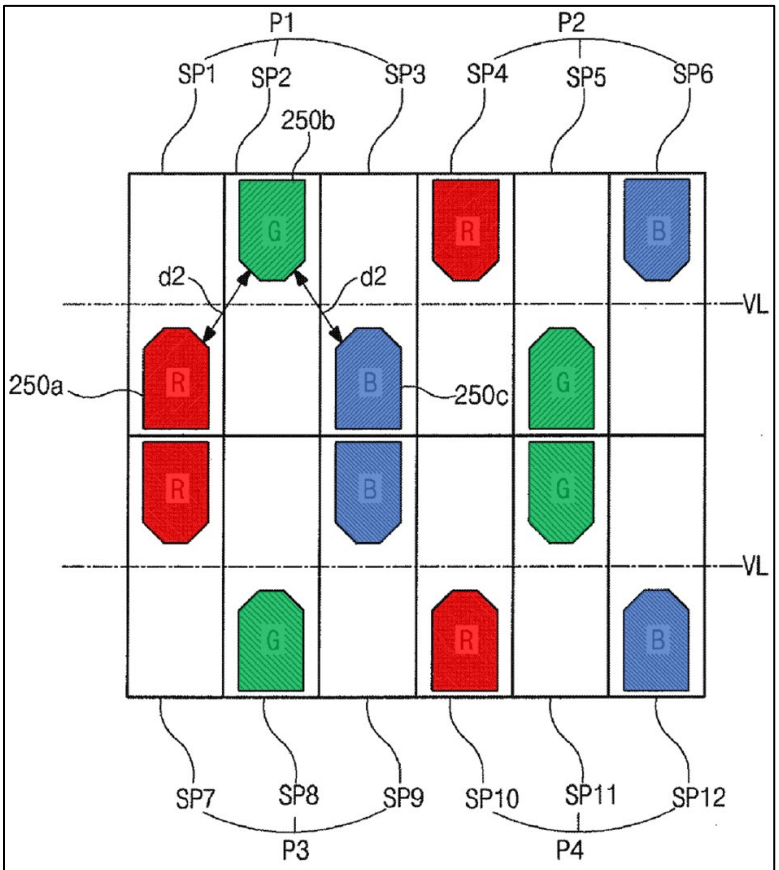
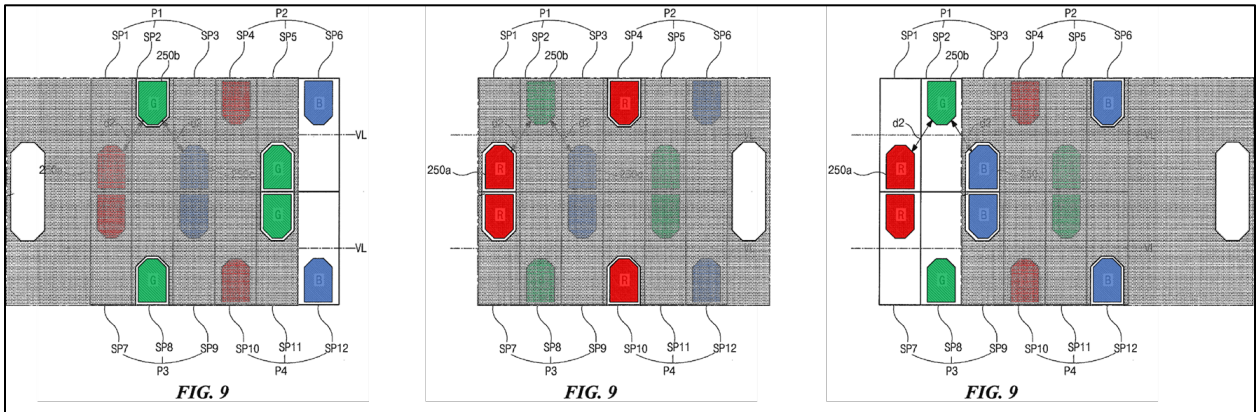


FIG. 9

The zigzag pattern is an important aspect of Hong's invention because it is what allows for greater separation between adjacent pixels of different colors to result in improved aperture ratio and resolution while reducing the shadowing effect. Hong, ¶¶[0036], [0043]-[0044], [0048]- [0049], [0052]. This diagonal separation can then further be exploited by truncating the diagonal corners and correspondingly increasing the pixel sizes, resulting in further improvements in aperture ratio and resolution. Hong, ¶¶[0061]-[0062]. The zigzag pattern is also what allows Hong to use one mask opening of the shadow mask to form two pixels of the same color to improve manufacturing yields. Hong, ¶¶[0071]-[0073], [0077]. To illustrate, the figures below show how the shadow mask shown in Figure 10B would be overlaid on top of the pixel regions shown in Figure 9 to deposit the organic emissive material for different colors:



Deposition of green material | Deposition of red material | Deposition of blue material

230. The zig-zag structure used by Hong is thus simply incompatible with both the RGB stripe structure of Yamada and the quad pixel tile structure of Matthies.

In fact, Hong expressly discourages using the types of pixel arrangements in Yamada and Matthies, where the shortest separation distance between adjacent pixels of different colors is not in the diagonal direction. Hong, ¶[0010].

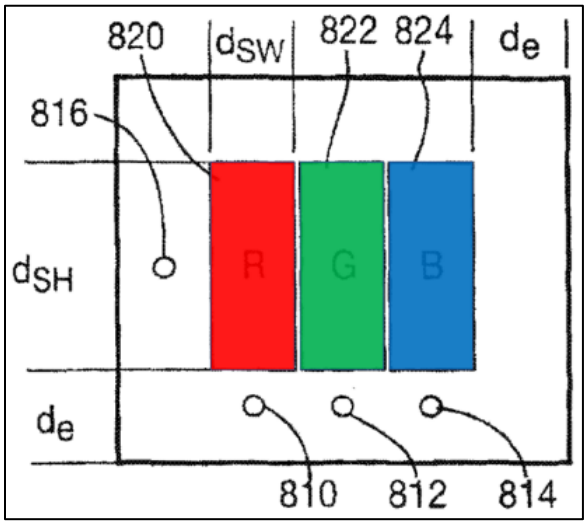
231. Additionally, Hong, like Yamada, is directed to a bottom emission type AMOLED display. *See, e.g.*, Hong, ¶¶[0033]-[0038]. Hong states that each subpixel includes "a switching thin film transistor (TFT) STr, a driving TFT DTr and a storage capacitor StgC," which describes the driving circuitry characteristic of an active-matrix display. Hong, ¶[0040]. As I have already explained regarding the combination of Matthies and Yamada, PMOLED and AMOLED are two different technologies that have disparate design considerations, manufacturing challenges, and commercial applications. *See* Section V. For the same reasons, a POSITA would not have considered Hong to be compatible with Matthies or the combination of Matthies with Yamada.

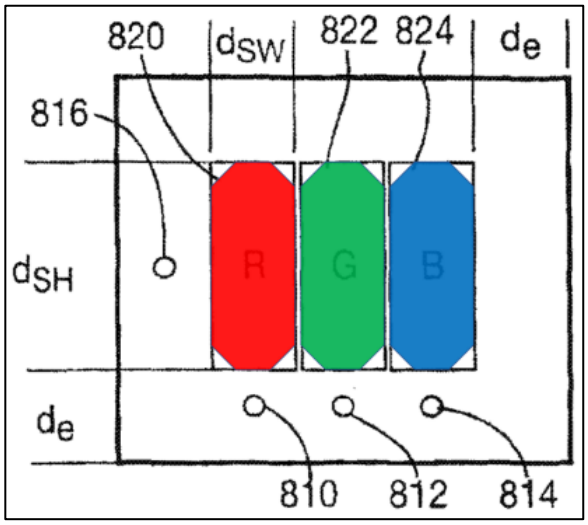
232. Further, Hong, again like Yamada, is directed to monolithic displays built on a single substrate, which is a fundamentally different type of display from Matthies' tiled displays. Hong, ¶¶ [0009], [0070]–[0071]. As I have already explained regarding the combination of Matthies and Yamada, Matthies is directed to addressing problems with designing and manufacturing tiled displays, and its design rules for pixel arrangement structures is based on unique considerations and constraints associated with tiled displays. *See* Section X.A. These considerations

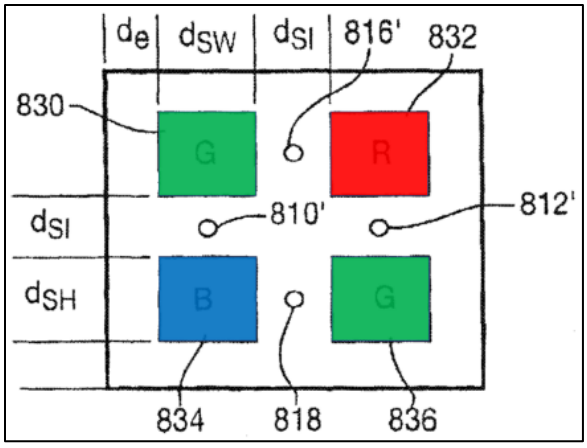
include, for example, the need for vias connecting the display components of the tiles to the "[d]riving circuitry" mounted on the back side of the tiles, Matthies, 2:23-26, and the need to have pixels that are "evenly spaced up to the edges of the tile," Matthies, 5:47-48. Hong's monolithic display built on a single substrate is fundamentally different from Matthies' tiled display, and does not offer any teachings that would address any of the concerns of a POSITA seeking to modify Matthies' display.

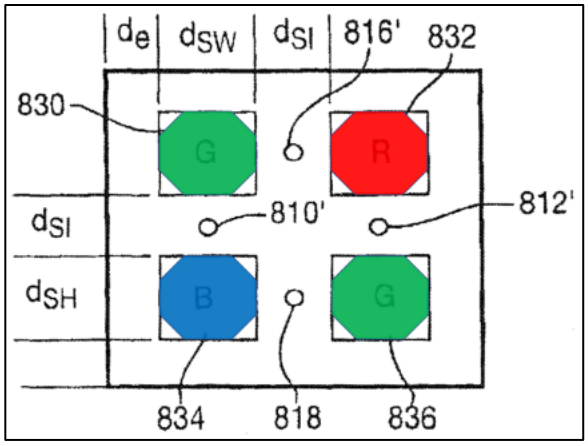
233. Further, the design of pixel shapes is not the focus of Hong, and the shape of its pixels is not what a POSITA would take away from Hong's teachings. As I've already explained, all of the benefits described by Hong are due in the first instance to Hong's zig-zag arrangement, not in the truncated shapes of the pixels. All of the benefits of Hong's invention inhere in Hong's first embodiment, described in Figures 3–7 and associated text. Hong, ¶¶[0032]-[0034], [0039]-[0040], [0046][0047], [0050]-[0051], [0056]-[0057]. And this first embodiment clearly describes rectangular shapes of organic patterns (which in Dr. Pattison's view are rectangular pixels) without any corner truncation. The second embodiment, described in Figures 8–9 and associated text, notes that the truncation of corners merely furthers the same benefits. Hong, ¶¶[0059[-[0064]. And it is only because the pixels are in the zig-zag pattern to begin with that truncating the corners can result in these incremental benefits; if the pixels instead were assumed to be in either

of the RGB stripe or quad-pixel arrangements shown in Matthies, truncating the corners would provide no benefit and in fact be actively detrimental and contrary to Hong's teachings because it would reduce the aperture ratio without creating the additional space in the diagonal direction necessary for the incremental benefits described in the second embodiment of Hong. For example, as I've shown below in annotated versions of Figures 8A and 8B of Matthies, truncating the corners of the pixels in the RGB and quad-pixel arrangements reduces the aperture ratio without increasing the distance between pixels. A POSITA would have no reason to make this type of modification.









234. For all of the reasons just discussed, a POSITA would not have had a reasonable expectation of success in combining Matthies, Yamada, and Hong. I have already explained why a POSITA would not have had a reasonable expectation of success in combining Matthies and Yamada. All of my opinions apply with equal, if not greater force, to the three-way combination of Matthies, Yamada, and Hong. Since a POSITA would not be motivated to combine Matthies and Yamada, and would not have had a reasonable expectation of success in doing so, then they would be even less motivated to make—and would have even less of an expectation of success with—the three-way combination.

235. There are also additional reasons why a POSITA would not have had a reasonable expectation of success in combining Matthies and Yamada with Hong as Dr. Pattison suggests. As explained above, a POSITA would not have considered Hong to be compatible with Matthies or the combination of Matthies with Yamada. Hong is directed to, and derives its benefits from, its zig-zag pattern placing adjacent

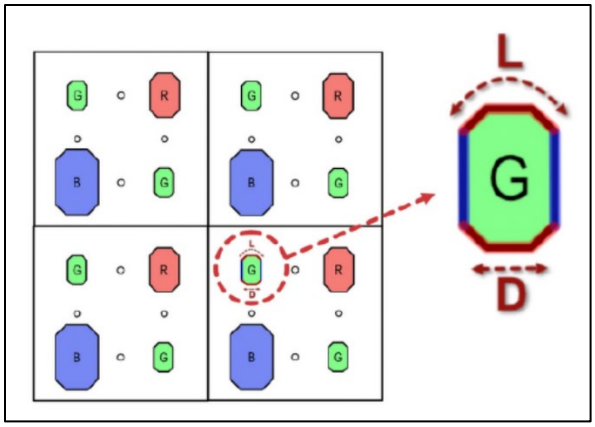
differently colored pixels along diagonal directions, which is incompatible with the pixel arrangements described in Matthies and Yamada; it also makes no sense to apply Hong's teachings regarding truncating pixel corners to the pixel arrangements described in Matthies and Yamada. As also explained above, a POSITA would not expect that any arbitrary choice of pixel shapes would work for any display, as pixel shapes are influenced by the presence of power and signal lines, and driving circuitry. And Hong's monolithic active-matrix display is fundamentally incompatible with Matthies' tiled passive matrix display. A POSITA thus would not have had any reason to believe that Matthies, Yamada, and Hong could be successfully combined.

B. A POSITA would not have been motivated to combine Matthies with Yamada and Hong in the manner proposed by Dr. Pattison

236. Even if a POSITA would have been motivated to look to Hong to further modify Dr. Pattison's proposed combination of Matthies and Yamada, a POSITA would not have elongated the sub-pixels or used octagonal sub-pixels.

1. A POSITA would not have been motivated to modify Matthies' quad sub-pixel tile to use octagonal pixels

237. Dr. Pattison proposes that his combination of Matthies and Yamada should be further modified by using oblong, octagonal pixels, as shown in a significantly modified version of Matthies' Figure 8B that appears in his declaration, and reproduced below.



238. But this oblong octagonal pixel shape does not appear anywhere in Hong. It also does not appear anywhere in Matthies, Yamada, or any other reference cited by Dr. Pattison. The illustrated elongated octagonal shape, including the relative dimensions and sizing, all appear to be entirely a creation of Dr. Pattison, created without explanation of how it was created, and with no basis in any of the cited references.

239. Hong does not teach, suggest, or use octagonal pixels. There does not *appear* to a dispute between myself and Dr. Pattison on this point, as Dr. Pattison seems to state that what Hong actually discloses is pairs of two same-color, but ***different***, pixels that are situated adjacent to each other in the vertical direction. *See* Ex. 1003, ¶469 ("Thus, only two corners are truncated on each part (the other two corners do not need to be truncated as they are directly next to ***a same-color pixel***).") (emphasis added). But Dr. Pattison is less than clear on this point. In the same paragraph he seems to state that two adjacent "parts" form a ***single*** pixel. *See* Ex. 1003, ¶469 ("Note that in Hong, ***each green/blue/red sub-pixel is divided into two***

abutting parts.") (emphasis added). Dr. Pattison's testimony on this is very confused and confusing; elsewhere in his declaration, Dr. Pattison just states that Hong discloses octagonal pixels, full stop. *See* Ex. 1003, ¶382 ("when Hong's (Ex. 1011) ***octagonal pixel shape*** is employed") (emphasis added); ¶488 ("pixels with truncated corners like ***the octagonal pixels Hong discloses***") (emphasis added).

240. If Dr. Pattison is taking the position that Hong uses octagonal pixels, that is wrong. A POSITA would certainly not have understood Hong as teaching octagonal pixels. Perhaps Dr. Pattison is confusing the octagonal shape of the shadow mask opening—which is used to deposit organic emissive material—with the shape of the pixels. *See, e.g.*, Hong, Fig. 10B. But Hong is clear that this mask is used to create two ***separate*** organic patterns which form parts of two ***different*** pixels. Hong, ¶¶[0055], [0068], [0071]-[0073], [0077]. Thus, the resulting organic patterns deposited for each individual pixel are certainly not octagonal. Hong, Figures 8, 9.

241. Dr. Pattison seems to be arguing that Hong arranges two hexagon-shaped pixels next to each other such that together, the combined area has "a generally octagonal shape," and that a POSITA would thus recognize that a single octagonal shaped pixel could be used instead. Ex. 1003, ¶¶468-469. I disagree. These pairs of hexagon-shaped regions are for two separate pixels in two separate pixel regions, individually driven by two separate sets of driving circuitry, and there is a clear separation in where the organic emissive material is deposited for each pixel.

Hong, Figure 4. Thus, each hexagon-shaped region is separate from the adjacent hexagon-shaped region and does not form an octagon-shaped region, each hexagon-shaped region is independently driven from the adjacent hexagon-shaped region, and the pair of adjacent regions would not always emit light through the entirety of the allegedly "generally octagonal shape" region. Each "pair" of regions is not a single octagonal pixel, and nothing in Hong indicates the pair would operate as if it were a single octagonal pixel. There is no reason that a POSITA would look at Hong's arrangements and conclude that each pair of hexagonal regions could or should be implemented as a single unitary pixel with some combined octagonal shape.

242. There is no justifiable reason to take Hong, which shows two corners truncated on each pixel, and to apply it to Matthies by truncating all four corners on each pixel. Dr. Pattison does not provide any explanation or rationale for doing so, and as I've explained above, it makes no sense to do so. Dr. Pattison simply declares that because Matthies does ***not*** divide its sub-pixels into two parts like Hong does, a "POSITA would understand that as a result, all four corners would be truncated." Ex. 1003, ¶469. But as I've just explained, Dr. Pattison's premise—that Hong shows a single pixel split into two parts—is incorrect. And even if it were correct, the fact that Matthies' quad sub-pixel structure is different from Hong's and does not divide each pixel into two parts would ***de***-motivate, not motivate, a POSITA from making a combination and modifying Matthies to truncate its pixel corners.

243. What's more, the hexagonal shapes shown in Hong's figures are also not pixels; they are patterns of organic material. Dr. Pattison incorrectly conflates the shapes of ***organic patterns*** with the shapes of ***pixels***. But there is nothing in Hong suggesting that the shapes of the organic patterns correspond exactly to the shapes of the emissive areas for the pixels. In fact, it suggests the opposite. Hong is a bottom-emission device. And as shown in Hong, some parts of the deposited organic patterns may ultimately overlap parts of the driving TFT circuitry, or be disconnected from the ITO electrode functioning as the anode for the corresponding pixel. Hong, Figures 3, 4. Those regions of the organic patterns would not be part of the emissive area of the pixel. The annotated versions of Figures 3 and 4 of Hong shown below illustrate this point: the regions identified in orange circles would not form part of the light-emitting region, despite the presence of organic material there:

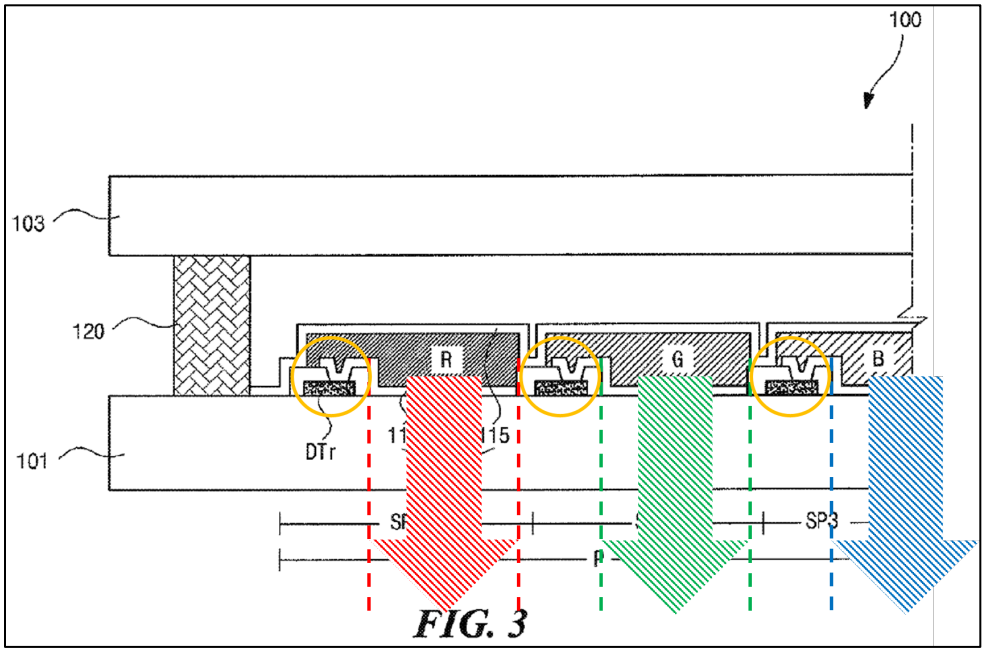


FIG. 3

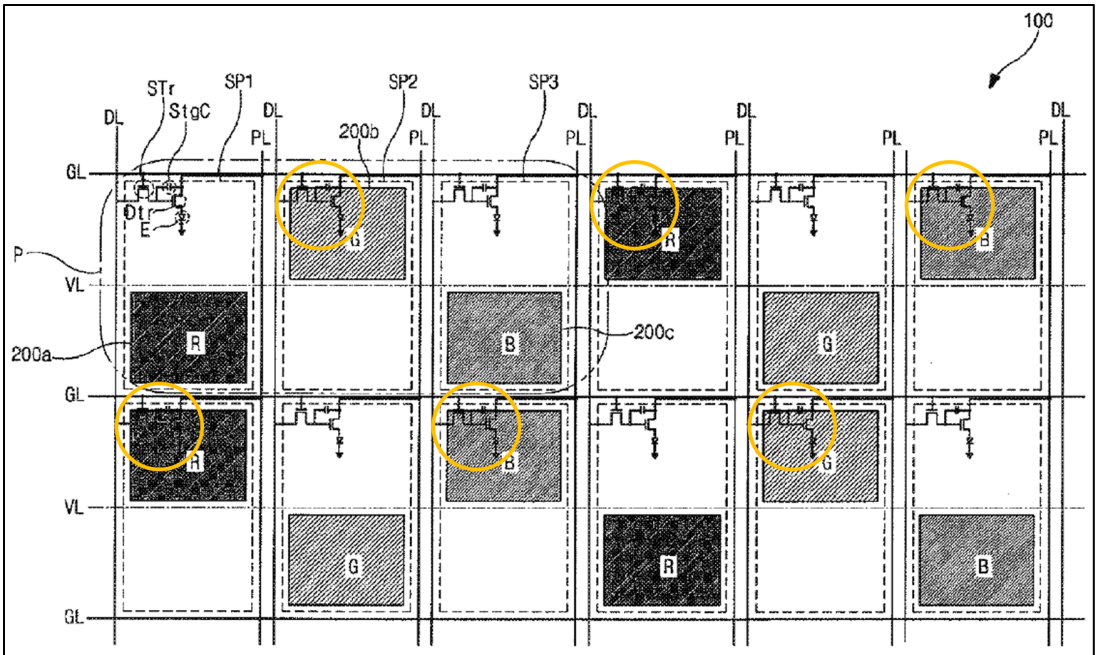


FIG. 4

Thus, Hong does not disclose, teach, or suggest that the shapes of its organic patterns are shapes of the OLED pixels, and so Hong does not teach hexagonal pixel shapes, or even octagonal pixel shapes, under Dr. Pattison's theory of "combined" pixel shapes.

244. There is thus no basis for Dr. Pattison's conclusion that Hong employs either hexagonal pixels, or octagonal pixels, or elongated pixels.

2. Dr. Pattison's proposed modification of Matthies' quad sub-pixel tile is contrary to Hong's teachings

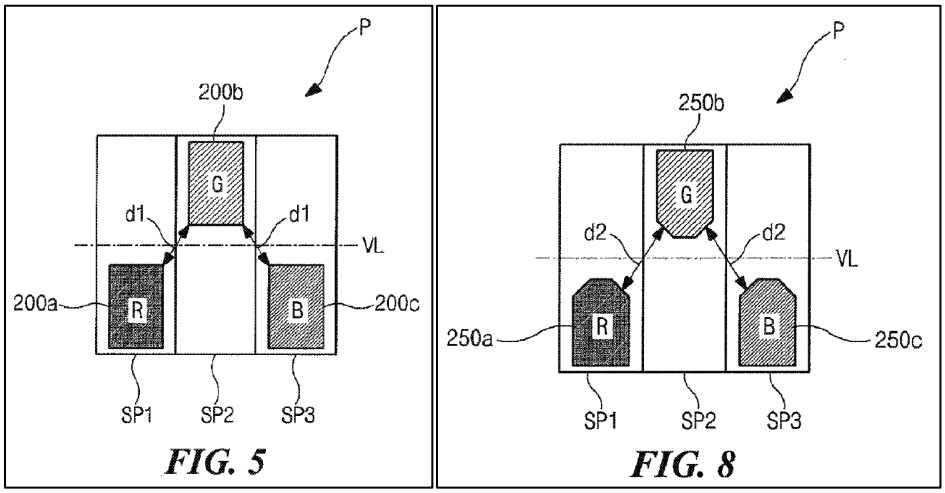
245. Even if a POSITA would have had a reason to modify Dr. Pattison's proposed combination of Matthies and Yamada based on Hong, a POSITA would have had no motivation to try and apply Hong's teachings to Dr. Pattison's modified quad sub-pixel structure.

246. As I discussed above in Section VIII.C, Hong is concerned with addressing a problem it calls the "shadowing effect." Hong, ¶¶[0010]-[0011]. Hong describes the vacuum thermal evaporation method for depositing organic emission layers onto a substrate when manufacturing an OLED display device. Hong, ¶¶[0009]-[0011]. When displays are designed to place pixels of different colors too close together, depositing the organic patterns for the pixels could result in the organic materials overlapping, which can then cause the pixels to emit the wrong color light. As Hong explains, "a border portion between the adjacent two sub-pixel regions does not emit a predetermined colored light due to overlapping, which may be referred to as a shadowing effect." Hong, ¶[0010]. Thus, the pixel arrangement must be designed to allow for sufficient space between different colored pixels, but this creates a "dead zone that is not used for emission." Hong, ¶[0011]. The need to maintain spacing between pixels limits the resolution and aperture ratio of the display. Hong, ¶[0011]. There is thus a tension between maintaining sufficient spacing between pixels to minimize the shadowing effect, and improving the resolution and aperture ratio of the display.

247. As I explained above, the zigzag pixel arrangement is Hong's solution intended to reduce the shadowing effect, and thus improve manufacturability of the display. The zigzag pattern is what allows for greater separation between adjacent pixels of different colors to result in improved aperture ratio and resolution while

reducing the shadowing effect. Hong, ¶¶[0036], [0043]-[0044], [0048]-[0049], [0052]. This diagonal separation can then further be exploited by truncating the diagonal corners and correspondingly increasing the pixel sizes, resulting in further improvements in aperture ratio and resolution. Hong, ¶¶[0061]-[0062].

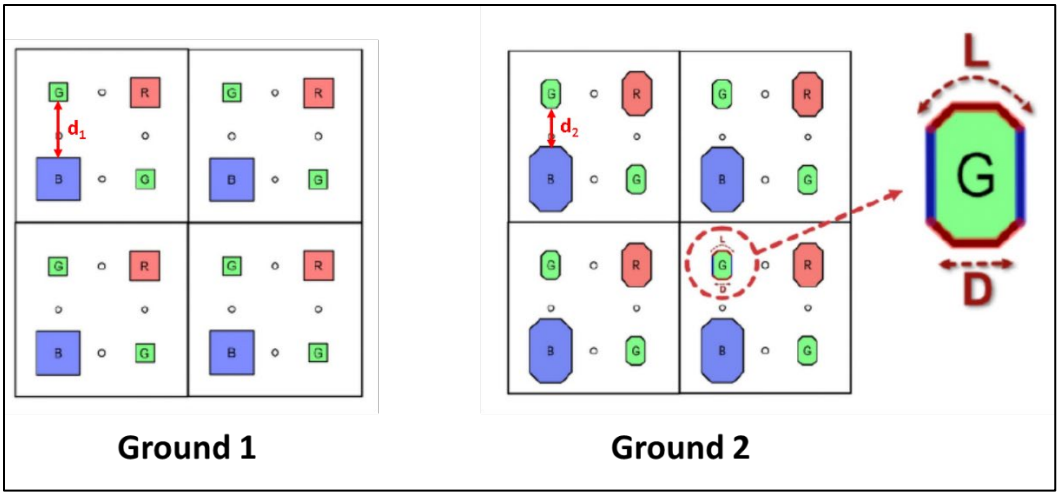
248. For example, in Hong's first embodiment, which uses rectangular pixels, the pixels are separated by a distance d_1, as shown in Figure 5 (below left). In Hong's second embodiment, which truncates the corners of the pixels, the pixels are separated by a distance d_2, as shown in Figure 8 (below right). The distance d_2 is a greater distance than the distance d_1. Hong, ¶[0061].



Hong's pixels with truncated corners can then subsequently be further enlarged in area than in the first embodiment, thus increasing the aperture ratio, Hong, ¶[0061], and even when subsequently reducing the area of the pixel region, can increase the resolution of the display by allowing for more pixel regions in a given unit area than before, Hong, ¶[0062].

249. And as I've explained above, a POSITA would not have been motivated to truncate the corners of the sub-pixels in Matthies' tiled display, and would not have expected success in doing so. In the quad sub-pixel structure of Matthies (and in Dr. Pattison's combination of Matthies with Yamada), the shortest distances between different color pixels are in the horizontal and vertical directions, rather than the diagonal directions. Thus, truncating the corners of the sub-pixels would not increase the shortest distance between pixels, and thus would not help with achieving increased aperture ratio or resolution. In fact it would just result in the opposite effect: it would reduce the useful area of the pixels and reduce the aperture ratio of the display, for no benefit and no reason. Note that this would also further reduce the lifetime of the display because a greater current density would have to be applied to the pixels with truncated corners to achieve the same level of brightness as before.

250. Dr. Pattison's proposed modification of Matthies and Yamada based on Hong also contradicts Hong's teachings. The figure below is an annotated version of images from Dr. Pattison's declaration illustrating his proposed combinations for the combination of Matthies and Yamada (Ground 1, shown below left) and the combination of Matthies, Yamada, and Hong (Ground 2, shown below right).



251. As shown above, in Dr. Pattison's proposed combination of Matthies and Yamada, the shortest distance between two pixels is d_1, between the blue and green pixels. In Dr. Pattison's proposed combination of Matthies and Yamada and Hong, the shortest distance between two pixels is d_2, between the blue and green pixels. The distance d_2 is actually ***smaller*** than the distance d_1. Thus, by further modifying his proposed combination of Matthies and Yamada by using an oblong, octagonal pixel, allegedly based on Hong, Dr. Pattison arrives at a pixel arrangement structure where adjacent pixels are ***closer together***. Dr. Pattison's proposal is thus contrary to Hong's teaching to increase the distance between organic patterns (thus increasing the distance between the light emitting regions for each pixel), and would exacerbate the "shadowing effect" and make the display more difficult to manufacture, contrary to Hong's goals.

C. Dr. Pattison fails to show that the proposed combination of Matthies, Yamada, and Hong satisfies all of the limitations of any claim of the ’578 Patent

252. Dr. Pattison also fails to show that his proposed combination of Matthies, Yamada, and Hong would meet all of the limitations of any claim of the ’578 Patent.

253. Dr. Pattison argues that claims 40, 43, 45–47, and 51–52 of the ’578 Patent would have been obvious over the combination of Matthies, Yamada, and Hong. Claim 40 depends from and incorporates all limitations of independent claim 1. Claim 43 depends from and incorporates all limitations of independent claim 42. Claims 46, 47, 51, and 52 all depend from and incorporate all limitations of independent claim 45.

254. Independent claims 1, 42, and 45 each include specific limitations specifying certain distances between pixels. For example, claims 1 and 42 recite:

> wherein a <u>shortest distance</u> between two nearest ones of the first pixels in one of the first sets is <u>greater than a shortest distance</u> between one of the second pixels and one of the third pixels that are nearest each other in one of the second sets

And claim 45 similarly recites:

> wherein a <u>shortest distance</u> between any two of the group of four neighboring ones of the plurality of first pixels is <u>greater than a shortest distance</u> between the only one of the second pixels and the third pixels included in the virtual quadrangle and a nearest one of the second pixels

> or the third pixels in a direction perpendicular to any side of the virtual quadrangle

Claim 1 additionally recites:

> wherein a region having a width in the second direction that is equal to a width of the first pixels in the second direction, extending parallel to the first direction, and completely overlapping a row of the first pixels extending in the first direction, is entirely offset in the second direction from at least one of the second pixels or the third pixels in at least one of rows of the second pixels and the third pixels adjacent to the row of the first pixels.

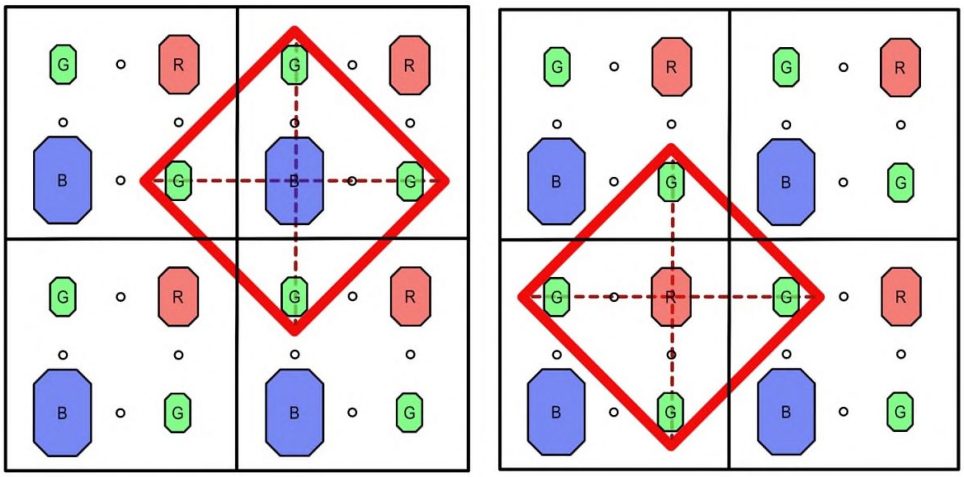
Dr. Pattison fails to show that any of these limitations are satisfied by his proposed combination of Matthies, Yamada, and Hong. In fact, Dr. Pattison fails to show how any one of the limitations in independent claims 1, 42, and 45 are met by his proposed combination.

255. As to claims 45–47 and 52, Dr. Pattison's entire analysis of these claims boils down to two paragraphs. Dr. Pattison does not even attempt to address the specific claim limitations of dependent claims 46, 47, and 52. As to independent claim 45, the entirety of Dr. Pattison's analysis is two sentences and two images, all reproduced below:

> 474. As I explained above (*see supra* Section VIII.B.r) claim 45—and the claims that depend on it--requires that "***some of the edges***" of the

green "first pixels" cooperate to form a "***virtual quadrangle***" that encloses a single red/blue pixel.

475. To the extent not already taught by Matthies and Yamada, as shown in the demonstrative below, when Hong's pixel shape with truncated corners is applied, two complete sides of each of Matthies' green sub-pixels form the claimed "virtual quadrangle" (i.e., the now truncated corners cooperate to form the quadrangle):



256. Dr. Pattison thus only addresses a single limitation of claim 45 relating to the limitation "a virtual quadrangle containing outer edges comprising some of the edges of a group of four neighboring ones of the plurality of first pixels." Dr. Pattison fails to show how any other limitations in independent claim 45 are met by his proposed combination.

257. And even Dr. Pattison's analysis of this single limitation fails to show that this limitation is met. Dr. Pattison alleges that "two complete sides" of each of four adjacent green pixels "cooperate to form the quadrangle." However, if the green

pixels are all to have the ***same*** size and shape (as Dr. Pattison appears to assume), the sides formed by the truncated corners of adjacent green pixels could only "cooperate to form" a side of the virtual quadrangle if the corners of the green pixels were truncated at 45 degree angles. Dr. Pattison has not even alleged that the green pixels are so truncated. And there is no teaching in Hong that the pixels must be truncated at 45 degree angles. On the contrary, a POSITA would understand that the optimum angle of truncation would be one that would maximize the distance between pixels while maximizing the available pixel area. (And for the reasons explained above, a POSITA would not truncate the corners in Dr. Pattison's proposed combination, as that would not increase the shortest distance between any pixel;s provide any gain any as Dr. Pattison proposes). The amount and angle of truncation would vary, depending on the pixel arrangement, the precise dimensions of the pixels, and the spacing between them.

258. As I noted above, the oblong octagonal pixel shape that Dr. Pattison creates for this combination with Hong does not appear anywhere in Hong. It also does not appear anywhere in Matthies, Yamada, or any other reference cited by Dr. Pattison. The illustrated elongated octagonal shape, including the relative dimensions and sizing, all appear to be entirely a creation of Dr. Pattison, created without explanation of how it was created, and with no basis in any of the cited references.

259. Dr. Pattison's proposed combination of Matthies, Yamada, and Hong does not provide enough information about which pixels are elongated and by how much, or what the dimensions of the pixels and distances between pixels are in this structure. Dr. Pattison states only that he "[a]ppl[ies] Hong's elongated pixel shape to Matthies." Ex. 1003, ¶469. But Dr. Pattison's illustration of his proposed combination cannot be drawn to scale, because there is simply nothing in any of the references relied on by Dr. Pattison that indicate to a POSITA how much the pixels should be elongated and how, or what the dimensions of the pixels and distances between pixels should be. He does not even attempt to explain why a POSITA making the combination would end up with the sizes and shapes in the drawings as he has drawn them. Thus, none of Dr. Pattison's opinions that simply rely on annotations of his drawings have support in the references he cites. Dr. Pattison's drawings of his proposed combination of Matthies, Yamada, and Hong are thus arbitrary.

260. Since each of the challenged claims include limitations that would be affected by changing the shapes and sizes of the pixels, Dr. Pattison has failed to demonstrate how these limitations would be satisfied by his proposed combination of Matthies, Yamada, and Hong.

XII. OBJECTIVE INDICIA OF NON-OBVIOUSNESS OF THE CHALLENGED CLAIMS

261. I have been asked by counsel for Samsung Display to provide my opinion on whether objective indicia of non-obviousness apply to the challenged claims. As I explain below, it is my opinion that the claimed inventions of the ’578 Patent satisfied a long-felt but unmet need, overcame industry skepticism, that others failed while Samsung Display was successful, and that others copied the claimed inventions of the ’578 Patent.

A. Long-felt But Unmet Need

262. It is my opinion that the inventions of the challenged claims of the ’578 Patent satisfied long-felt but unmet needs.

263. Samsung Display pioneered the successful commercialization of AMOLED displays in 2007 and has since continued to lead the display industry in research and development of AMOLED display technologies.

> In early 2007, Samsung Display confirmed AMOLED’s marketability by applying a handful of small and medium-sized OLED panels . . . In September and October of the same year, a mass production line started its official operation in Cheonan, South Chungcheong Province . . . At the time when Samsung Display announced its intention to mass-produce small and medium-sized OLED products, other global companies expressed little interest, dismissing it as having no marketability . . . 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. According to a Samsung Display official, "Ever since the official mass production of AMOLED panels, Samsung Display's small and medium-sized AMOLED panel technology has also made rapid progress along with the development of mobile IT devices."

Ex. 2064 at 5-6.

264. But AMOLED displays at the time, particularly AMOLED displays for mobile devices such as smartphones and tablets, suffered from low display resolution and image quality. As reported in the Hankyung News in November 2013:

> People have said that it would ***not be easy to realize the full HD*** (1920 × 1080 pixels) definition with active-matrix organic light-emitting diode (AMOLED) display. It was also said that even with the successful development of full HD AMOLED panel, securing a sufficient yield rate (ratio of finished products) for mass production will be difficult . . . However, it is difficult for the resolution of the small-sized displays to be at the level of full HDs as the pixels are realized by evaporating the light emitting organic materials. This is why even some internal voices at Samsung Display opined that that AMOLED should be abandoned and pursue LCD instead.

Ex. 2065 at 5-6 (emphasis added).

265. As another example, a Korea Industry Post article from March 2013 observed that "[r]eaching the high-resolution point with true pixel densities greater

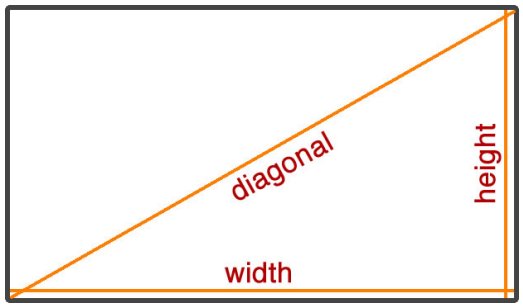
than 300 pixels per inch (ppi) has been a challenge for AMOLED displays, as it is ***difficult to achieve dense pixel arrangements*** . . . while still securing enough display brightness and not compromising power consumption"). Ex. 2013 at 3 (emphasis added).

266. There was a longstanding need in the industry for pixel arrangements that would allow the mass-production of mobile device AMOLED displays with high resolution and high pixel densities (measured as pixels per inch or "PPI") while ensuring sufficient aperture ratio and adequate pixel lifetime, all in order to support "full high definition" displays.

267. Full high definition or "full HD" resolutions typically require 1920 x 1080 pixels to be present on a display screen. By the time of the '578 Patent, "there [wa]s a tremendous amount of . . . 1920x1080 content available" and "[d]isplaying that content at its native resolution (without the need to rescale up or down)" was understood to "result[] in the best possible image quality." Ex. 2014 at 2.

268. Therefore, the technical challenge leading up to the inventions of the '578 Patent for display manufacturers was being able to manufacture small/medium-sized AMOLED displays that are suitable for use in mobile devices with *pixel densities* that are sufficiently high to enable the packing of 1920 x 1080 pixels on the display (*i.e.*, full HD).

269. Pixel densities are commonly expressed as pixels per inch or PPI. PPI indicates how many pixels are on a 1-inch line on a display. Calculating a display's PPI involves two steps. First, the Pythagorean Theorem and the screen's width and height in pixels (*e.g.*, 1920 pixels in width and 1080 pixels in height) are used to calculate the screen's *diagonal* length in pixels.



$$diagonal\ (pixels) = \sqrt{width\ (pixels)^2 + height\ (pixels)^2}$$

Then, to calculate the PPI, the display's diagonal length in pixels is divided by the length of the diagonal in inches.

$$PPI = \frac{diagonal\ (pixels)}{diagonal\ (inches)}$$

270. Thus, in order to enable full HD on an AMOLED display for a typical mobile device measuring 5.5 inches diagonally, the AMOLED display must have a pixel density of 400 ppi (or more).

$$\sqrt{1920\ width\ (pixels)^2 + 1080\ length\ (pixels)^2} \cong\ 2{,}203\ diagonal\ (pixels)$$

$$\frac{2{,}203\ diagonal\ (pixels)}{5.5\ diagonal\ (inches)} \cong 400\ PPI$$

271. Increasing the pixel densities in AMOLED displays was not a straightforward task for display companies, as factors such as manufacturing limitations, pixel aperture ratio (and display brightness/luminance), organic material lifetime, and power consumption were intertwined with the packing of additional pixels on a display. U.S. Patent No. 9,697,760 (Ex. 2015) assigned to BOE provides an in-depth discussion of these challenges:

> In practice, the resolution of a display device can be improved by increasing Pixels Per Inch (PPI) of the display device . . . Above all, the following technical problems usually occur in the display devices of the related art:
>
> 1) The actual display resolution of a display device is the same as the physical resolution thereof. To obtain higher display resolution, it is needed to improve the physical resolution of the display device by increasing the number of sub-pixels. As described above, ***it is difficult to further increase the resolution when the number of sub-pixels increases up to a certain amount, due to the limit of the improvement to the process;***
>
> 2) The fact that the number of sub-pixels in a display device is large results in large number of data lines, and thus ***increases the power consumption of the display device and reduces the aperture ratio of the display device*** (Generally, the aperture ratio in the art refers to the ratio of the area of light-emitting region in the pixel region and the area of the repeatable pixel unit in the display region. The larger the aperture ratio is, the lower the required brightness of each pixel light-emitting

> region is and the lower the current density of the brightness of the light-emitting region is so as to achieve the same display brightness). ***When the resolution is high, it is hard to ensure the aperture ratio of sub-pixel, which may influence on the characteristics of the products, such as lifetime, brightness*** and the like, consequently.
>
> 3) The number of sub-pixels in the display device is large, and the area of each sub-pixel is small, which thus causes the manufacture process of the display device to have great difficulties and high cost. Take the organic light emission display (referred to as OLED) for example, in the related art of manufacturing top-emitting active matrix organic light emission diode (AMOLED), since the fine metal mask (referred to as FMM) usually has limitation to the minimum opening when used for evaporating the pixels arranged in parallel, the sub-pixels with different colors have limitations to the distance between the openings. ***Thereby, the manufacture process of the display device is inevitably limited to the area of openings of the fine metal mask and the precision of evaporation process, which causes the difficulty in implementing the display device with high resolution***.

Ex. 2015, 1:40-2:22 (emphases added).

272. A 2006 Society for Information Display ("SID") paper likewise explains that "physical limitations of manufacturing" were "bottlenecks of achieving high display resolution on active-matrix OLED displays," with "the highest resolution" limited to "about 180ppi." Ex. 2016 at 1. On a typical smartphone with a 5 inch diagonal display, the resolution on a 180ppi display would be just over

720x480 pixels, which is comparable to the resolutions available on VHS tapes used in the 1980s and 1990s.

273. The longstanding challenge to develop higher resolution AMOLED displays for mobile devices that could be produced at commercial scales was made especially difficult because of manufacturing challenges with OLEDs, and particularly with depositing the light-emitting organic materials. By the time of the inventions (and even today), fine metal mask ("FMM," also referred to as "shadow mask") had become the "most common method for patterning primary colors for full color AMOLED" displays. Ex. 2017 at 4 (explaining that "it is almost impossible to realize a resolution higher than 230ppi in a mass production environment" using FMM). FMM was understood as having "many disadvantages" even though the display industry was heavily relying on it. For example, a 2007 patent publication by researchers at AU Optronics Corp. states that:

> *Lower resolution of the panel:* … the area of the opening of the [fine metal] mask determines the resolution of the organic electroluminescent panel, and the resolution of the conventional full-color panel is limited to the process capability. The resolution of the conventional panel adopting the shadow mask process is … usually not more than 180 ppi.

Ex. 2018, ¶[0009].

274. Because of the difficulties posed by FMM manufacturing, display manufacturers considered alternative methods to pattern organic materials, including inkjet printing and laser-induced thermal imaging ("LITI"). However, these alternative methods did not show sufficient promise to be used for commercial scale manufacturing of high pixel density AMOLED displays. In addition, manufacturers had already expended significant resources to utilize FMM in their AMOLED manufacturing lines, including to set up "all kinds of equipment[] such as mask fabrication, … precise alignment system[s], … mask chamber[s], … mask cleaning system[s], and mask inspection equipment." Ex. 2018 ¶[0007].

275. In 2007 (just after the start of Samsung Display's successful mass-production of AMOLED displays), the authors of the "Advances in AMOLED Technologies" chapter in a 2008 textbook on mobile displays titled "Mobile Displays Technology and Applications" wrote:

> The merging of several multimedia applications such as DSC, cellular phones, and DMB into one mobile device will become a trend in the near future. It makes the development of high resolution a critical factor in OLED displays. However, ***the limitations of FMM for high resolution will become a key issue when it comes to considering mass production***.

Ex. 2019 at 23 (emphasis added). And in December 2010 (about a year before the inventions of the '578 Patent), LG Display's researchers wrote that "the key

challenging issue" for "AMOLEDs for mobile application" was the "limitation on . . . realizing a high resolution[,]" Ex. 2020 at 3, with "the highest display resolution resulting from the use of a shadow mask [being] about 230 ppi." Ex. 2020 at 4.

276. In order to successfully design an AMOLED display with sufficiently high pixel densities for a full HD display, it was understood that the specific shapes, sizes, and layouts of the red, green, and blue sub-pixels (pixel arrangements) would be key to overcoming manufacturing limitations such as FMM. As explained by researchers at AU Optronics ("AUO"):

> [The] arrangement of the sub-pixel devices may pose a considerable level of difficulty in the display panel manufacturing process…The resolution of an OLED display panel depends on the opening dimensions of the shadow mask…Misalignment in the sub-pixel devices results in problems such as no deposition of the organic layer and thus the short-circuiting of the lower electrode and the upper electrode of the sub-pixel device, and deposition of the organic layer in an adjacent sub-pixel, which causes mixing of colors or non-emission of light.

Ex. 2021, ¶[0004]. The '578 Patent likewise discusses the impact of pixel arrangements on critical display characteristics such as aperture ratio: "An organic emission layer included in the pixel of an OLED display may be deposited and formed by using a mask such as a fine metal mask (FMM). When reducing a gap between the neighboring pixels to obtain a high aperture ratio of the pixel, deposition

reliability may be deteriorated. On the other hand, when increasing the gap between the pixels to improve the deposition reliability, the aperture ratio of the pixel may be deteriorated." '578 Patent, 1:46–53.

B. Overcoming Industry Skepticism

277. As I explained above, the industry recognized a longstanding technical need for higher resolution displays with high pixel densities, sufficient aperture ratio, and manufacturability that would make them suitable as full HD AMOLED displays. Because of the significant challenges with their research and development, the industry was skeptical that any company or research group could develop a pixel arrangement that would enable the manufacture of full HD AMOLED displays for mobile devices. In fact, the industry expressed a desire to use LCDs (which did not suffer from similar manufacturing limitations) as a preferred alternative for future full HD displays for smartphones. A November 2013 Hankyung News article captures the industry's skepticism (including skepticism from within Samsung Display itself) leading up to the inventions of the '578 Patent:

> People have said that ***it would not be easy to realize the full HD (1920 × 1080 pixels) definition with active-matrix organic light-emitting diode (AMOLED) display***. It was also said that even with the successful development of full HD AMOLED panel, ***securing a sufficient yield*** rate (ratio of finished products) f***or mass production will be difficult*** . . . [I]t is difficult for the resolution of the small-sized displays to be at the level of full HDs as the pixels are realized by evaporating the light

> emitting organic materials. This is why ***even some internal voices at Samsung Display opined that that AMOLED should be abandoned and pursue LCD instead***.

Ex. 2065 at 5-6 (emphases added). The article goes onto explain that the Diamond Pixel arrangement of the '578 Patent overcame the industry skepticism:

> Nevertheless, the company persevered to uphold the principle of "Samsung smartphone is AMOLED itself," and it finally overcame all the barriers . . . ***boast[ing] a sharper image quality by adopting the Diamond Pixel structure***.

Ex. 2065 at 6 (emphasis added).

278. Samsung Electronics, the maker of the popular Samsung Galaxy series devices, "consider[ed] using LCD for the Galaxy S4, due to the supposed insurmountable technical difficulties that would prevent it from making enough panels for the upcoming blockbuster." Ex. 2022 at 2. Likewise, an article published by ZDNet Korea reported on similar expressions of skepticism by the industry:

> [F]oreign press expressed ***skepticism about AMOLED*** and said, 'Possibility to develop as the next-generation display is limitless, but there are questions as to whether it can overcome fierce competition against existing Liquid Crystal Device (LCD)' . . . AMOLED faced difficulties in implementing high resolution due to a tricky process in implementing pixels that involved detailed deposition of red, green and blue organic light emitting devices.

Ex. 2023 at 1-2. The ZDNet Korea article goes onto explain that Samsung Display overcame this industry skepticism through the introduction of the patented Diamond Pixel arrangement.

> Samsung Display invented the 'diamond pixel structure' that is beneficial to character expression and legibility starting with Galaxy S4 by continuously carrying out experiments to change the pixel structure that is deposited on the pixel to overcome the issues of resolution. This structure enhanced the character expression capability and space utilization by laying out sub pixels in a diagonal manner to create a diamond structure instead of the existing row format. Through this, the resolution was improved from Galaxy S4 to Full HD(1920×1080) level to completely resolve existing concerns that "it is difficult to implement Full HD resolution in 5-inch level screens with AMOLED."

Ex. 2023 at 2.

279. Apple did not adopt AMOLED displays for its iPhones until the iPhone X which was launched in 2017. Ex. 2024 at 2. Instead, Apple used LCD displays (under the marketing name "Retina Display") that outperformed the AMOLED displays in Samsung's Galaxy smartphones in display resolution and pixel densities. As an example, the iPhone 4 (released in 2010) featured a LCD display with 326 ppi at 960x640 pixels, beating Galaxy S1's 233 ppi AMOLED display (800x480 pixels). Ex. 2025 at 2 (DisplayMate awarding the "Best Mobile Display Award" to the iPhone 4's LCD "Retina" display, finding it "the brightest and sharpest display").

With the patented Diamond Pixel arrangement, Samsung Display overcame Apple's skepticism, and the Galaxy S4 (which was the first commercial product to adopt the '578 Patent's pixel arrangement) outperformed the LCD display in Apple's iPhone 5:

> ***Samsung Display neatly overturned the competitors' expectation of the "impossibility."*** The company developed the 4.99-inch Full HD AMOLED panel at the end of last year and in April, it was successful in mass production by applying it to Galaxy S4. ***The number of pixels per inch is 441 ppi, much higher than the iPhone 5's 326 ppi.*** A company official said that "It is putting 441 dots on one inch," and mentioned that "it required a highly sophisticated evaporation technology to accurately place the fine dots."

Ex. 2065 at 5 (emphases added).

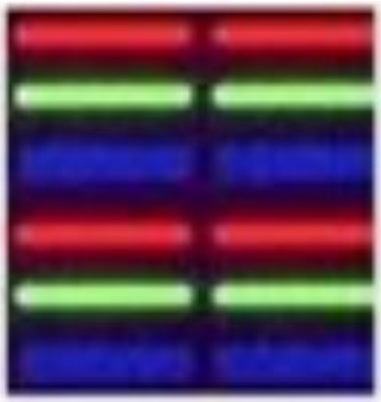
C. Failure of Others

280. Failure of others furthers supports my opinion that the challenged claims would not have been obvious. In the years before the '578 Patent (and even after the introduction of the novel pixel arrangements of the '578 Patent), many research groups and display manufacturers proposed pixel arrangements that would be suitable for use in commercial AMOLED displays for mobile devices that would enable higher resolution and pixel densities.

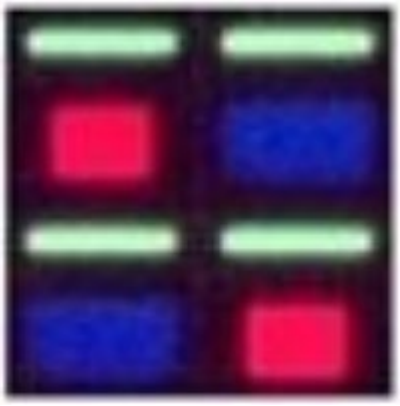
281. Companies such as Sarnoff (assignee of the Matthies reference published in 2005), Sanyo Electric (assignee of the Yamada reference published in

2002), and Seiko-Epson (assignee of the Murai reference published in 2005) and researchers such as Phan (whose reference was published in 2004) had been proposing ideas for display pixel arrangements well before the ’578 Patent. I am not aware of any of these prior pixel arrangements having been used in flagship mobile devices that use AMOLED displays. Moreover, the long duration of time between the publications of the Matthies, Yamada, Murai, and Phan references and the invention of the ’578 Patent support the non-obviousness of the challenged claims.

282. There are many examples of display pixel arrangements that came before Samsung Display’s Diamond Pixel arrangement. This includes the traditional RGB Stripe arrangement shown below which was used, for example, in the Samsung Galaxy S2 product launched in 2011. The RGB Stripe arrangement enabled a 800 x 480 resolution with 207 PPI. Ex. 2023 at 2. The Pentile arrangement (also shown below) was used in the Samsung Galaxy S product launched in 2010 and enabled a display resolution of 800 x 480 with 233 PPI. Ex. 2023 at 2.



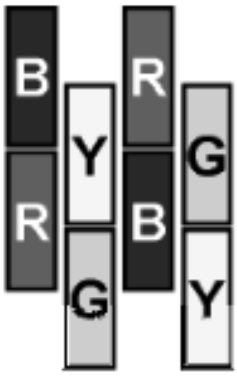
RGB Stripe Arrangement



Pentile Arrangement

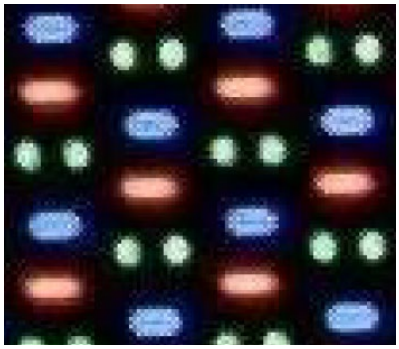
283. In December 2010, researchers at LG Display proposed a "pixel arrangement scheme based on the conventional shadow mask process and ability" which involved "shared emitting aperture area[s] between horizontally adjacent 2 sub-pixel[s]." Ex. 2020 at 3-5. LG Display's proposed pixel arrangement (shown below) led to a prototype that was still displaying images at 229 PPI ("4.3-in-sized WVGA (854xRGBx480)"), which fell short of the full HD standard. *See* Ex. 2020. at 3.

284. And in 2015, AU Optronics proposed a RGBY pixel arrangement in 2015 (Ex. 2033 at 3 fig. 4, shown below). I am not aware of any of these proposed pixel arrangements having been implemented in any full HD AMOLED display. I am also not aware of these pixel arrangements being used for any AMOLED display for a flagship mobile device.



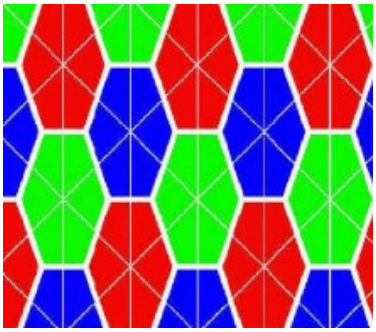
AUO's RGBY Arrangement

285. Display manufacturer BOE proposed a pixel arrangement known as "Delta" arrangement (shown below), which has also been called the "Zhou Dongyu" pixel arrangement. *See* Ex. 2034 at 1. But this arrangement was criticized as being "inferior to [Samsung Display's] diamond arrangement," having the problem "that the arrangement of sub-pixels is not uniform," Ex. 2034 at 1, and described as looking "greenish" with "blurring of the edges," Ex. 2035 at 2.



286. Display manufacturer Tianma proposed an alternative "hexagon shape" pixel arrangement (Ex. 2036 at 2, reproduced below), it avoids the use of FMM by employing an "inkjet printing process"—a method that I am not yet aware of having

resulted in successfully mass-produced AMOLED displays for flagship mobile devices.



D. Industry Praise and Recognition

287. There has been significant praise for commercial products that implemented the ’578 Patent’s pixel arrangements, including specific praise for the pixel arrangements themselves and the higher display resolution (including high PPI) and superior image quality enabled by them.

288. The Samsung Galaxy S4 smartphone was released in April 2013 with a 5-inch “Super AMOLED” display by Samsung Display with a screen resolution of 1080 x 1920 pixels and 441 PPI. Ex. 2013 at 2. Samsung Galaxy S4’s AMOLED display was the first commercial embodiment of the ’578 Patent. *See* Ex. 2026 at 4. Industry praise for the Galaxy S4’s AMOLED display, and specifically the novel pixel arrangement of the ’578 Patent, was overwhelming:

- “Samsung Display’s proprietary new technology that places pixels in a diamond form was used in the 5-inch full HD-level Super AMOLED display that Galaxy S4 is equipped with;” “[A]ll weaknesses of the existing

AMOLED displays were eliminated through the pixel array method on a proprietary diamond structure;" "Full HD Super AMOLED provides the same color as the monitor for professionals." Ex. 2026 at 2.

- "Reaching the high-resolution point with true pixel densities greater than 300 pixels per inch (ppi) has been a challenge for AMOLED displays . . . Samsung Display, however, was able to enhance AMOLED display performance . . . with its new [pixel] structure . . . [a]s a result, the AMOLED display was able to achieve a denser pixel arrangement, boosting its pixel density to greater than 400 ppi and resulting in 1920x1080 Full HD display in the Galaxy S4." Ex. 2013 at 3.
- "For the first time, Active matrix (AM) . . . OLED exceeded LCD in the competition for resolution of smartphones through Galaxy S4. Until now, the established theory was that it would be difficult for AMOLED to exceed the resolution of LCD due to its light emitting diode and patterning limits . . . Samsung Display succeed[ing] in innovating resolution by changing the existing rectangular patterning structure to a diamond structure. A completely new structure was devised because it was difficult to overcome the 400ppi barrier with the existing rectangular patterning[.]" Ex. 2037 at 3.

- "A high resolution screen shot . . . shows an interesting design and sub-pixel arrangement, which Samsung calls Diamond Pixels. First of all, the Red, Green, and Blue sub-pixels have very different sizes – Blue is by far the largest because it has the lowest light emission efficiency, and Green is by far the smallest because it has the highest efficiency. The alternating Red and Blue subpixel arrangement leads to a 45 degree diagonal symmetry in the subpixel layout This allows vertical horizontal and particularly diagonal line segments and vectors to be drawn with reduced aliasing and artifacts In order to maximize the subpixel packing and achieve the highest possible pixels per inch (ppi) that leads to diamond rather than square or stripe shaped Red and Blue subpixels . . . It's a form of high-tech display art…" Ex. 2027 at 1.

289. Moreover, after years of using LCD displays for its iPhone products, Apple adopted Samsung Display's AMOLED displays using the pixel arrangement of the '578 Patent starting with the iPhone X, drawing significant industry praise:

- "Samsung Display has made the iPhone X a very good screen . . . Apple and Samsung Display have used a diamond [pixel] layout for the OLED screen's sub-pixels on the iPhone X . . . The iPhone X is the most innovative and high performance Smartphone display that we have ever tested." Ex. 2038 at 1-2.

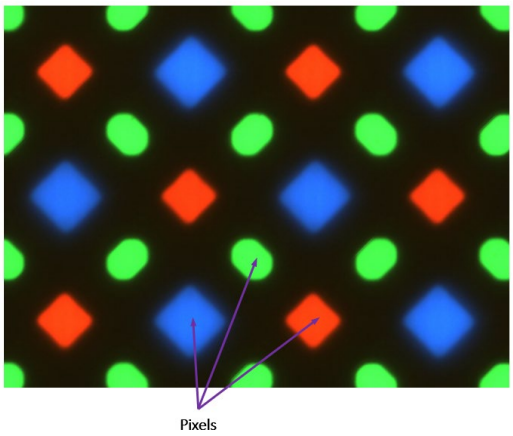
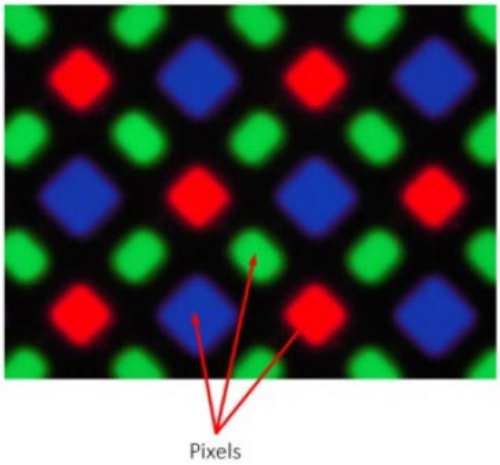
- "[W]e need to congratulate Samsung Display for developing and manufacturing the outstanding OLED display hardware in the iPhone X . . ."; The display has Diamond Sub-Pixels . . . with 458 pixels per inch (ppi), providing significantly higher image sharpness than can be resolved with normal 20/20 Vision at the typical viewing distances of 12 inches or more for Smartphones, so the display appears perfectly sharp." Ex. 2039 at 3-6.
- "The iPhone X display is a whole other level of definition . . . this OLED display is phenomenal . . . it is hard to believe. The individual pixel size on the iPhone X is around 458 pixels/inch with blacker blacks than I've ever seen on a display and the colors are incredibly vivid. This looks to be a Samsung Super AMOLED display with a PenTile diamond matrix configuration with . . . green sub-pixels in a 2:1 ratio with the red and blue sub-pixels." Ex. 2040 at 1-2.

290. Flagship mobile device products following the Galaxy S4 and iPhone X have similarly received praise for having innovative displays that embody the '578 Patent's pixel arrangement. *See, e.g.*, Ex. 2068 (iPhone XS Max); Ex. 2069 (iPhone X); Ex. 2070 (iPhone 14 Pro Max); Ex. 2071 (iPhone 13 Pro Max); Ex. 2072 (iPhone 12 Pro Max).

E. Widespread Copying

291. There is extensive evidence showing that other display manufacturers, including Petitioner Mianyang BOE, copied Samsung Display's patented Diamond Pixel arrangements that practice the challenged claims of the '578 Patent.

292. I reviewed evidence of Petitioner Mianyang BOE's copying of the inventions of the '578 Patent. The teardown image shown below (left) shows the pixel arrangement used in the AMOLED display for the Samsung Galaxy S22 Ultra product. The teardown image shown to its right is of the pixel arrangement used in Mianyang BOE's AMOLED display used in the iPhone 12 and comes from a complaint filed against Mianyang BOE. *See* Ex. 2041 (*Samsung Display Co., Ltd. v. BOE Tech. Co. Ltd. et al.*, Case No. 2-23-cv-00309, Compl. (E.D. Tex. Jun. 26, 2023)). As shown below, the pixel arrangement used in Mianyang BOE's AMOLED display for the iPhone 12 is near identical to Samsung Display's patented pixel arrangement.

Samsung Display AMOLED (Galaxy S22 Ultra)	Mianyang BOE AMOLED (iPhone 12)
 Ex. 2029 at 5 (annotated)	 Ex. 2041 at ¶84

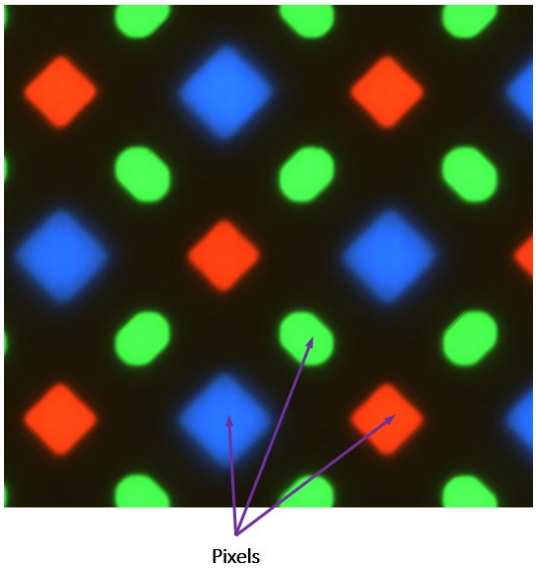
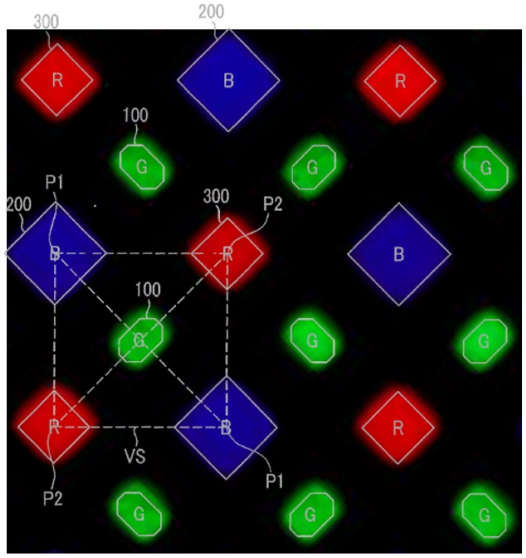
293. I have also reviewed extensive evidence of copying by other display manufacturers, including teardown photographs obtained from samples of AMOLED displays sold by vendors of replacement AMOLED displays for mobile phones. *See* Ex. 2061 (Declaration of Aris Silzars, Ph.D. identifying teardown photographs Ex. 2044-2060).

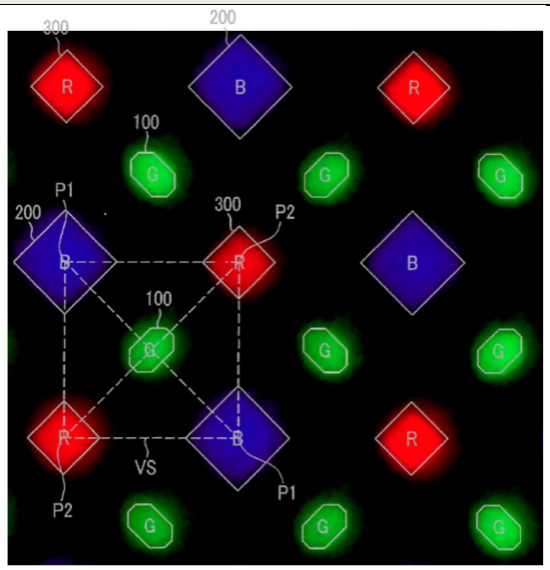
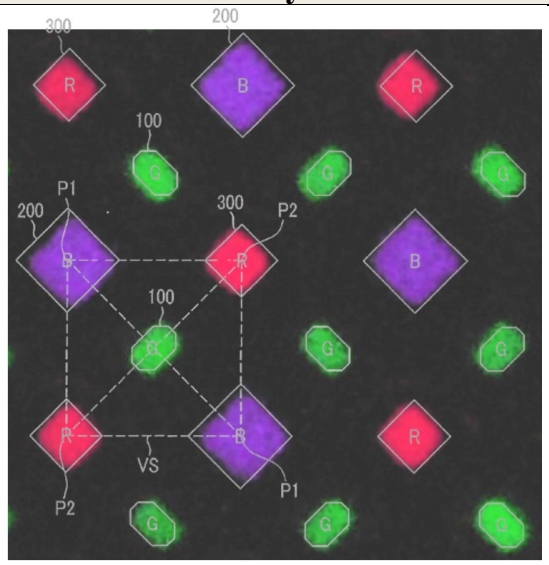
294. A software package called ImageJ was used to obtain certain information about the images of the Galaxy S22 Ultra's pixel arrangement structures, including data such as the areas of the sub-pixels and coordinates of the centers of the sub-pixels. ImageJ is a highly reliable image processing program developed at the National Institutes of Health and is a commonly used tool for microscope image processing, both in academia and commercially. For example, the "Analyze Particles" tool in ImageJ can extract, among other things, the area and center for each region of interest from the outline of the region.

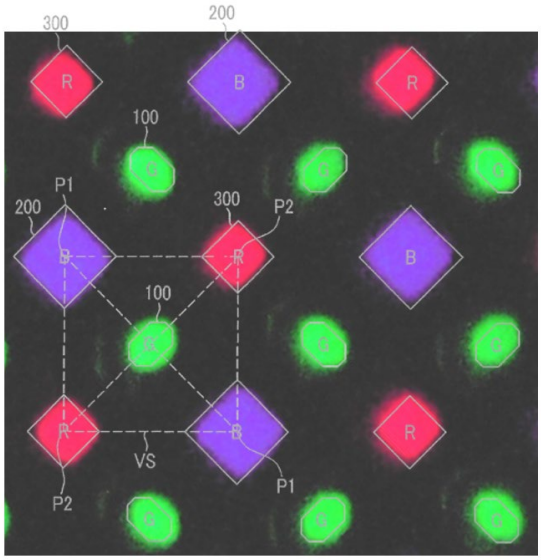
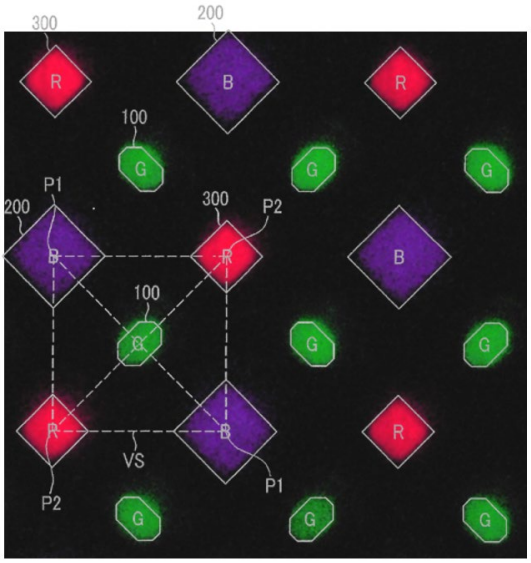
295. Based on the teardown photos and corresponding ImageJ data, I prepared claim charts demonstrating how exemplary copycat products distributed by Group Vertical and Sourcely Plus practice the challenged claims. Ex. 2042 (chart mapping challenged claims 1–6, 10, 12, 17–19, 21–23, 40–47, and 51–52 to Group Vertical AMOLED Display); Ex. 2043 (chart mapping challenged claims 1–6, 10, 12, 17–19, 21–23, 40–47, and 51–52 to Sourcely Plus AMOLED Display).

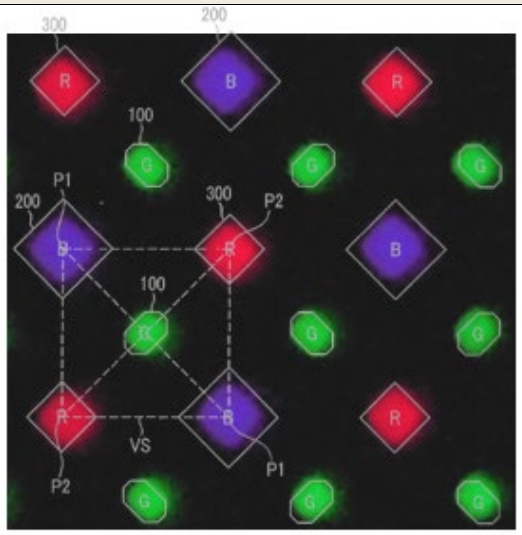
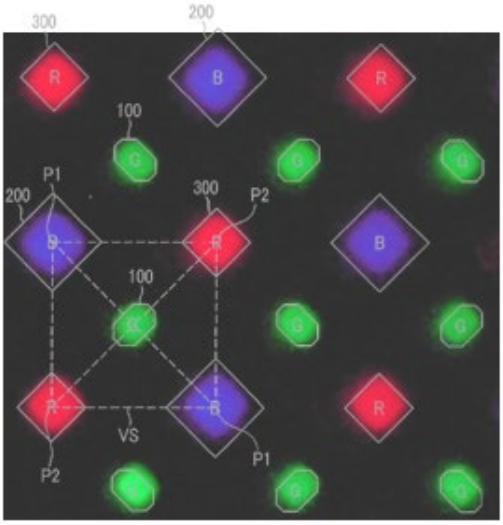
296. These replica AMOLED products and Samsung Display's products have pixel arrangements that appear almost identical, including in the grouping, shaping, sizing, and placement of the red, green, and blue sub-pixels and the formation of pixel arrangements as required by the claims of the '578 Patent. It thus appears from the teardown photographs that other display manufacturers deliberately copied Samsung Display's pixel arrangement designs, including by having access to Samsung Display's patented products or non-public technical information.

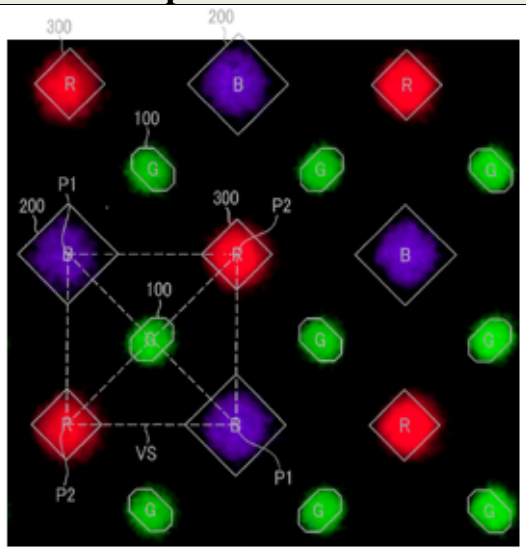
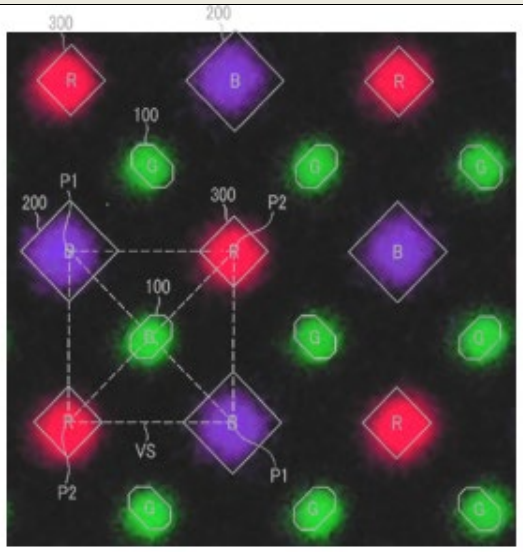
297. Exemplary teardown images of the replica products are shown below with Figure 5 of the '578 Patent overlayed on top. The pixel arrangement used in the Samsung Galaxy S22 Ultra AMOLED Display (which practices the challenged claims) is shown as well for reference.

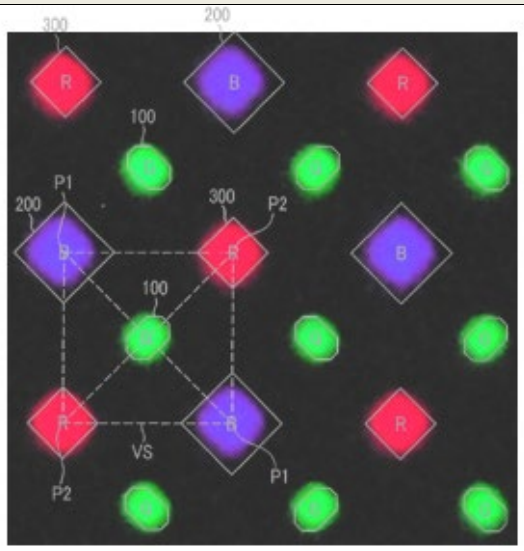
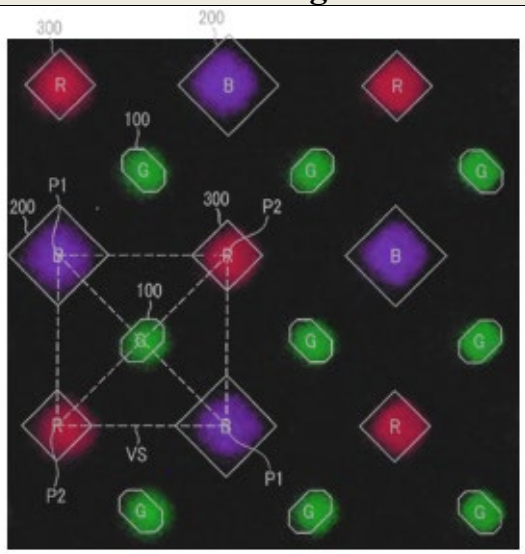
Samsung Display AMOLED (Galaxy S22 Ultra)	Group Vertical
 Ex. 2029 at 5 (annotated)	 Ex. 2044 at 4 (annotated)

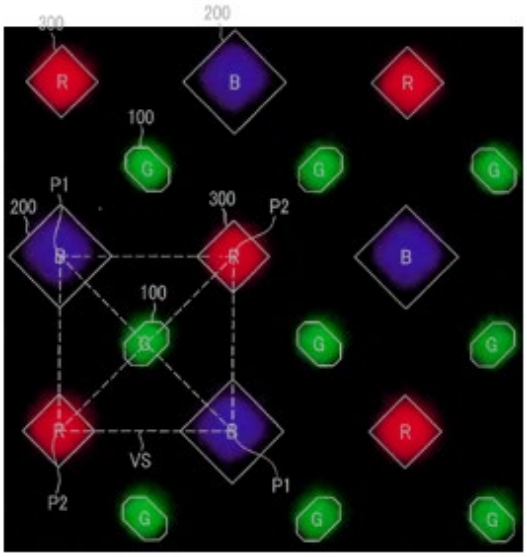
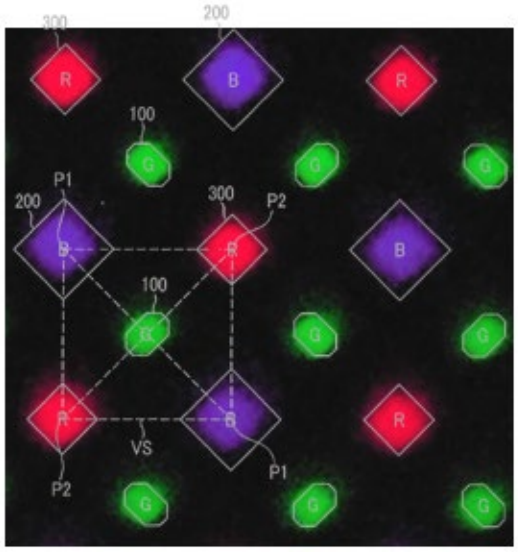
Phone LCD Parts	Sourcely Plus
 Ex. 2045 at 5 (annotated)	 Ex. 2046 at 6 (annotated)

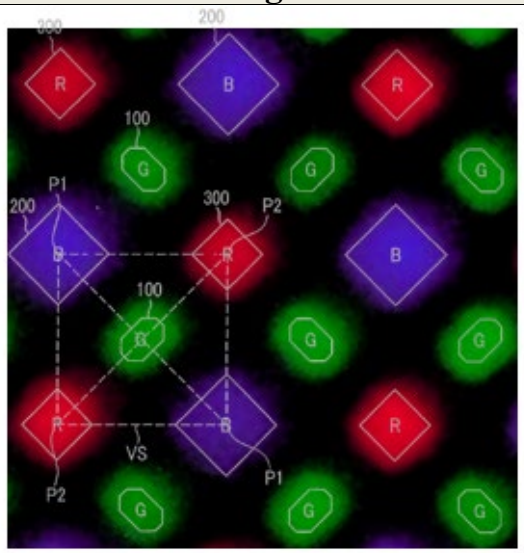
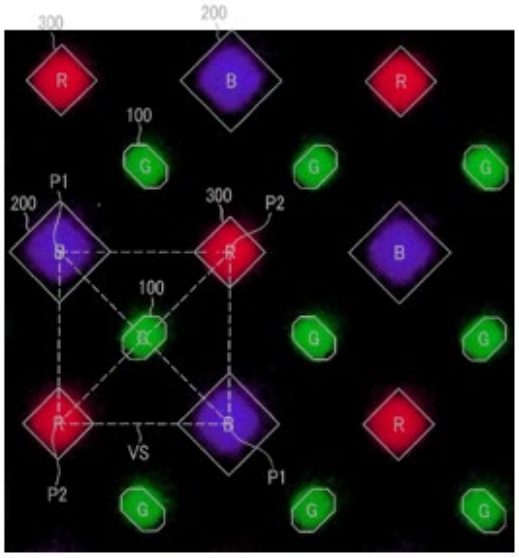
eTech Parts	Parts4LCD
 Ex. 2047 at 6 (annotated)	 Ex. 2048 at 5 (annotated)

MobileSentrix	Mobile Defenders
 Ex. 2049 at 6 (annotated)	 Ex. 2050 at 6 (annotated)

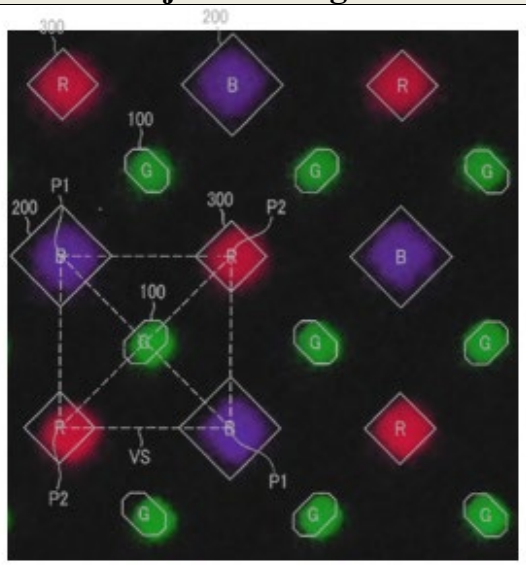
Repairs Universe	SEGMobile
 Ex. 2053 at 6 (annotated)	 Ex. 2054 at 6 (annotated)

Parts4Cells	Wholesale Gadget Parts
 Ex. 2055 at 6 (annotated)	 Ex. 2056 at 5 (annotated)

Captain Mobile Parts	DFW
 Ex. 2057 at 5 (annotated)	 Ex. 2058 at 5 (annotated)

Mengtor	Gadgetfix
 Ex. 2059 at 5 (annotated)	 Ex. 2060 at 5 (annotated)

Injured Gadgets



Ex. 2051 at 6 (annotated)

F. Nexus

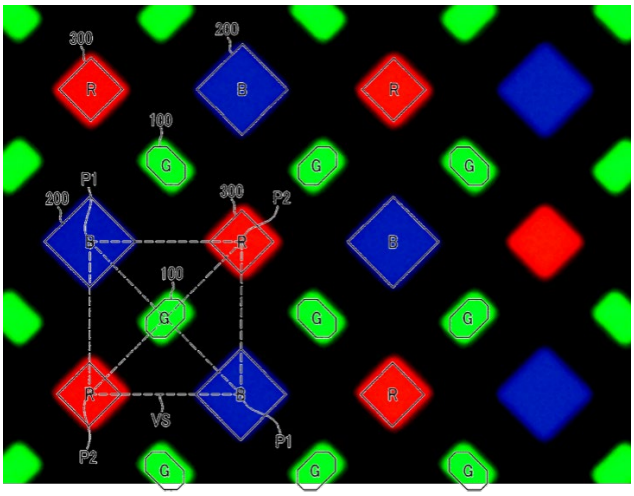
298. In my opinion, the objective indicia of nonobviousness of the ’578 Patent discussed above is sufficiently connected to the claimed inventions of the ’578 Patent.

299. The novel pixel arrangement of the ’578 Patent satisfied the industry’s long-felt need for full HD resolution AMOLED displays for mobile devices that could display images at higher PPI and could be manufactured using then-existing manufacturing methods such as FMM. The ’578 Patent’s pixel arrangement, which Samsung Display calls “Diamond Pixel,” was implemented for the first time in the AMOLED display for the Samsung Galaxy S4 smartphone product. *See* Ex. 2026 at 2 (“On [March] 20th, Samsung Display and relevant industry confirmed that Samsung Display’s proprietary new technology that places pixel[s] in a diamond

form was used in the 5-inch full HD-level Super AMOLED display that Galaxy S4 is equipped with."). Samsung Display's introduction of the novel "pixel array method . . . [using] [its] proprietary diamond structure" allowed "all weakness of the existing AMOLED displays [to be] eliminated," and "full HD-level" resolutions could be realized in AMOLED displays for mobile devices. Ex. 2026 at 2.

300. Dr. Raymond Soneira, author of DisplayMate's technology "shoot-out" article series, observed that Samsung Display's patented "Diamond Pixel[]" arrangement "maximize[s] the sub-pixel packing" to "achieve the highest possible pixels per inch (ppi)," calling it "a form of high-tech display art." Ex. 2027 at 1. *See also* Ex. 2067 (describing Dr. Raymond Soneira and DisplayMate). The '578 Patent's novel pixel arrangement has been successfully used in AMOLED displays for flagship mobile devices, including every Samsung Galaxy and Apple iPhone models that have used AMOLED displays.

301. A teardown image of the pixel arrangement obtained from a Galaxy S22 Ultra sample is reproduced below, with Figure 5 of the '578 Patent superimposed.



Ex. 2029 at 5 (Galaxy S22 Ultra teardown photograph) (annotated); *see also* Ex. 2063.

302. A software package called ImageJ was used to obtain certain information about the images of the Galaxy S22 Ultra's pixel arrangement structures, including data such as the areas of the sub-pixels and coordinates of the centers of the sub-pixels. ImageJ is a highly reliable image processing program developed at the National Institutes of Health and is a commonly used tool for microscope image processing, both in academia and commercially. For example, the "Analyze Particles" tool in ImageJ can extract, among other things, the area and center for each region of interest from the outline of the region.

303. Based on the teardown photos and corresponding ImageJ data, I prepared a claim chart demonstrating how the AMOLED display used in the Samsung Galaxy S22 Ultra product practices all challenged claims of the '578 Patent. Ex. 2028 (Galaxy S22 Ultra Claim Chart). As explained in the claim chart, the

AMOLED display in the Galaxy S22 Ultra product practices the challenged claims of the ’578 Patent.

304. The ’578 Patent introduced pixel arrangements which allow the red, green, and blue sub-pixels to be placed more densely in particular arrangements (which allows for AMOLED displays with higher resolution, and in particular, higher pixel densities for full HD displays) while maintaining sufficient inter-pixel distances (which improves manufacturability, including when using FMM). *See* ’578 Patent, 1:46-2:3, 5:30-36, 6:46-60, 7:27-43, 8:10-16, 8:53-59. The ’578 Patent also explains, for example, that “the neighboring first pixels 100 have a[n] octagonal shape and are symmetrical to each other, while the second pixels 200 have a larger area than the third pixels 300” and “[t]his results in improved deposition reliability in the deposition process using the fine metal mask to form the green, blue, and red organic emission layers respectively included in the first pixels 100, the second pixels 200, and the third pixels 300.” ’578 Patent, 8:44-52, Fig. 5.

305. The pixel arrangement structures recited by the challenged claims of the ’578 Patent offset the green pixels, arranged in lines, from the blue pixels, the red pixels, or both. The arrangements further form the red, green, and blue pixels in particular patterns with specified spacings, shapes, and/or sizes. The challenged claims recite specific ways to group, shape, size, and lay out the red, green, and blue OLED sub-pixels, including, for example, requiring the pixels to be placed along a

"first direction," "second direction," "third direction," or "fourth direction" and forming "first lines," "second lines," "third lines," or "fourth lines" (*e.g.*, claims 1, 23, 40, 42, 45, 47, 51, 52); forming "virtual quadrangle" with pixels (*e.g.*, claims 23, 45, 52); requiring pixels to have differential areas (*e.g.*, claims 17, 23, 42); requiring pixels to emit different colors of light (red, blue, or green colors) (*e.g.*, claims 1, 6, 19, 46); requiring pixels to take on certain shapes such as "polygonal" or "two elongated sides that are elongated in the third direction or a fourth direction crossing the third direction and different from the first and second directions, and two connection portions that connect the two elongated sides to each other at respective ends" (*e.g.*, claims 12, 40, 43, 45–47, 51–52); and requiring certain distances between pixels (*e.g.*, claims 1, 5, 22, 40–45, 51–52).

306. Moreover, by arranging the red, green, and blue pixels in a RGBG format (using more green pixels than red and blue pixels)—instead of the alternative RGB, RGBW, or RGBY pixel arrangements that other display manufacturers and research groups have proposed over the years which have failed to be adopted in flagship mobile devices—and by sizing and shaping the subpixels in ways that had not previously been attempted in the prior art, the '578 Patent achieved a novel balance of improving the AMOLED display's aperture ratio (by enlarging the emissive areas) while *also* allowing for a more reliable deposition of the organic

material (by ensuring sufficient gaps between pixels). The '578 Patent explains these challenges. *See* '578 Patent, 1:48-53:

> When reducing a gap between the neighboring pixels to obtain a higher aperture ratio of the pixel, deposition reliability may be deteriorated. On the other hand, when increasing the gap between the pixels to improve deposition reliability, the aperture ratio of the pixel may be deteriorated.

By reciting specific ways to group, shape, size, and lay out the red, green, and blue OLED sub-pixels, the novel pixel arrangements of the '578 Patent overcame the manufacturing and design challenges associated with the emissive layers of the OLED display, *see, e.g.*, '578 Patent, 6:50-60, which were long understood by POSITAs to be the bottleneck to full HD AMOLED displays for mobile devices.

307. Prior to the '578 Patent, the "established theory" in the display industry had been that "it would be difficult for AMOLED[s] to exceed the resolution of LCD[s] due to their light emitting diode and patterning limits." Ex. 2037 at 3. However, Samsung Display overcame industry skepticism and satisfied the longstanding need by "changing the existing rectangular patterning structure to a diamond structure . . . to overcome the 400ppi barrier," delivering "the 5-inch 441ppi (pixels per inch) Full HD Super AMOLED to Galaxy S4." Ex. 2037 at 3.

XIII. CONCLUSION

308. For the reasons stated above, it is my opinion that claims 1–5 and 19–21 of the ’578 Patent were not obvious to a person of ordinary skill in the art based on the references cited and reasons presented by Dr. Pattison.

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

* * *

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: April 1, 2024 By:

Date

Ioannis (John) Kymissis, Ph.D.