UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

BOE TECHNOLOGY GROUP CO., LTD.
Petitioner,

v.

SAMSUNG DISPLAY CO., LTD.
Patent Owner.

Patent No. 10,832,616

Inter Partes Review No. IPR2025-01544

DECLARATION OF THOMAS CREDELLE

I, Thomas Credelle, make this declaration in connection with the proceeding identified above.

I. INTRODUCTION

1. I have been retained as an expert witness on behalf of BOE Technology Group Co., Ltd. ("Petitioner" or "BOE") to provide expert opinions on the patentability of United States Patent No. 10,832,616 ("the '616 patent").

2. I am being compensated at my normal rate, plus reimbursement for expenses, for my analysis. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

II. QUALIFICATIONS

3. In formulating my opinions, I have relied upon my knowledge, training, and experience in the relevant art. My qualifications are stated more fully in my curriculum vitae, which has been provided as Appendix A. Here, I provide a brief summary of my qualifications.

4. As shown in my curriculum vitae, I have devoted my career to the research and development and product engineering of flat panel displays and materials/optics/electronics for flat panel displays and touch sensors. I have over 20 years of involvement in active-matrix LCD R&D, starting in 1983 at RCA Labs and continuing at GE. I led the product development of active matrix LCDs for notebook computers at Apple in the early 1990s and had close collaboration with

many LCD developers in Asia. Later in my career, I made significant contributions to the design and implementation of new pixel architectures for LCDs and OLEDs while at Clairvoyante; both efforts involved Thin Film Transistor ("TFT") design modifications to achieve the desired goals of high pixel transmission and reduced circuit complexity. The contributions I made to advanced pixel architectures ("Pentile Matrix") and related circuit design optimization at Clairvoyante led to a decision by Samsung to acquire the IP (2007). More recently, I have testified in several patent litigation cases which required a detailed knowledge of TFT design, materials, and processing for both LCD and OLED.

5. After receiving my Master's in Electrical Engineering from MIT in 1970, I was employed by RCA at Sarnoff Labs in Princeton, NJ as a Member of the Technical Staff and later as a Group Manager in charge of all Active Matrix LCD research. During my time at RCA, I participated in research and development projects relating to optical materials and flat panel displays, including LCD devices. In 1983, I established the TFT LCD Program at Sarnoff Labs. As a Group Manager, I led a project that resulted in the development of the first poly silicon TFT LCD at Sarnoff Labs. I received the Sarnoff Outstanding Achievement Award for Large Area Flat Panel TV Developments.

6. From 1986 to 1991, I was employed by GE as the Manager of TFT LCD Research and Development at the GE Research and Development Center in Schenectady, NY. My duties included contributing to and managing research and development efforts relating to TFT and LCD technology for avionics applications. While employed by GE, I led the team that built the world's first 1-million-pixel color LCD device. I also led the development of numerous other optical devices utilizing LCD technology.

7. From 1991 to 1994, I was employed by Apple Computer as the Manager of Display Engineering. In my role at Apple, I supervised all TFT-LCD design (in-house and at vendors), engineering, and qualification for the first PowerBook notebook computers introduced to market in the United States. A key part of my effort was the evaluation and development of active matrix LCDs with improved performance, such as viewing angle, contrast ratio and uniformity.

8. From 1994 to 1996, I was employed as the Director of Advanced Product Marketing by Allied Signal, where I was involved with the design and engineering of optical films and custom focusing backlight designs for improving the viewing angle performance of LCD devices.

9. From 1996 to 1999, I was employed as the Director of Product Marketing for Motorola's Flat Panel Display Division, where I worked in the development of new flat panel technology. I also worked closely with Motorola

groups responsible for integrating TFT-LCD technology into mobile phone products and materials development for OLED displays.

10. From 1999 to 2001, I served as the Vice President of Operations of Alien Technology Corporation. During my time at Alien Technology, I was involved with the design and architecture of drive electronics packaging technology suitable for flexible display devices.

11. From 2001 to 2007, I served as the Vice President of Engineering for Clairvoyante, Inc. My responsibilities as the VP of Engineering included managing research, development, engineering, and marketing of technologies for improving the resolution and power consumption of color flat panel displays, which required significant changes to the active matrix layout. During my time at Clairvoyante, I was therefore heavily involved with the design of the active matrix array and the LCD or OLED pixel circuit and driving circuitry. My work resulted in the issuance of multiple patents relating to TFT-LCD and TFT-OLED display technology.

12. From 2007 to 2008, I served as the Senior VP of Engineering for Puredepth, Inc. My responsibilities included the design of hardware and software to create 3D images on TFTLCDs.

13. From 2012 through 2015, I served as the Vice President of Application Engineering and Device Performance for Innova Dynamics, Inc., a

nanotechnology company developing materials to be used in LCDs and touch sensors. In that effort, I led the collaboration with major capacitive touch sensor makers to replace brittle Indium Tin Oxide ("ITO") transparent conductors with transparent silver nanowire conductors, which are compatible with flexible touch sensors. We successfully fabricated flexible capacitive touch sensors that could be bent without breaking.

14. In 2008, I founded TLC Display Consulting, a company that provides technical consulting in the areas of flat panel displays, liquid crystal displays, OLED, touch sensors, LEDs, and related electronics. I currently serve as the President of TLC Display Consulting.

15. I have been an active member of the Society for Information Display ("SID") for over 40 years, and am currently a Life Member. I was a member of the Society for Information Display's Program Committee for 15 years, and the Director of the Society for Information Display's Symposium Committee for 10 years. In 1984, I was awarded the title of Fellow of the Society for Information Display in recognition of my achievements and contributions to flat panel display technology.

16. I am a named inventor on over 80 US patents relating to flat panel display, LCD, and OLED technology. I have also authored several articles relating to LCD technology and flat panel displays that were published by industry

periodicals such as Information Display and peer reviewed journals such as the Society for Information Display's Digest of Technical Papers.

17. My curriculum vitae contains further details regarding my experience, education, publications, and other qualifications that allow me to render expert opinions in connection with this proceeding.

III. MATERIALS CONSIDERED

18. In preparing this declaration, I have reviewed, among other things, the '616 patent and file history. I have also considered each of the documents cited in this Declaration and the documents specifically identified below and in the Exhibit list. In formulating my opinions, I have further relied upon my extensive experience in the relevant fields.

IV. OVERVIEW OF THE ORGANIC LIGHT-EMITTING DEVICE (OLED) DISPLAY DEVICE TECHNOLOGY AT THE TIME OF THE '616 PATENT

19. Organic light-emitting devices ("OLEDs") are a type of display technology. In contrast to light-emitting diodes ("LEDs"), OLEDs are made of organic compounds that emit light when electric current is applied. OLEDs have benefits over LEDs. For example, OLEDs are very thin, flexible, and transparent.

20. There are, however, shortcomings with OLED displays. For example, the manufacturing of OLED displays can be costly and complicated. An error

during manufacturing can impact the quality of the OLED display by causing luminance errors such as aliasing, chromatic aberration, Moiré defects, Mura, etc.

21. The idea of arranging the red, green, and blue pixels of an OLED display in a non-standard arrangement (*e.g.*, an arrangement with red, blue, and green pixels in a non 1:1:1 ratio) and adjusting the relative sizes of subpixels was known by at least March 6, 2012 (which I have been informed is the earliest possible priority date for the '616 patent). Further, arranging pixels of OLED displays to form equally spaced pixels vertically and horizontally (e.g., in a "virtual square" arrangement) by arranging red, green, and blue pixels in alternating patterns in both rows and columns to form a checkerboard pattern (as opposed to color stripes or delta arrangement) was also known by at least March 6, 2012.

22. Additionally, pixel arrangements with an unequal number of red, green, and blue pixels (*e.g.*, RGBG arrangements) were known by at least March 6, 2012. It was well known that the human eye is most sensitive to green light and less sensitive to red and blue light, both in terms of luminance and spatial resolution. Thus, RGBG pixel arrangements that have more green pixels than red or blue pixels were developed and commonly known by at least March 6, 2012. By providing more green pixels in a display than red and blue pixels and using subpixel rendering software, the display resolution seen by the human visual system is maintained and yet the manufacturing processes are simplified.

23. Numerous patent publications, including those discussed herein, disclose these ideas before the earliest priority date of the ’616 patent.

V. SUMMARY OF THE ’616 PATENT

A. Filing and Priority Dates

24. The ’616 patent was filed on April 26, 2013, and issued on November 10, 2020. The ’616 patent is a continuation in part of U.S. Application Ser. No. 13/614,197, filed September 13, 2012, which became U.S. Patent No. US 9,818,803. The ’616 patent claims priority to Korean Patent Application No. 10-2012-0022967, which was filed on March 6, 2012, and to Korean Patent Application No. 10-2013-0044993, which was filed on April 23, 2013. For the purposes of this declaration only, I am using the March 6, 2012, priority date. I am not opining on whether the claims are, in fact, entitled to that priority date.

B. Specification and Claims

25. The ’616 patent is titled “Pixel Arrangement Structure for Organic Light Emitting Diode Display.” The ’616 patent discloses “[a] pixel arrangement structure of an OLED display….” (EX1001, Abstract.) The OLED display may include a plurality of pixels, including blue, red, and green pixels. (EX1001, 3:1-3.) The pixels may be arranged to form virtual squares. (EX1001, 10:26-33.)

26. The ’616 specification explains that reducing a gap between neighboring pixels to obtain a high aperture ratio of the pixels may deteriorate

deposition reliability, but increasing the gap to improve deposition reliability decreases the aperture ratio. (EX1001, 1:51-56.)

27. Figure 6, annotated below, shows a pixel arrangement structure. Independent claim 1 is directed to a pixel arrangement structure of an organic light emitting diode (OLED) display, comprising a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:

- a **"first pixel"** 100 (EX1001, 9:52-53) having a center coinciding with a center of a **"virtual square"** (EX1001, 10:26-30)**;**
- **"another first pixel"** (EX1001, FIG. 6) having a center coinciding with a center of **"another virtual square"** (EX1001, FIG. 6), the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;

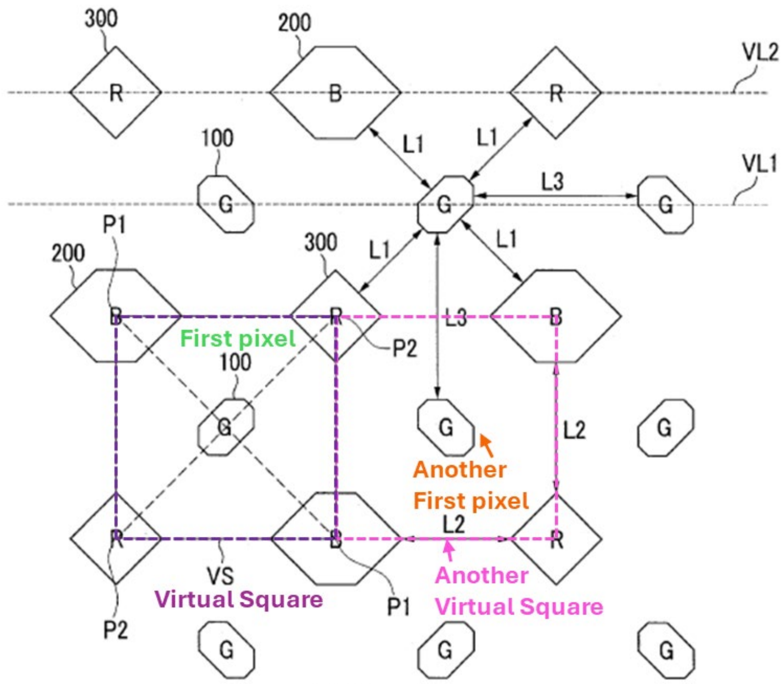

FIG. 6

- **"a second pixel"** 200 (EX1001, 9:52-54) separated from the first pixels and having a **"center at the first vertex"** P1 (EX1001, 11:34-36);

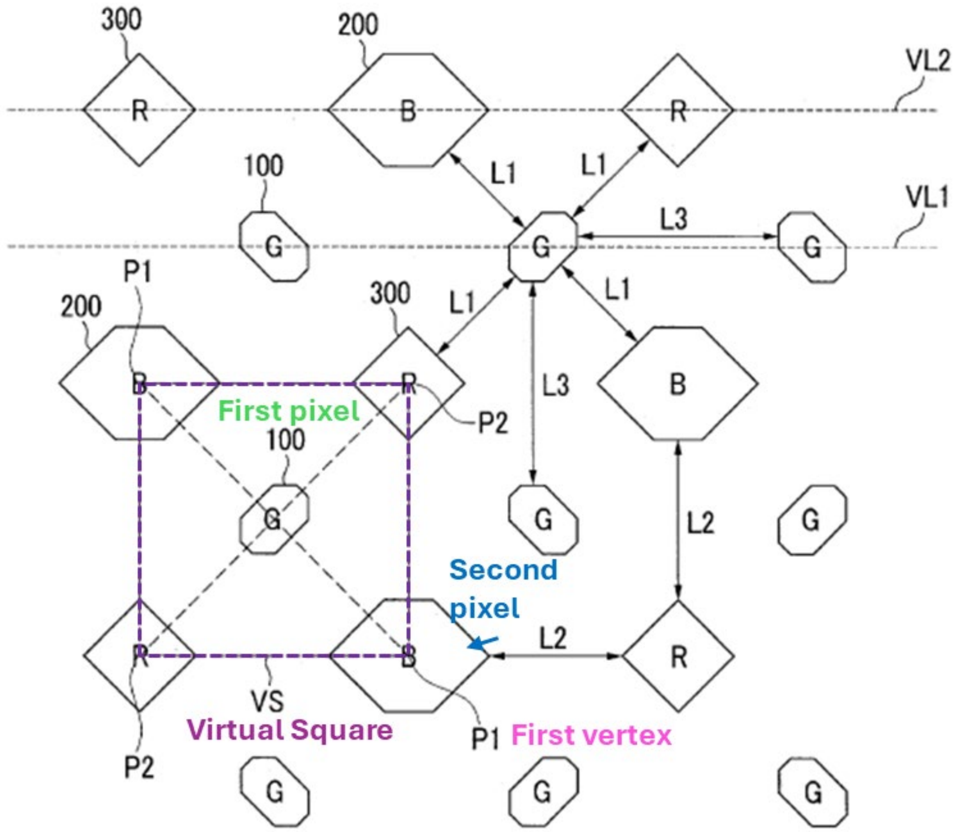

FIG. 6

- **"an other first pixel"** on **"a line"** defined by the center of the virtual square and the first vertex, **"the first pixel,"** **"the second pixel,"** and "**the other first pixel"** being consecutive pixels on the line; and

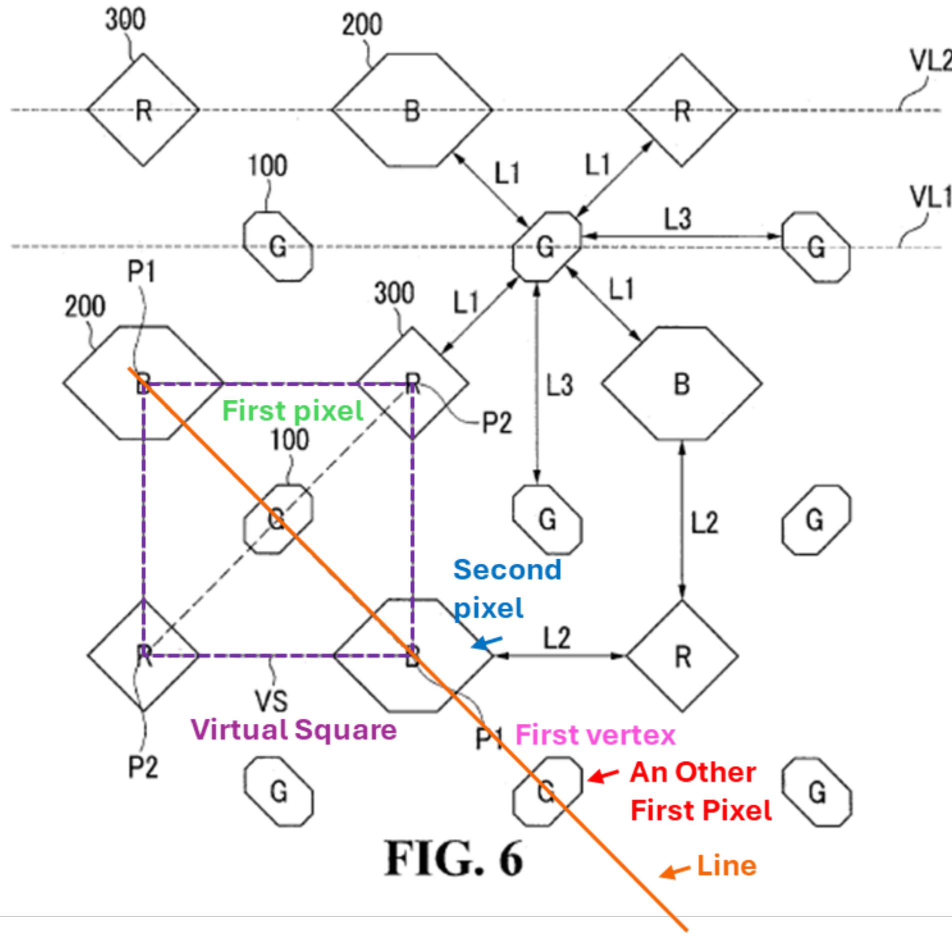

FIG. 6

- **"a third pixel"** 300 (EX1001, 9:52-55) separated from the first pixels and the second pixel, and having **"a center at the second vertex"** P2 (EX1001, 11:38-39),

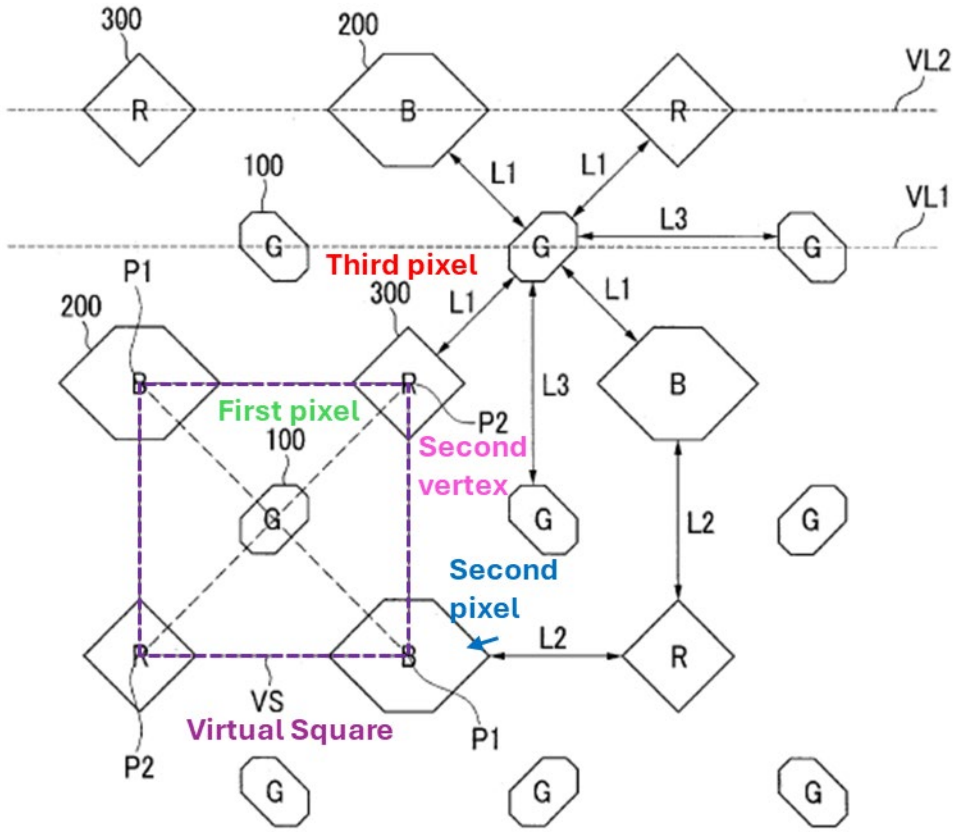

FIG. 6

- wherein a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is **"a same first length"** L1 (EX1001, 11:47-50),

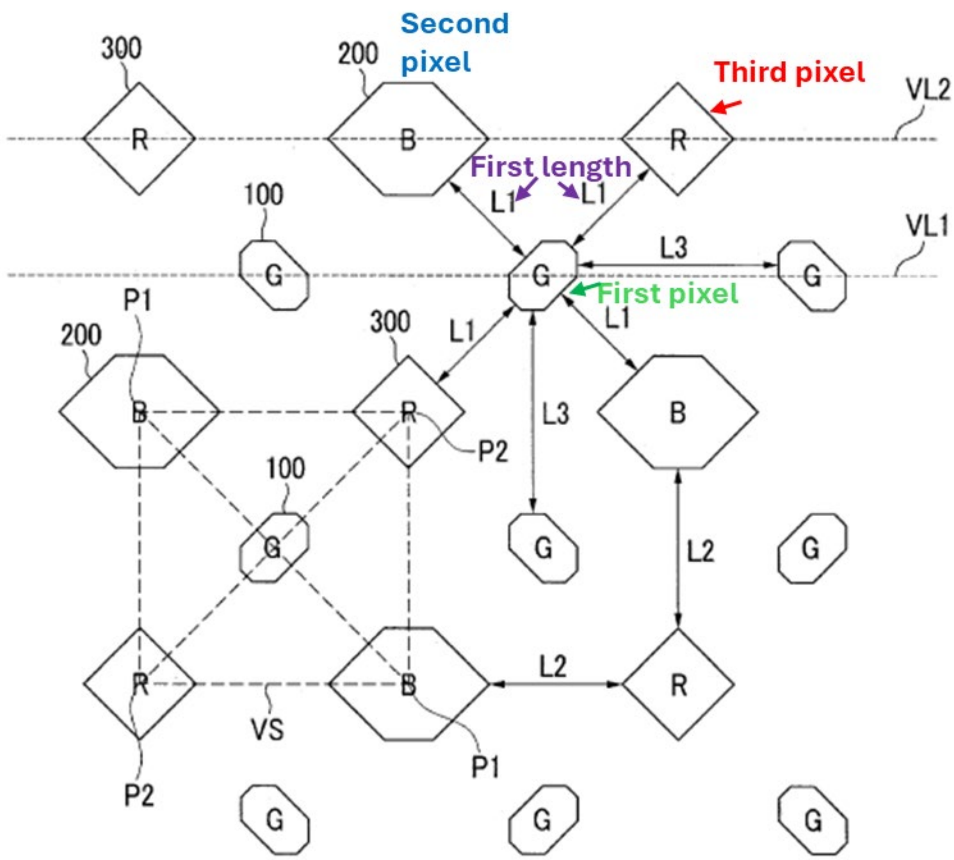

FIG. 6

- wherein a shortest distance between the first pixels is **"a second length"** L3 that is longer than the first length and **"a shortest distance between each of the second pixels and the third pixels"** L2 (EX1001, 13:26-29),

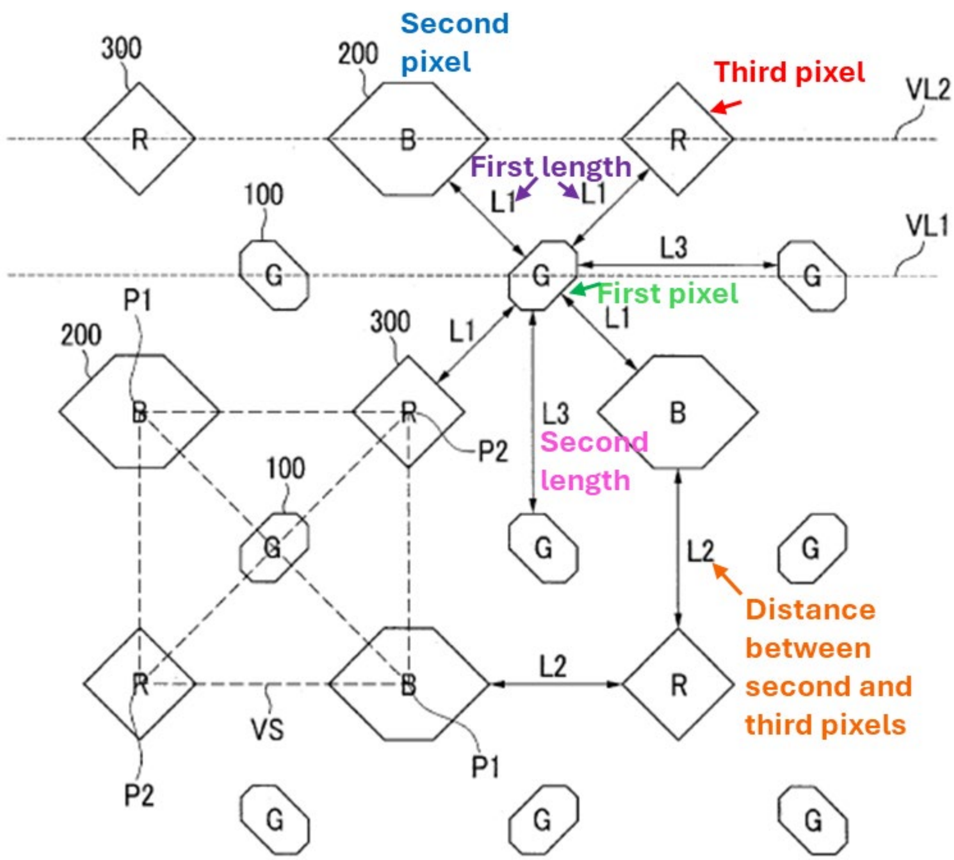

FIG. 6

- wherein "the second pixel" 200 and "the third pixel" 300 have polygonal shapes, and
- wherein "the second pixel" 200 has a larger area than that of "the third pixel" 300.

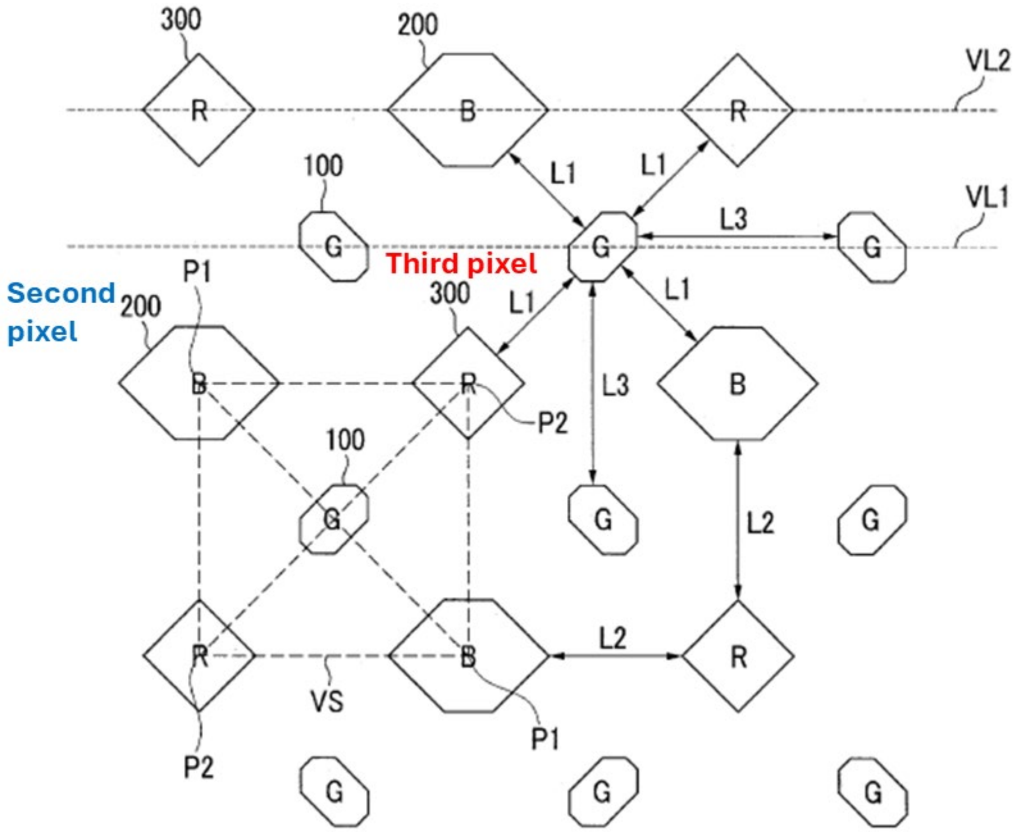

FIG. 6

28. Independent claim 13 recites elements similar to independent claim 1, except claim 13 does not require the second pixel to have a larger area than that of the third pixel or "an other" first pixel on a line defined by the center of the virtual square and the first vertex. I am not opining in this declaration whether or not the claim language, such as "an other" is in fact definite.

29. Claims 2-12 are dependent claims. Claims 2-4 are directed to pairs of second and third pixels. Claims 5 and 8 relate to the relative sizes of the pixels. Claims 6, 7, 9, and 12 relate to the shapes of the first, second, and third pixels. Claims 10 and 11 relate to the colors emitted by the first, second, and third pixels.

C. Prosecution History

30. I understand that during prosecution of the ’616 patent, the Examiner rejected the claims as lacking novelty and as being obvious in light of a number of prior art references, including U.S. Patent No. 7,274,383 to Elliott[1] (“Elliott-383” (EX1010)); U.S. Patent Pub. No. 2008/0001525 to Chao et al. (“Chao” (EX1011)); U.S. Patent No. 6,867,549 to Cok et al. (“Cok” (EX1004)); U.S. Pub. No. 2009/0302331 to Smith et al. (“Smith” (EX1012)); U.S. Patent Pub. No. 2003/0128179 to Credelle (“Credelle-179” (EX1013)); U.S. Patent Pub. No. 2006/0274090 to Koyama (“Koyama” (EX1014)); U.S. Patent No. 6,882,364 to Inuiya et al. (“Inuiya” (EX1015)); and U.S. Patent Pub. No. 2004/0183764 to Kim et al. (“Kim” (EX1016)).

31. The Patent Owner ultimately pursued an appeal, arguing against the Examiner’s reliance on Credelle-179 and Kim, particularly concerning pixel separation distances and configurations. (EX1003, 240-247.) The Board found claim 11 patentable. In its view, the Examiner failed to provide sufficient explanation of why Credelle-179 disclosed the claimed distances, because the

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[1] Although the patent refers to “Elliot” with one “t,” other patent publications to the same inventor utilize two “t”s. For consistency, Elliott is used with two “t”s throughout the Declaration.

Examiner vaguely asserted that "Adjacent pixels in a display panel should have some distance between them such as an (insulating) gap between them." (*Id.*, 200, 240-247.) However, the Board concluded all the remaining claims were unpatentable, finding that it would have been obvious to change the pixel sizes in Credelle-179 to correct white balance and color coordinate. (*Id.*, 116-122.)

32. The Patent Owner did not further challenge the Board's decision, and, on remand, it amended claim 1 to incorporate key features of claim 11. (*Id.*, 70-74, 107-113.) The Examiner then allowed the application on February 19, 2020. (*Id.*, 70.) The Patent Owner subsequently filed a series of information disclosure statements, each time reopening prosecution; the patent finally issued on November 10, 2020. (*Id.*, 1-69.)

VI. RELEVANT LEGAL STANDARDS AND DEFINITIONS

A. Anticipation

33. It is my understanding that the claims of a patent are anticipated by a prior art reference if each and every element of the claim is found either explicitly or inherently in a single prior art reference or system. I understand that inherency requires a showing that the missing descriptive matter in the claim is necessarily or implicitly present in the allegedly anticipating reference and that it would have been so recognized by a POSITA. In addition, I understand that an enabling disclosure is a disclosure that allows a POSITA to make the invention without

undue experimentation. Although anticipation typically involves the analysis of a single prior art reference, I understand that additional references may be used to show that the primary reference has enabling disclosure, to explain the meaning of a term used in the primary reference, and/or to show that a characteristic is inherent in the primary reference.

B. Obviousness

34. I understand that a claim is unpatentable if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the claimed subject matter was made to a POSITA to which the subject matter pertains. I understand that a patent claim may be obvious to a POSITA in view of the prior art teachings of a single reference or a combination of references.

35. To assess obviousness, I understand that I am to consider the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in the art, and any secondary considerations to the extent they exist.

36. It is also my understanding that there are principles that may be used as further guidance in an obviousness analysis (especially when considering combinations of references), which include considering whether:

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;
- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;
- the claimed subject matter would have been “obvious to try” choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;
- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of conception and reduction to practice a known problem for which there was an obvious solution encompassed by the patent’s claims; and

- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

37. I understand that there are secondary considerations that may tend to show that a claimed invention would not have been obvious to a POSITA. These include, for example, commercial success, long-felt but unsolved needs, failure of others, and unexpected results. I further understand that there must be a relationship, or nexus, between any secondary considerations and the novelty of the claimed invention.

C. Prior Art

38. I am informed and understand that prior art includes patents and printed publications that existed before the effective filing date of the claimed invention. The effective filing date is the earliest claimed priority date or the earliest filing date of the application that describes the subject matter. A patent or published patent application is prior art if it was filed before the earliest filing date of the claimed invention, absent a few exceptions. I am informed that a patent or published patent application is entitled to have its effective filing date as the filing date of its provisional application if the disclosure of the provisional application provides support for the claim(s) of the patent or published patent application.

VII. LEVEL OF ORDINARY SKILL IN THE ART FOR THE ’616 PATENT

39. I am informed and understand that various factors can be considered in determining a person of ordinary skill in the art (POSITA). I am informed and understand that those factors include: (1) the educational level of the inventors; (2) the type of problems encountered in the art; (3) prior art solutions to those problems; (4) the rapidity with which innovations are made; (5) sophistication of the technology; and (6) education level of active workers in the field.

40. A person of ordinary skill in the art (POSITA) in the field of the ’616 patent would have a bachelor’s degree in electrical engineering or materials science and two years of experience working on display devices, including OLED displays, or an equivalent level of skill, knowledge, and experience. This POSITA would have been aware of and generally knowledgeable about OLED materials, display pixel design, layout, and operation. I believe this level of skill was utilized in previous *inter partes* reviews of related patents.

41. I agree with this level of ordinary skill for the ’616 patent. Based on my experience, I understand and know of the capabilities of a person of this skill level as of the time the ’616 priority application was filed in 2012. I am familiar with how a POSITA would have understood and used the terminology found in the ’616 patent at the time of the filing of the priority application, and with the state of the art at that time.

VIII. CLAIM CONSTRUCTION

42. I have been informed that claim construction requires consideration of the words of the claims themselves, the specification, the prosecution history, and extrinsic evidence concerning relevant scientific principles, the meaning of technical terms, and the state of the art. I have also been informed that the specification is usually definitive, as it is the single best guide to the meaning of a disputed term.

43. I have been informed that, in the context of this proceeding, Petitioner did not propose any terms for construction. Instead, Petitioner believes each of the terms of the ’616 patent carries its ordinary and customary meaning, which is the meaning that the term would have to a POSITA. I agree with Petitioner and apply the ordinary and customary meaning of the terms in my analysis below.

IX. PRIOR ART

44. I understand that each of the references discussed herein qualifies as prior art against the ’616 patent (that is, they were published well before whatever priority date the patent is entitled to):

45. U.S. Patent No. 6,867,549 (“Cok,” EX1004) was filed on December 10, 2002, published on June 10, 2004, and issued on March 15, 2005.

46. U.S. Patent Pub. No. 2011/0234550 (“Hong,” EX1008) was filed on August 13, 2010, and published September 29, 2011.

47. U.S. Patent No. 7,492,379 ("Credelle-379," EX1005) was filed on October 22, 2002, published on July 10, 2003, and issued on February 17, 2009. It claims priority to U.S. Provisional Application No. 60/346,738 filed Jan. 7, 2002, and is a continuation-in-part of U.S. patent application 2004/0051724 filed on Sep. 13, 2002.

48. U.S. Patent Pub. No. 2004/0051724 ("Elliott-724," EX1006) was filed on September 13, 2002, and published on March 18, 2004.

X. ANALYSIS AND OPINION

A. Claims 1-5, 10, 11, And 13 Are Obvious Over Cok and Hong

1. Summary of Cok

49. Cok describes "OLED displays having repeated patterns of colored light emitting elements." (EX1004, 1:8-10.) For example, Cok describes OLED displays having repeated RGBG patterns, as shown below in FIG. 1, with each pattern including two green light emitting elements 14, one red light emitting element 12, and one blue light emitting element 16.

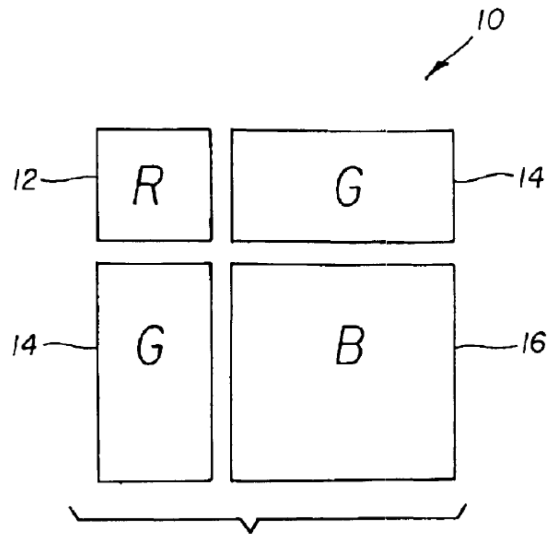


FIG. 1

50. Cok explains that the lifetime and color quality (over time) of an OLED display can be improved by adjusting relative sizes of the red, blue, and green light emitting elements based on the properties of the materials used. (*Id.*, 4:31-45.) For example, Cok describes "that the efficiency of light production by various OLED light emitters of different colors varies." (*Id.*, 1:50-51.) To solve this problem, Cok describes that "[l]ight emitting elements made with higher efficiency materials can be made smaller than light emitting elements made with lower efficiency materials while producing the same light output." (*Id.*, 3:19-22.)

51. Accordingly, although FIG. 1 shows the red pixel being the smallest, "[d]ifferent materials may produce different relative sizes of pixel elements 12, 14, and 16." (*Id.*, 4:16-17.) As an example, Cok describes that "for some combinations of materials, the green light emitting elements may be smaller than

both the red and blue light emitting elements." (*Id.*, 4:17-20.) Thus, Cok recognizes that different materials can be used, and relative pixel size can be determined based on OLED material properties, including efficiency.

52. Cok is directed to the same problem (pixel arrangements) in the same field of endeavor (OLED displays) as the '616 patent.

2. Summary of Hong

53. Hong is directed to organic electroluminescent display devices and methods of fabricating such devices. Hong describes that regions between adjacent two sub-pixel regions in a display do not emit a predetermined colored light due to overlapping, which is referred to as a shadowing effect. (EX1008, ¶ [0010].) As described by Hong, "[t]o prevent the shadowing effect, the adjacent organic patterns 60 may be spaced apart by a first distance d1." (*Id.*, ¶ [0010].) For example, as illustrated by FIG. 5, "the first and second organic patterns 200a and 200b are spaced apart from each other by a first distance d1 for preventing a shadowing effect along a diagonal direction with respect to the first and second directions, and the second and third organic patterns 200b and 200c are spaced apart from each other by the first distance d1 along the diagonal direction." (*Id.*, ¶ [0048].) The distance d1 is sufficient to prevent the shadowing effect and the subsequent mixing of colors during deposition of the organic patterns. (*Id.*, ¶ [0044], ¶ [0048].)

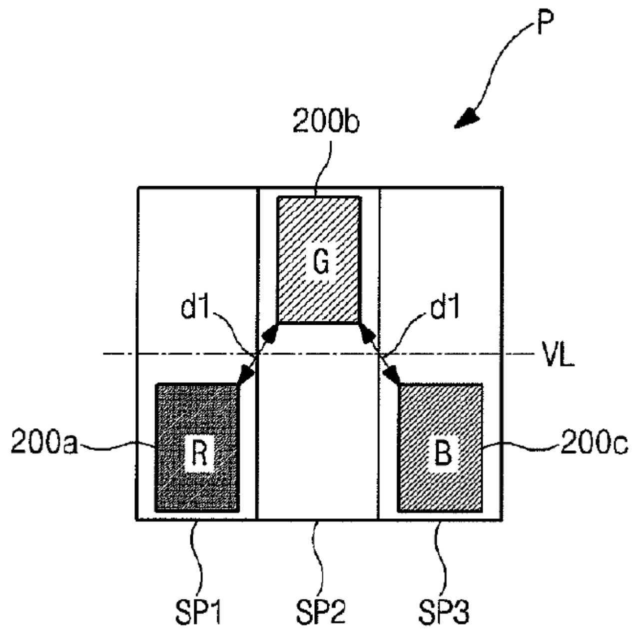


FIG. 5

54. Although FIG. 5 shows the red, blue, and green sub-pixels having the same size, Hong describes that "first, second and third organic patterns may be formed to have different areas based on an emission efficiency of each organic pattern." (*Id.*, ¶ [0074].) For example, "[w]hen the first, second and third organic patterns 250a, 250b and 250c emit red, green and blue colored lights, respectively, the emission efficiency of the first organic pattern 250a may be greater than the emission efficiency of the third organic pattern 250c and may be smaller than the emission efficiency of the second organic pattern 250b." (*Id.*) To account for this difference in efficiency, "the area of the first [red] organic pattern 250a may be greater than the area of the second [green] organic pattern 250b and may be smaller than the area of the third [blue] organic pattern 250c so that the lights

emitted from the first, second and third organic patterns 250a, 250b and 250c can have the same brightness as each other." (*Id.*) Such an arrangement would improve "uniformity in brightness and controllability of white balance." (*Id.*)[2]

[2] Hong incorrectly states "For example, the organic pattern having a higher emission efficiency may have an area ***greater*** than the organic pattern having a lower emission efficiency," instead of the correct "smaller" area. (EX1008, ¶ [0074] (emphasis added)). A POSITA would have known that this was a mere typo given the context of the rest of the paragraph, which applies the correct rule (that greater efficiency patterns should have a smaller area). For example, the same paragraph says "When the first, second and third organic patterns 250a, 250b and 250c emit red, green and blue colored lights, respectively, the emission efficiency of the first organic pattern 250a may be greater than the emission efficiency of the third organic pattern 250c and may be smaller than the emission efficiency of the second organic pattern 250b. Accordingly, the area of the first organic pattern 250a may be greater than the area of the second organic pattern 250b and may be smaller than the area of the third organic pattern 250c so that the lights emitted from the first, second and third organic patterns 250a, 250b and 250c can have the same brightness as each other." (*Id.*)

55. Hong also describes how the organic electroluminescent display device is fabricated using a shadow mask. (EX1008, ¶ [0072].) The shadow mask (or shadow masks if the subpixels have different areas) includes a plurality of open portions 350, through which organic material is deposited during a vacuum thermal evaporation process to form the subpixels. (*Id.*) Hong describes that "[s]ince the shadow mask 300 is formed of a metallic material, the shadow mask 300 may expand due to heat to cause deformation such as warpage while the first, second and third organic patterns 250a, 250b and 250c are formed through a vacuum thermal evaporation method." (*Id.*) Such "deformation of the shadow mask 300 causes a shadowing effect." (*Id.*) The shadowing or color mixing can occur even if multiple masks are used because all masks will experience deformations such as warpage.

56. Hong is analogous art to the '616 patent at least because Hong is directed to the same problem (pixel arrangements) in the same field of endeavor (OLED displays) as the '616 patent.

3. Claim 1

a. Preamble: "A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

57. Cok meets the preamble. For example, Cok describes "A pixel arrangement structure of an organic light emitting diode (OLED)." For example, Cok describes "[a]n OLED display device for displaying a color image that

includes an array of different colored independently controllable light emitting elements arranged in repeated patterns." (EX1004, 2:14-18; Abstract.) Although Cok describes the individual light emitting elements as "light emitting elements," a POSITA would have understood that these terms are merely referring to the same components as the claimed "pixels" in the '616 patent.

b. 1[A]: "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

58. Cok meets limitation 1[A], e.g., as set forth above with respect to the Preamble. Cok teaches "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display." For example, Cok teaches "an OLED display device for displaying a color image that includes an array of different colored independently controllable light emitting elements arranged in repeated patterns." (EX1004, 2:14-18; Abstract.)

c. 1[B]: "a first pixel having a center coinciding with a center of a virtual square;"

59. Cok teaches "a first pixel having a center coinciding with a center of a virtual square." As discussed above, Cok discloses "an array of different colored independently controllable light emitting elements arranged in repeated patterns." (EX1004, 6:2-4.) Further, "the repeated patterns are aligned with each other."

(*Id.*, 6:25-26.) One such pattern is "the square pixel arrangement" shown in FIG. 1 (reproduced below), which includes "two green light emitting elements 14 having a first size (area), a red light emitting element 12 having a second smaller size, and a blue light emitting element 16 having a larger size." (*Id.*, 4:8-13.)

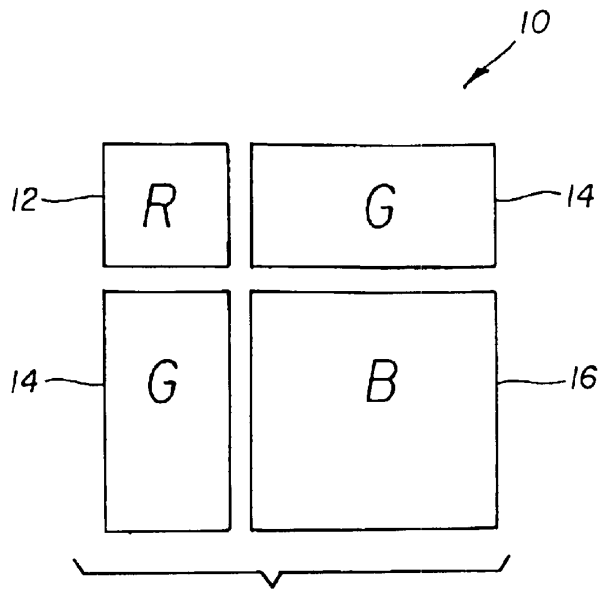
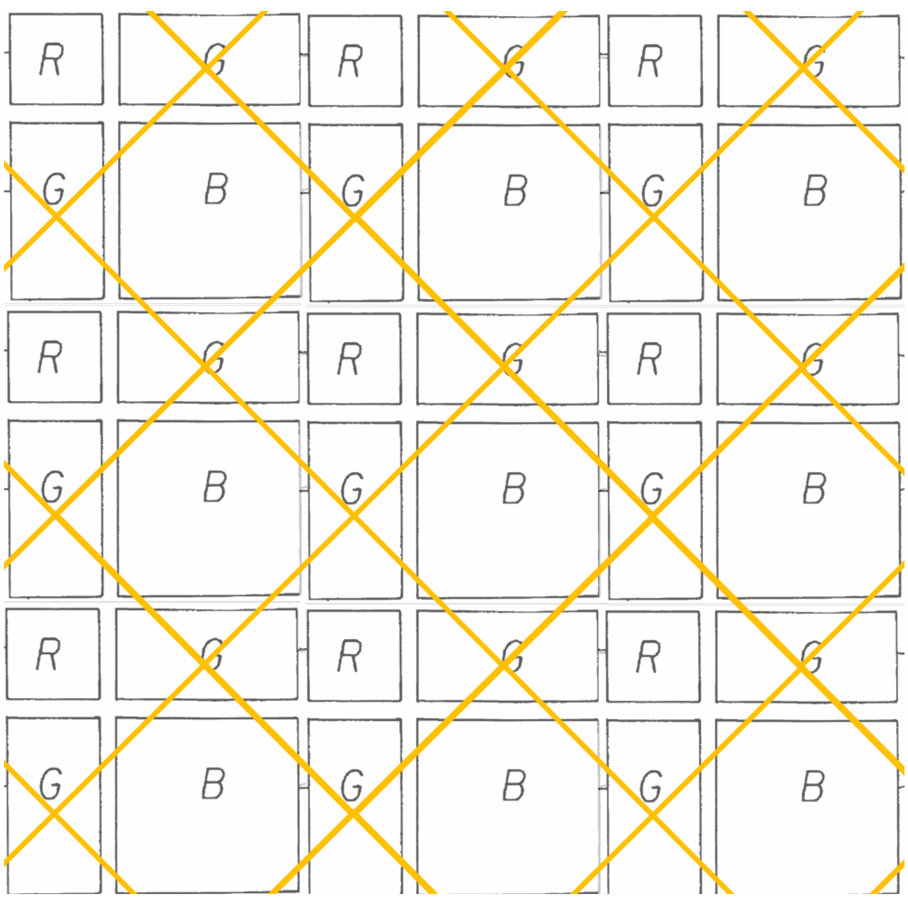


FIG. 1

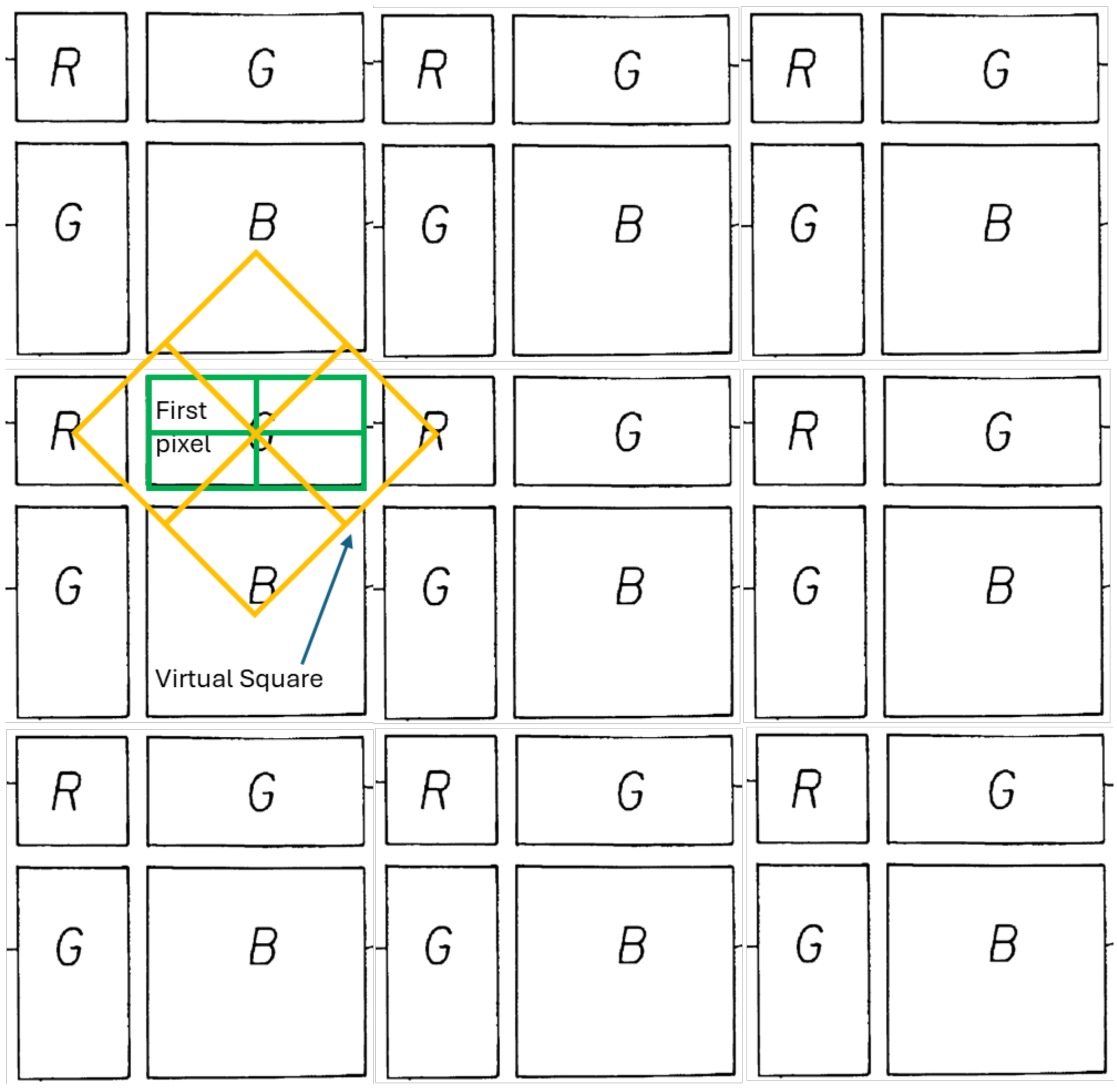
I note that a POSITA would have understood that each green pixel would not only have the same area, as Cok states, but also the same dimensions (*i.e.*, side lengths). This is because Cok describes the RGBG arrangement as forming a square (a "square pixel arrangement"). As such, the width of the red pixel (W_R), the width of the upper-right green pixel (W_{G1}), and the spacing between the red pixel and the upper-right green pixel must sum to the same value as the height of the red pixel (H_R), the height of the lower-left green pixel (H_{G2}), and the spacing between the red pixel and the lower-left green pixel. In addition, as shown, the width of the red pixel is the same as the width of the lower-left green pixel (W_{G2}) and the height of the red pixel is the same as the height of the upper-right green pixel (H_{G1}). Further, the POSITA would understand that the shortest distance between the lower-left green pixel and the red pixel as well as the shortest distance between the upper-right green pixel and the red pixel is a same first length E due to the equal spacing between the four-pixel pattern, as explained in detail below with respect to paragraph 66. Thus, Cok's disclosure that Figure 1 shows a square indicates that $W_{G1} + W_{G2} + E = H_{G1} + H_{G2} + E$. Meanwhile, Cok's disclosure that the green pixels are each of a "first size (area)" indicates that $W_{G1}*H_{G1} = W_{G2}*H_{G2}$. Given these constraints, a POSITA would have understood that $W_{G1} = H_{G2}$ and $H_{G1} = W_{G2}$; that the two green pixels have the same dimensions, in other words. Not only would a POSITA have deduced this from Cok from the reasoning I have just outlined, but it would also have been consistent with ordinary practice in the art, where keeping pixels of the same color the same shape and size would have allowed for greater predictability during manufacturing and performance. (I also note that, based on the congruence between the green pixels, a POSITA would have understood that $W_R = H_R$, making the red pixel a square, and that the same is true of the blue pixel for parallel reasons.)

60. Cok teaches repeating such patterns to form an array. (*Id.*, 6:1-4, 6:25-26.) The pattern shown in FIG. 1 of Cok can be repeated as shown below.

The green pixels are positioned such that the centers of the green pixels are on an equal grid spacing, as shown by the orange grid below. A POSITA would have maintained the relative centers of the light emitting elements, such that the centers of each pixel line up as shown in the pattern of FIG. 1. (*Id.*, 3:65-67.) Further, a POSITA would have repeated the RGBG pattern as taught by Cok, of four pixels with equal spacing between the four-pixel pattern, because it is important for the accurate display of information that digital image data be displayed on a uniform, equal-spaced grid of RGBG patterns.



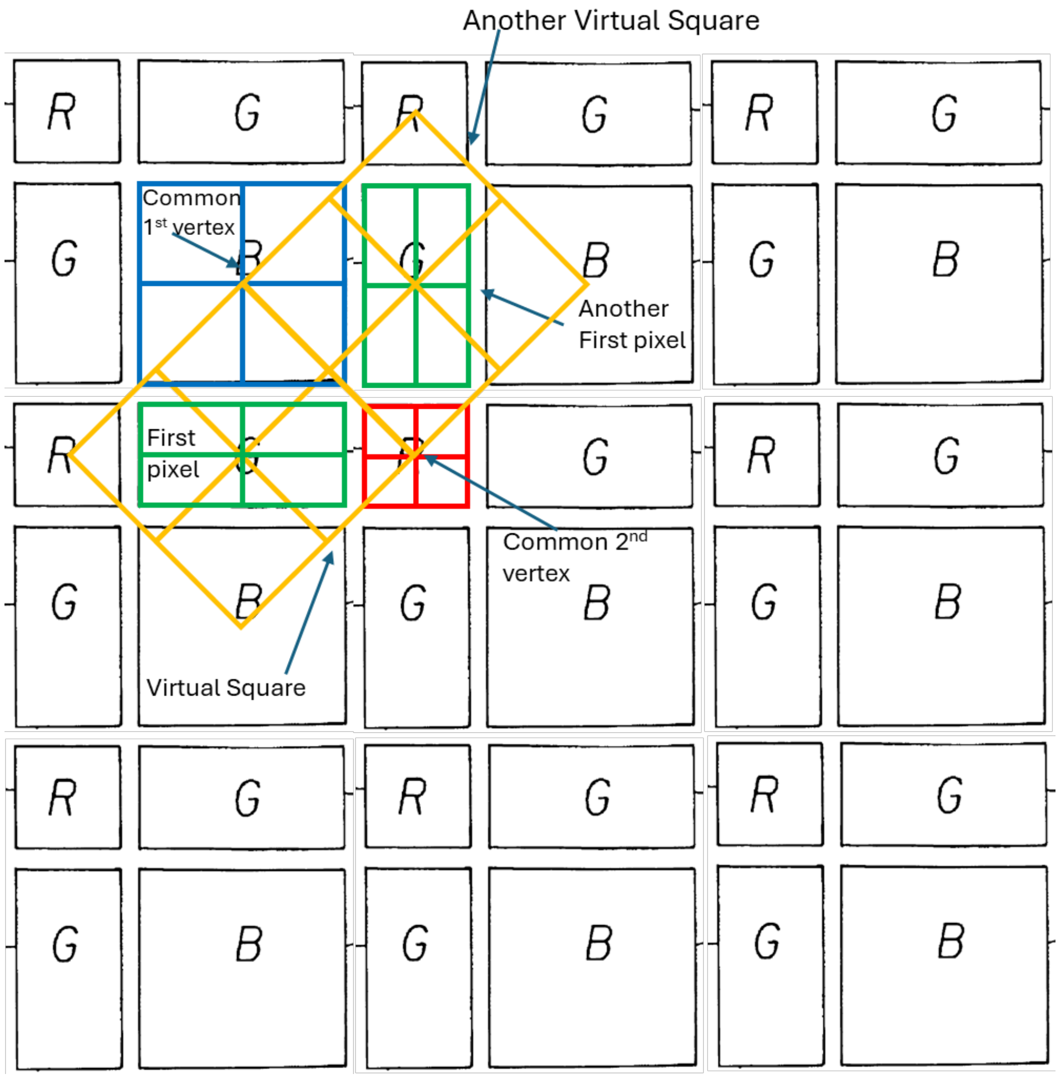
61. As shown below, a green light emitting element (e.g., corresponding to the claimed "first pixel") has a center coinciding with a center of a virtual square. A POSITA would have recognized this virtual object to be a square because (1) the red and blue pixels are squares (as explained above in paragraph 59) so as to make each angle of the object—with a vertex at the center of either a red or blue pixel—90 degrees, and (2) because the symmetry of the arrangement ensures that each side of the object has a length equal to the uniform distance between diagonally adjacent red and blue pixels.



d. 1[C]: "another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

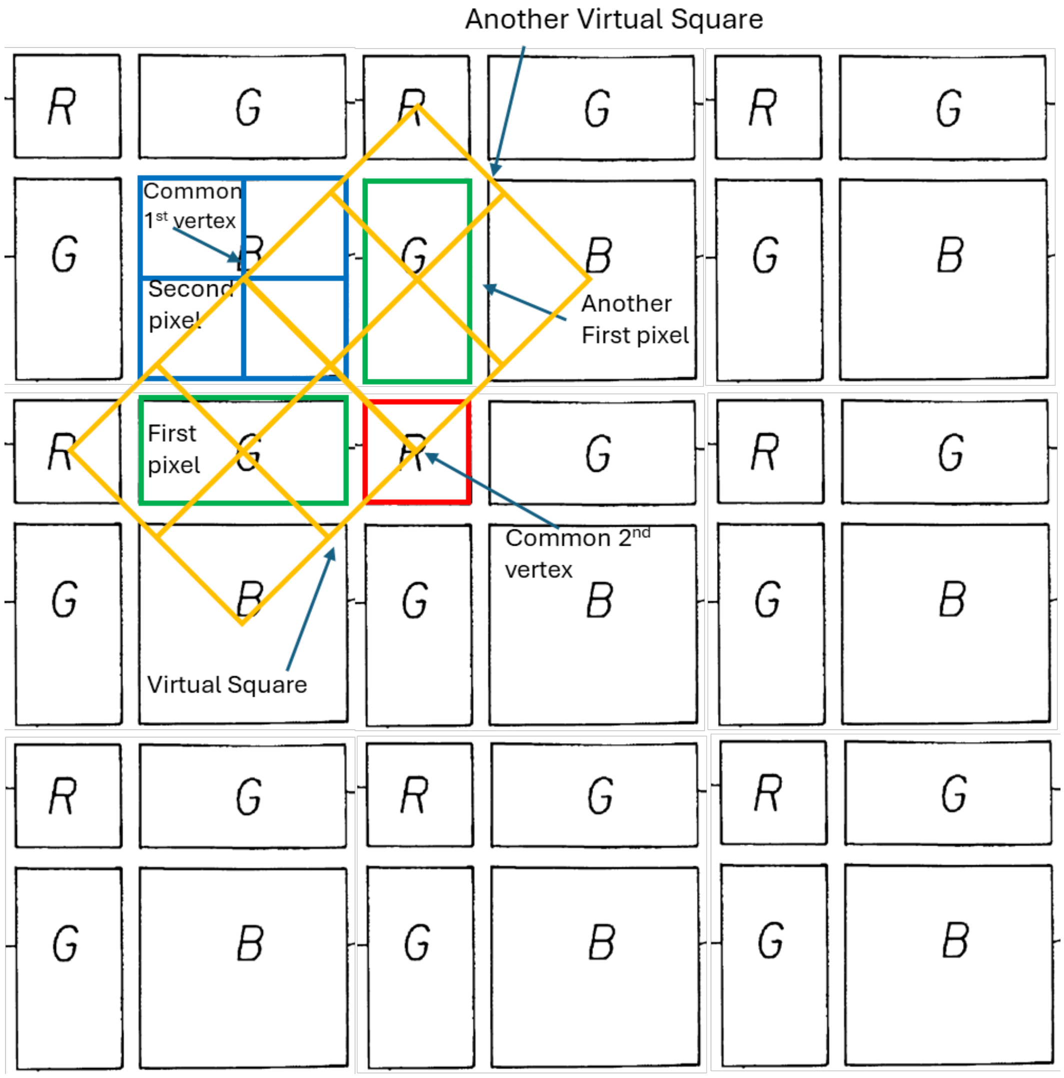
62. Cok teaches this Element. As shown below, another green pixel (*e.g.*, corresponding to the claimed "another first pixel") is at the center of another virtual square having a shared side and two common vertices with the first virtual

square, with neighboring vertices corresponding to pixels having different colors (*e.g.*, blue and red).



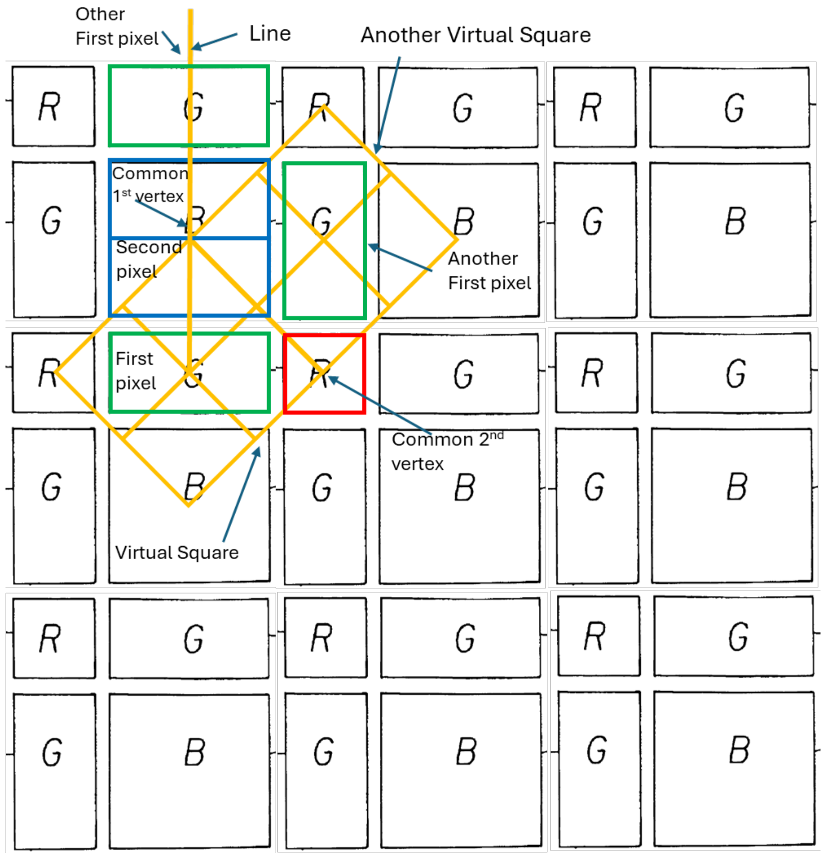
e. **1[D]: "a second pixel separated from the first pixels and having a center at the first vertex;"**

63. Cok teaches this Element. The blue pixel (*e.g.*, corresponding to the claimed "second pixel") is separated from the first (*e.g.*, green) pixels, and has a center at the first vertex of the virtual square, as shown below.



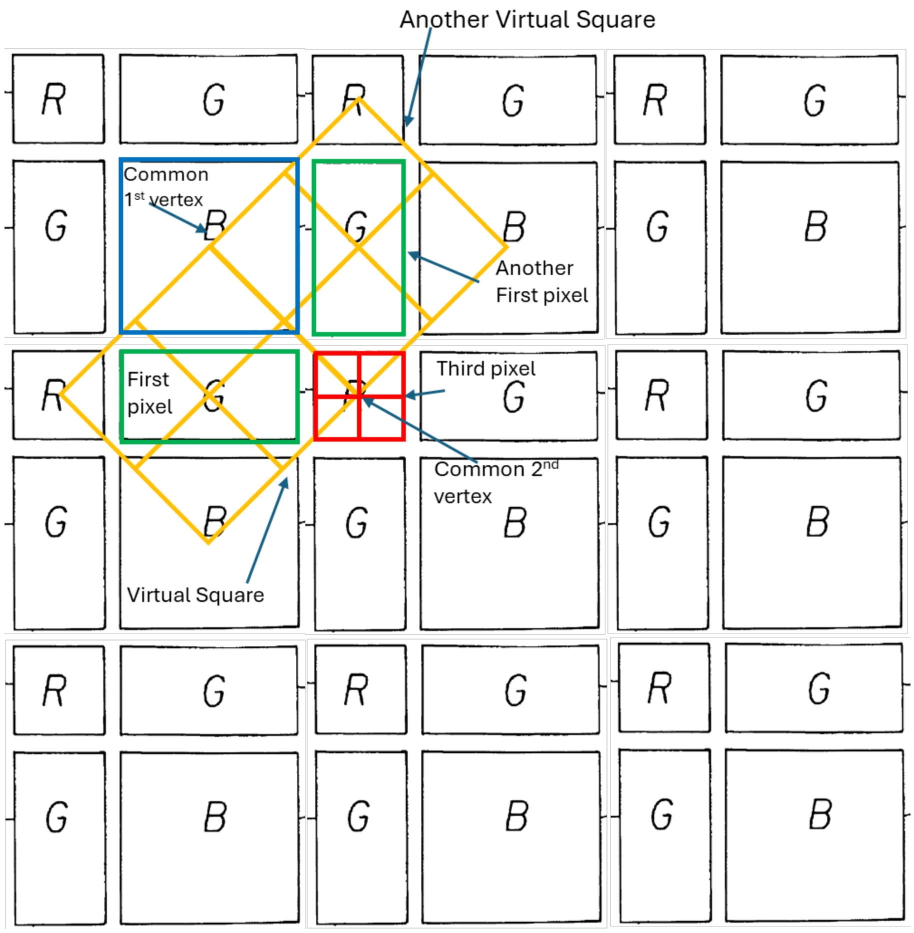
f. 1[E]: "an other first pixel on a line defined by the center of the virtual square and the first vertex, the first pixel, the second pixel, and the other first pixel being consecutive pixels on the line; and"

64. Cok teaches this Element. As shown below, an "other" green pixel (*e.g.*, corresponding to the claimed "an other first pixel") is located on a line defined by the center of the first virtual square, with the first pixel, the second pixel, and the other pixel being consecutive pixels on the line.



g. 1[F]: "a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

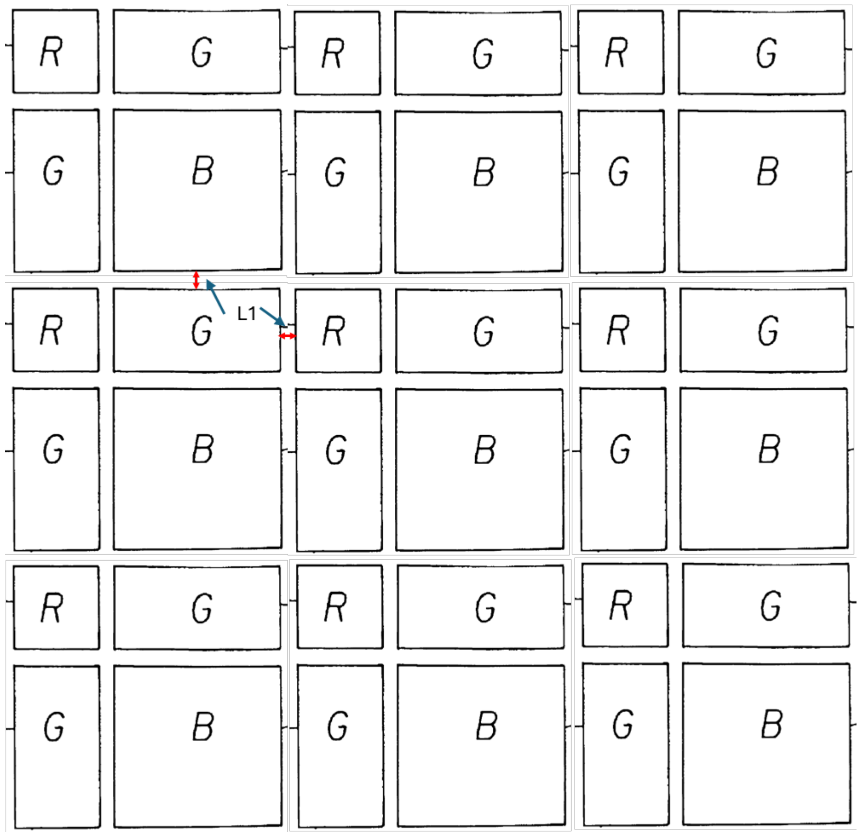
65. Cok teaches this Element. The red pixel (*e.g.*, corresponding to the claimed "third pixel") is separated from the first (*e.g.*, green) pixels and the second (*e.g.*, blue) pixel, and has a center at the second vertex of the virtual square, as shown below.



h. 1[G]: "wherein a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length,"

66. This limitation is met by Cok. As described above, a POSITA would have repeated the RGBG pattern as taught by Cok, of four pixels with equal spacing between the four-pixel pattern, because it is important for the accurate display of information that digital image data be displayed on a uniform, equal-spaced grid of RGBG patterns. Under the Cok arrangement, the shortest distance L1 between the first pixel (green) and the second pixel (red) as well as the shortest

distance L1 between the first pixel (green) and the third pixel (blue) is a same first length d1 due to the equal spacing between the four-pixel pattern, as shown below:



67. To the extent a POSITA would not have understood this element to be disclosed by or obvious from Cok, the POSITA would nevertheless have found it obvious to provide even spacing between adjacent green-red and green-blue pairs of pixels based on the teachings of Hong. As illustrated in FIG. 5 below, Hong teaches that "the first and second organic patterns 200a and 200b are spaced apart from each other by a first distance d1 for preventing a shadowing effect along a diagonal direction with respect to the first and second directions, and the second

and third organic patterns 200 b and 200 c are spaced apart from each other by the first distance d1 along the diagonal direction." (EX1008, ¶ [0048].)

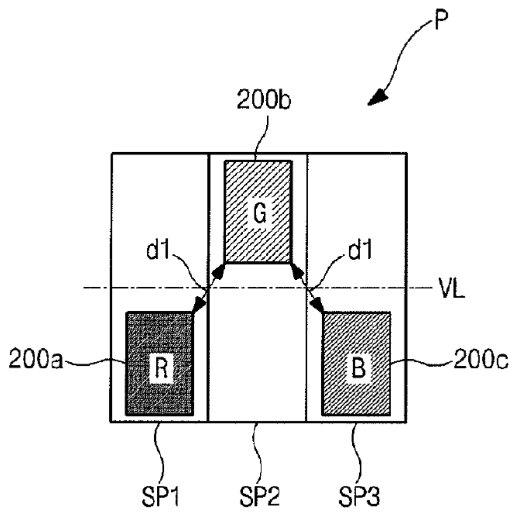


FIG. 5

That is, Hong teaches a pixel arrangement layout where the distance between the first (e.g., green) pixel and the second (e.g., blue) pixel as well as a shortest distance between the first (e.g., green) pixel and the third (e.g., red) pixel is a same first length d1 in order to prevent shadowing. (*Id.*, ¶ [0048].) In accordance with this teaching, a POSITA would have been motivated to modify Cok as shown below, such that the distance between the first (e.g., green) pixel and the second (e.g., blue) pixel as well as a shortest distance between the first (e.g., green) pixel and the third (e.g., red) pixel is a same first length d1 in order to prevent shadowing.

Motivation to Combine Cok with Hong

68. A POSITA would have found it obvious to implement the pixel arrangement pattern of Cok in view of Hong's teachings. Both Cok and Hong are in the same field as the '616 patent. Like the '616 patent, Cok is directed to "OLED displays having repeated patterns of colored light emitting elements." (EX1004, 1:8-10.) Similarly, Hong is directed to an "organic electroluminescent display (ELD) device." (EX1008, ¶ [0005].)

69. A POSITA would have been motivated to make this combination in order to improve the manufacturability and performance of an OLED display. Doing so would have been a simple application of the spacing taught by Hong to form the OLED display taught by Cok with predictable results because the two references describe the same, underlying OLED technology. A POSITA would have viewed Hong as disclosing just one more way to space the pixels in the OLED display of Cok.

70. Furthermore, modifying the device of Cok to have the spacings of Hong would be advantageous to prevent shadowing. For example, as described by Hong, spacing the green pixels from the blue pixels and the green pixels from the red pixels "by a first distance d1" can prevent a shadowing effect along the direction of the space between the pixels. (*Id.*, ¶ [0048].)

71. Additionally, a POSITA would have recognized that such a spacing would improve the manufacturability of an OLED display by preventing or reducing shadowing caused by the deposition process. Cok is silent with respect to manufacturing an OLED display, and thus a POSITA would have looked to Hong to supply those details. As discussed above, Hong teaches the use of a shadow mask for patterning the pixels. (*Id.*, ¶¶ [0070]-[0072].) Such a shadow mask, because it is made of metal, is susceptible to thermal expansion, such that the shadow mask may warp while the pixels are being formed during a vacuum thermal evaporation method. (*Id.*, ¶ [0072].) A POSITA would have understood that shadowing or color mixing can occur even if multiple masks are used because all masks will experience deformations such as warpage. The POSITA would have also recognized that the equal spacing taught by Hong can minimize the effects of such warpage and thermal deformation. This is at least because a POSITA would have known that thermal expansion in any direction is proportional to the original length of the material in that direction and that the error in position can occur in any direction.

72. Because the direction and extent mask deformations are unknown, a POSITA would have understood that keeping the spacings between the green-blue pixel pairs and the green-red pixel pairs the same will result in the least amount of shadowing. This consistency of spacing and positioning allows for a more

consistent application of each color, reducing the likelihood of color mixing or unintended patterns that can arise from uneven deposition. Additionally, since the direction and extent of mask deformations are unpredictable, maintaining equal spacings acts as a safeguard, ensuring that any deformation will have a consistent effect rather than creating localized areas of excessive shadowing or color mixing.

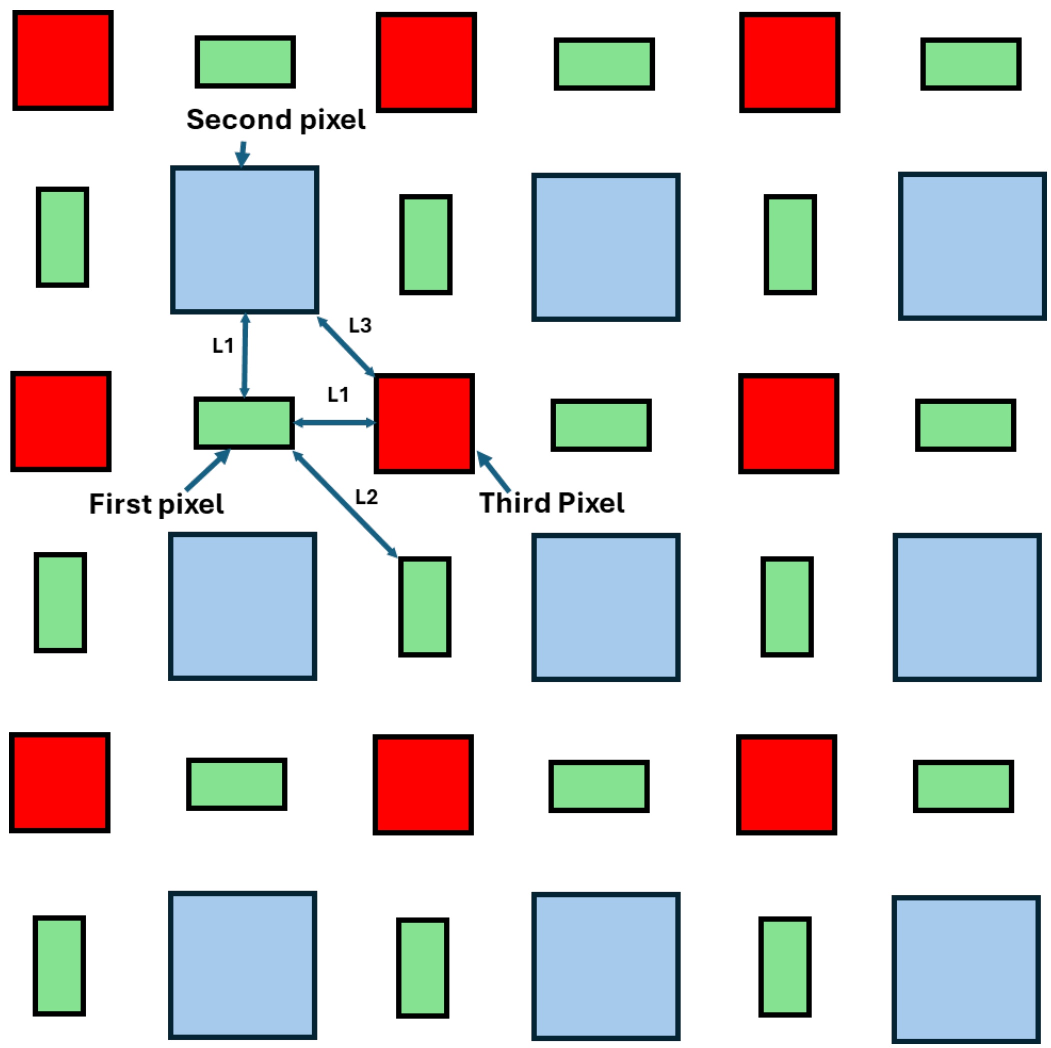
73. Thus, the POSITA would have been motivated to maintain an equal minimum distance between the green-blue pixel pairs and the green-red pixel pairs, such that the shadowing effect will be reduced equally in any direction. Similarly, a POSITA would have recognized that shadow masks for forming a display with unequal subpixel sizes would benefit in the same manner as with equal size subpixels; that is, a minimum equal distance between the green-blue pixel pairs and the green-red pixel pairs will mitigate the shadowing effect. Accordingly, the POSITA would have recognized that adopting Hong's teaching of equal distances between the green-blue pixel pairs and the green-red pixel pairs would mitigate the adverse effects of thermal expansion. If the distances between the green-blue pixel pairs and the green-red pixel pairs are equal, any expansion that occurs will affect all patterns uniformly, thus maintaining the integrity of the design and reducing the likelihood of shadowing.

74. A POSITA would have reasonably expected the combination to succeed. Both references relate to OLED display technology. A POSITA would

have viewed Hong as disclosing just one more way to space Cok's pixels. The combination of Cok and Hong, with its resulting pixel arrangement above, would have been straightforward.

i. 1[H]: "wherein a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels,"

75. A POSITA would have been further motivated to modify the sizes of the pixels in Cok's arrangement in view of Hong as shown below, such that a shortest distance between the first (green) pixels is a second length L2 that is longer than the first length L1 and a shortest distance between each of the second (blue) pixels and the third (red) pixels L3.



Motivation to Modify Cok

76. A POSITA would have found it obvious to modify the pixel sizes of Cok based on the teachings of Hong. As discussed above, Cok and Hong are analogous art. A POSITA would have been motivated to make this combination, as above, in order to improve the lifetime and performance of an OLED display. As taught by both Cok and Hong, the sizes of different color pixels can be different based on the emission efficiency of the material used for each color pixel. (EX1004, 3:18-24; EX1008, ¶ [0074].) Between the publication date of Cok in

2004 and the earliest claimed priority date of the ’066 patent in 2012, there was “rapid development” of OLED technology, including in the organic materials used for the emission layers of an OLED display. (EX1007 (“Nishimura”), 310.) A POSITA would have known that such materials provided better longevity and performance for OLED displays.

77. For example Hong, filed in 2010, when describing known efficiencies of materials commonly used at the time, discloses that green pixels can be the most efficient, blue pixels can be the least efficient, and red pixels can have an intermediate efficiency. (EX1008, ¶ [0074].) In another example, Nishimura (circa 2009) describes new phosphorescent host materials for red and green phosphorescent emitters that demonstrated lower driving voltages, higher efficiency, and longer lifetimes. (EX1007, 310-312.) Table 3 (below) of Nishimura shows the performance of OLED displays using older, fluorescent materials (shown in the blue table) and newer green and red phosphorescent materials (shown in the yellow table).

Table 3. Estimated results of 2.0" QVGA display performance. The power by TFT is not included.

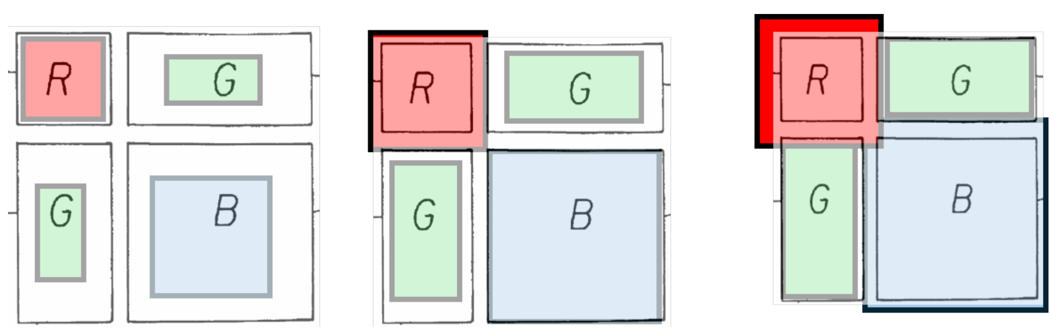
	CIEx	CIEy	L/J (cd/A)	Voltage (V)	Power (mW)	Half lifetime (hr)
All fluorescence						
Blue	0.13	0.08	5.1	5	91	19,000
Green	0.21	0.69	37.1	5	67	126,000
Red	0.67	0.33	20.8	5	57	230,000
				total	215	
Blue:Fluorescence, G,R:Phosphorescence						
Blue	0.13	0.08	5.1	5	91	19,000
Green	0.24	0.71	77.5	5	32	25,000
Red	0.67	0.33	26.9	5	44	>600,000
				total	167	

78. Nishimura shows the luminous flux for a given input energy L/J (also referred to as current efficiency) of the red, blue, and green materials in candelas/ampere (cd/A), such that green pixels can be the most efficient, blue pixels can be the least efficient, and red pixels can have an intermediate efficiency. (EX1007, Table 3.) Based on Table 3 above, a POSITA would have understood that, although the older fluorescent materials showed better lifetime for green emitters, the improved red and green phosphorescent materials resulted in an OLED display that consumed overall less power (167 mW) when driven at the same voltage (5 V). In addition to consuming less power, the newer red and green phosphorescent materials enabled brighter displays so that OLEDs could be used in bright environments. The newer materials also enabled a wider color gamut due to the improved green color. A POSITA would have understood decreasing the power consumption of an OLED is important as decreased power consumption

allows for OLEDs with higher efficiency and longer lifetimes. (EX1007, 310.) In view of this knowledge, as well as the ability to increase the brightness and color of OLEDs, a POSITA would have been motivated to use such improved materials to improve the lifetime, as well as reduce power-consumption, of an OLED display.

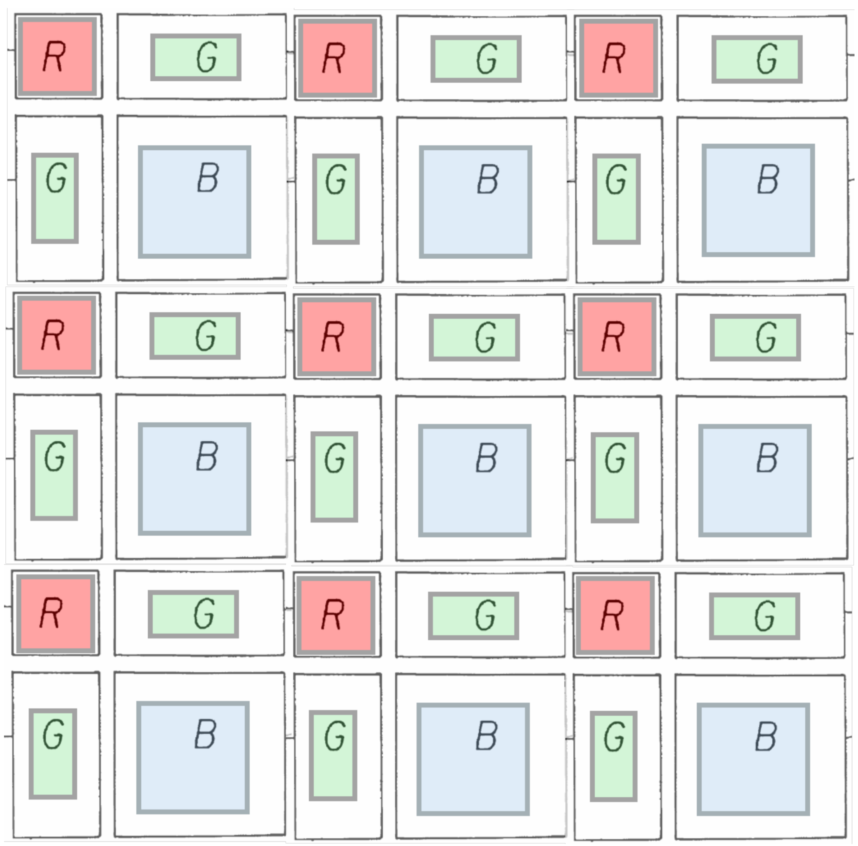
79. To account for the difference in efficiency when using such improved materials, the POSITA would have been motivated to make the green pixels the smallest and the blue pixels the largest, with the red pixels having an intermediate size compared to the green and blue pixels, in accordance with the teachings of both Hong and Cok. (EX1004, 3:18-24; EX1008, ¶ [0074].) Such a modification would have been a simple application of the sizing taught by Hong to form the OLED display taught by Cok with predictable results because the two references describe the same, underlying OLED technology. As Cok does not teach absolute sizes, to achieve these area ratios, a POSITA would have begun, as taught by Cok (EX1004, 3:57-67), with choosing the size of one of the light emitting elements, and used the area ratios to adjust the size of the other light emitting elements accordingly. Furthermore, in determining how to implement the area ratios relative to Cok's RGBG arrangement, the POSITA would have recognized that there were four possible options: 1) changing the size of each pixel, 2) maintaining the red pixels and adjusting the blue and green pixels relative to the red, 3)

maintaining the green pixels and adjusting the red and blue pixels relative to the green, and 4) maintaining the blue pixels and adjusting the red and green pixels relative to the blue. Depending on other design choices, the POSITA would have understood that all or only some of these four options would have been viable, but in any event would have found each to be obvious to try with a reasonable expectation of success. Here, the POSITA would have found it especially obvious to try to maintain the area of the red pixel, since the red pixel is of an intermediate size. In addition, as discussed in greater detail below, the POSITA would also have aimed to maintain the same pixel centers as shown in FIG. 1 of Cok. Keeping the red pixel unchanged relative to FIG. 1 would have helped to achieve this objective because maintaining the size of the red pixel, as opposed to either the blue or green pixel, would be most likely to avoid overlapping pixels, as illustrated below.



Where the desired area ratios require smaller changes to pixel area than what is shown above, a POSITA would have recognized that maintaining the size of the green or blue pixels may have been viable without leading to overlap. But in any event, the simple adjustments proposed in paragraph 76—based on maintaining the size of the red pixel while applying Hong's teachings regarding relative pixel area—would have been obvious to try as one of a finite set of predictable solutions with a reasonable expectation of success.

80. A POSITA would have maintained the relative centers of pixels (as shown below in relation to FIG. 1 of Cok) and repeated the RGBG pattern as taught by Cok, of four pixels with equal spacing between the four-pixel pattern because it is important for the accurate display of information that digital image data be displayed on a uniform, equal-spaced grid of RGBG patterns.



81. A POSITA would have known that since green pixels contain the majority of the white luminance (e.g., ~ 60% for typical OLEDs), it would have been critical that the centers be equally spaced. If they are not, luminance errors, jagged edges (aliasing), color fringing or chromatic aberrations, or Moiré defects can occur. A POSITA would have known of one metric, known as "Just Noticeable Difference" ("JND") which was developed by at least 2012. (EX1009, ("Vogels"), 820). A defect with one JND is detectable more than 50% of the time by a standard observer. A POSITA would have known that the size or spatial frequency of the defect and the viewing distance would affect the detectability. A deviation from a regular array of green subpixels can result in noticeable luminance or chroma errors greater than one JND. In addition, since the human visual system is extremely sensitive to deviations in parallel line spacing ("vernier acuity"), a POSITA would have known that even small deviations in pixel spacing could create noticeable errors. A POSITA would have also known that the equal spaced grid could have a pixel pitch with a unit length of 160 µm, such that the centers of the green pixels are 160 µm apart. (*See* Ex. 1006, FIG. 12.)

82. It would also have been important to a POSITA to also maintain equal centers for red and blue pixels although the sensitivity is lower for several reasons. First, the subpixels are larger, second, the luminance is lower, and third, subpixel rendering is used to average the information to be displayed among pixels and can

adjust for offsets. However, the positional accuracy (*e.g.*, the centers of red and blue pixels) must be uniform for the same reasons as for green.

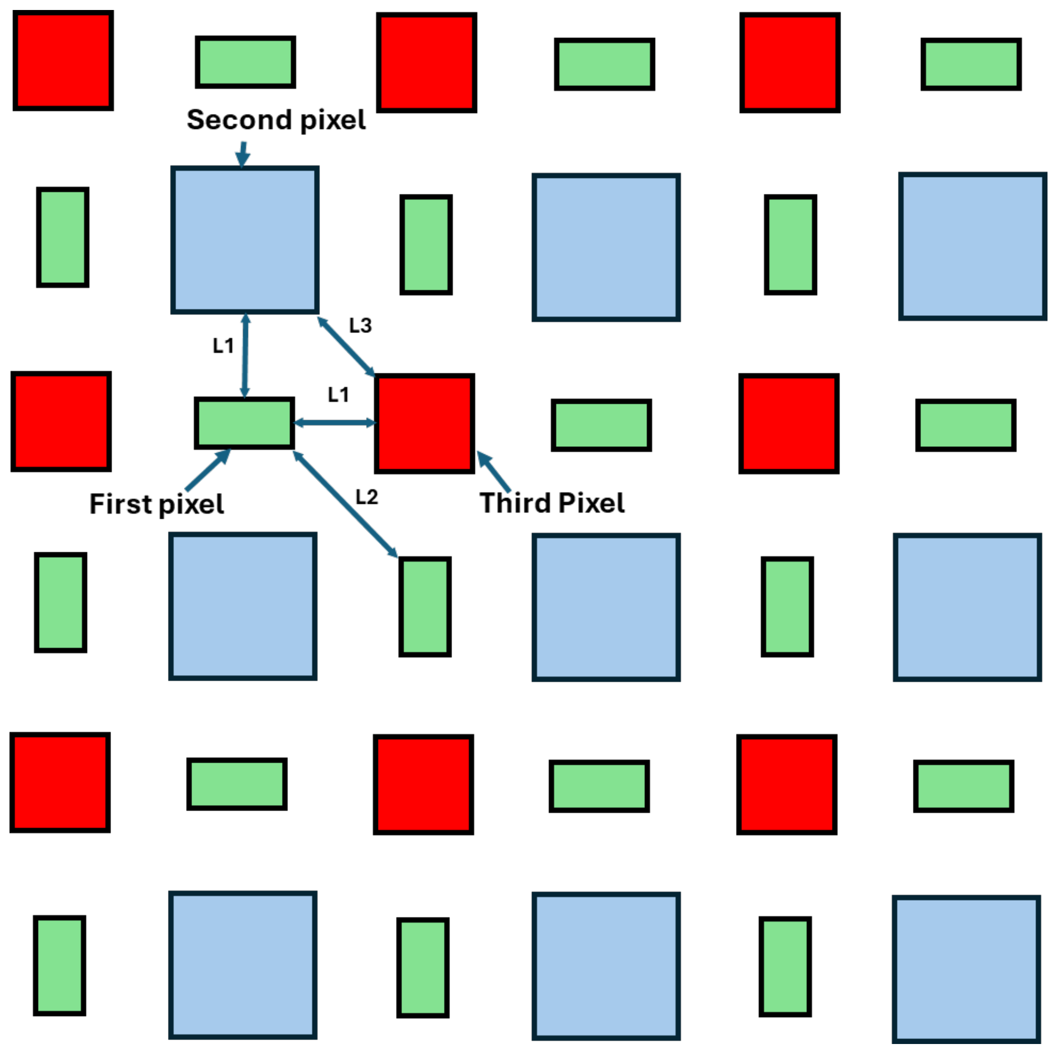
83. A POSITA would also have found it obvious to maintain the aspect ratios of the pixels shown in FIG. 1 because these aspect ratios are part of the specified pattern of FIG. 1. (EX1004, 3:65-67.) A POSITA, when considering the teachings of Cok, would have identified two possible options: using the aspect ratios taught by FIG. 1 of Cok or further modify FIG. 1 of Cok to use different area ratios. Considering these finite options, it would have been obvious to try maintaining the aspect ratios shown in FIG. 1 of Cok when modifying the pixel sizes with a reasonable expectation of success. A POSITA would have then repeated the resulting pattern to form the OLED display as shown above. (EX1004, 3:65-67.)

84. Moreover, a POSITA would have recognized that the combination would provide benefits. As taught by Hong, adjusting the sizes of the pixels in this manner would allow the different color pixels to "have the same brightness as each other," such that "uniformity in brightness and the controllability of white balance are improved." (EX1008, ¶ [0074].) At the same time, the POSITA would have sought to weigh the benefits of the white balance taught by Hong with the benefits of reducing the effect of shadowing taught in the same reference. Accordingly, the POSITA would have sought to maintain the equal green-red and green-blue

spacing between adjacent pixels that I have described with respect to element 1[G] above when resizing the pixels to achieve area ratios that better balance white light and brightness. To do so would have been particularly beneficial given Cok's RGBG pattern, wherein green-red and green-blue adjacent pairs share parallel horizontal sides that, as Hong teaches, would amplify the shadowing effect (as opposed to, for example, red-blue adjacent pairs that are closest to each other at their corners, which have a reduced risk of shadowing due to the limited area of overlap compared to pairs sharing full sides). (EX1008, ¶¶ [0010], [0036].)

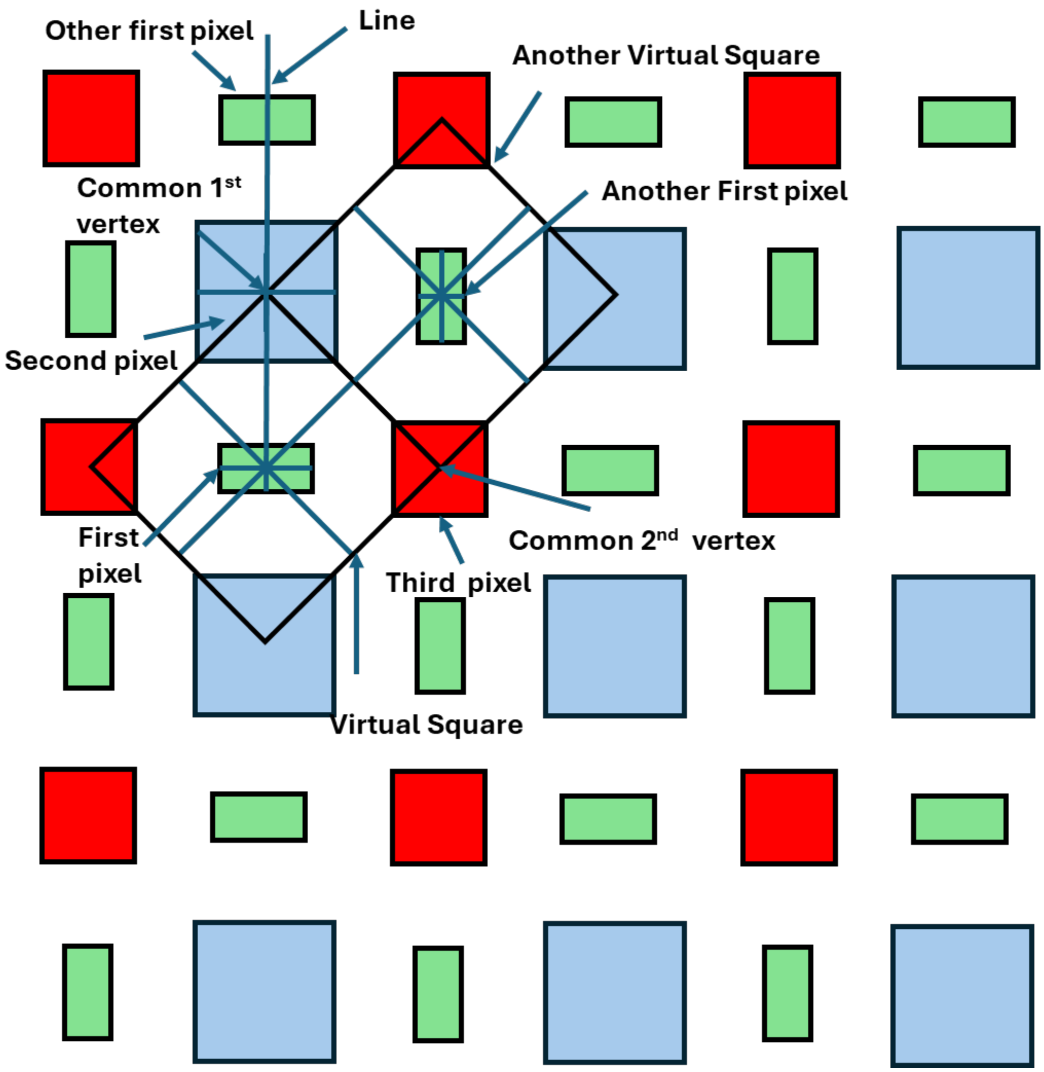
85. A POSITA would have reasonably expected the combination to succeed. Both references relate to OLED display technology. And Cok itself discloses that the relative sizes of the pixels can be changed according to the efficiencies of the materials used and that "for some combinations of materials, the green light emitting elements may be smaller than both the red and blue light emitting elements." (EX1004, 4:18-21.) A POSITA would have viewed Hong as disclosing just one more way to dimension Cok's pixels given improvements in OLED materials between the filing date of Cok and the filing date of Hong. The combination of Cok and Hong, with its resulting pixel arrangement above, would have been straightforward.

86. As illustrated below, when the green (first) pixels are the smallest and the blue (second) pixels are the largest, L2 is greater than both L1 and L3.



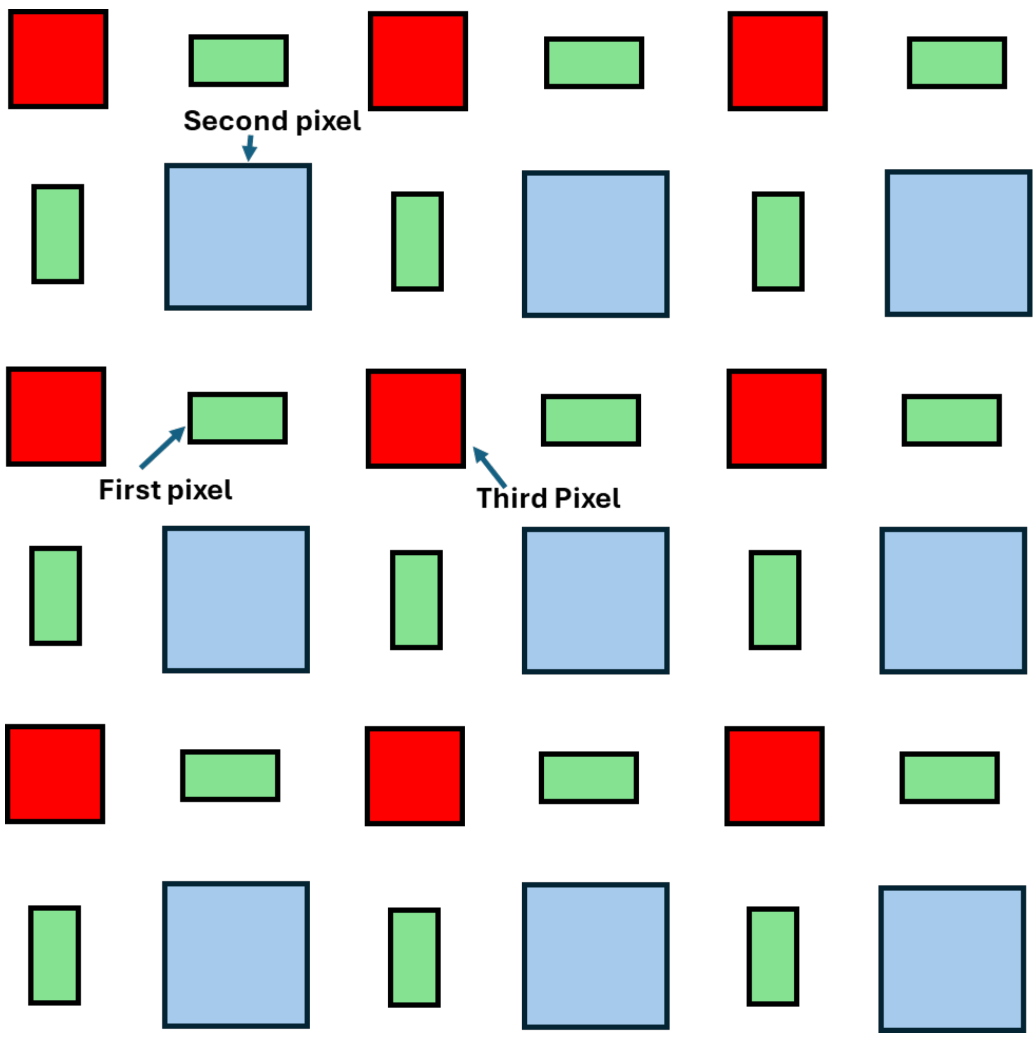
87. Such a modification would also preserve the aspects of Cok that teach limitations 1[A]-1[G], as discussed above. For example, as shown above, the distance between the green and blue pixels and the distance between the green and red pixels are kept equal as described above with respect to limitation 1[H]. Additionally, as shown below, the first (green) pixel has a center coinciding with a center of a virtual square, another first (green) pixel has a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual

squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light (e.g., red and blue), a second (blue) pixel is separated from the first pixels and having a center at the first vertex; an other (green) first pixel is on a line defined by the center of the virtual square and the first vertex, the first pixel, the second pixel, and the other first pixel being consecutive pixels on the line; and a third (red) pixel is separated from the first pixels and the second pixel, and has a center at the second vertex.



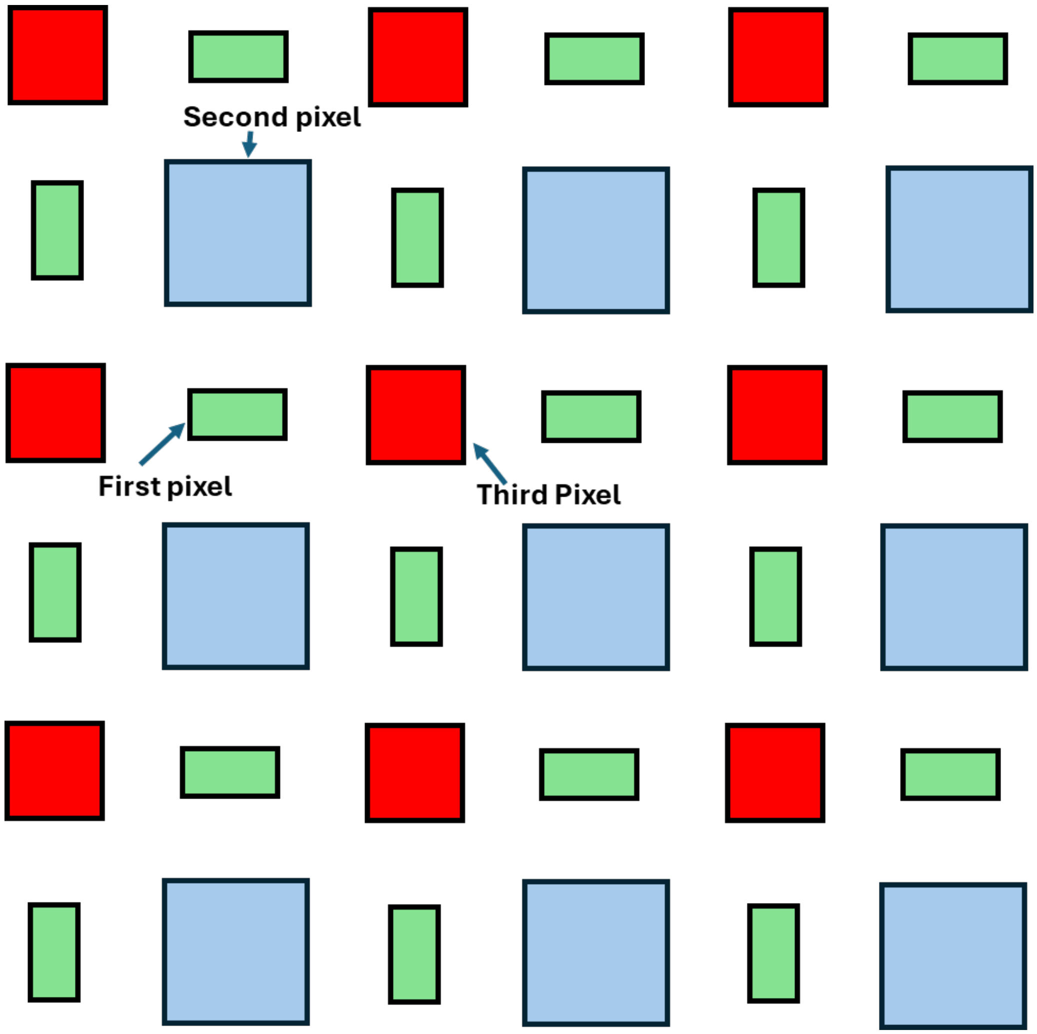
j. 1[I]: "wherein the second pixel and the third pixel have polygonal shapes, and,"

88. Cok teaches this Element. FIG. 1 of Cok, as modified, shows rectangle and square pixels. As described in the '616 patent, a polygonal shape can include "shapes such as an octagon, a hexagon, and a quadrangle." (EX1001, 12:29-30.)



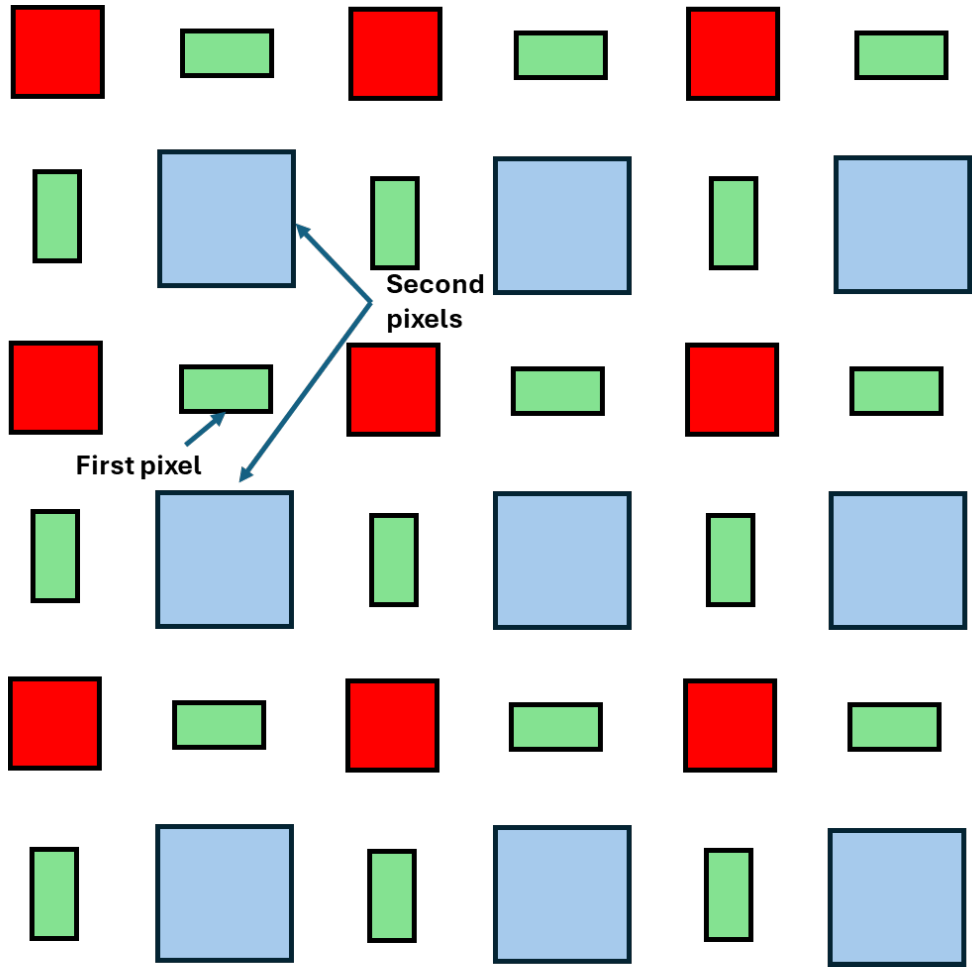
k. 1[J]: "wherein the second pixel has a larger area than that of the third pixel."

89. Cok discloses "a pixel pattern 10 in an OLED display device according to one embodiment of the present invention includes two green light emitting elements 14 having a first size (area), a red light emitting element 12 having a second smaller size, and a blue light emitting element 16 having a larger size." (EX1004, 4:8-14). Cok also discloses that "[f]or example, for some combinations of materials, the green light emitting elements may be smaller than both the red and blue light emitting elements." (EX1004, 4:17-21.) Additionally, as explained above, when considering the teachings of Hong, a POSITA would have modified Cok as shown below, with the blue pixel (e.g., the second pixel) having a larger area than the red pixel.



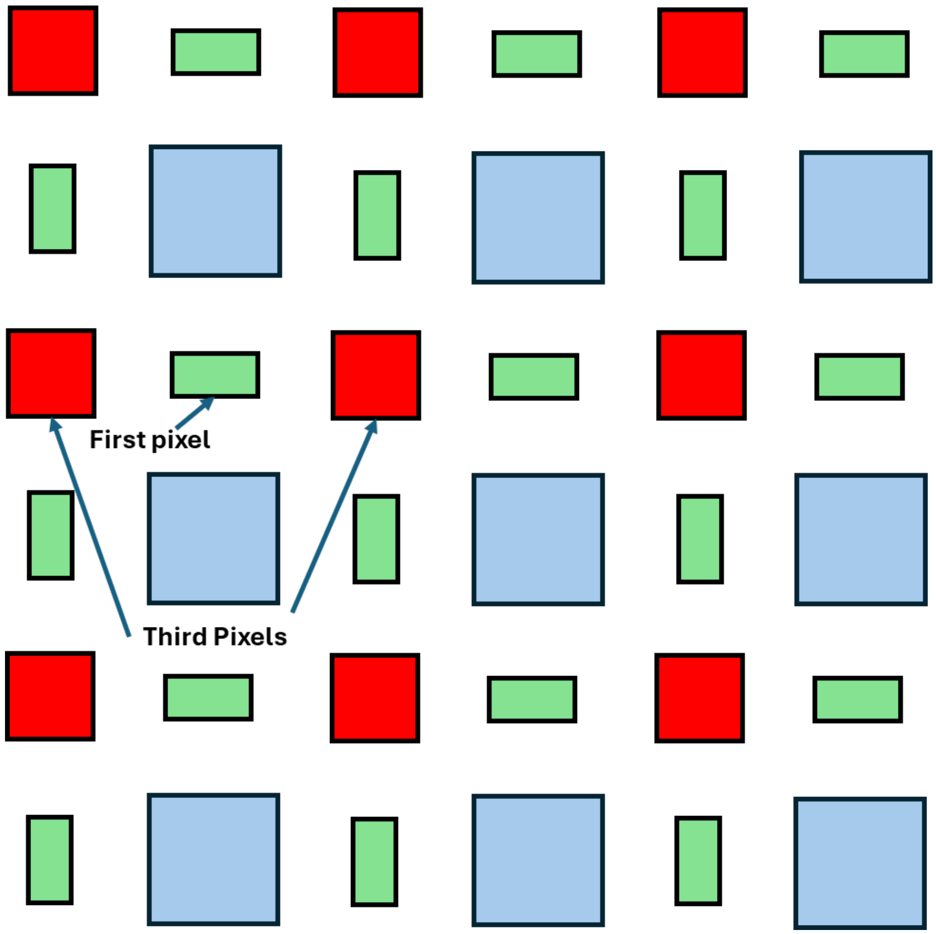
4. **Claim 2: "The pixel arrangement structure of claim 1, wherein the second pixel comprises a pair of second pixels, and the second pixels are separated from each other by the first pixel."**

90. Cok teaches claim 1, as shown in § X.A.2. Cok further teaches this claim. There is a pair of blue pixels (*e.g.*, corresponding to the claimed "pair of second pixels"), which are separated by a green pixel (*e.g.*, the first pixel), as shown below.



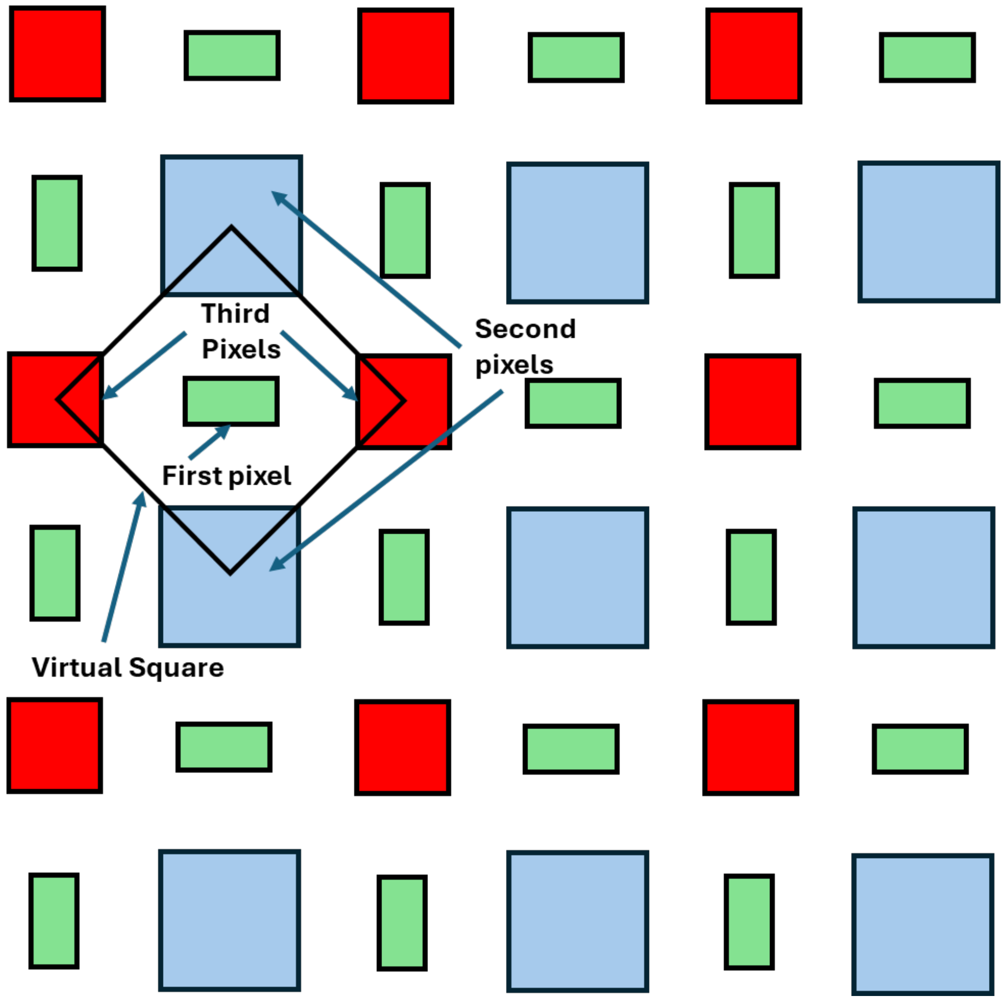
5. Claim 3: "The pixel arrangement structure of claim 1, wherein the third pixel comprises a pair of third pixels, and the third pixels are separated from each other by the first pixel."

91. Cok teaches claim 1, as shown in § X.A.2. Cok further teaches this claim. As shown below, there is a pair of red pixels (*e.g.*, corresponding to the claimed "pair of third pixels"), which are separated by a green pixel (*e.g.*, the first pixel).



6. **Claim 4: "The pixel arrangement structure of claim 1, wherein the second pixel comprises a pair of second pixels, the third pixel comprises a pair of third pixels, and the second pixels and the third pixels enclose the first pixel in the virtual square."**

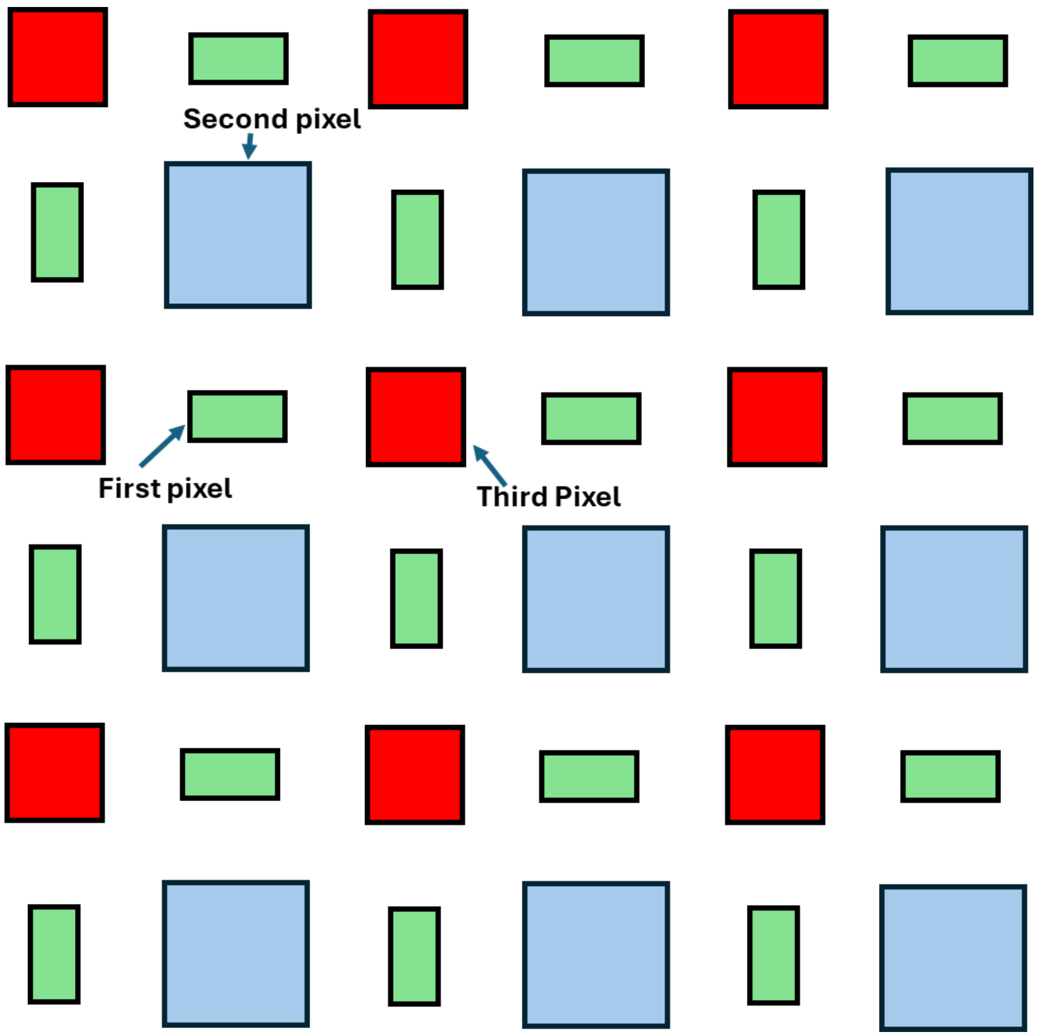
92. Cok teaches claim 1, as shown in § X.A.2. Cok further teaches this claim. As shown below, there is a pair of blue pixels (*e.g.*, a pair of second pixels) and a pair of red pixels (*e.g.*, a pair of third pixels), which enclose a pixel (*e.g.*, the first pixel) in a virtual square.



7. **Claim 5: "The pixel arrangement structure of claim 4, wherein each of the second pixels and the third pixels is larger in area than the first pixel."**

93. Cok teaches claim 4, as shown as shown in § X.A.5. Cok further teaches this claim. Cok discloses that "for some combinations of materials, the green light emitting elements may be smaller than both the red and blue light emitting elements." (EX1004, 4:16-19.) Additionally, as explained above, when using the relative sizes taught by Hong with the arrangement of Cok, a POSITA would have modified Cok as shown below, with the blue pixel (e.g., the second

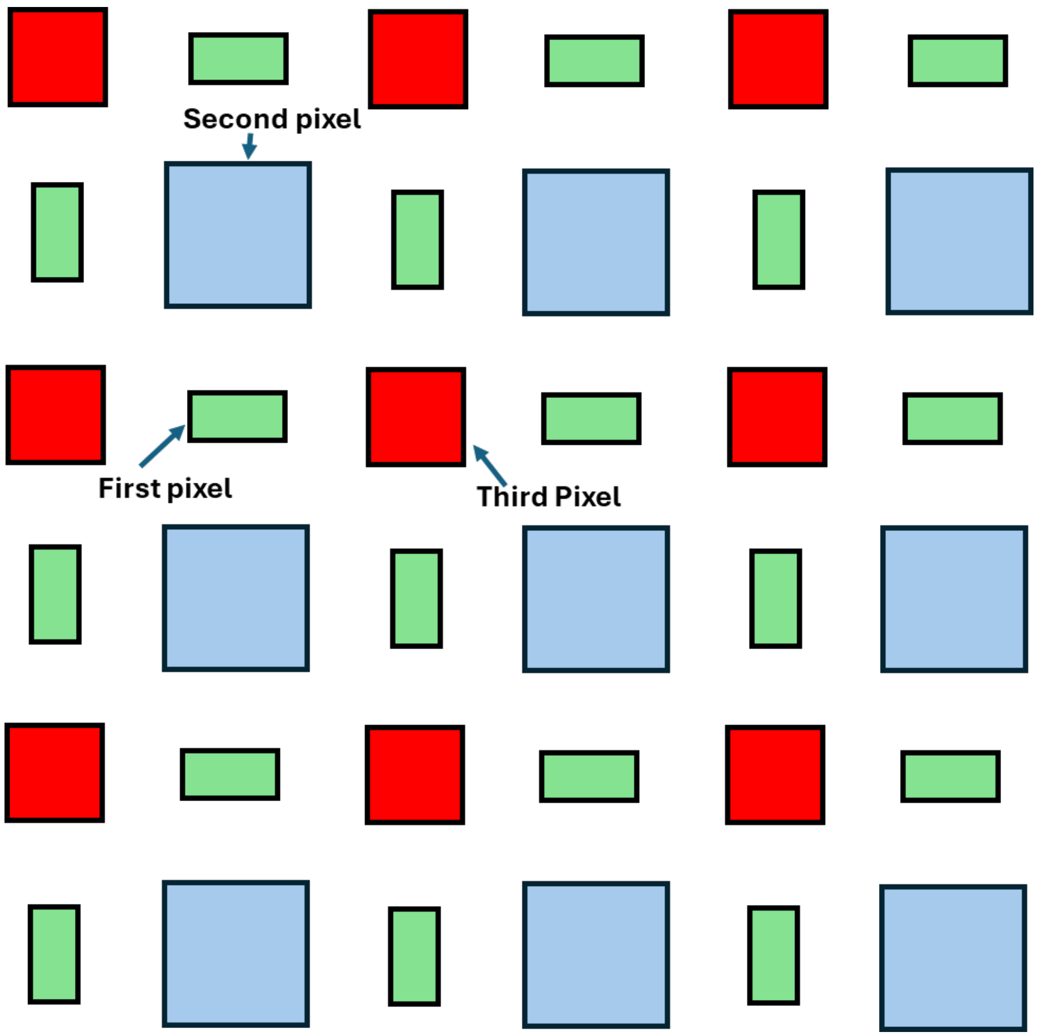
pixel) having the largest area, the red pixel (e.g., the third pixel) having an intermediate area, and the green pixel having the smallest area.



8. Claim 10: "The pixel arrangement structure of claim 1, wherein the first pixel, the second pixel, and the third pixel are configured to emit different color light."

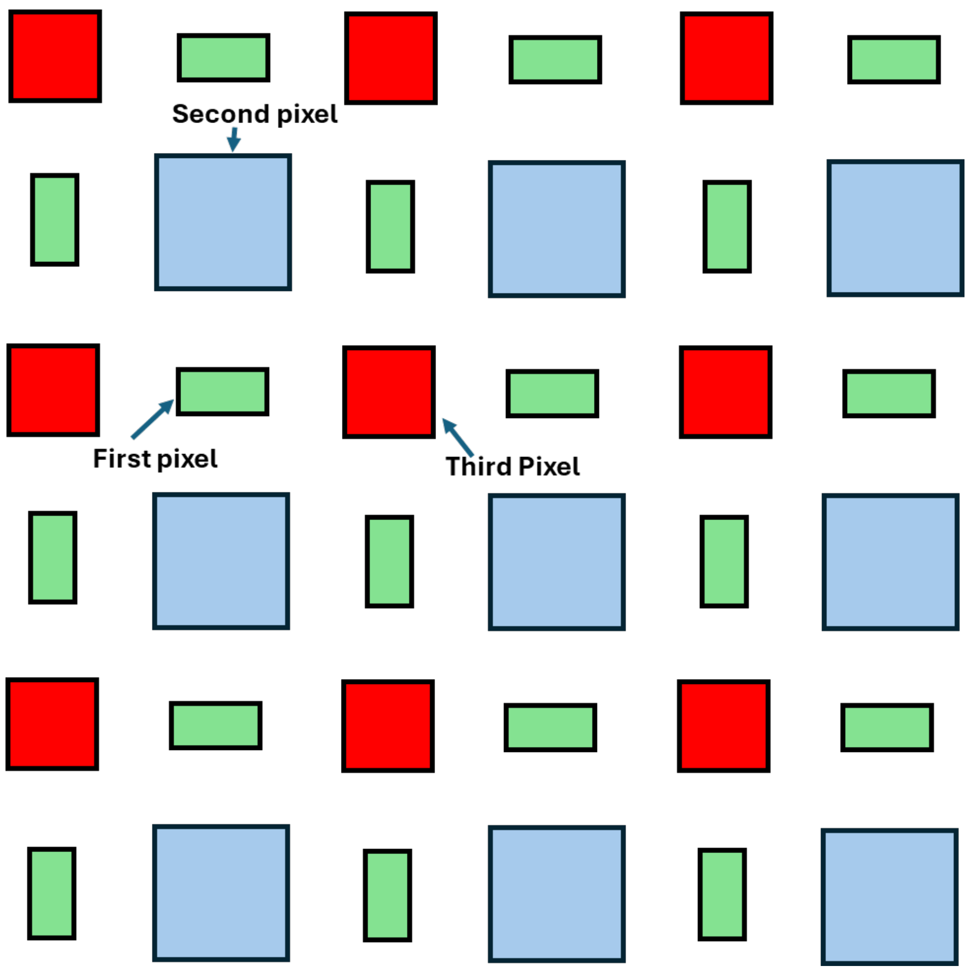
94. Cok teaches claim 1, as shown in § X.A.2. Cok further teaches this claim. Cok discloses "a pixel pattern 10 in an OLED display device according to one embodiment of the present invention includes two green light emitting

elements 14 having a first size (area), a red light emitting element 12 having a second smaller size, and a blue light emitting element 16 having a larger size." (EX1004, 4:7-12.) This is also shown below in Cok's FIG. 1, as modified.



9. Claim 11: "The pixel arrangement structure of claim 1, wherein the first pixel is configured to emit green light, one of the second pixel and the third pixel is configured to emit blue light, and another of the second pixel and the third pixel is configured to emit red light."

95. Cok teaches claim 1, as shown in § X.A.2. Cok further teaches this claim. Cok discloses "a pixel pattern 10 in an OLED display device according to one embodiment of the present invention includes two green light emitting elements 14 having a first size (area), a red light emitting element 12 having a second smaller size, and a blue light emitting element 16 having a larger size." (EX1004, 4:7-12.) This is also shown below in Cok's FIG. 1, as modified.



10. Claim 13

a. Preamble: "A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

96. The preamble of claim 13 is similar to the preamble of claim 1, which Cok renders obvious. (*Supra* § X.A.2.a.) The table below shows the similarities.

Preamble of Claim 1	Preamble of Claim 13
"A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"	"A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

b. 13[A]: "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

97. Element 13[A] is similar to element 1[A], which Cok renders obvious. (*Supra* § X.A.2.b.) The table below shows the similarities.

Element 1[A]	Element 13[A]
"a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"	"a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

c. 13[B]: "a first pixel having a center coinciding with a center of a virtual square;"

98. Element 13[B] is similar to element 1[B], which Cok renders obvious. (*Supra* § X.A.2.c.) The table below shows the similarities.

Element 1[B]	Element 13[B]
"a first pixel having a center coinciding with a center of a virtual square;"	"a first pixel having a center coinciding with a center of a virtual square;"

d. 13[C]: "another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

99. Element 13[C] is similar to element 1[C], which Cok renders obvious. (*Supra* § X.A.2.d.) The table below shows the similarities.

Element 1[C]	Element 13[C]
"another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"	"another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

e. 13[D]: "a second pixel separated from the first pixels and having a center at the first vertex;"

100. Element 13[D] is similar to element 1[D], which Cok renders obvious. (*Supra* § X.A.2.e.) The table below shows the similarities.

Element 1[D]	Element 13[D]
"a second pixel separated from the first pixels and having a center at the first vertex;"	"a second pixel separated from the first pixels and having a center at the first vertex;"

f. 13[E]: "a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

101. Element 13[E] is similar to element 1[F], which Cok renders obvious. (*Supra* § X.A.2.g.) The table below shows the similarities.

Element 1[F]	Element 13[E]
"a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"	"a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

g. 13[F]: "the second pixel and the third pixel have polygonal shapes,"

102. Element 13[F] is similar to element 1[I], which Cok renders obvious. (*Supra* § X.A.2.j.) The table below shows the similarities.

Element 1[I]	Element 13[F]
"the second pixel and the third pixel have polygonal shapes,"	"the second pixel and the third pixel have polygonal shapes,"

h. 13[G]: "a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length, and"

103. Element 13[G] is similar to element 1[G], which Cok in view of Hong renders obvious. (*Supra* § X.A.2.h.) The table below shows the similarities.

Element 1[G]	Element 13[G]
"wherein a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length,"	"a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length, and"

i. Element 13[H]: "a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels."

104. Element 13[H] is similar to element 1[H], which Cok in view of Hong renders obvious. (*Supra* § X.A.2.i.) The table below shows the similarities.

Element 1[H]	Element 13[H]
"wherein a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels,"	"a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels."

B. Claims 1-5, 10, 11, and 13 Are Obvious Over Credelle-379 And Hong

1. Summary of Credelle-379

105. Credelle-379 discloses "improved color pixel arrangements" which can be "implemented in other display technologies such as Organic Light Emitting Diode (OLED)." (EX1005, 1:45-46, 10:52-54.) Credelle-379 discloses arrangements of sub-pixel emitters comprising repeated octal groupings 120, as shown below in FIG. 1B (below), where "the colors are assigned as red 104, blue 102, and non-luminance balanced green 106." (*Id.*, 4:22-23.) Each octal pattern 120 includes "twice as many green 106 as there are of the other two colors, red 104 and blue 102," creating an RGBG pixel pattern. (*Id.*, 4:24-25.)

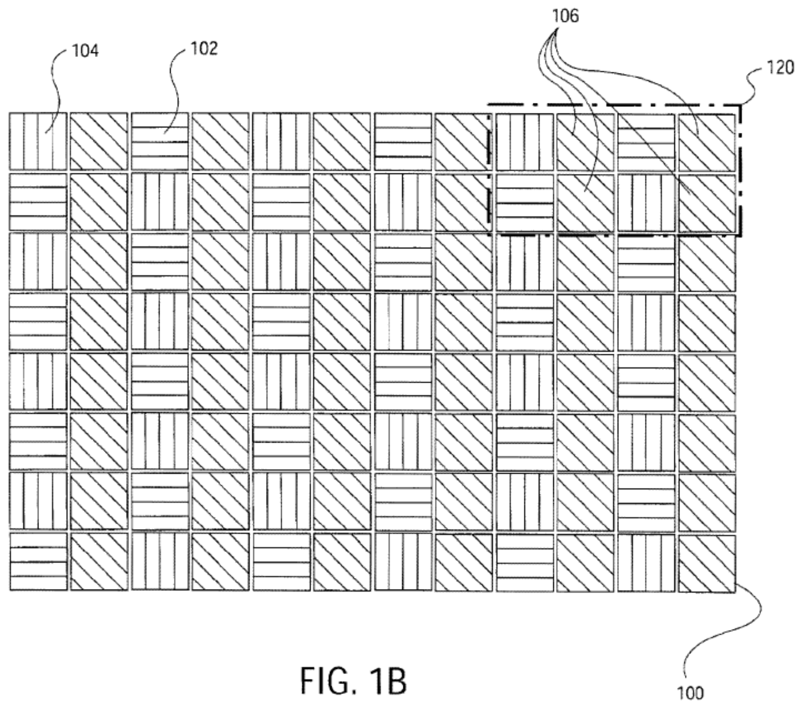


FIG. 1B

106. Credelle-379 also describes various ways the pixel arrangement of FIG. 1B can be altered. For example, FIG. 1C shows the sub-pixels adjusted in size and aspect ratio, with the green sub-pixels 106 reduced in size compared to the blue and red sub-pixels 102 and 104. (*Id.*, 4:11-14.)

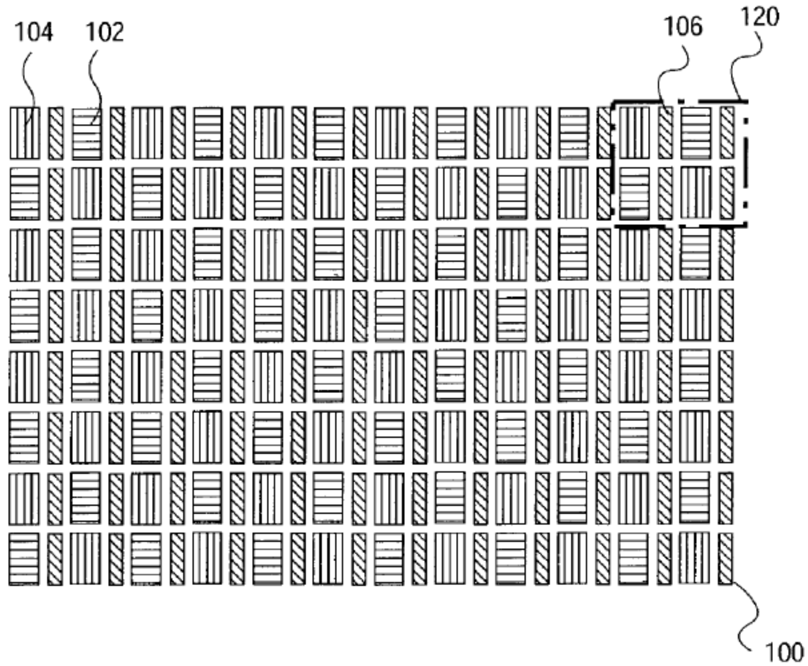
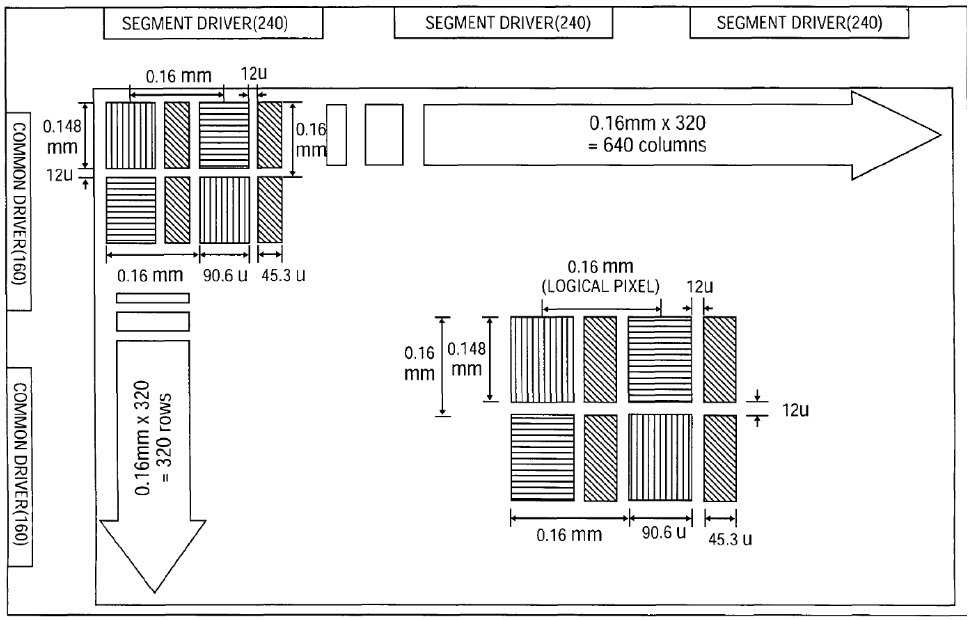


FIG. 1C

107. Credelle-379 also discloses that the sub-pixels are spaced apart from one another, as seen in FIGS. 1B and 1C, as well as FIG. 12. The pixel array in FIG. 12 also teaches that the pixels are arranged in a grid with equal spacing between the centers of the pixels. For example, FIG. 12 of Credelle-379 also shows the distance between the center of a blue pixel and the center of a red pixel is 160 μm for a typical display in the 2000s.

FIG. 12



108. FIG. 12 shows a spacing of 12 μm between edges of the sub-pixels, but Credelle-379 explains that "[a]lthough various sub-pixel dimensions are also disclosed in FIG. 12, it should be appreciated that other dimensions would also suffice and that FIG. 12 is merely offered for illustrative purposes for a single embodiment." (*Id.*, 10:39-44.)

109. As seen in FIGS. 1B and 1C, the sub-pixels are spaced apart, and when the sizes and aspect ratios of the sub-pixels are altered, the spacings between the sub-pixels are also altered to achieve the desired repeat group 120 shape. (*Id.*, FIGS. 1B and 1C.) For example, Credelle-379 discloses that "the sub-pixel aspect ratios may be adjusted so that the display array 100 consists of square repeat cell groups 120. This will put the majority color sub-pixel emitter 106 on a square

grid. It will also put the minority color sub-pixel emitters 102 and 104 on, or nearly on, an idealized "checkerboard." (*Id.*, 4:27-32.)

110. Beyond changing the sizes, aspect ratios, and spacings of the sub-pixels, Credelle-379 also discloses that "so too may the exact positions of the subpixels be varied under the scope of the present invention. For example, FIGS. 8A and 8B depict a similar octal subpixel grouping wherein one or both of the majority stripes 106 are offset (relatively or otherwise) from the other subpixels 102 and 104. Other vertical offsets are also possible." (*Id.*, 4:59-65.)

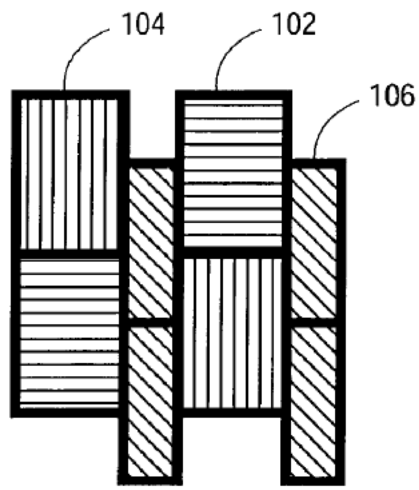


FIG. 8A

111. Although the figures show rectangular sub-pixels, Credelle-379 explains that "[i]t should be appreciated that other shapes to the subpixels are also possible and are contemplated within the scope of the present invention. For

example, a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable. It suffices only that there is an octal grouping of colored subpixels in the fashion herein described." (*Id.*, 4:51-57.)

112. Credelle-379 is directed to the same problem (pixel arrangements) in the same field of endeavor (displays, including OLED displays) as the '616 patent.

2. Claim 1

a. Preamble: "A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

113. Credelle-379 describes "A pixel arrangement structure of an organic light emitting diode (OLED) display." For example, Credelle-379 discloses that "[t]he present application relates to improvements to display layouts, and, more particularly, to improved color pixel arrangements," which can be used for display technologies such as "Active Matrix Organic Light Emitting Diode Display (AMOLED)." (EX1005, 1:44-46, 5:55-57, 13:26-33.)

b. 1[A]: "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

114. Credelle-379 discloses "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display." For example, Credelle-379 discloses "improved color pixel arrangements," which can be used for display technologies

such as "Active Matrix Organic Light Emitting Diode Display (AMOLED)." (EX1005, 1:44-46, 5:55-57, 13:26-33.) Although Credelle-379 describes the individual light emitting elements as "emitters" or "sub-pixels," a POSITA would have understood that this term is merely referring to the same components as the claimed "pixels" in the '616 patent. (*Id*., 2:34-37.) A POSITA would have known that a characteristic of AMOLEDs is that each sub-pixel of Credelle-379 (corresponding to the claimed "pixels") has its own dedicated circuitry, such that the sub-pixels are individually addressable.

c. 1[B]: a first pixel having a center coinciding with a center of a virtual square;

115. Credelle-379 teaches the pixel arrangement shown in FIG. 1C, below. The green pixels are positioned such that the centers of the green pixels are on an equal grid spacing, as shown by the red square (*e.g.*, a virtual square) below.

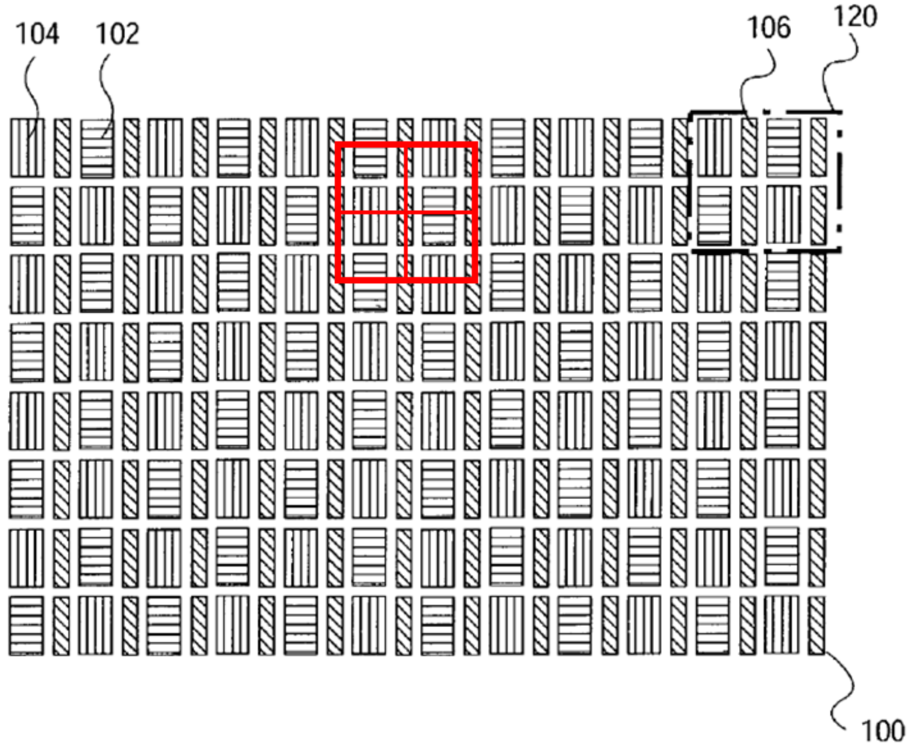
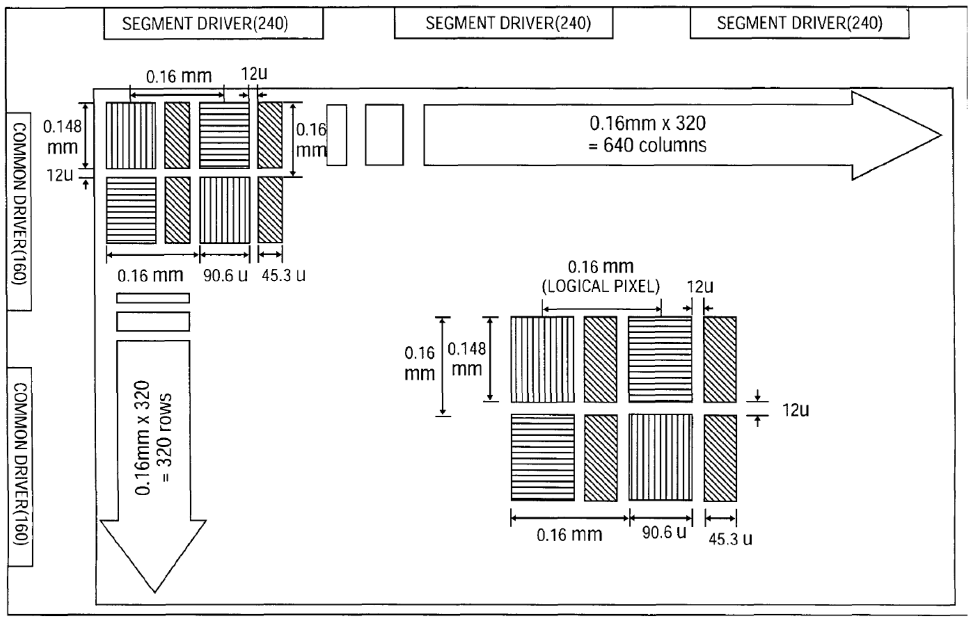


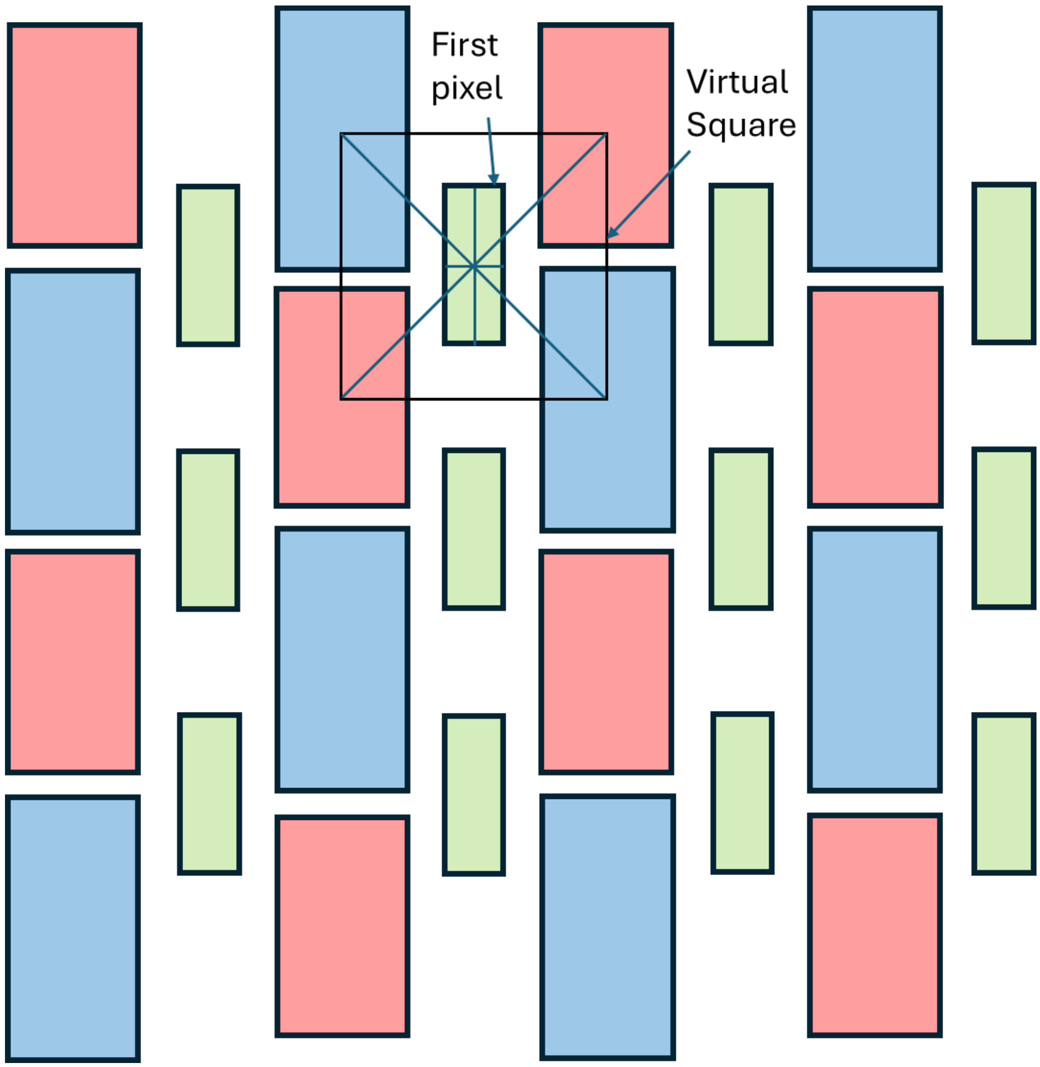
FIG. 1C

116. FIG. 12 of Credelle-379 also teaches that the spacing between the centers of the blue and red pixels, and correspondingly, the spacing between the centers of the green pixels, is 160 μm for an exemplary display.

FIG. 12



117. As discussed above, Credelle-379 teaches that the relative sizes, aspect ratios, spacings (*e.g.*, as shown by the modification of the pixel arrangement structure of FIG. 1B to the one shown in FIG. 1C), and positions (*e.g.*, particularly vertical offsets as shown in FIG. 8A and 8B) of the pixels can be altered. (EX1005, 4:27-32, 4:52-57, 4:59-65, 10:39-44, FIGS. 1B, 1C, 8A, and 8B.) As discussed below, a POSITA would have been motivated to modify FIG. 1C of Credelle-379 as follows, with a green sub-pixel (*e.g.*, the claimed "first pixel") of Credelle-379 having a center coinciding with a center of a virtual square.



118. First, a POSITA would have been motivated to modify FIG. 1C of Credelle-379 in order to improve the lifetime and performance of an OLED display. Between the publication date of Credelle-379 in 2003 and the publication of Hong in 2011, and certainly by the priority date of the challenged patent here, there was "rapid development" of OLED technology, including in the organic materials used for the emission layers of an OLED display. (EX1007, 310.) For example Hong, filed in 2010, when describing known efficiencies of materials

commonly used at the time, discloses that green pixels can be the most efficient, blue pixels can be the least efficient, and red pixels can have an intermediate efficiency. (EX1008, ¶ [0074].) In another example, Nishimura (circa 2009) describes new phosphorescent host materials for red and green phosphorescent emitters, such that green pixels can be the most efficient, blue pixels can be the least efficient, and red pixels can have an intermediate efficiency. (EX1007, Table 3.) In view of this knowledge, a POSITA would have been motivated to use such improved materials to improve the lifetime, as well as reduce power-consumption, of an OLED display.

119. To account for the difference in efficiency when using such improved materials, the POSITA would have been motivated to provide the least area to the green pixels and the most to the blue pixels, with the red pixels having an intermediate area compared to the green and blue pixels, in accordance with the teachings of Hong. (EX1004, 3:18-24; EX1008, ¶ [0074].) But, as shown in Figure 12, the Credelle-379 layout assigns equal total area to each color: The red and blue pixels have the same size, which is twice the size of each green pixel, offsetting the fact that there are twice as many green pixels as red or blue. Thus, a POSITA would have followed Hong in increasing the area of the blue pixels and decreasing the area of the green pixels. Such a modification would have been a simple application of the sizing taught by Hong to form the OLED display taught

by Credelle-379 with predictable results because the two references describe the same, underlying OLED technology. Furthermore, while a POSITA would have been able to resize the pixels relative to Credelle-379 in any of a number of ways based on the POSITA's knowledge and skill, one particularly straightforward and readily apparent modification would have been to increase the height of the blue pixels and decrease the height of the green pixels while otherwise maintaining Credelle-379's layout. To the extent the POSITA would have concluded, based on the specific design needs for the intended application, that greater increases to the blue pixel area are necessary than permitted by the available space between the red and blue pixels, a POSITA would have understood that all of the pixels could be spaced proportionally apart to provide for the additional space required.

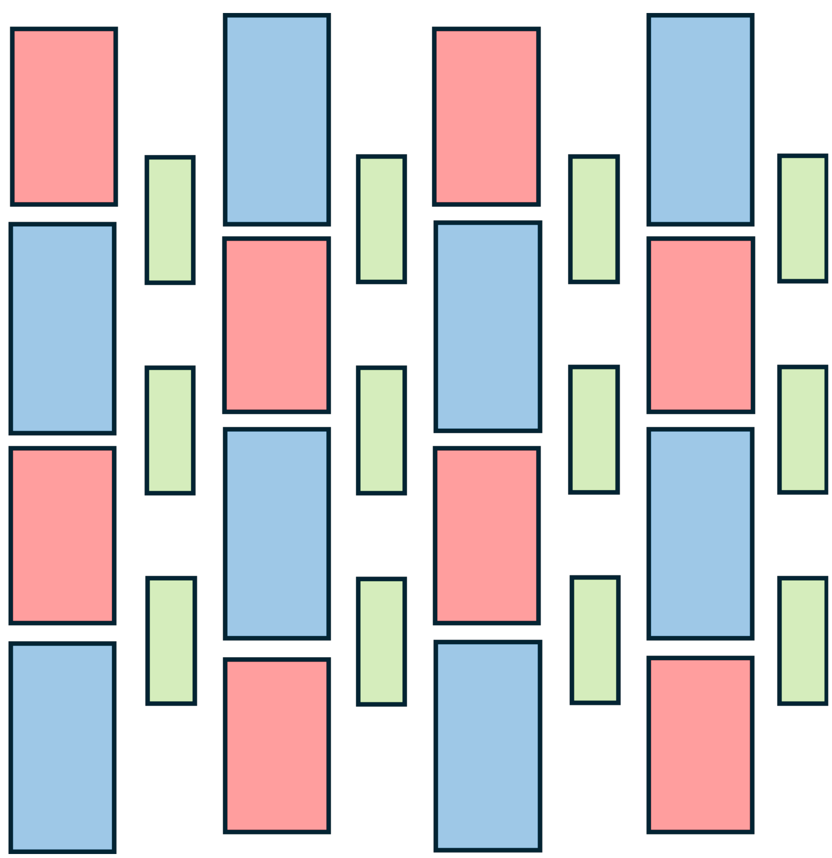
120. Second, a POSITA would have understood that vertically offsetting the green pixels as taught by FIG. 8A of Credelle-379 would create an array with improved visual properties and improved manufacturability. For example, the pixel arrangement in Fig. 8A creates a pattern with a green pixel at the center and surrounded by shared red and blue pixels. Additionally, a POSITA would have known that shifting the green sub-pixels vertically by one half of the pixel spacing would have allowed the array of pixels to be rotated. This would have allowed for manufacturing flexibility in the position of thin film transistors and interconnections. A POSITA would have also known that offsetting the green

pixel is compatible with sub-pixel rendering. Red and blue information is displayed on the red and blue sub-pixels by weighting the red and blue digital data from a 3x3 sampling of incoming data. The weighting factors can be adjusted to create a virtual center of luminance for red or blue information and thus can be shifted vertically or horizontally. Because of this feature, the green pixels (which do not require sub-pixel rendering) can be shifted vertically.

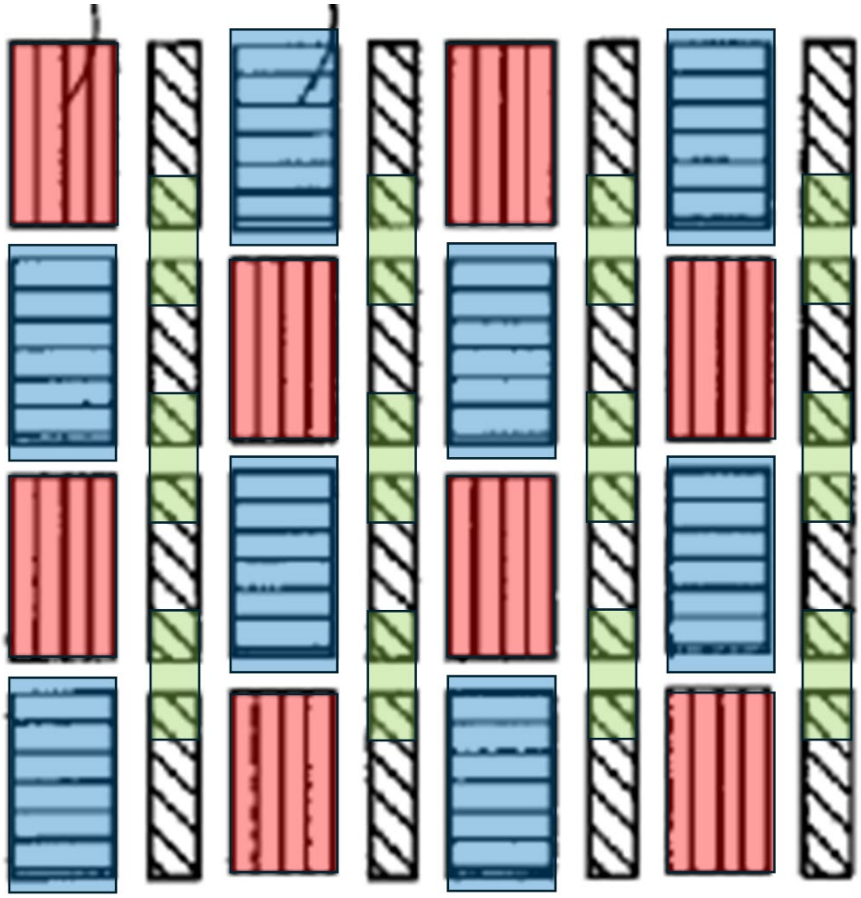
121. A POSITA would also have maintained the spacing between the centers of the blue and red pixels, and correspondingly, the spacing between the centers of the green pixels, as 160 µm, as taught by FIG. 12 of Credelle-379. For example, a POSITA would have known that since green pixels contain the majority of the white luminance (e.g., ~ 60% for typical OLEDs), it would have been critical that the centers by equally spaced. If they are not, luminance errors, jagged edges (aliasing), color fringing or chromatic aberrations, or Moiré defects can occur. A POSITA would have known of one metric, known as “Just Noticeable Difference” (JND) which was developed by at least 2012. (EX1009, 820). A defect with one JND is detectable more than 50% of the time by a standard observer. A POSITA would have known that the size or spatial frequency of the defect and the viewing distance would affect the detectability. A deviation from a regular array of green subpixels can result in noticeable luminance or chroma errors greater than one JND. In addition, since the human visual system is

extremely sensitive to deviations in parallel line spacing (“vernier acuity”), a POSITA would have known that even small deviations in pixel spacing could create noticeable errors. A POSITA would have also known that the equal spaced grid could have a pixel pitch with a unit length of 160 µm, such that the centers of the green pixels are 160 µm apart. (*See* Ex. 1006, FIG. 12.)

122. Combining Hong’s teachings about the relative sizes between pixels of different colors with FIG. 1C of Credelle-379 and vertically offsetting the green sub-pixels as shown in FIG. 8A of Credelle-379, a POSITA would arrive at the arrangement of rectangular pixels shown below (and annotated above).



123. Shown below is an overlay of the arrangement from FIG. 1C on the modified arrangement shown above.



124. A POSITA would have maintained the grid-like spacing of the green pixels because it is important for the accurate display of information that digital image data be displayed on a uniform, equal-spaced grid of RGBG patterns. A POSITA would have known that since green pixels contain the majority of the white luminance (e.g., ~ 60% for typical OLEDs), it would have been critical that the centers by equally spaced. If they are not, luminance errors, jagged edges (aliasing), color fringing or chromatic aberrations, or Moiré defects could occur. A

POSITA would have known of one metric, known as "Just Noticeable Difference" (JND) which was developed by at least 2012. (EX1009, 820). A defect with one JND is detectable more than 50% of the time by a standard observer. A POSITA would have known that the size or spatial frequency of the defect and the viewing distance would affect the detectability. A deviation from a regular array of green subpixels can result in noticeable luminance or chroma errors greater than one JND. In addition, since the human visual system is extremely sensitive to deviations in parallel line spacing ("vernier acuity") a POSITA would have known that small deviations in pixel spacing can create noticeable errors.

125. It would have been important to a POSITA to also maintain equal centers for red and blue pixels although the sensitivity is lower for several reasons. First, the subpixels are larger, second, the luminance is lower, and third, subpixel rendering is used to average the information to be displayed among pixels and can adjust for offsets. However, the positional accuracy (*e.g.*, the centers of red and blue pixels) must be uniform for the same reasons as for green.

126. The POSITA would have also recognized that such a modification would be compatible with the teaching of Hong to maintain the distance between the first (e.g., green) pixel and the second (e.g., blue) pixel as well as a shortest distance between the first (e.g., green) pixel and the third (e.g., red) pixel as a same first length d1 in order to prevent shadowing. (EX1008, ¶ [0048].)

127. A POSITA would have found it obvious to use the relative sizes taught in Hong for adjusting the pixel arrangement of Credelle-379. Both Credelle-379 and Hong are in the same field as the '616 patent. Like the '616 patent, Credelle-379 is directed to "improvements to display layouts, and, more particularly, to improved color pixel arrangements" that can be used in OLED (including AMOLED) displays. (EX1005, 1:44-46, 5:55-57.) Similarly, Hong is directed to "organic electroluminescent display (ELD) device." (EX1008, ¶ [0005].)

128. Making this combination would have been a simple substitution of one set of dimensions (the relative areas taught by Hong) for another (the relative areas of Credelle-379 FIG. 1C) with predictable results given that the two references describe the same, underlying OLED technology. Indeed, a POSITA would have viewed Hong as disclosing just one more way to dimension Credelle-379's sub-pixels given improvements in OLED materials.

129. Moreover, a POSITA would have recognized that the substitution would provide benefits. As taught by Hong, adjusting the sizes of the pixels in this manner would allow the different color pixels to "have the same brightness as each other," such that "uniformity in brightness and the controllability of white balance are improved." (EX1008, ¶ [0074].)

130. Additionally, as found by the Board during the original examination of the ’616 patent, “an artisan would have been motivated at the time of the invention to combine [Credelle-179’s] system with Kim’s different sub-pixel sizes because the different sub-pixel sizes can correct white balance and color coordinate.” (EX1003, 121.) Although the Examiner’s analysis refers to Credelle-179, which taught different shapes and vertical offsets and not explicitly different sizes, the same analysis applies even more strongly to Credelle-379, which explicitly contemplates altering pixel size in addition to altering shapes and vertical offsets. (EX1003, 121; EX1005, 4:27-32, 4:52-57, 4:59-65, 10:39-44, FIGS. 1B, 1C, 8A, and 8B; *see also* EX1018 for a comparison of Credelle-179 and Credelle-379.)

131. Further, the POSITA would have recognized that maintaining the distance between the first (e.g., green) pixel and the second (e.g., blue) pixel as well as a shortest distance between the first (e.g., green) pixel and the third (e.g., red) pixel as a same first length, as taught by Hong, would improve the manufacturability of an OLED display by preventing or reducing shadowing caused by the deposition process. Credelle-379 is silent with respect to manufacturing an OLED display, and thus a POSITA would have looked to Hong to supply those details. As discussed above, Hong teaches the use of a shadow mask for patterning the pixels. (EX1008, ¶¶ [0070]-[0072].) Such a shadow mask,

because it is made of metal, is susceptible to thermal expansion, such that the shadow mask may warp while the pixels are being formed during a vacuum thermal evaporation method. (EX1008, ¶ [0072].) A POSITA would have understood that shadowing or color mixing can occur even if multiple masks are used because all masks will experience deformations such as warpage. The POSITA would have also recognized that the equal spacing taught by Hong can minimize the effects of such warpage and thermal deformation. This is at least because a POSITA would have known that thermal expansion in any direction is proportional to the original length of the material in that direction and that the error in position can occur in any direction.

132. Because the direction and extent mask deformations are unknown, a POSITA would have understood that keeping the spacings between the green and red pixels the same as the spacing between the green and blue pixels would result in the least amount of shadowing. This consistency in spacing and positioning allows for a more consistent application of each color, reducing the likelihood of color mixing or unintended patterns that can arise from uneven deposition. Additionally, since the direction and extent of mask deformations are unpredictable, maintaining equal spacings between the green-blue pixel pairs and the green-red pixel pairs acts as a safeguard, ensuring that any deformation will

have a consistent effect rather than creating localized areas of excessive shadowing or color mixing.

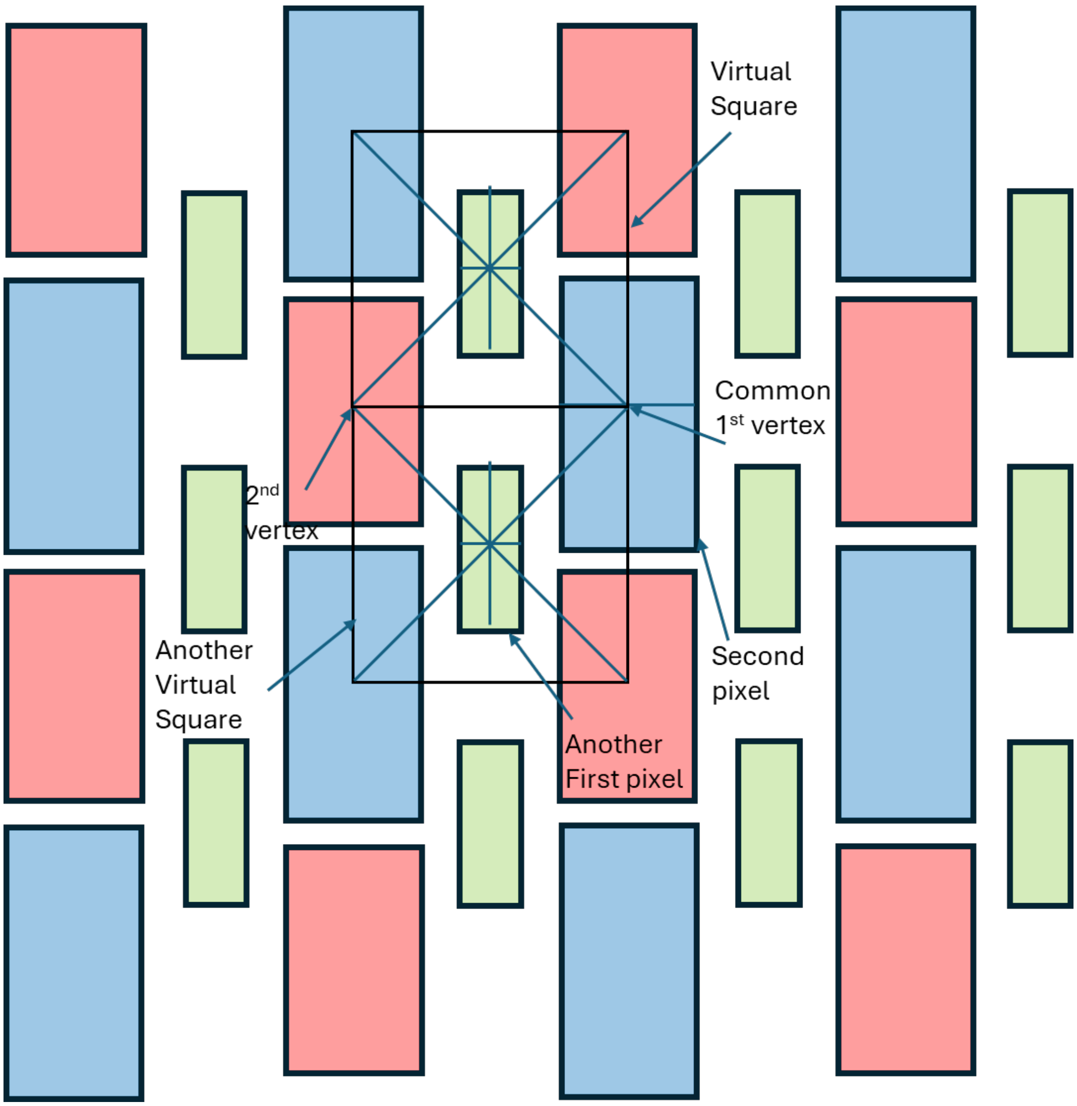
133. Thus, the POSITA would have been motivated to maintain an equal minimum distance between the green-blue pixel pairs and the green-red pixel pairs, such that the shadowing effect will be reduced equally in those directions. Similarly, a POSITA would have recognized that shadow masks for forming a display with unequal subpixel sizes would benefit in the same manner as with equal size subpixels; that is, a minimum equal distance between the green-blue pixel pairs and the green-red pixel pairs will mitigate the shadowing effect. Accordingly, the POSITA would have recognized that adopting Hong's teaching of equal distances between adjacent pixels would mitigate the adverse effects of thermal expansion. If the distances between the green-blue pixel pairs and the green-red pixel pairs are equal, any expansion that occurs will affect all patterns consistently, thus maintaining the integrity of the design and reducing the likelihood of shadowing.

134. A POSITA would have reasonably expected the combination to succeed. Both references relate to OLED display technology. And Credelle-379 itself discloses that the relative sizes, aspect ratios, spacings (*e.g.*, as shown by the modification of the pixel arrangement structure of FIG. 1B to the one shown in FIG. 1C), and positions (*e.g.*, particularly vertical offsets as shown in FIG. 8A and

8B) of the pixels can be altered. (EX1005, 4:27-32, 4:52-57, 4:59-65, 10:39-44, FIGS. 1B, 1C, 8A, and 8B.) The combination of Credelle-379 and Hong, with its resulting pixel arrangement above, would have a reasonable expectation of success.

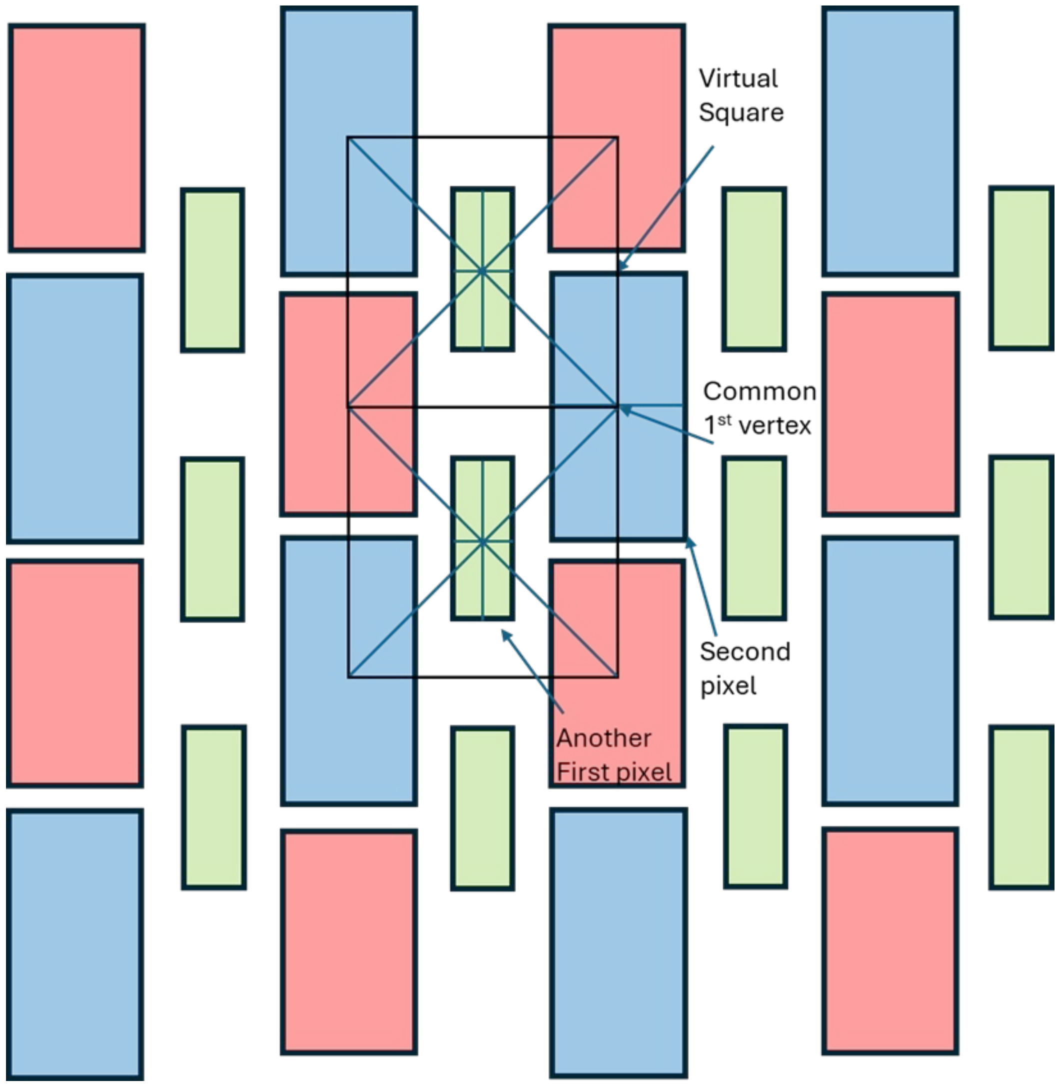
d. 1[C]: "another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

135. Credelle-379 in view of Hong teaches this element. As shown below, another green sub-pixel (*e.g.*, corresponding to the claimed "another first pixel") is at the center of another virtual square having a shared side and two common vertices with the first virtual square, with neighboring vertices corresponding to sub-pixels having different colors (*e.g.*, blue and red).



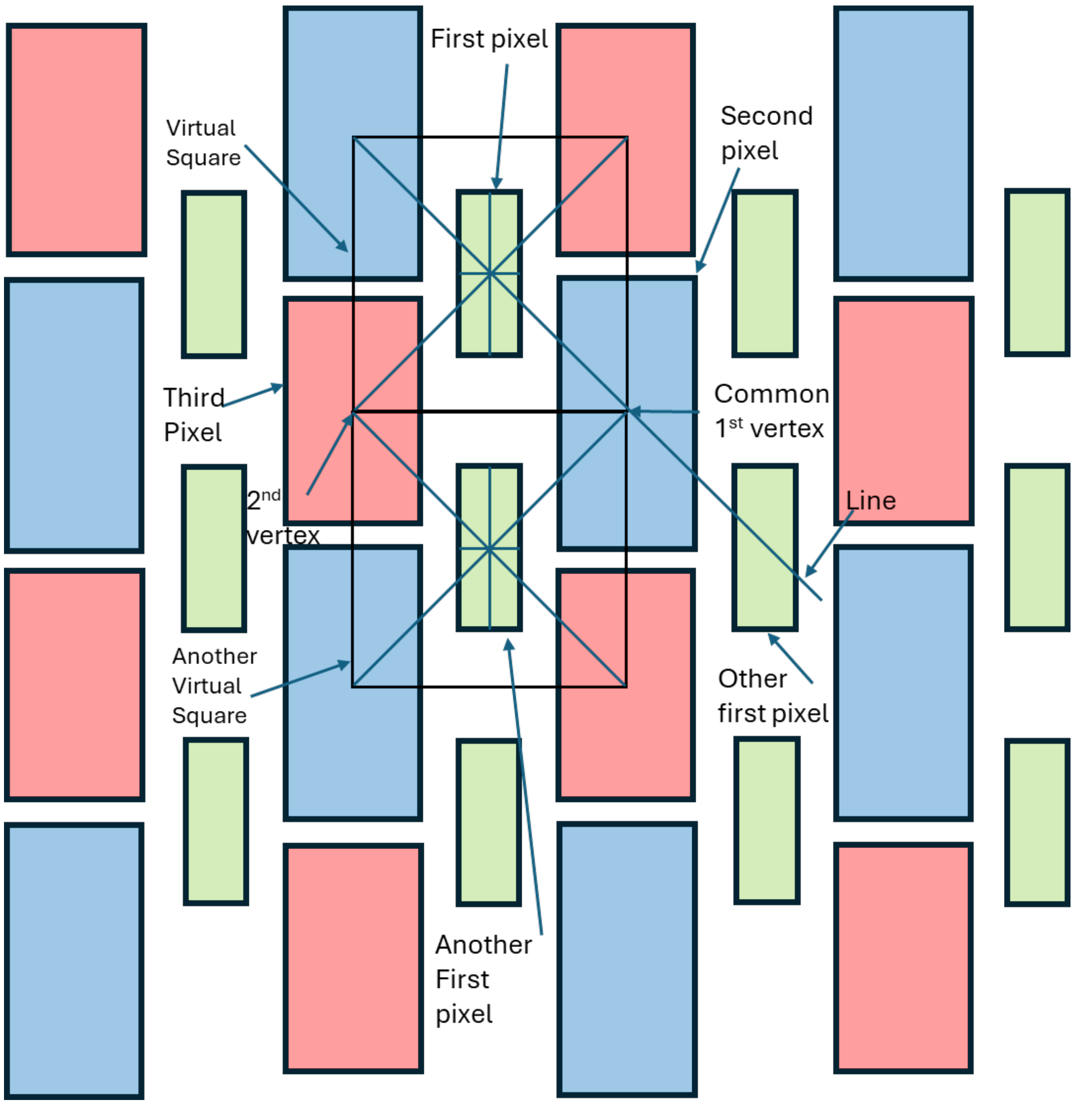
e. **1[D]: "a second pixel separated from the first pixels and having a center at the first vertex;"**

136. Credelle-379 in view of Hong teaches this element. As shown below, the blue sub-pixel (*e.g.*, corresponding to the claimed "second pixel") is separated from the first (*e.g.*, green) sub-pixels, and has a center at the first vertex of the virtual square.



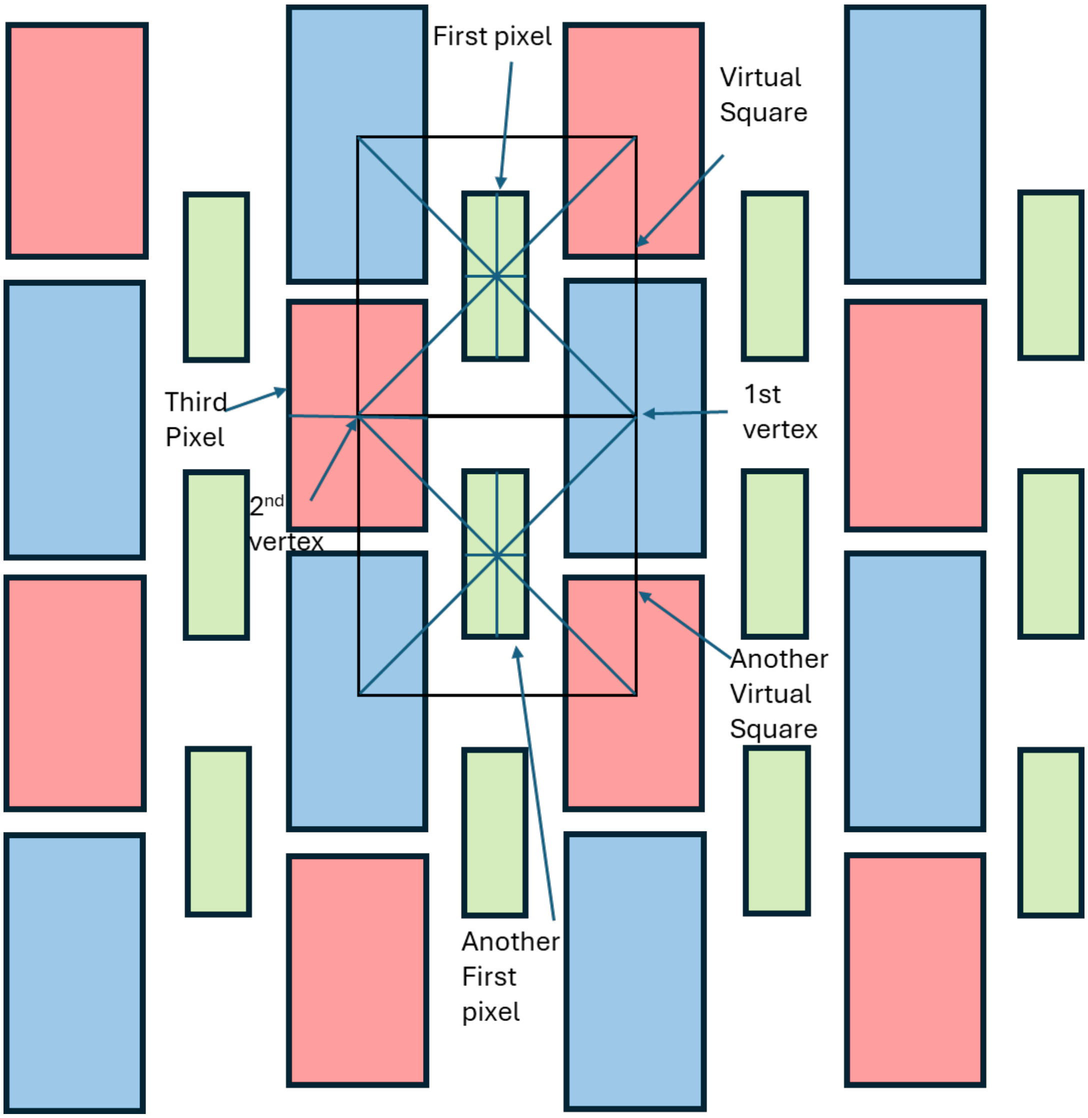
f. 1[E]: "an other first pixel on a line defined by the center of the virtual square and the first vertex, the first pixel, the second pixel, and the other first pixel being consecutive pixels on the line; and"

137. Credelle-379 in view of Hong teaches this element. As shown below, an other green sub-pixel (*e.g.*, corresponding to "an other first pixel") is located on a line defined by the center of the first Virtual Square, with the pixel, second, and other pixel being consecutive pixels on the line.



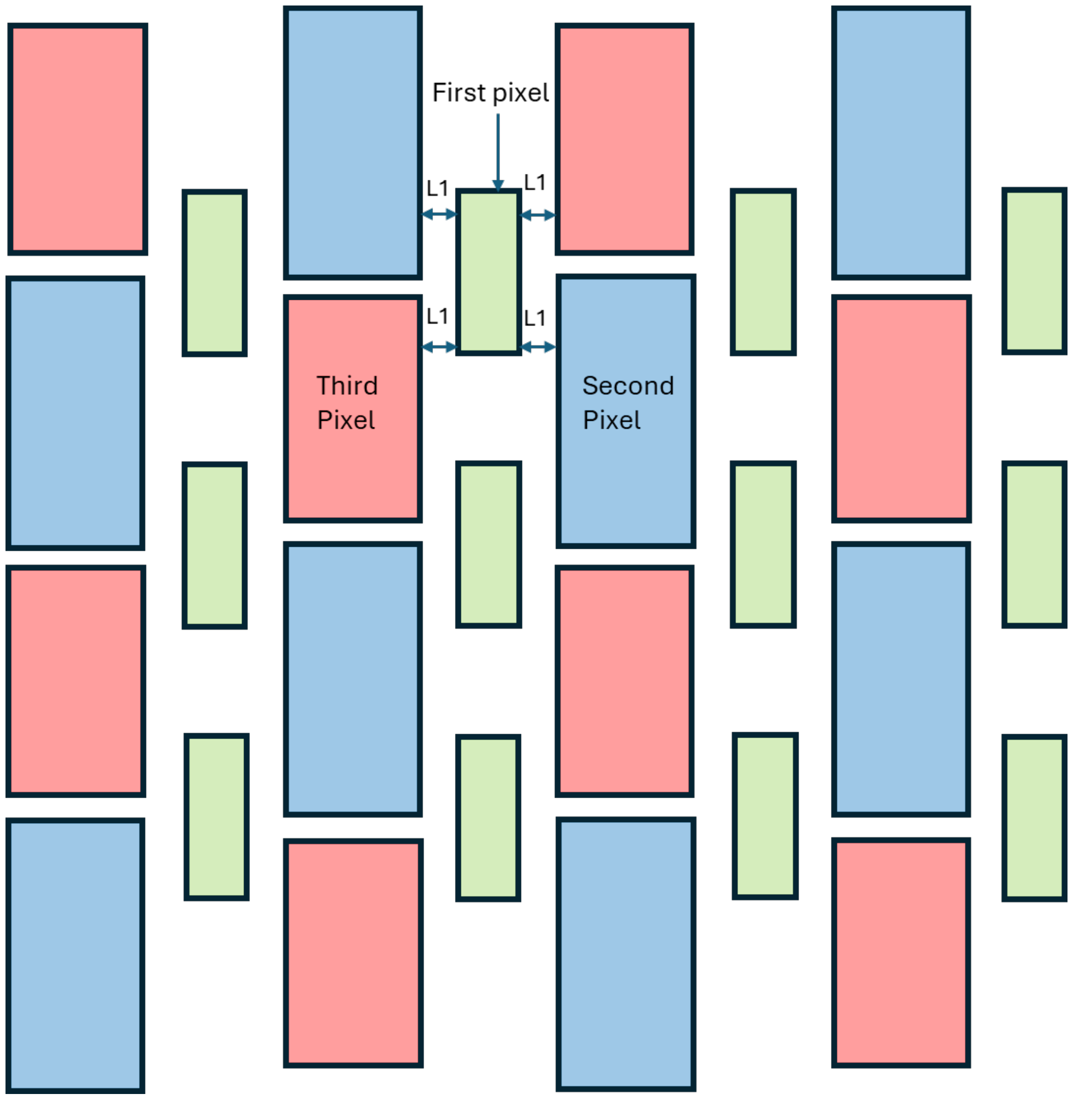
g. 1[F]: "a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

138. Credelle-379 in view of Hong teaches this element. The red sub-pixel (*e.g.*, corresponding to the claimed "third pixel") is separated from the first (*e.g.*, green) sub-pixels and the second (*e.g.*, blue) sub-pixel, and has a center at the second vertex of the virtual square, as shown below.



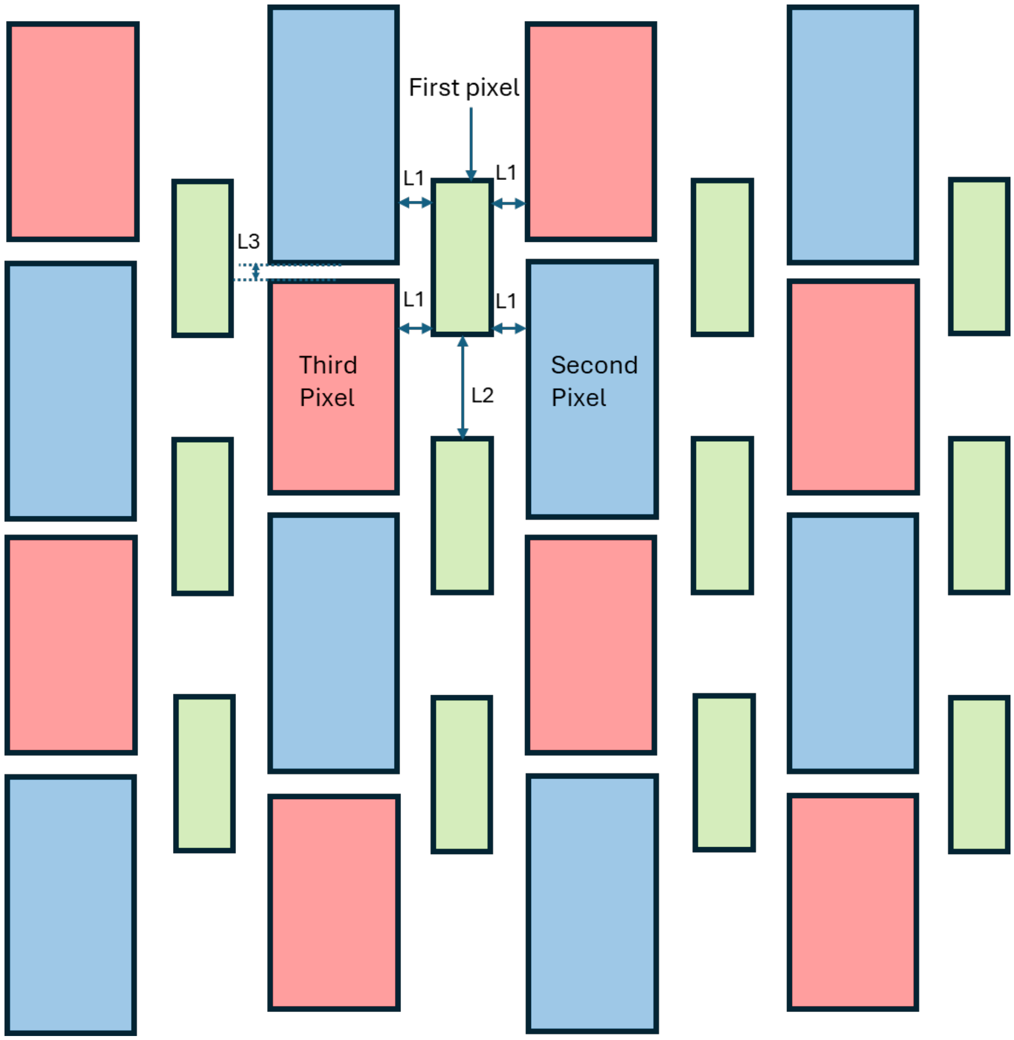
h. 1[G]: "wherein a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length,"

139. Credelle-379 in view of Hong teaches this element. As shown below, a shortest distance between the first (green) pixel and the second (blue) pixel as well as a shortest distance between the first (green) pixel and the third (red) pixel is a same first length.



i. 1[H]: "wherein a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels,"

140. Credelle-379 in view of Hong teaches this element. As shown below, a shortest distance between the first pixels is a second length L2 that is longer than the first length L1 and a shortest distance between each of the second pixels and the third pixels L3.

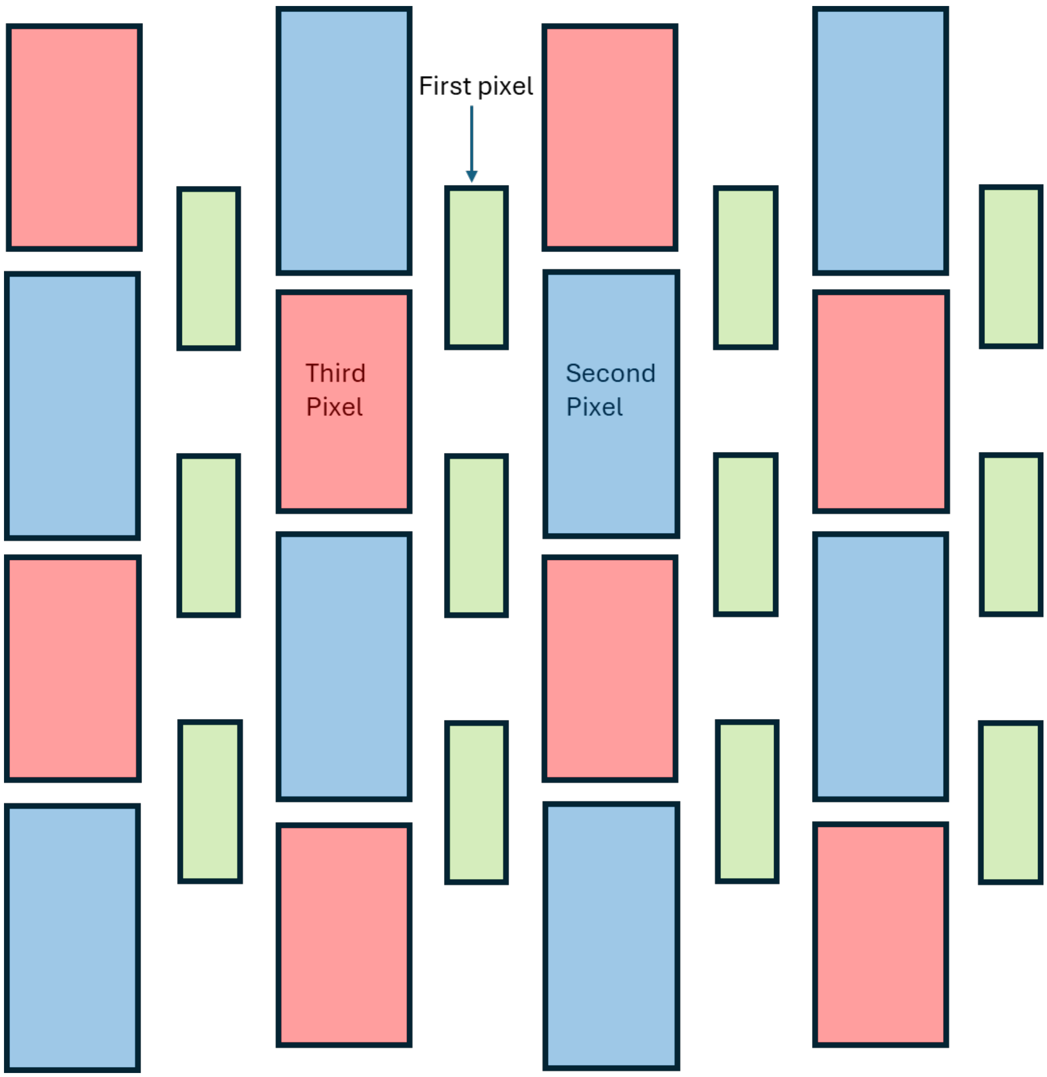


j. Element 1[I]: "wherein the second pixel and the third pixel have polygonal shapes, and,"

141. Credelle-379 in view of Hong teach this element. Credelle-379 discloses "the subpixels appear to have a substantially rectangular appearance. … a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable." (EX1005, 4:50-56.) As defined in the '616 patent, a polygonal shape can include "a triangle, a rectangle, a pentagon, a hexagon, a heptagon, and the like." (EX1001, 10:10-13.)

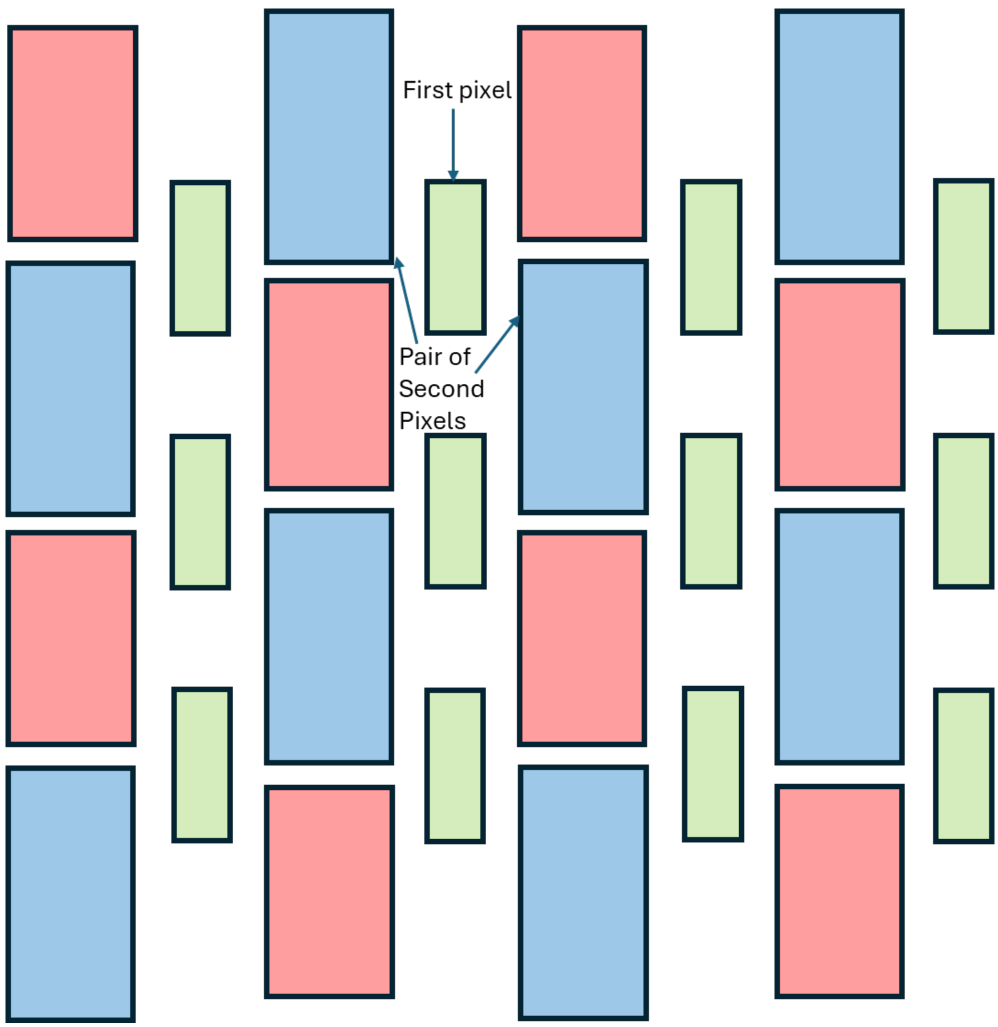
k. 1[J]: "wherein the second pixel has a larger area than that of the third pixel."

142. As explained above, using the relative sizing taught by Hong, a POSITA would have modified Credelle-379 FIG. 1C as shown below, with the blue pixel having the largest area, the red pixel having an intermediate area, and the green pixel having the smallest area.



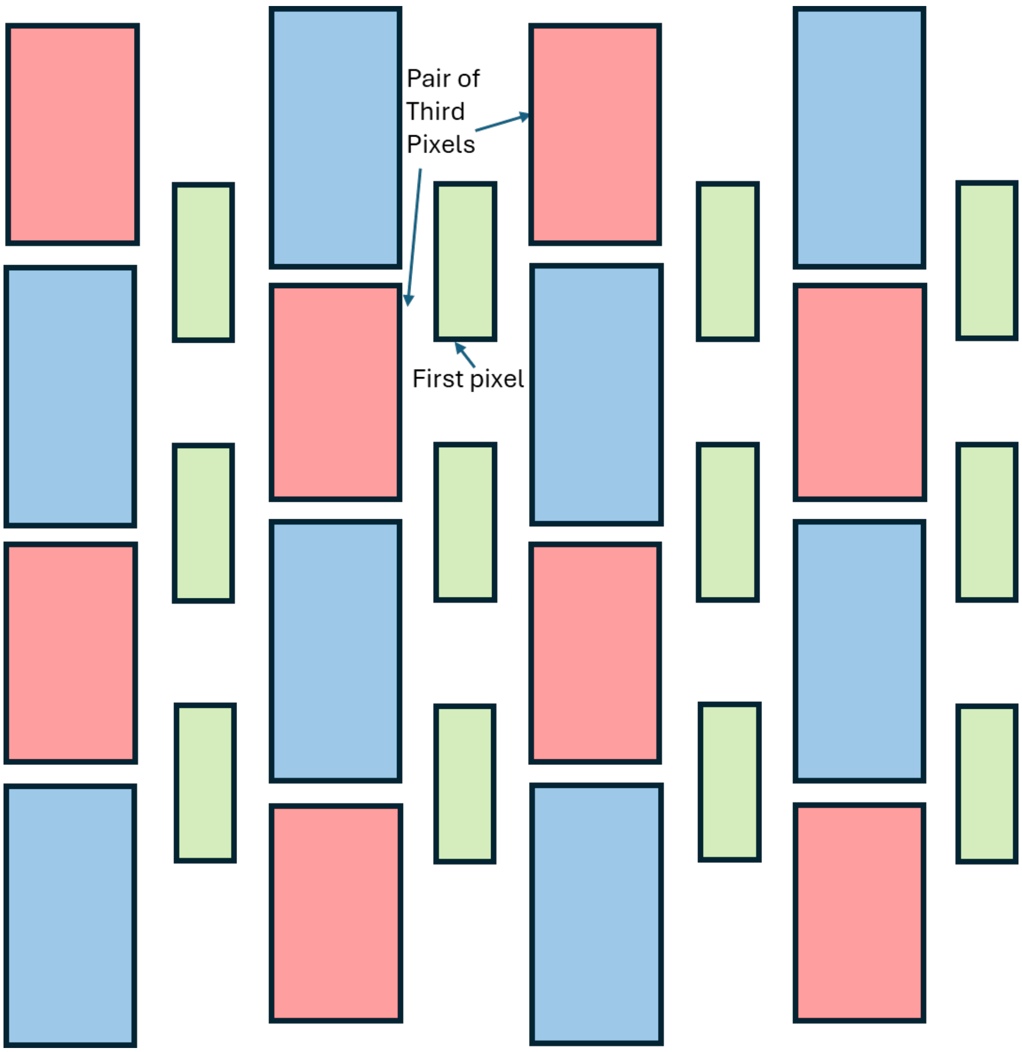
3. Claim 2: "The pixel arrangement structure of claim 1, wherein the second pixel comprises a pair of second pixels, and the second pixels are separated from each other by the first pixel."

143. Credelle-379 in view of Hong teach claim 1, as shown in § X.B.3. Credelle-379 in view of Hong further teach this claim. As shown below, a pair of blue sub-pixels (*e.g.*, corresponding to the claimed "pair of second pixels") are separated by a green sub-pixel (*e.g.*, the first pixel).



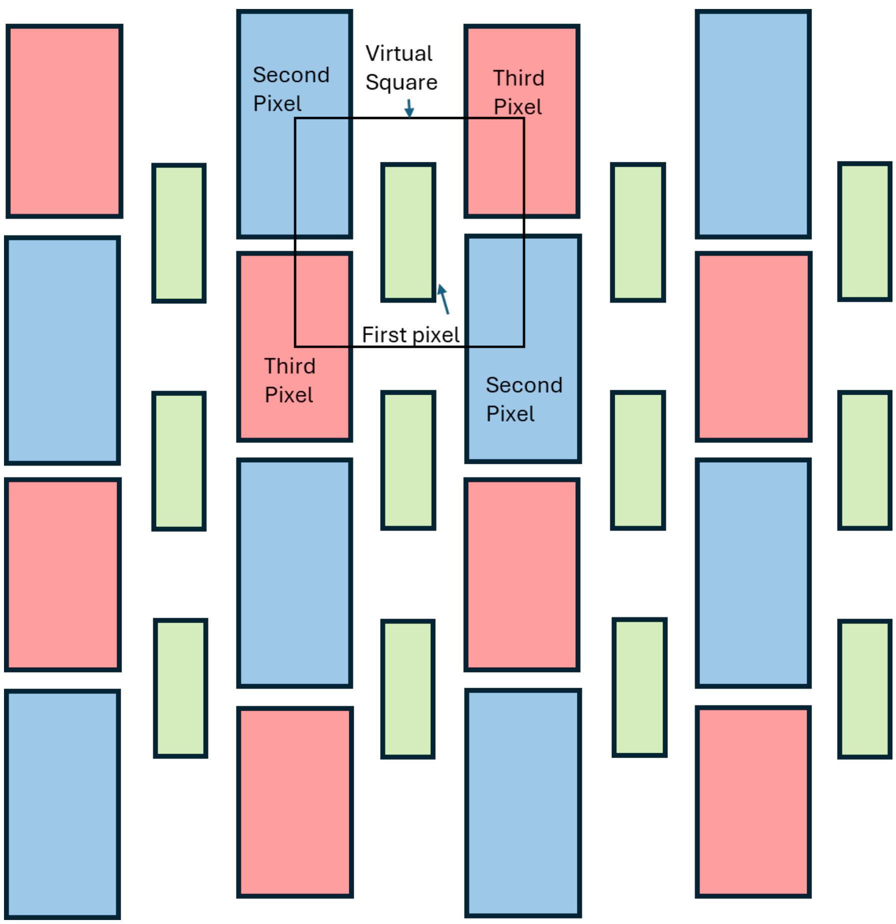
4. Claim 3: "The pixel arrangement structure of claim 1, wherein the third pixel comprises a pair of third pixels, and the third pixels are separated from each other by the first pixel."

144. Credelle-379 in view of Hong teach claim 1, as shown in § X.B.3. Credelle-379 in view of Hong further teach this claim. As shown below, a pair of red sub-pixels (*e.g.*, corresponding to the claimed "pair of third pixels"), are separated by a green sub-pixel (*e.g.*, the first pixel).



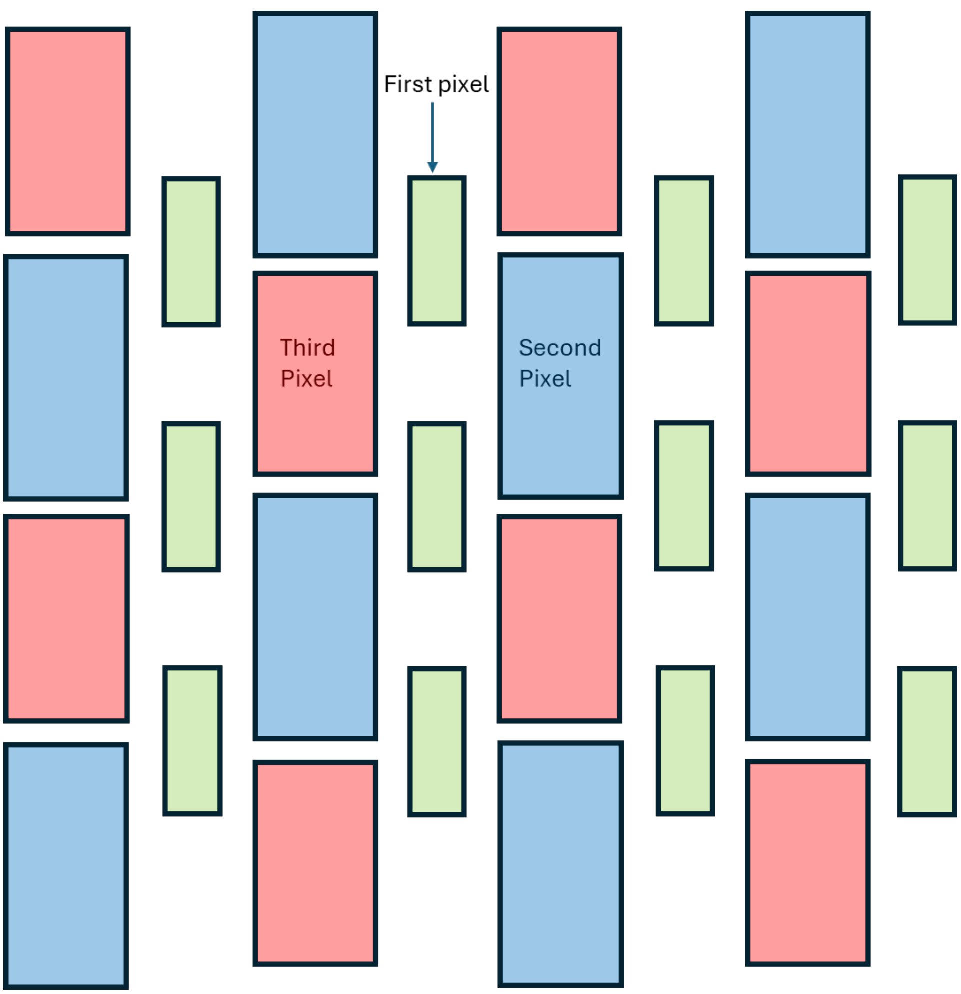
5. Claim 4: "The pixel arrangement structure of claim 1, wherein the second pixel comprises a pair of second pixels, the third pixel comprises a pair of third pixels, and the second pixels and the third pixels enclose the first pixel in the virtual square."

145. Credelle-379 in view of Hong teach claim 1, as shown in § X.B.3. Credelle-379 in view of Hong further teach this claim. The pair of blue sub-pixels (*e.g.*, a pair of second pixels) and the pair of red sub-pixels (*e.g.*, a pair of third pixels) enclose a green sub-pixel (*e.g.*, the first pixel) in a virtual square, as shown below.



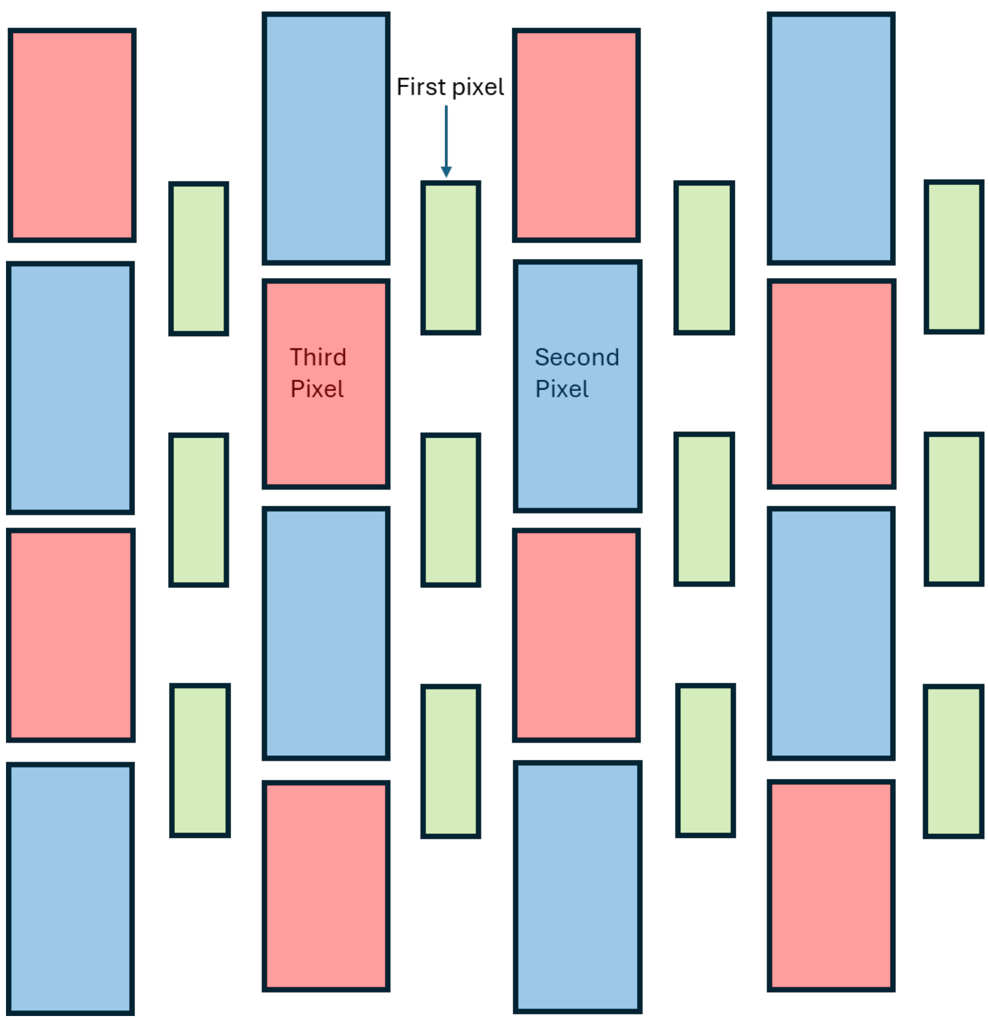
6. Claim 5: "The pixel arrangement structure of claim 4, wherein each of the second pixels and the third pixels is larger in area than the first pixel."

146. Credelle-379 in view of Hong teach claim 4, as shown in § X.B.6. Credelle-379 in view of Hong further teach this claim. As explained above, using the relative sizing taught by Hong, a POSITA would have modified Credelle-379 FIG. 1C as shown below, with the blue pixel having the largest area, the red pixel having an intermediate area, and the green pixel having the smallest area.



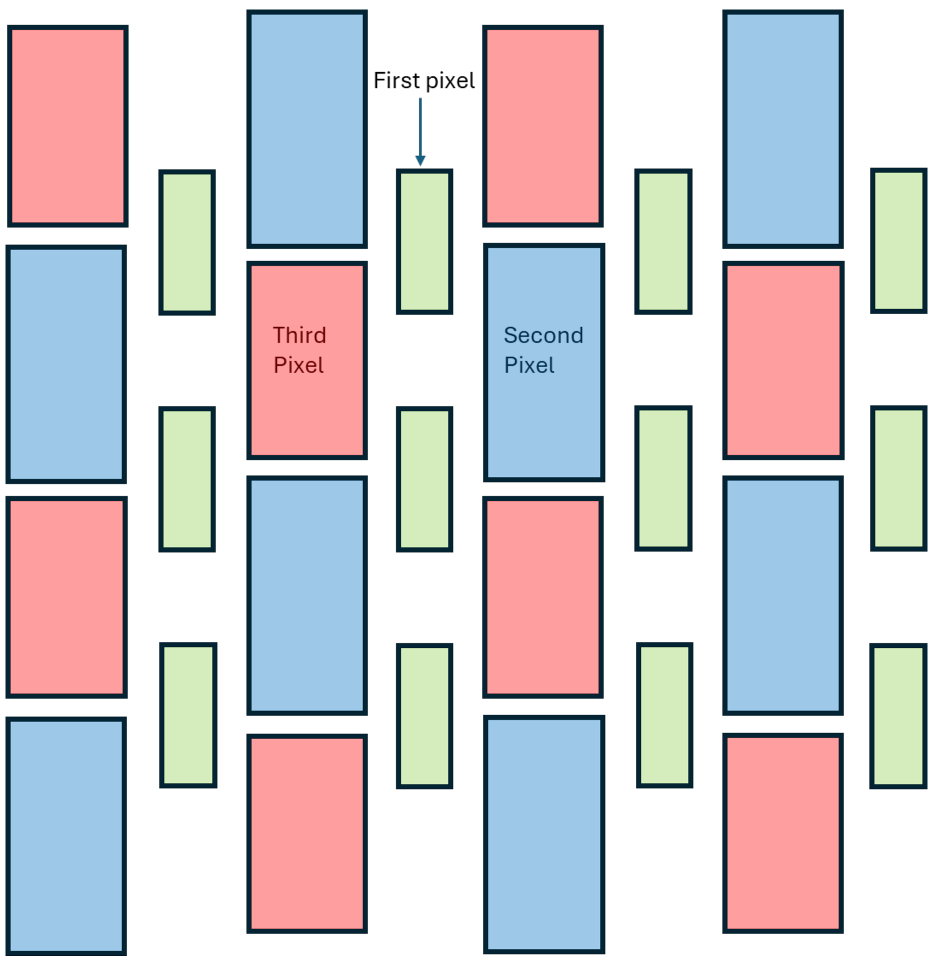
7. Claim 10: "The pixel arrangement structure of claim 1, wherein the first pixel, the second pixel, and the third pixel are configured to emit different color light."

147. Credelle-379 in view of Hong teach claim 1, as shown in § X.B.3. Credelle-379 in view of Hong further teach this claim. Credelle-379 discloses "For example, these four emitters 106 may be set to be … green in color. For example, the other sub-pixel emitters may be set to be red 104 and blue 102." (EX1005, 3:67-4: 3.) As shown below, the first pixel is green, the second pixel is blue, and the third pixel is red.



8. Claim 11: "The pixel arrangement structure of claim 1, wherein the first pixel is configured to emit green light, one of the second pixel and the third pixel is configured to emit blue light, and another of the second pixel and the third pixel is configured to emit red light."

148. Credelle-379 in view of Hong teach claim 1, as shown in § X.B.3. Credelle-379 in view of Hong further teach this claim. Credelle-379 discloses "these four emitters 106 may be set to … green in color. For example, the other sub-pixel emitters may be set to be red 104 and blue 102." (EX1005, 3:67-4: 3.) As shown below, the first pixel is green, the second pixel is blue, and the third pixel is red.



9. Claim 13

a. Preamble: "A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

149. The preamble of claim 13 is similar to the preamble of claim 1, which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.a.) The table below shows the similarities.

Preamble of Claim 1	Preamble of Claim 13
"A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"	"A pixel arrangement structure of an organic light emitting diode (OLED) display, comprising:"

b. 13[A]: "a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

150. Element 13[A] is similar to element 1[A], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.b.) The table below shows the similarities.

Element 1[A]	Element 13[A]
"a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"	"a plurality of individually addressable pixels for displaying images, the individually addressable pixels being minimum addressable units of the OLED display and comprising:"

c. 13[B]: "a first pixel having a center coinciding with a center of a virtual square;"

151. Element 13[B] is similar to element 1[B], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.c.) The table below shows the similarities.

Element 1[B]	Element 13[B]
"a first pixel having a center coinciding with a center of a virtual square;"	"a first pixel having a center coinciding with a center of a virtual square;"

d. 13[C]: "another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

152. Element 13[C] is similar to element 1[C], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.d.) The table below shows the similarities.

Element 1[C]	Element 13[C]
"another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"	"another first pixel having a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light;"

e. 13[D]: "a second pixel separated from the first pixels and having a center at the first vertex;"

153. Element 13[D] is similar to element 1[D], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.e.) The table below shows the similarities.

Element 1[D]	Element 13[D]
"a second pixel separated from the first pixels and having a center at the first vertex;"	"a second pixel separated from the first pixels and having a center at the first vertex;"

f. 13[E]: "a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

154. Element 13[E] is similar to element 1[F], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.g.) The table below shows the similarities.

Element 1[F]	Element 13[E]
"a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"	"a third pixel separated from the first pixels and the second pixel, and having a center at the second vertex,"

g. 13[F]: "the second pixel and the third pixel have polygonal shapes,"

155. Element 13[F] is similar to element 1[I], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.j.) The table below shows the similarities.

Element 1[I]	Element 13[F]
"the second pixel and the third pixel have polygonal shapes,"	"the second pixel and the third pixel have polygonal shapes,"

h. 13[G]: "a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length, and"

156. Element 13[G] is similar to element 1[G], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.h.) The table below shows the similarities.

Element 1[G]	Element 13[G]
"wherein a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length,"	"a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length, and"

i. 13[H]: "a shortest distance between the first pixels is a second length that is longer than the first length and a shortest distance between each of the second pixels and the third pixels."

157. Element 13[H] is similar to element 1[H], which Credelle-379 in view of Hong renders obvious. (*Supra* § X.B.3.i.) The table below shows the similarities.

Element 1[H]	Element 13[H]
"wherein a shortest distance between the first pixels is a second length that is longer than the first length and a	"a shortest distance between the first pixels is a second length that is longer than the first length and a shortest

shortest distance between each of the second pixels and the third pixels,"	distance between each of the second pixels and the third pixels."

C. Ground 3: Credelle-379, Hong, And Elliott-724 Render Obvious Claims 6-9 and 12

1. Summary of Elliott-724

158. Elliott-724 discloses "novel embodiments of three and four color subpixel arrangements" and that "Organic Light Emitting Diode (OLED) displays," will also be improved using this teaching. (EX1006, ¶ [0041], ¶ [0075].) In one embodiment, as shown in FIG. 19, some sub-pixels are made hexagonal. (*Id.*, FIG. 19.)

159. Elliott-724 is directed to the same problem (pixel arrangements) in the same field of endeavor (OLED displays) as the '616 patent. (EX1006, ¶ [0041], ¶ [0075].)

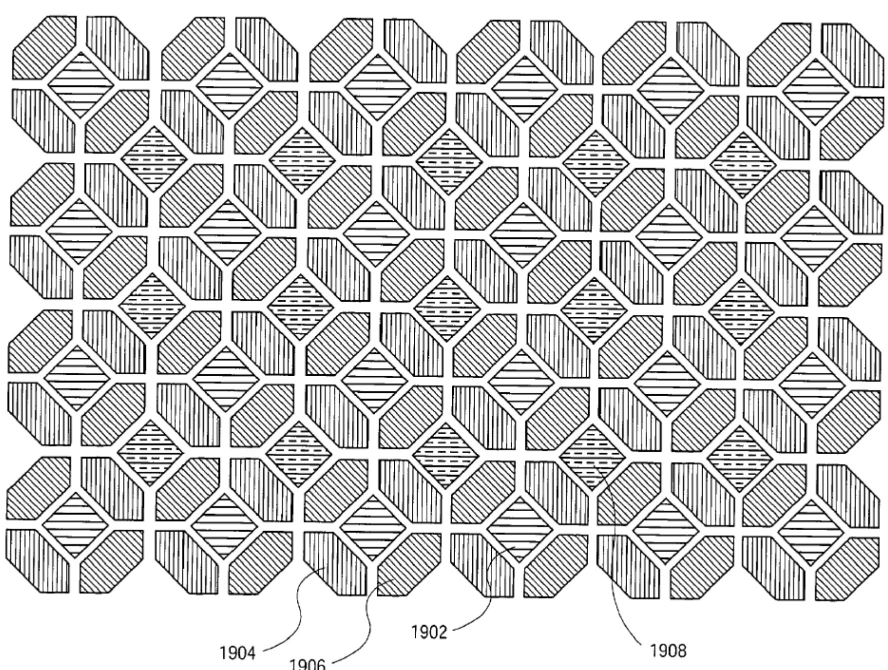
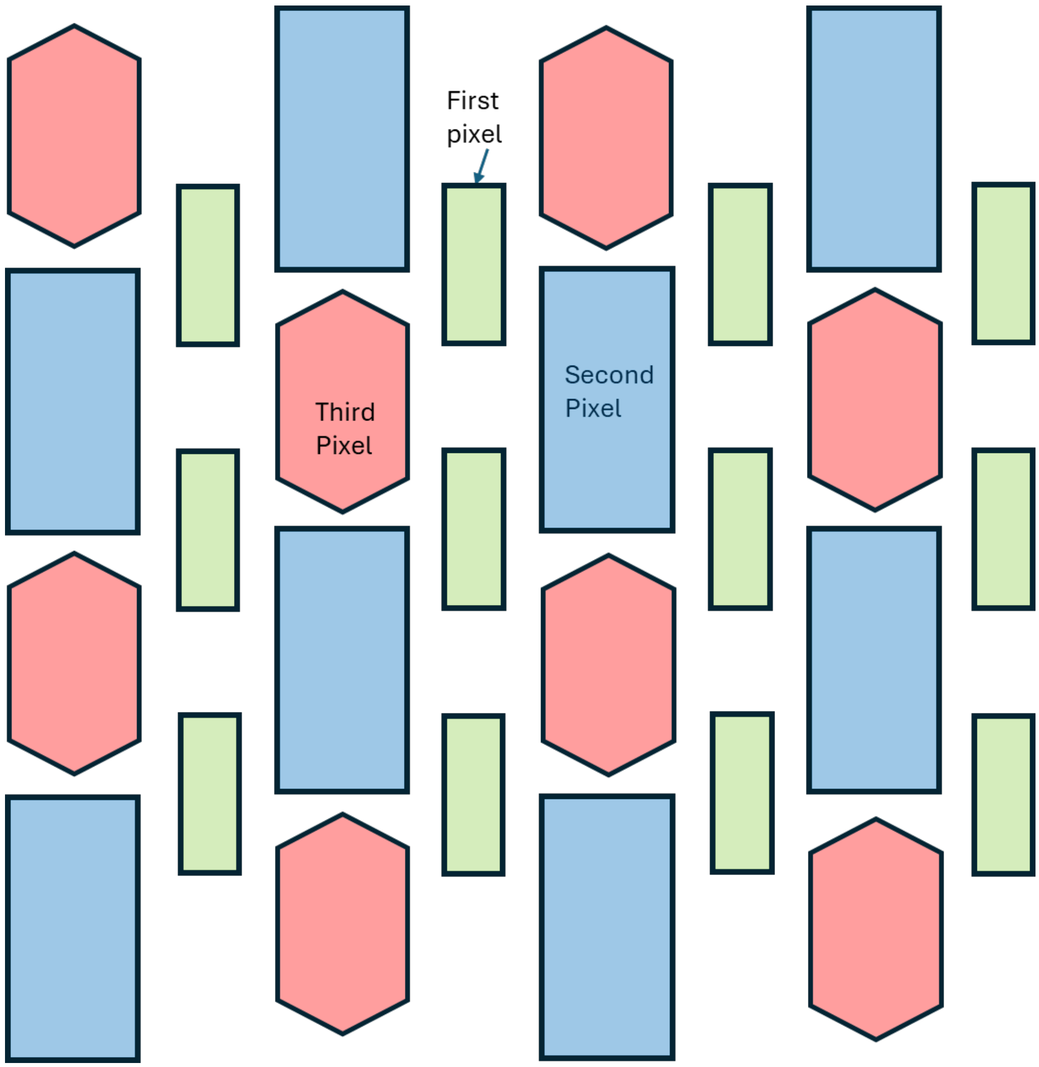


FIG. 19

2. Claim 6: "The pixel arrangement structure of claim 5, wherein one of the second pixel and the third pixel has a hexagonal shape and another of the second pixel and the third pixel has a quadrilateral shape."

160. Credelle-379 in view of Hong teach claim 5, as shown in § X.B.7. Credelle-379 in view of Hong and Elliott-724 further teach this claim. Credelle-379 discloses "[i]t should be appreciated that other shapes to the sub-pixels are also possible and are contemplated …a multitude of other regular or irregular shapes for the sub-pixels are possible and are desirable if manufacturable." (EX1005, 4:50-56.) Further, Elliott-724, which is the parent application of Credelle-379, teaches in FIG. 19 that sub-pixels can be made hexagonal. (EX1006, FIG. 19.)

161. Accordingly, Credelle-379 in view of Hong, when further considering that Elliott-724 teaches hexagonal sub-pixels are manufacturable, teaches that sub-pixels can be made hexagonal. A POSITA would have been motivated to substitute the rectangular red sub-pixels with hexagonal sub-pixels, such that the third pixel has a hexagonal shape, and the second pixel has a quadrilateral shape, as shown below.



162. As discussed in detail above, a POSITA would have found it obvious to use the relative areas taught in Hong to adjust the pixel arrangement of Credelle-379. Further, a POSITA would have found it obvious to combine the hexagonal sub-pixels of Elliott-724 with Credelle-379 in view of Hong. Like Credelle-379 and Hong, Elliott-724 is in the same field as the ’616 patent. Like the ’616 patent, Elliott-724 is directed to “subpixel arrangements” that can be used in “Organic Light Emitting Diode (OLED) displays.” (EX1006, ¶ [0041], ¶ [0075].)

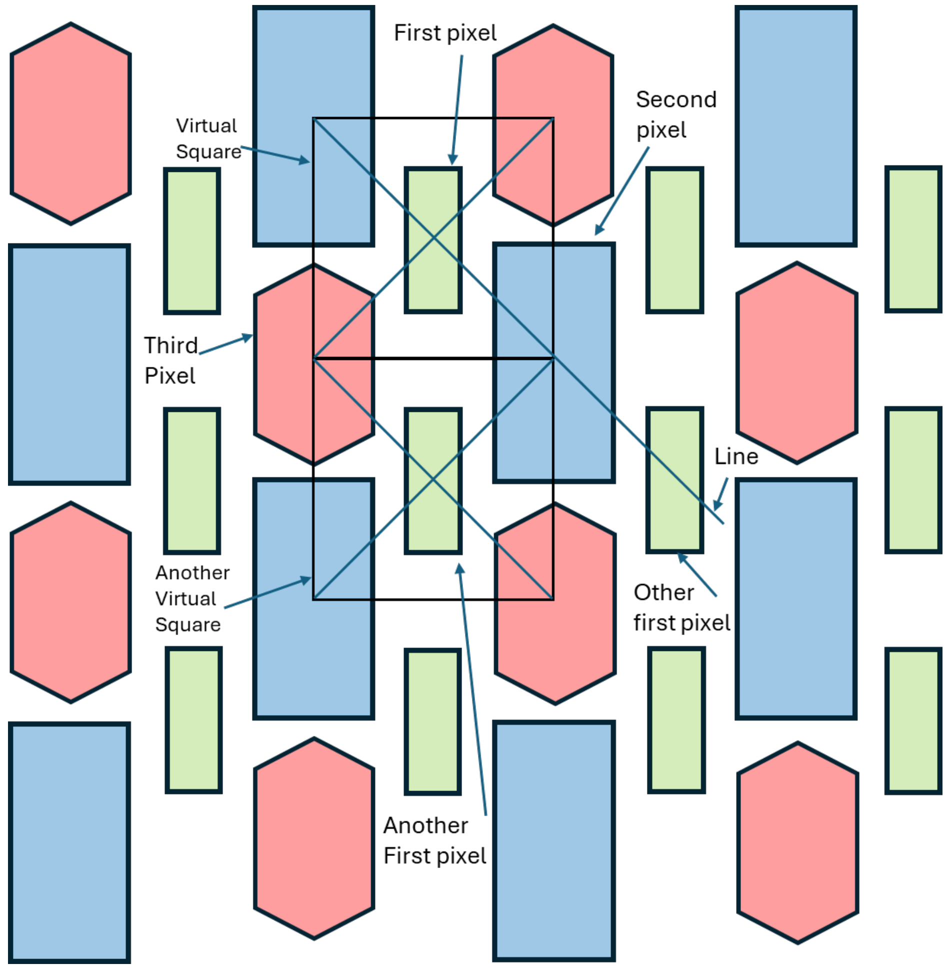
163. Credelle-379 itself discloses "[i]t should be appreciated that other shapes to the subpixels are also possible and are contemplated … a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable." (EX1005, 4:51-56.) And, given that Elliott-724 is the parent application of Credelle-379 and is incorporated by reference, a POSITA would have been motivated to use the hexagonal pixel shapes taught by Elliott-724 for the sub-pixels of Credelle-379. (EX1005, 1:13-21.) Further, it would have been obvious to try making the red pixels hexagonal, while maintaining the shapes of the green and blue pixels. When choosing to modify pixels to take on a certain shape, a POSITA would have recognized a finite number of identified, predictable solutions. For example, there would have been 8 possible solutions when considering whether to use hexagonal pixels with Credelle-379's default pattern: 1) making only green pixels hexagonal, 2) making only red pixels hexagonal, 3) making only blue pixels hexagonal, 4) making green and red pixels hexagonal, 5) making green and blue pixels hexagonal, 6) making red and blue pixels hexagonal, 7) making all pixels hexagonal, and 8) making no pixels hexagonal. Accordingly, it would have been obvious for a POSITA to try option 2, making the red pixels hexagonal while maintaining the shape of the green and blue pixels with a reasonable expectation of success.

164. Making this combination would have been a simple substitution of one pixel shape for another with predictable results given the two references describe the same, underlying OLED technology. Indeed, a POSITA would have viewed Elliott-724 as disclosing just one more way to shape Credelle-379's sub-pixels.

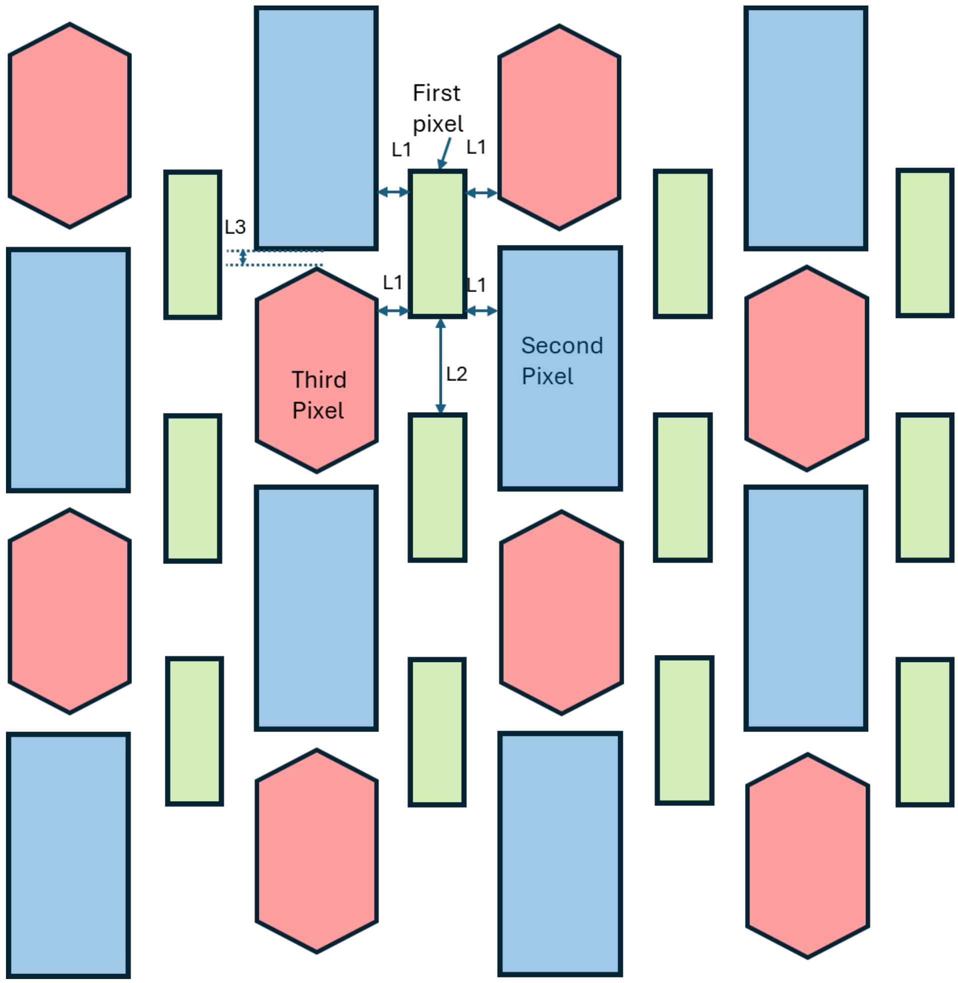
165. Moreover, a POSITA would have reasonably expected the combination to succeed. All references relate to OLED display technology. Further, Elliott-724 is the parent application of Credelle-379 and is incorporated by reference. (EX1005, 1:13-21.) Credelle-379 discloses "[i]t should be appreciated that other shapes to the subpixels are also possible and are contemplated … a multitude of other regular or irregular shapes for the subpixels are possible and are desirable if manufacturable," thereby contemplating the hexagonal pixel shapes shown in Elliott-724. (EX1005, 4:51-56.) Given these disclosures and the knowledge of a POSITA, the POSITA would have reasonably expected the combination to succeed.

166. Such a modification still maintains the aspects of Credelle-379 in view of Hong that teach claims 1 and 5. As shown above, the second and third pixels have polygonal shapes, the second pixel has a larger area than that of the third pixel, and each of the second pixels and the third pixels is larger in area than the first pixel.

167. Additionally, as shown below, the first (green) pixel has a center coinciding with a center of a virtual square, another first (green) pixel has a center coinciding with a center of another virtual square, the virtual squares sharing a common side having endpoints at a common first vertex and a common second vertex of the virtual squares, with neighboring vertices in each of the virtual squares corresponding to pixels configured to emit different color light (e.g., red and blue), a second (blue) pixel is separated from the first pixels and having a center at the first vertex; an other (green) first pixel is on a line defined by the center of the virtual square and the first vertex, the first pixel, the second pixel, and the other first pixel being consecutive pixels on the line; and a third (red) pixel is separated from the first pixels and the second pixel, and has a center at the second vertex.

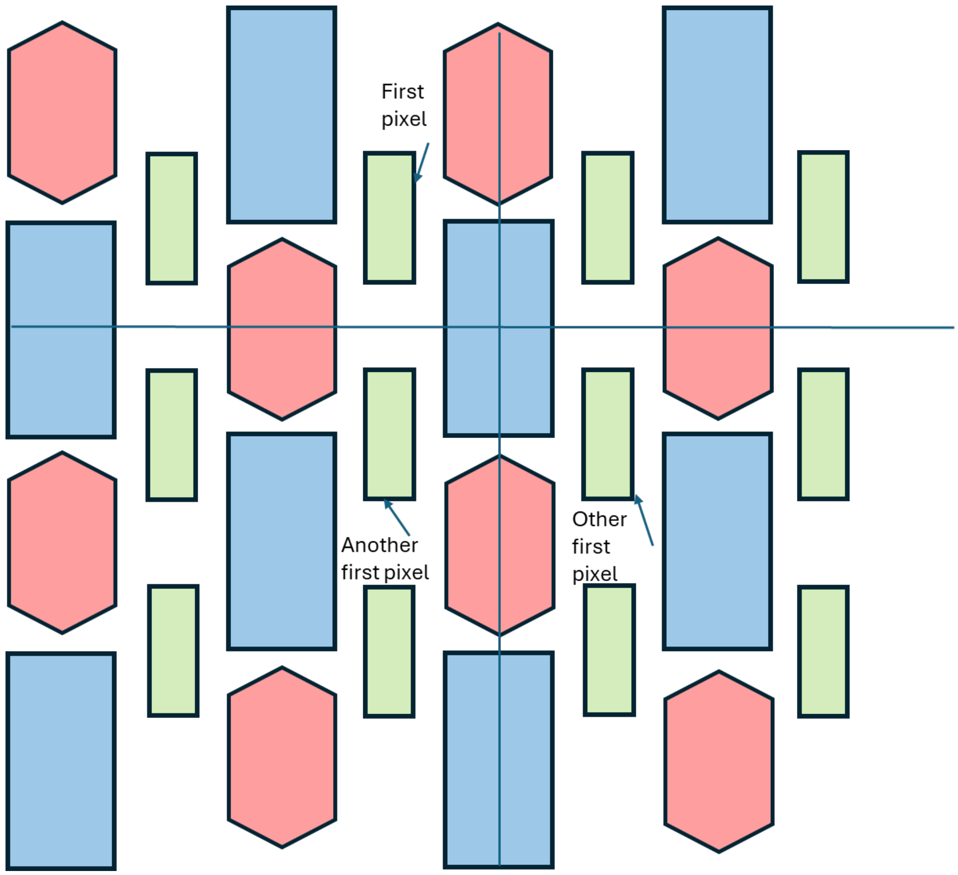


168. Additionally, as shown below, a shortest distance between the first pixel and the second pixel as well as a shortest distance between the first pixel and the third pixel is a same first length L1 and a shortest distance between the first pixels is a second length L2 that is longer than the first length L1 and a shortest distance L3 between each of the second pixels and the third pixels.



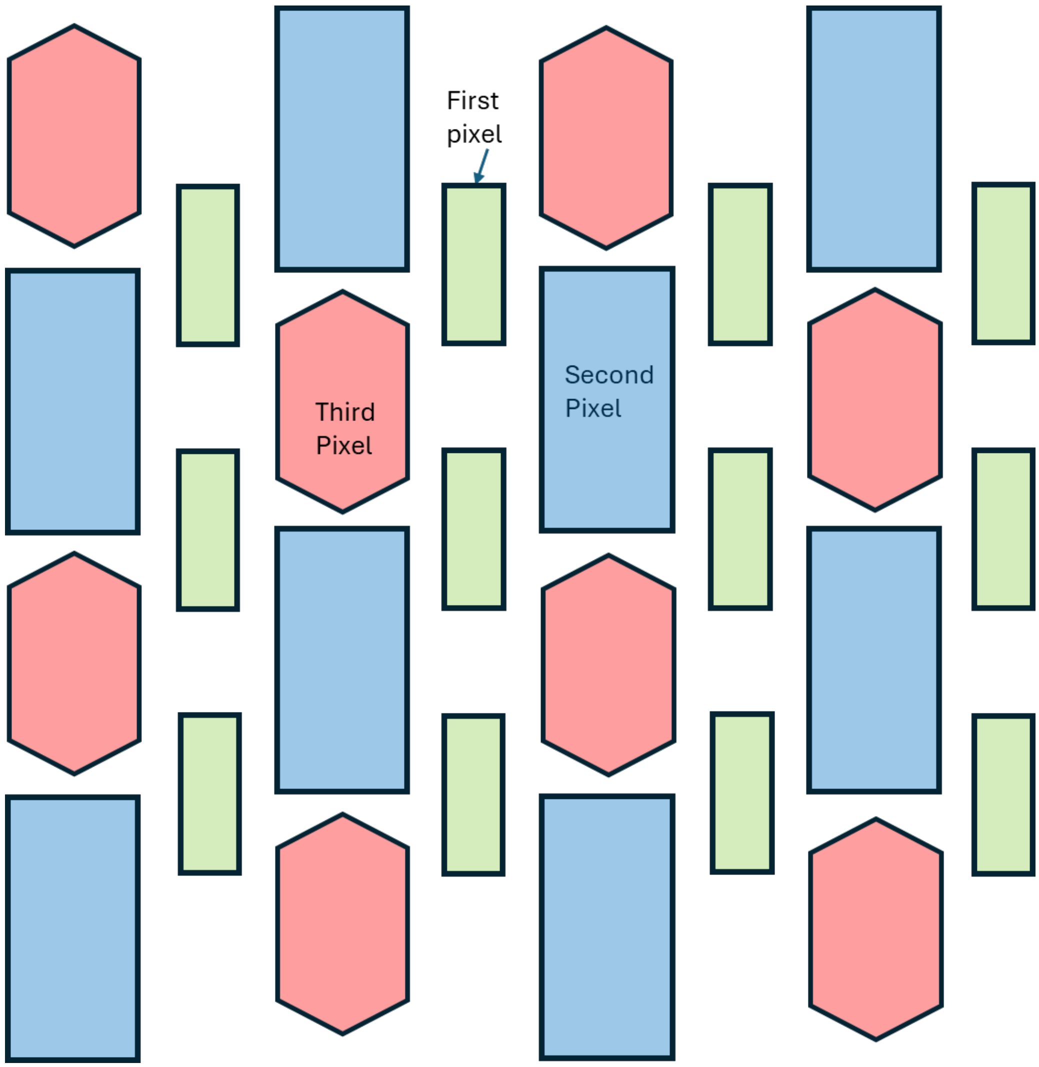
3. Claim 7: "The pixel arrangement structure of claim 6, wherein the first pixels are symmetrical to each other."

169. Credelle-379 in view of Hong and Elliott-724 teach claim 6, as shown in § X.C.2. Credelle-379 in view of Hong and Elliott-724 further teach this claim. As shown below, the first pixel is symmetrical to the another first pixel across the horizontal line and the another first pixel is symmetrical to the other first pixel across the vertical line.



4. Claim 8: "The pixel arrangement structure of claim 6, wherein each of the second pixels is larger in area than each of the third pixels."

170. Credelle-379 in view of Hong and Elliott-724 teach claim 6, as shown in §X.C.2. Credelle-379 in view of Hong and Elliott-724 further teach this claim. As explained above, using the relative sizing taught by Hong, a POSITA would have modified Credelle-379 FIG. 1C as shown below, with the blue pixel having the largest area, the red pixel having an intermediate area, and the green pixel having the smallest area.



5. **Claim 9: "The pixel arrangement structure of claim 5, wherein at least one of the second pixel and the third pixel has a hexagonal shape."**

171. Credelle-379 in view of Hong teach claim 5, as shown in § X.B.7. Credelle-379 in view of Hong and Elliott-724 further teach this claim. Claim 9 is similar to claim 6 which Credelle-379 in view of Hong and Elliott-724 render obvious. (*Supra* § X.C.2.) The table below shows the similarities.

Claim 6	Claim 9
"The pixel arrangement structure of claim 5, wherein one of the second pixel and the third pixel has a hexagonal shape and another of the second pixel and the third pixel has a quadrilateral shape."	"The pixel arrangement structure of claim 5, wherein at least one of the second pixel and the third pixel has a hexagonal shape."

6. Claim 12: "The pixel arrangement structure of claim 1, wherein the second pixel has a different polygonal shape from the third pixel."

172. Credelle-379 in view of Hong teach claim 1, as shown above. Credelle-379 in view of Hong and Elliott-724 further teach this claim. Claim 12 is similar to claim 6 which Credelle-379 in view of Hong and Elliott-724 render obvious. (*Supra* § X.C.2.) The table below shows the similarities.

Claim 6	Claim 9
"The pixel arrangement structure of claim 5, wherein one of the second pixel and the third pixel has a hexagonal shape and another of the second pixel and the third pixel has a quadrilateral shape."	"The pixel arrangement structure of claim 1, wherein the second pixel has a different polygonal shape from the third pixel."

* * *

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 that these statements were made with 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.

Dated: Sept 23, 2025

Thomas Credelle

Thomas L. Credelle
Curriculum Vitae

Professional Summary

Mr. Credelle is a recognized expert in the flat panel/touch industry with over 40 years of expertise in all aspects of flat panel displays, LEDs, LED displays, and optics. He has made significant contributions in the areas of R&D, engineering, marketing, and senior management. He has served at an executive level at start-up businesses within major corporations and start-up companies in Silicon Valley and has had extensive interaction with flat panel producers and customers in Japan, Taiwan, Korea and China. Mr. Credelle holds 84 issued US patents in various flat-panel related technologies including display design, display electronics, materials, algorithms, systems, RFID, and optics, with additional pending.

Mr. Credelle is a Fellow of the Society for Information Display and currently consults regarding technology, business, and patent issues involving Flat Panel Display and LED Technology for various clients. He has written expert-analysis reports for private clients on patent portfolios of over 500 patents and has written numerous IPR ITC, and District Court Case reports and has given depositions on many. He has testified at four District Court cases and three ITC Hearings.

Expertise

- Flat Panel Display Technology
- LEDs and LED lighting
- Display electronics
- Electro-optics
- Patent analysis
- Expert witness (reports, testimony)
- TFT and Liquid Crystal Display R&D

Education

Year	College or University	Degree
1970	Massachusetts Institute of Technology	M.S., Electrical Engineering Emphasis: Electro-optics and Solid State Physics Thesis: “Optical Properties of High Purity Stannic Oxide”
1969	Drexel University	B.S., Electrical Engineering (Honors Program)

Thomas L. Credelle
Curriculum Vitae

Professional Experience

From: 2008
To: Present
Organization: **TLC Display Consulting**
Title: President
Summary:
- Technical consulting in the field of flat panel displays, LEDs, and display electronics
- Business/patent consulting in the fields of displays, LEDs, optics, new technology

From: 2016
To: 2018
Organization: **RealD**
Title: Acting CEO, RealD Me (2016-2017), Strategic Advisor, RealD 2017-2019)
Summary:
- Business and technical advisor to RealD Intelligent Backlight Business Unit

From: 2012
To: 2016
Organization: **Innova Dynamics, Inc.,** San Francisco, CA
Title: VP, Application Engineering and Device Performance
Summary:
- Primary interface between customer and product engineering
- Testing and qualification of all products
- Business development/technical contact for new opportunities

From: 2008
To: 2018
Organization: **Display Engineering, Inc.** San Jose, CA
Title: Contractor
Summary:
- Design and testing of high-brightness LED backlights for outdoor signage
- Circuit design and thermal analysis of LED light bars
- Developed new methods for passive cooling of LED light sources

From: 2007
To: 2008
Organization: **Puredepth, Inc**., Redwood City, CA and Auckland, NZ
Title: Senior VP Engineering
Summary:

- Recruited to establish first senior management leadership position for hardware and software engineering related to Puredepth's Multi Layer Display (MLD) technology.
- Rapidly learned details of technology, established new development plans, and supported customer engagements in US, Korea, and Japan.
- Divided time between US and NZ offices, supporting sales/marketing and leading engineering effort.

From: 2001
To: 2007
Organization: **Clairvoyante, Inc**, Cupertino, CA
Title: VP Engineering
Summary:

- Responsible for engineering, product development, product roadmap, marketing of technology that improves resolution and reduces power of color flat panel displays.
- Responsible for applied R&D, IC development, customer training and support for all technology integration programs.
- Creation of new intellectual property to advance adoption of Clairvoyante technology.
- Monthly interaction with leading LCD producers in Taiwan, Korea, Japan; management of all vendors relating to product development (8-10 on-site visits per year).

From: 1999
To: 2001
Organization: **Alien Technology Corporation**, Morgan Hill, CA
Title: VP of Operations
Summary:

- Key member of management team to develop novel technology for nanoblock-IC assembly using fluidic process. Responsible for facilities, manufacturing operations, IT, and HR; managed $20M construction project for mfg.
- Key contributor to display-related use of Alien manufacturing processes.
- Contributed to patent portfolio for Alien with key inventions in Nanoblock™ IC manufacturing techniques for displays and RFID tags.

Thomas L. Credelle
Curriculum Vitae

From: 1996
To: 1999
Organization: **Motorola**, Flat Panel Display Division, Tempe, AZ
Title: Director, Product Marketing
Summary:

- Responsible for establishing market direction and initial sales approach for new Field Emission Displays (FED) under development within the Division.
- Won potential business for initial small FEDs in industrial and automotive applications.
- Established and managed marketing communications department, creating new brand image for product as well as managing all trade show activities.
- Contributed to product development and spec generation. Generated patent disclosures aimed at solving customer-related issues.

From: 1994
To: 1996
Organization: **Allied Signal**, Los Gatos, CA
Title: Director, Advanced Product Marketing
Summary:

- Responsible for establishing product marketing direction and establishing customer contacts for newly-developed optical films for viewing angle enhancement for LCDs.
- Participated in product development, product improvement based on customer input.

From: 1991
To: 1994
Organization: **Apple Computer**, Cupertino, CA.
Title: Manager, Display Engineering
Summary:

- Responsible for all LCD engineering and qualification for first PowerBook notebook computers introduced to market.
- Extensive interaction with Asian suppliers.
- Generated patent disclosures related to LCD integration in notebook PCs

From: 1986
To: 1991
Organization: **GE** R&D Center, Schenectady, NY
Title: Manager, TFT LCD Research and Development
Summary:
- Managed R&D in TFT and LCD technology for avionics applications. Led the team that built the first 1 million pixel color LCD. Led development of various optical devices based on liquid crystal materials.
- Established photonics effort based on liquid crystal technology.

From: 1970
To: 1986
Organization: **RCA** Sarnoff Labs, Princeton, NJ
Title: Individual Contributor, then Group Manager
Summary:
- Increasing levels of responsibility in the R&D of optical materials and flat panel displays.
- Key contributor to novel methods for large screen flat panel TFT.
- Established TFT LCD Program at Sarnoff Labs in 1983.
- Led development of first polySi TFT LCDs at Sarnoff Labs.

Legal Consulting

Expert Engagement:
Type of Matter: Deposition on patent dispute
Client: Alien Technology
Case Name: Alien v. Avery, Case No. 08-cv-00795
Services Provided: Deposed as expert and inventor on behalf of Alien
Date: October 29, 2008

Expert Engagement:
Type of Matter: Patent Infringement, LCD Projection
Client: McKenna Long & Aldridge LLP
Case Name: Undisclosed
Services Provided: Non-testifying expert on ITC case
Date: November 2011

Expert Engagement:

Type of Matter:	LCD backlight
Client:	Steptoe and Johnson LLP on behalf of LG
Case Name:	In the Matter of Certain Devices for Improving Uniformity Used in a Backlight Module and Products Containing the Same Inv. No. 337-TA-805
Services Provided:	Non-testifying expert on ITC case (settled)
Date:	November 2011

Expert Engagement:

Type of Matter:	Display driving method for eBooks
Client:	Klarquist Sparkman LLP on behalf of Amazon (v. Positive Technologies)
Case Name:	2:11-cv-2226, N.D. Calif.
Services Provided:	Expert Reports, Testifying Expert (settled)
Date:	October 2012 – April 2013

Expert Engagement:

Type of Matter:	Display driving method for eBooks
Client:	Alston and Bird LLP on behalf of Barnes and Noble (v. Positive Technologies)
Case Name:	3:11-cv-02226-SI
Services Provided:	Testifying expert on District Court Case (settled) Non infringement and non-enablement reports written.
Date:	March 2013 – July 2013

Expert Engagement:

Type of Matter:	LCD driving method
Client:	Kenyon and Kenyon LLP on behalf of Sony (v. Surpass)
Case Name:	IPR2015-0863
Services Provided:	IPR Reports and Deposition
Date:	Jan 2015-Mar 2016

Expert Engagement:

Type of Matter:	LCD Optics and TFT design
Client:	Marc Labgold on behalf of Funai (v. Gold Charm Ltd.)
Case Name:	IPR2015-01448
Services Provided:	IPR Report
Date:	Apr, 2015 – Jul, 2015

Expert Engagement:

Type of Matter:	LCD Backlights using LEDs
Client:	Shearman & Sterling LLP/Fried Frank LLP on behalf of Mercedes Benz (v. Innovative Display Technologies)
Case Name:	IPR2015-01995, IPR2015-01115, IPR2015-01113 and 2: 14-cv-00535 TXEDC
Services Provided:	IPR Expert Reports
Date:	Mar 2015 – May 2015

Expert Engagement:
Type of Matter: TFT array and LCD panel interconnect
Client: Covington & Burling on behalf of Samsung Display Co. (v. MiiC & Partners)
Case Name: IPR205-01469, IPR2015-01499
Services provided: IPR Expert Reports
Date: May 2015- Mar 2016

Expert Engagement:
Type of Matter: LCD Backlights using LEDs
Client: Mayer Brown on behalf of KJ Pretech (v. Innovative Display Technologies)
Case Name: IPR2015-01866, IPR2015-01867, IPR2015-01868
Services Provided: IPR reports and depositions (3)
Date: Aug 2015-Jun 2016

Expert Engagement:
Type of Matter: LCD backlights using LEDs
Client: Gibson, Dunn, and Crutcher LLP on behalf of Vizio (v. Delaware Display Group LLC)
Case Name: Case No. 13-cv-2112
Services Provided: Non-infringement Report, Deposition, Testifying Expert (settled)
Date: Sep 2015-Mar 2017

Expert Engagement:
Type of Matter: LCD manufacturing, TFT array design
Client: Sughrue Mion PLLC on behalf of TCL
Case Name: Arbitration (Hong Kong) between AUO and TCL
Services Provided: Non-infringement analysis of TFT array design (settled)
Date: Jun 2017 – Sep 2017

Expert Engagement:
Type of Matter: LED display panels
Client: Adduci Mastriani & Schaumberg on behalf of Ultravision Technologies LLC (v. >20 Chinese companies)
Case Name: ITC Case 337-TA-1114
Services Provided: Expert Reports (Invalidity and Non-infringement) and Deposition (3 days)
Date: Jan 2018 – Feb, 2019

Expert Engagement:
Type of Matter: LCD gamma circuit
Client: K&L Gates on behalf of Wistron (v. plaintiff Phenix Longhorn)
Case Name: IPR2018-01255, 2:17 cv-00711 TXEDC
Services Provided: Expert report and Expert Testimony as needed (settled)
Date: May 2018 – Jun 2019

Expert Engagement:
Type of Matter: LED packaging
Client: Davidson, Berquist, Jackson & Gowdey, LLP on behalf of Document Security Systems (v. defendants Seoul Semiconductor, Nichia Corp, Cree, Inc., Everlight Electronics)
Case Name: IPR2018-00966, 2018-01165
Services Provided: Expert Reports, Depositions (2) and Expert Testimony at trial as needed
Date: June 2018 – May 2019

Expert Engagement:
Type of Matter: TFT-LCD technology
Client: Vinson and Elkins on behalf of AUO (v. plaintiff Vista Park Ventures)
Case Name: 2:18 cv-00276, 00278, 00279 TXEDC
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Dec 2018 – Sep 2019

Expert Engagement:
Type of Matter: LED Display Panels
Client: Fabricant LLP on behalf of Plaintiff Ultravision (v. >10 companies)
Case Name: 2:18 cv-00112, 00118, 00150 TXEDC
Services Provided: Expert report and Expert Testimony as needed; two days deposition in 2020, two depositions in 2021. **Testified at trial May 2021**
Date: Jan 2019 – Present

Expert Engagement:
Type of Matter: TFT-LCD technology
Client: McDermott, Will and Emery on behalf of TCL (v. plaintiff Vista Park Ventures)
Case Name: 2:19 cv-00188, 00189, 00190, 00191 TXEDC
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Aug 2019 – Oct 2019

Expert Engagement:
Type of Matter: TFT-LCD technology
Client: McDermott, Will and Emery on behalf of GiantPlus (v. plaintiff Vista Park Ventures)
Case Name: 2:19 cv-00183, 00184, 00185, 00187 TXEDC
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Oct 2019 – Jan, 2020

Expert Engagement:

Type of Matter: TFT-LCD technology
Client: Vincent and Elkins on behalf of JDI (v. plaintiff Vista Park Ventures)
Case Name: 2:19 cv-00323, 00324, 00325 TXEDC
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Nov 2019 – Jun 2020

Expert Engagement:
Type of Matter: TFT-LCD technology
Client: Sidley on behalf of LG Electronics (v. defendant Hisense)
Case Name: 2:19 cv-09474 CACDC
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Feb. 2020 – Jan. 2021

Expert Engagement:
Type of Matter: Quantum dot technology
Client: Murtha Law on behalf of RPI (v. defendant Samsung)
Case Name: 2:19 cv-20097 KM-ESK
Services Provided: Expert reports and Expert Testimony as needed
Date: Jan. 2020 – Jun 2021

Expert Engagement:
Type of Matter: OLED, touch panels
Client: RAK Law on behalf of Solas (v. defendant Samsung)
Case Name: 2:19-cv-00152-JRG (E.D. Tex)
Services Provided: Expert reports and Expert Testimony; two depositions in 2020. **Testified at trial Mar. 2021**.
Date: Apr. 2020 – Mar. 2021

Expert Engagement:
Type of Matter: LCD technology
Client: Morgan Lewis on behalf of Fuji Film (v. plaintiff Vista Park Ventures)
Case Name: 2:20 cv-00064, 65, 66 E.D. Tex.
Services Provided: Expert reports and Expert Testimony as needed (settled)
Date: Jul. 2020 – Oct 2020

Expert Engagement:
Type of Matter: Touch panels
Client: DLA Piper, Alston and Bird, on behalf of Microsoft, Dell (v. plaintiff Neodron)
Case Name: 2:19-cv-00318-ADA (W.D. Tex)
Services Provided: Expert Reports and Expert Testimony as needed (settled)
Date: Aug. 2020 – Nov. 2020

Expert Engagement:
Type of Matter: LCD
Client: Vincent and Elkins on behalf of Japan Display Inc (v. defendant Tianma)
Case Name: 2:20-CV-00283, 284, 285-JRG (E.D. Tex)
Services Provided: Expert Reports, depositions, and Expert Testimony as needed (settled)
Date: Jan 2021 – Jan 2022

Expert Engagement:
Type of Matter: LCD
Client: Perkins Coie on behalf of Truly Semiconductor, Hannstar (v. plaintiff Vista Park Ventures)
Case Name: 2:20-CV-250, 251, 252 (E.D. Tex)
Services Provided: Expert Reports and Expert Testimony as needed (settled)
Date: Jan 2021 – June 2021

Expert Engagement:
Type of Matter: Quantum dots
Client: Mintz on behalf of Nanoco (v. defendant Samsung)
Case Name: 2:20-CV-00038-JRG (E.D. Tex)
Services Provided: Expert Reports, depositions, case settled day before trial opening arguments
Date: Jan 2021 – Jan 2023

Expert Engagement:
Type of Matter: OLED circuits
Client: Morrison Forster on behalf of JOLED (v. defendant Samsung)
Case Name: Case No. 6:20cv559 (W.D. Tex.)
Services Provided: Expert Reports and Expert Testimony (settled)
Date: July 2020 – April 2021

Expert Engagement:
Type of Matter: OLED circuits
Client: Perkins Coie on behalf of AUO (v. defendant Samsung)
Case Name: TBD
Services Provided: Expert Reports and Testimony (settled)
Date: Feb. 2021 – May 2021

Expert Engagement:
Type of Matter: LED circuits
Client: Kim IP on behalf of CAST Lighting (v. Plaintiff WAC Lighting)
Case Name: ITC Inv. No. 337-TA-1261
Services Provided: Expert Reports and Testimony (settled)
Date: May 2021 – Oct 2021

Expert Engagement:
Type of Matter: OLED circuits
Client: RAKLaw on behalf of Solas, Ltd. (v. Defendant Samsung)
Case Name: ITC Inv. No. 337-TA-1243
Services Provided: Expert Reports and **Testified at Hearing Nov. 15-19, 2021**
Date: May 2021 – Dec 2021

Expert Engagement:
Type of Matter: OLED circuits
Client: PV Law on behalf of TCL (vs. Plaintiff SEL Co.)
Case Name: 8:21-cv-00554-JAK-ADS (CDCA)
Services Provided: Expert Reports and Depositions; case settled
Date: July 2021 – July 2023

Expert Engagement:
Type of Matter: LED circuits
Client: Carmichael IP on behalf of Lynk Labs (vs. defendant Samsung)
Case Name: IPR Proceedings
Services Provided: Expert Reports and Depositions, case settled.
Date: Jan 2022 – Jan 2023

Expert Engagement:
Type of Matter: OLED circuits
Client: Baker Botts on behalf of FujiFilm (vs. defendant ButterflyQ)
Case Name: C.A. No. 22-309-JPM
Services Provided: Expert Reports and Depositions, testify at trial if needed (settled Nov, 2023)
Date: Jul 2022 – Nov. 2023

Expert Engagement:
Type of Matter: Outdoor LCD signage
Client: Kilpatrick Townsend on behalf of MRI, Inc. (vs. defendants Samsung et al)
Case Name: ITC 337-TA-1331
Services Provided: Expert Reports, Depositions, **Testified at Hearing June 26-30, 2023**
Date: Oct 2022 – Aug 2023

Expert Engagement:
Type of Matter: OLED circuits and pixel arrangements
Client: Orrick Herrington & Sutcliffe LLP on behalf of BOE (vs. plaintiff Samsung et al)
Case Name: ITC 337-TA-1351
Services Provided: Expert Reports, Depositions. **Testified at Hearing July 16, 2024**
Date: Sep 2023 – Sept 2024

Expert Engagement:
Type of Matter: Light concentrators, LCD backlights
Client: Katz PLLC on behalf of SVV (vs. defendants Asus and Acer)
Case Name: WD Tex 6:22-cv-0311, 312, 313, 511, 512, 513, 639, 640, 641-ADA
Services Provided: Expert Reports, Depositions, **testified at trial (v. Acer), June, 2024; testified at trial (v. ASUS), Sept, 2024**
Date: Jan 2023- Oct 2024 (Plaintiff won in both trials)

Expert Engagement:
Type of Matter: LCD AMOLED circuits,
Client: Kramer Alberti on behalf of Polaris PowerLED Technologies, LLC (vs. defendant Samsung et al)
Case Name: EDTEX 2:22-cv-oo469-JRG
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert (trial scheduled for Jan 2025)
Date: Mar 2023- Dec 2024 (settled)

Expert Engagement:
Type of Matter: LCD AMOLED circuits,
Client: Morrison & Forester LLP on behalf of Crystal Leap (vs. defendant HKC)
Case Name: No. 2:22-cv-00382 (EDTEX)
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert, settled Mar, 2024
Date: Jul 2023- Mar 2024 (settled)

Expert Engagement:
Type of Matter: LCD AMOLED circuits,
Client: Kramer Alberti on behalf of Polaris PowerLED Technologies, LLC (vs. various defendants)
Case Name: 2:23-cv-03478-GW-PD (CD CAL)
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert
Date: Dec 2023- present

Expert Engagement:
Type of Matter: Image sensor circuits,
Client: PVLaw on behalf of Keyence (vs. plaintiff Al Core Technologies, LLC)
Case Name: 2:24-cv-00438-RWS-RSP,
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert
Date: Dec 2023- Nov 2024 (settled)

Expert Engagement:
Type of Matter: AMOLED design, circuits
Client: Morrison & Forester LLP on behalf of BOE (vs. Plaintiff SDC)
Case Name: No. 2:25-cv-00430 (E.D. Tex.), *Samsung Display Co., Ltd. v. BOE Technology Group Co., Ltd. et al.*, No. 2:23-cv-00426 (E.D. Tex.)
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert
Date: Jun 2025 - present

Expert Engagement:
Type of Matter: AMOLED design, circuits
Client: Orrick on behalf of BOE
Case Name: Not yet assigned
Services Provided: Expert Reports (IPR and DC), Depositions, testifying expert
Date: May 2025 - present

Expert Engagement:
Type of Matter: AMOLED design
Client: PVLaw on behalf of defendant CSOT (v. SDC)
Case Name: No. 3:25-cv-01430-S (NDTEX)
Services Provided: Technical Expert
Date: Aug 2025 - present

Consulting Projects

Consulting Engagement:
Client: Tessera
Services Provided: Business case analysis for M&A department
Date: Mar 2008 to 2011

Consulting Engagement:
Client: Sipix Imaging
Services Provided: Technical consulting on display algorithms
Date: Mar 2008 to 2009

Consulting Engagement:
Client: Holox Technologies, Inc. (self-funded start up in holographic optics)
Services Provided: CEO; business leadership, fund raising, market analysis, optical design of advanced diffusers for LCD backlights, solar collectors, window films.
Date: Sept 2008 to June 2012

Consulting Engagement:
Client: Innova Dynamics, Inc.

Services Provided:	Technical and business development consulting in touch screen technology
Date:	October 2011 to November 2012

Technical and Patent Consulting:

Client:	LG Display
Services Provided:	Technical consulting on pixel processing algorithms, OLED displays; patent generation for advanced pixel concepts for OLED.
Date:	Aug 2009 to Dec 2011

Consulting Engagement:

Client:	Scivax
Services Provided:	Technical and business development consulting in nanoimprinting technology
Date:	Feb 2018 to Jul 2018

Professional Affiliations, Achievements & Awards

- Fellow of the Society for Information Display (SID)
- Past Director, SID Symposium Committee (10 years)
- Conference and Program Chair, SID Symposium and IDRC
- Past Member, SID Program Committee (15 years)

US Patents & Publications

Patent	Date	Description
10,163,985	12/25/2018	Subpixel arrangement structure for a display device
9,583,034	02/28/2017	Subpixel arrangement structure for a display device
9,041,625	05/26/2015	Subpixel arrangement structure for a display device and display device
9,001,167	04/07/2015	Display panel having crossover connections effecting dot inversion
8,933,959	01/13/2015	Subpixel layouts and subpixel rendering methods for directional displays and systems
8,876,937	11/04/2014	Production of nanostructures
8,797,344	08/05/2015	Memory structures for image processing
8,754,913	06/17/2014	Subpixel arrangement structure of display device
8,704,744	04/22/2014	Systems and methods for temporal subpixel rendering of image data
8,633,886	01/21/2014	Display panel having crossover connections effecting dot inversion
8,519,910	08/27/2013	Image processing method and display device using the same
8,516,683	08/27/2013	Methods of making a radio frequency identification (RFID) tags
8,456,496	06/04/2013	Color flat panel display sub-pixel arrangements and layouts for sub-pixel rendering with split blue sub-pixels
8,456,414	06/04/2013	Gamma adjustment with error diffusion for electrophoretic displays
8,436,799	05/07/2013	Image degradation correction in novel liquid crystal displays with split blue subpixels
8,421,820	04/16/2013	Methods and systems for sub-pixel rendering with adaptive filtering
8,411,022	04/02/2013	Multiprimary color display with dynamic gamut mapping
8,405,692	03/26/2013	Color flat panel display arrangements and layouts with reduced blue luminance well visibility
8,378,947	02/19/2013	Systems and methods for temporal subpixel rendering of image data
8,294,741	10/23/2012	Four color arrangements of emitters for subpixel rendering
8,259,127	09/04/2012	Systems and methods for reducing desaturation of images rendered on high brightness displays
8,144,094	03/27/2012	Liquid crystal display backplane layouts and addressing for non-standard subpixel arrangements

8,134,583	03/13/2012	Two color flat panel display sub-pixel arrangements and layouts for sub-pixel rendering with split blue sub-pixels
8,035,599	10/11/2011	Display panel having crossover connections effecting dot inversion
8,018,476	09/13/2011	Subpixel layouts for high brightness displays and systems
8,013,867	09/06/2011	Systems and methods for implementing improved gamut mapping algorithms
7,969,456	06/28/2011	Methods and systems for sub-pixel rendering with adaptive filtering
7,876,341	06/25/2011	Subpixel layouts for high brightness displays and systems
7,864,194	01/04/2011	Systems and methods for motion adaptive filtering
7,791,679	09/07/2010	Alternative thin film transistors for liquid crystal displays
7,755,652	07/13/2010	Color flat panel display sub-pixel rendering and driver configuration for sub-pixel arrangements with split sub-pixels
7,701,476	04/20/2010	Four color arrangements of emitters for subpixel rendering
7,646,430	01/12/2010	Display system having improved multiple modes for displaying image data from multiple input source formats
7,592,996	09/22/2009	Multiprimary color display with dynamic gamut mapping
7,583,279	09/01/2009	Subpixel layouts and arrangements for high brightness displays
7,573,493	08/11/2009	Four color arrangements of emitters for subpixel rendering
7,573,448	08/11/2009	Dot inversion on novel display panel layouts with extra drivers
7,559,131	07/14/2009	Method of making a radio frequency identification (RFID) tag
7,505,053	03/17/2009	Subpixel layouts and arrangements for high brightness displays
7,492,379	02/17/2009	Color flat panel display sub-pixel arrangements and layouts for sub-pixel rendering with increased modulation transfer function response
7,417,648	08/26/2008	Color flat panel display sub-pixel arrangements and layouts for sub-pixel rendering with split blue sub-pixels
7,397,455	07/08/2008	Liquid crystal display backplane layouts and addressing for non-standard subpixel arrangements
7,283,142	10/16/2007	Color display having horizontal sub-pixel arrangements and layouts
7,260,882	08/28/2007	Methods for making electronic devices with small functional elements supported on a carriers
7,248,271	07/24/2007	Sub-pixel rendering system and method for improved display viewing angles
7,218,301	05/15/2007	System and method of performing dot inversion with standard drivers and backplane on novel display panel layouts
7,187,353	03/06/2007	Dot inversion on novel display panel layouts with extra drivers
7,184,066	02/27/2007	Methods and systems for sub-pixel rendering with adaptive filtering
7,167,186	01/23/2007	Systems and methods for motion adaptive filtering
7,084,923	08/01/2006	Display system having improved multiple modes for displaying image data from multiple input source formats
7,068,287	06/27/2006	Systems and methods of subpixel rendering implemented on display panels
7,046,256	05/16/2006	System and methods of subpixel rendering implemented on display panels
6,985,361	01/10/2006	Electronic devices with small functional elements supported on a carrier
6,917,368	07/12/2005	Sub-pixel rendering system and method for improved display viewing angles

6,816,380	11/09/2004	Electronic devices with small functional elements supported on a carrier
6,731,353	05/04/2004	Method and apparatus for transferring blocks
6,693,384	02/17/2004	Interconnect structure for electronic devices
6,606,247	08/12/2003	Multi-feature-size electronic structures
5,961,362	10/05/1999	Method for in situ cleaning of electron emitters in a field emission device
5,883,467	03/16/1999	Field emission device having means for in situ feeding of hydrogen
5,477,350	12/19/1995	Interferometric spatial switch for polarized or unpolarized light using liquid crystal
5,373,393	12/13/1994	Optical interferometric device with spatial light modulators for switching substantially coherent light
5,363,228	11/08/1994	Optical device with spatial light modulators for switching arbitrarily polarized light
5,345,321	09/06/1994	Compact polarization dependent optical switching units
5,319,477	06/07/1994	Compact polarization independent optical switching units
5,317,445	05/31/1994	Optical device with spatial light modulators for switching polarized light
4,630,893	12/23/1986	LCD pixel incorporating segmented back-to-back diode
4,598,227	07/01/1986	Electron beam convergence and scanning structures for flat panel display device
4,517,489	05/14/1985	Modulator structure and method for flat panel display devices
4,484,103	11/20/1984	Color selection electron beam guide assembly for flat panel display devices
4,362,966	12/07/1982	Electron leakage reduction in flat panel display devices
4,335,332	06/15/1982	Focus mesh structure and biasing technique for flat panel display devices
4,316,118	02/16/1982	Guided beam display device
4,298,819	11/03/1981	Beam Clean up structure for flat panel display devices
4,234,815	11/18/1980	Flat display tube having shielding member between beam guide and screen
4,174,881	11/20/1979	Recording a synthetic focused-image hologram on a thermally deformable plastic
4,153,856	05/08/1979	Proximity focused element scale image display device
4,148,636	04/10/1979	Broadening the spatial frequency pass band of a thermoplastic layer
4,137,478	01/30/1979	Color flat panel television
4,137,077	01/30/1979	Broadening the spatial frequency pass band of a thermoplastic layer
4,131,823	12/26/1978	Modular flat display device with beam convergence
4,121,137	10/17/1978	System for achieving image uniformity in display devices
4,103,205	07/25/1978	Flat display device with beam guide
4,103,204	07/25/1978	Flat display device with beam guide
4,088,920	05/09/1978	Flat display device with beam guide

Publications

1. "Thermoplastic Media for Holographic Recording," RCA Review: A Technical Journal (1972)
2. "Guided Beam Displays for Large Screen Flat-Panel Color TV," Information Display (1983)
3. "Recent trends in color avionic LCDs," Information Display (1987)
4. "Thin-film transistors for video applications," Inter. Display Research Conference Record (1988)
5. "TFT-LCD for video applications," Information Display (1989)
6. "LCDs," JTEC Panel Report on Display Technologies in Japan (1992)
7. "Viewing-Angle-Enhancement System for LCDs" SID Digest of Technical Papers (1995)
8. "SpectraVue™: A new system to enhance the viewing angle of LCDs," SID Journal (1997)
9. "The Business Case for Motorola's Flat-Panel-Display Division," Information Display (1997)
10. "MTF of high-resolution PenTile Matrix™ displays," Proc Eurodisplay (2002)
11. "Adding a White Subpixel," Information Display (2005)
12. "Low Power, High-Pixel-Density Mobile Displays Using PenTile RGBW™ Architectures**,"** SID Mobile Displays Digest of Technical Papers (2006)
13. *"Invited Paper:* High-Pixel-Density Mobile Displays: Challenges and Solutions," SID Digest of Technical Papers (2006)