UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Hisense USA Corporation,
Petitioner,

v.

Light Guide Innovations LLC,
Patent Owner

Case: IPR2025-01537
U.S. Patent No. 7,936,415

DECLARATION OF MICHAEL R. KRAMES, PH.D. IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW

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PETITIONER'S EXHIBIT LIST

Exhibit No.	Description
1001	U.S. Patent No. 7,936,415 ("the '415 patent")
1002	File history of U.S. Patent No. 7,936,415 ("'415-FH")
1003	Declaration of Michael Krames, Ph.D.
1004	U.S. Patent Application Publication No. 2007/0247414 ("Roberts")
1005	U.S. Patent Application Publication No. 2006/0187660 ("Liu")
1006	U.S. Patent Application Publication No. 2003/0193789 ("Karlicek")
1007	Certified English Translation of Korean Patent Application No. 10-2006-0080215
1008	U.S. Patent Application Publication No. 2007/0115671 to Roberts et al. ("Roberts-671").
1009	Certified English translation of International Patent Application Publication No. WO2006/028073A1 ("Nishida")
1010	U.S. Patent No. 4,851,862 to Newman et al. ("Newman")
1011	U.S. Patent No. 7,178,951 to Hsiao et al. ("Hsiao")
1012	Certificate of translation for Korean Patent Application No. 10-2006-0080215
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1014	Certificate of translation for International Patent Application Publication No. WO2006/028073A1
1015	Original Japanese language version of International Patent Application Publication No. WO2006/028073A1
1016	U.S. Patent Application Publication No. 2006/0012991 ("Weaver")
1017	U.S. Patent No. 6,404,131 to Kawano et al. ("Kawano")

Exhibit No.	Description
1018	U.S. Patent No. 5,139,890 to Cowie et al. (“Cowie”)

I, Michael R. Krames, Ph.D., declare as follows:

I. Introduction

1. I am over the age of 21 and am competent to make this declaration.

2. I have been retained on behalf of Petitioner Hisense USA Corp. ("Hisense" or "Petitioner") to provide my opinions regarding the validity of claims 1-18 ("Challenged Claims") of U.S. Patent No. 7,936,415 (EX-1001, the "'415 patent"). I submit this declaration based on my personal knowledge and in support of Petitioner's *inter partes* review Petition (the "Petition") against the '415 patent.

3. I have been asked to provide my independent analysis of the '415 patent in light of the materials cited below and my knowledge and experience in this field during the relevant period. I have been asked to consider whether the references cited in the Petition render obvious the invention described by the Challenged Claims.

4. I am being compensated at my normal hourly rate for my time. My compensation is not contingent in any way on the content of my analysis or the outcome of this proceeding. I am not and never have been an employee or agent of Hisense.

5. My opinions are based on my study, experience, and background discussed below, informed by my extensive experience regarding the subject matter of the '415 patent and the related prior art.

II. Qualifications

6. I have over thirty years of experience in compound semiconductors, with an emphasis on wide-bandgap semiconductor materials and devices and specifically including the field of light emitting diodes ("LEDs"). I have extensive experience in R&D and manufacturing settings, creating innovative LEDs and LED-based products for various solid-state lighting applications. I am a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and a Fellow of the Illuminating Engineering Society (IES), and a member of the U.S. National Academy of Engineering (NAE).

7. Currently, I am the President of Arkesso LLC, which is a consulting firm specializing in wide bandgap semiconductors and applications.

8. From 2009 to 2015, I was the Chief Technology Officer at Soraa, Inc., where I worked with Nobel Prize winner Shuji Nakamura and other key innovators from the University of California, Santa Barbara, to develop leading LED products for professional directional lighting by creating a new LED materials platform based on bulk gallium-nitride substrates (GaN-on-GaN).

9. I was also the Executive Vice President of Advanced Laboratories at Philips Lumileds/Lumileds Lighting and was a design engineer and engineering scientist at Hewlett Packard Co. While at Philips Lumileds/Lumileds Lighting (from 1999-2009), I developed key innovations behind the LUXEON high power LED

platform and managed the advanced technology roadmaps, identified Auger recombination as the primary loss mechanism in InGaN-based LEDs, and designed LED solutions for the iMac, iPhone Flash, digital imaging, and general illumination. My contributions there also led to the first automotive LED headlights for the Audi R8.

10. I am a named inventor on 176 U.S. granted patents in the fields of LEDs and wide bandgap semiconductors and am a named author on over 100 publications in these fields.

11. In 1989, I earned a Bachelor of Science in Electrical Engineering with High Honors from the University of Texas in Austin, TX.

12. In 1995, I earned a Ph.D. in Electrical Engineering from the University of Illinois at Urbana-Champaign in Urbana, IL, under the supervision of Prof. Nick Holonyak, Jr., the original inventor of the LED.

13. My Curriculum Vitae is provided as Appendix A, which contains further details on my education, experience, publications, and other qualifications.

III. Materials Considered

14. As described in more detail below, based on my experiences, I understand and know the capabilities of a person of ordinary skill in the art in the field of the ’415 patent as of August 24, 2006, when the application to which the ’415 patent claims priority was filed. I have relevant personal knowledge and experience, in

addition to working directly with many such persons in these fields during that time frame.

15. I have also relied on my review and analysis of the prior art cited in the Petition, information provided to me in connection with this case, and information I have independently reviewed.

16. In forming my opinions, I have been asked to review the ’415 patent, including the specification and the Challenged Claims. I have also considered the materials cited herein, including those itemized in the Table of Exhibits that precedes this Declaration.

17. My opinions are based on the materials I reviewed and my knowledge and professional judgment. My opinions have also been guided by my understanding of how a person of ordinary skill in the art would have understood the claims of the ’415 patent in the relevant time frame.

18. I also understand from counsel that the prior art references cited herein qualify as prior art under U.S. law.

19. In my analysis below, emphasis in my citations has been added unless otherwise noted. Likewise, annotations to images and figures (typically highlighting of various colors) have been added unless otherwise noted.

20. I reserve the right to supplement and amend any of my opinions in this declaration based on documents, testimony, and other information that becomes

available to me after the date of this declaration.

IV. Legal Standards

21. I am not a lawyer. My understanding of the legal standards to apply in reaching the conclusions in this Declaration is based on discussions with counsel for Petitioner, my experience applying similar standards in other patent-related matters, and my reading of the documents submitted in this proceeding. In preparing this Declaration, I have tried to faithfully apply these legal standards to the challenged claims.

22. I have been informed that there are two ways in which prior art may render a patent claim unpatentable. First, I have been informed that the prior art can "anticipate" a claim. Second, I have been informed that the prior art can render a claim "obvious" to a person of ordinary skill in the art. I understand that a claim may be patentable if it was not anticipated and would not have been obvious over the prior art as of the effective filing date of the patent. In this Declaration, I only address obviousness.

23. I have been informed that a dependent claim is a patent claim that refers back to another patent claim. I have been informed that a dependent claim includes all of the limitations of the claim to which it refers.

24. I have been asked to provide my opinions as to whether the cited prior art renders obvious the Challenged Claims of the '415 patent from the perspective of a

person of ordinary skill in the art at the '415 patent's earliest possible effective filing date (*i.e.*, August 24, 2006), as described in more detail below.

25. I have been informed that in *inter partes* review proceedings, such as this one, the party challenging the patent bears the burden of proving unpatentability by a preponderance of the evidence. I understand that a preponderance of the evidence means "more likely than not."

26. For purposes of this Declaration, I have been asked to provide my opinions on issues regarding unpatentability. I have been informed of the following legal standards, which I have applied in forming my opinions.

A. Level of Ordinary Skill

27. I understand that my assessment of the claims of the '415 patent must be undertaken from the perspective of what would have been known or understood by a person having ordinary skill in the art as of the '415 patent's earliest effective filing date. I will refer to such a person as a "POSITA."

28. I understand that my analysis and opinions expressed in this Declaration must be rendered based on the perspective of a POSITA as of the earliest effective filing date of the '415 patent. I also understand that a POSITA is a hypothetical person who is presumed to know the relevant art at the time of the alleged invention claimed in the '415 patent.

29. I understand that, in determining the level of ordinary skill in the art, I am

to consider the following factors:

- the type of problems encountered in the art or field of invention,
- prior art solutions to those problems,
- the rapidity with which innovations are made,
- sophistication of the technology, and
- the educational level of active workers in the field.

30. I have been instructed to assume a person of ordinary skill in the art is not a specific real individual, but rather a hypothetical individual having the qualities reflected by the factors discussed above.

31. I understand that a POSITA is a person of ordinary creativity, but not an automaton. I also understand that I may consider the inferences and creative steps that a POSITA would employ. In addition, I understand that a POSITA would necessarily have been capable of understanding the scientific and engineering principles applicable to the pertinent art. I also understand that when I consider what would have been obvious to a POSITA, I am not considering what would have been obvious to me at the time, nor to the inventors, judges, laymen, those skilled in other arts, or to geniuses in the art.

B. Prior Art

32. I have been advised and understand that the information used to evaluate whether an invention was new and not obvious when made is generally referred to as "prior art." I understand that prior art includes patents and printed publications that existed before the earliest claimed priority date or the earliest filing date of the

patent (which I have been informed is also called the "effective filing date").

33. I have been informed and understand that a patent or published patent application is prior art if it was filed before the effective filing date of the claimed invention.

34. I have also been informed and understand that a printed publication is prior art if it was publicly available before the earliest filing date and could be located by a POSITA exercising reasonable diligence.

C. Anticipation

35. I understand that a patent is invalid as anticipated if each and every feature of the claim is found, expressly or inherently, in a single item of prior art. I understand that anticipation by inherent disclosure is appropriate only when a prior art reference necessarily includes or discloses the unstated claim element. I also understand that the discovery of a new or previously unreported or unappreciated property of a prior art composition, or of a scientific explanation for how a prior art composition operates, does not make the prior art composition patentably new to the entity or person that discovered the new property or mode of operation.

36. For anticipation by a prior art publication or document, I understand that the reference's description must enable a POSITA to practice the claimed invention without undue experimentation.

D. Obviousness

37. I understand that a claim may be invalid if the subject matter described by the claim as a whole would have been obvious to a POSITA in view of a prior art reference, or in view of a combination of references at the time the claimed invention was made. Therefore, I understand that obviousness is determined from the perspective of a POSITA, and that the asserted claims of the patent should be read from the point of view of such a person at the time the claimed invention was made. I further understand that a POSITA is assumed to know and to have all relevant prior art in the field of endeavor covered by the patent and all analogous prior art. I understand that obviousness in an *inter partes* review proceeding is evaluated using a preponderance of the evidence standard, which means that the claims must be more likely obvious than nonobvious.

38. I also understand that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I understand as well that a prior art reference should be viewed as a whole. I understand that in considering whether an invention for a claimed combination would have been obvious, I may assess whether there were apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references,

the effects of demands known to the design community or present in the marketplace, and/or the background knowledge possessed by a POSITA. I also understand that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a POSITA can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a POSITA would have recognized that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill;
- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;
- "Common sense" teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a POSITA will be able to fit the teachings of multiple patents together like pieces of a puzzle;
- A POSITA is also a person of ordinary creativity, not an automaton;

- A patent claim can be proved obvious by showing that the claimed combination of elements was "obvious to try," particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a POSITA would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

39. I have been informed that the relevant time for considering whether a claim would have been obvious to a person of ordinary skill in the art is the time of the alleged invention. For my obviousness analysis, counsel for Petitioner has instructed me to assume that the earliest effective filing date is August 24, 2006, and that I should assume this is the date of invention for the Challenged Claims. My opinions regarding the appropriate skill level of a POSITA would not change if I assumed a later date of invention, *e.g.*, if the alleged invention is not entitled to an effective filing date of August 24, 2006.

V. Claim Construction

40. I understand that claim terms in an IPR are generally interpreted according to their ordinary and customary meaning. I further understand that the claims are read in light of the patent's specification and that the claims themselves often provide significant guidance as to the meaning of a particular term. I also understand that extrinsic evidence may be helpful when construing a claim term, but that it is less relevant than the intrinsic evidence and is often unreliable.

41. The prior art discussed herein would disclose and/or obviate the

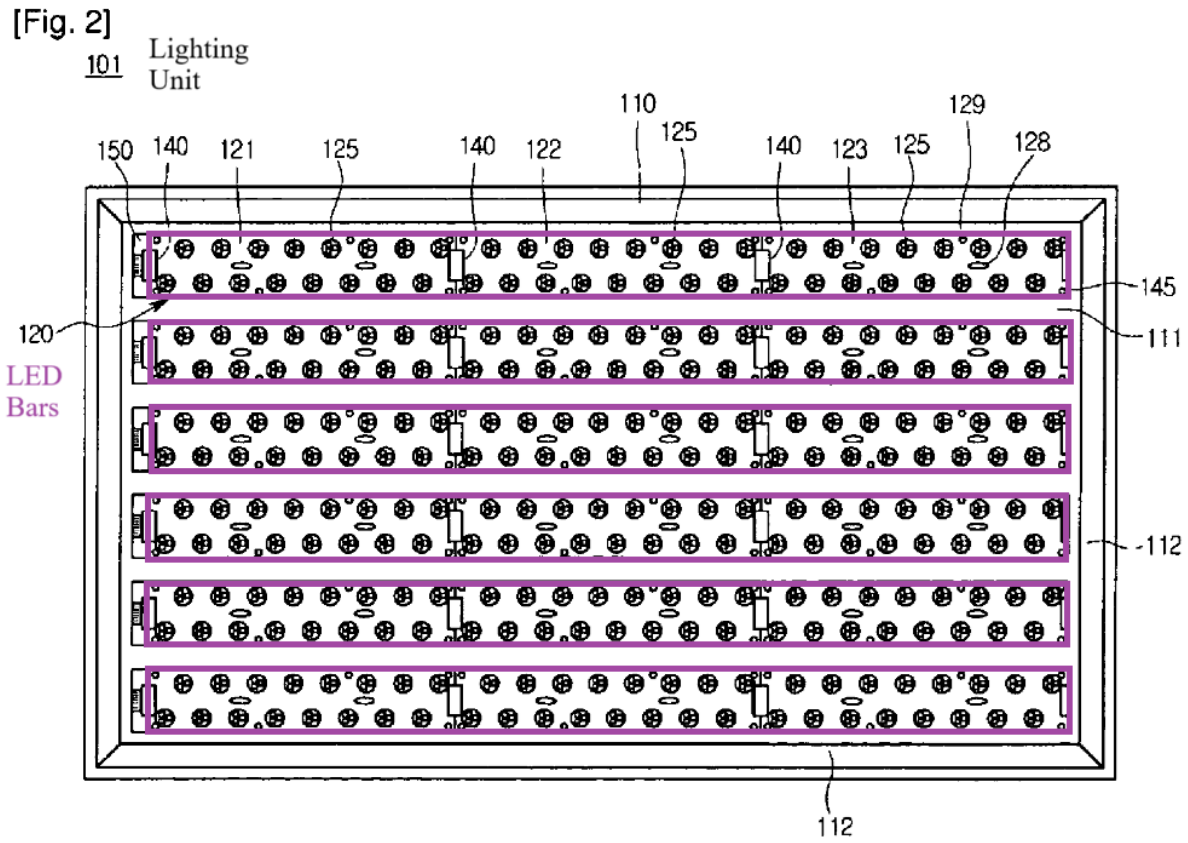
Challenged Claims under any reasonable constructions, and thus, I believe no formal claim constructions are required.

VI. The '415 Patent

A. Overview

42. The "Technical Field" of the '415 patent relates to "a light source apparatus and a liquid crystal display having the same." (Ex-1001 at 1:6-7.)

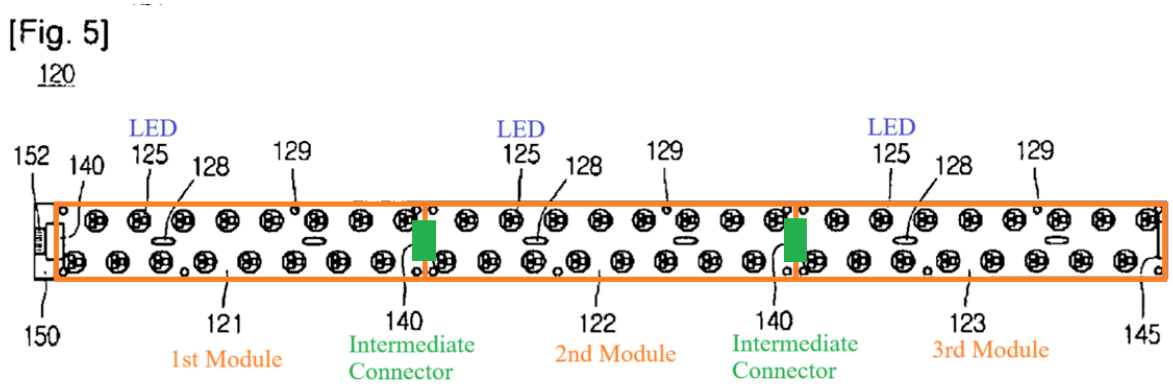
43. The '415 patent discloses an LCD (100) that includes a housing (110) and a lighting unit (101) having a plurality of ***LED bars*** 120:



(*Id.* at FIG. 2, 2:48-63; *see also id.* at FIG. 1, 2:40-43.)

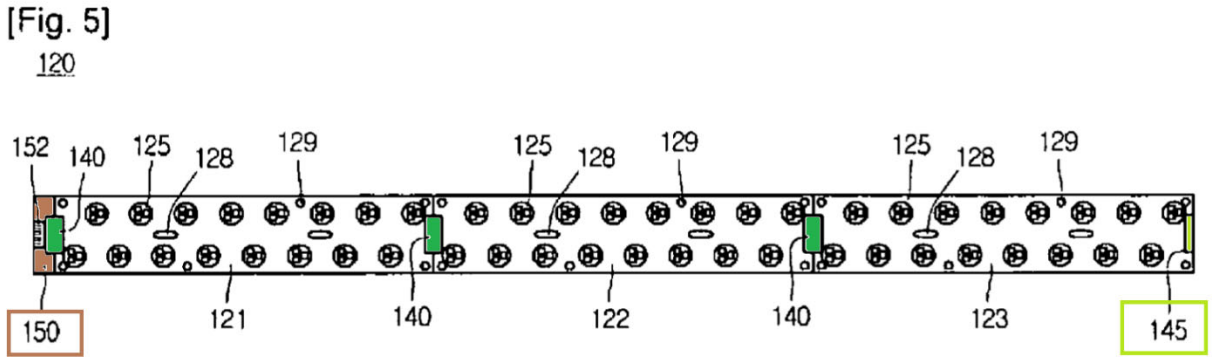
44. Each ***LED bar*** (120) includes a plurality of ***module substrates*** (121, 122,

123) interconnected via ***intermediate connecting substrate*** 140:



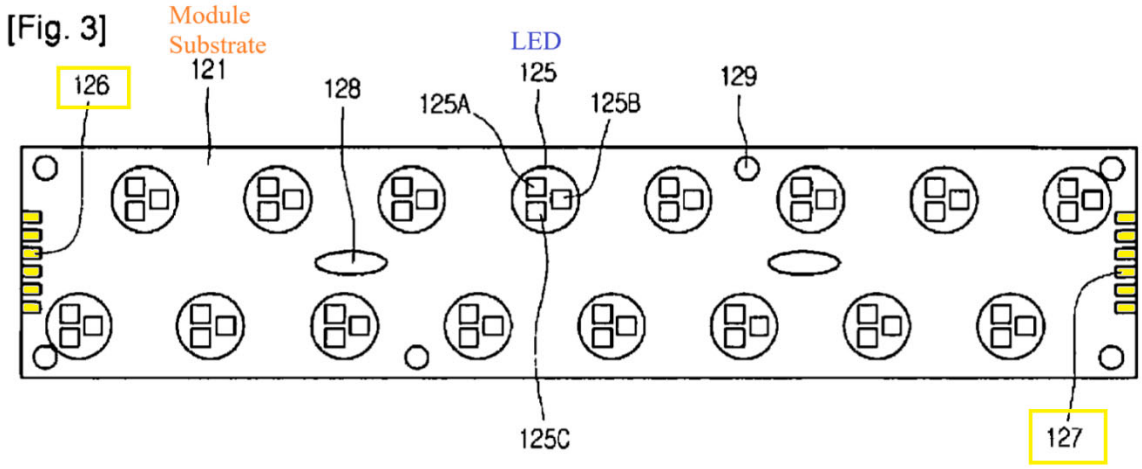
(*Id.* at FIG. 5, 3:19-23, 3:31-37.)

45. One end of each ***LED bar*** (120) includes a ***terminating connecting substrate*** (145) "so that the end portion of the third module substrate 123 is provided as a closed loop." (*Id.* at 3:39-40.) The other end of each ***LED bar*** (120) is connected to ***external connecting substrate*** (150) for connection to "an external LED driver." (*Id.* at 3:40-44.)



(*Id*. at FIG. 5.)

46. ***Connecting terminals (126, 127)*** are provided at both ends of a ***module substrate*** for mating with connecting substrates:



(*Id*. at FIG. 3, 4:4-50.)

B. Prosecution History

47. I understand that the prosecution of the ’415 patent at the USPTO was minimal. I understand that a first office action rejected various claims based on US2003/0053307 to Talamo, and that a few claims were rejected based on Talamo in view of US2007/0115671 to Roberts et al. (“Roberts-671”). (Ex-1002 at 29-34.) I understand that other claims were found allowable because Roberts-671 allegedly did not disclose a closed loop circuit. (*Id.* at 34.) I further understand that the applicant amended the claims to require a closed loop circuit, after which the application was allowed. (*Id.* at 7-10, 17-24.)

48. In my opinion, the Examiner erred in allowing the claims over Roberts-671 at least because Roberts-671 discloses a closed loop circuit.

49. More specifically, Roberts-671 discloses a lighting panel 40 comprising a plurality of bar assemblies 30 made up of a plurality of tiles 10. (Ex-1008-Roberts-

671 at FIG. 5, 0076-78.) Each bar assembly 30 includes a first group 19 and a second group 21 of series connected "strings" of colored LEDs. (*Id*. at FIG. 3, 0064-67.)

50. Roberts-671 further discloses a loopback connector 35 that connects each string (30R, 30G, 30B) in the first group 19 to its corresponding string (31R, 31G, 31B) in the second group 21, thus forming a closed loop circuit at the rightmost tile 10":

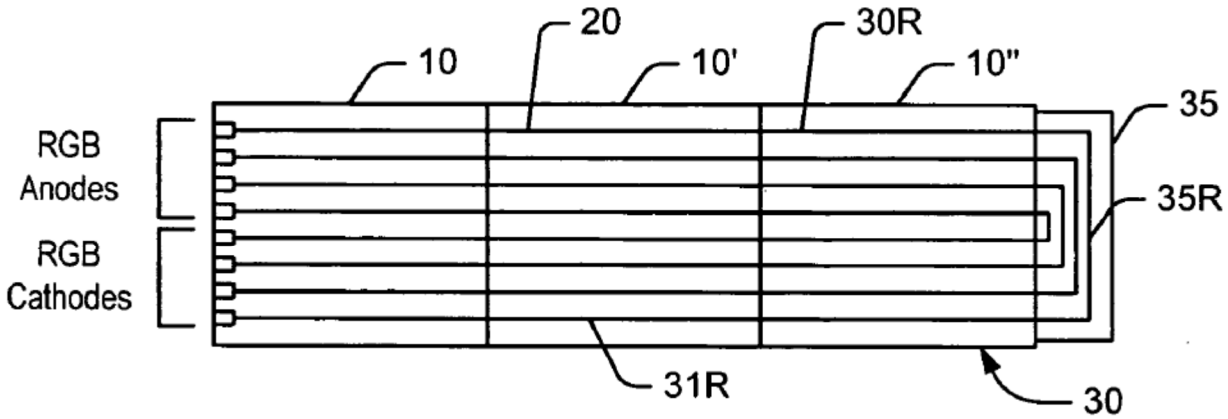


FIGURE 4

(*Id*. at FIG. 4; *see also id*. at FIG. 5.)

> "Furthermore, the cathode contacts 24 of the first path 19 of the rightmost tile 10″ may be electrically connected to the anode contacts 26 of the second path 21 of the rightmost tile 10″ by a loopback connector 35. For example, the loopback connector 35 may electrically connect the cathode 24R of the string 30R of red LED chips 16R of the first path 19 of the rightmost tile 10″ with the anode 26R of the string 31R of red LED chips of the second path 21 of the rightmost tile 10″. In this manner, the string 30R of the first path 19 may be connected in series with the string 31R of the second path 21 by a conductor 35R of

> the loopback connector 35 to form a single string of red LED chips 16R. The other strings of the paths 19, 21 of the tiles 10, 10′, 10″ may be connected in a similar manner."

(*Id*. at 0074; *see also id*. at 0009, 0071, 0075, 0077, claim 10.)

51. As shown further below, U.S. Patent Application Publication No. 2007/0247414, also to John K. Roberts, similarly discloses a closed loop circuit and includes additional material disclosures beyond Roberts-671. Thus, for at least these reasons, the Examiner erred in allowing the claims of the '415 patent.

C. The Challenged Claims

52. I understand that Petitioner is challenging claims 1-18 (collectively, the "Challenged Claims") of the '415 patent. Claims 1, 12, and 16 are independent claims.

D. Person of Ordinary Skill in the Art ("POSITA")

53. After considering the factors identified above regarding the level of ordinary skill in the art and my own experience in the field of the '415 patent, in my opinion a POSITA as of August 24, 2006, would have had 2 years of experience in LED-based lighting device design and fabrication as well as at least a bachelor's degree in a relevant field (*e.g*., mechanical engineering), or alternatively would have an equivalent combination of advanced education and practical experience, such as an advanced degree that is based on work involving LED-based lighting device design and fabrication.

54. A POSITA also would have been knowledgeable regarding backlighting devices that use LED.

E. Priority Date

55. I have been instructed to assume that the ’415 patent is entitled to an August 24, 2006, priority date based on a priority claim to Korean Application No. 10-2006-0080215 (“KR’215”). (Ex-1001 at [30].) I have been informed that the prior art applied herein is effective irrespective of whether the ’415 patent may properly claim priority to KR’215.

VII. Overview of the Prior Art

56. I understand that the Petition addresses the following grounds:

Ground	’415 Patent Claims	Basis for Obviousness
1	1-2, 7-8, 11	Obvious over Roberts (Ex-1004)
2	12, 15	Obvious over Roberts in view of Liu (Ex-1005)
3	1-8, 11	Obvious over Roberts in view of Karlicek (Ex-1006)
4	12-15	Obvious over Roberts in view of Liu and Karlicek
5	9	Obvious over Roberts in view of Nishida (Ex-1009), optionally in view of Karlicek
6	10	Obvious over Roberts in view of Newman (Ex-1010), optionally in view of Karlicek
7	16-18	Obvious over Roberts in view of Liu, Karlicek, and Hsiao (Ex-1011)

57. I provide a brief overview of the prior art references identified in Petitioner's grounds below. Each reference discussed below and relied upon in the challenges is analogous prior art and in the same field of endeavor as the '415 patent.

A. Roberts (Ex-1004)

58. Roberts is US2007/0247414. I understand that Roberts qualifies as prior art.

59. Roberts discloses a lighting panel (40) having a plurality of ***light bar assemblies (30)***, each assembly comprising a plurality of ***solid state lighting tiles (10)*** (also referred to as "LED modules"):

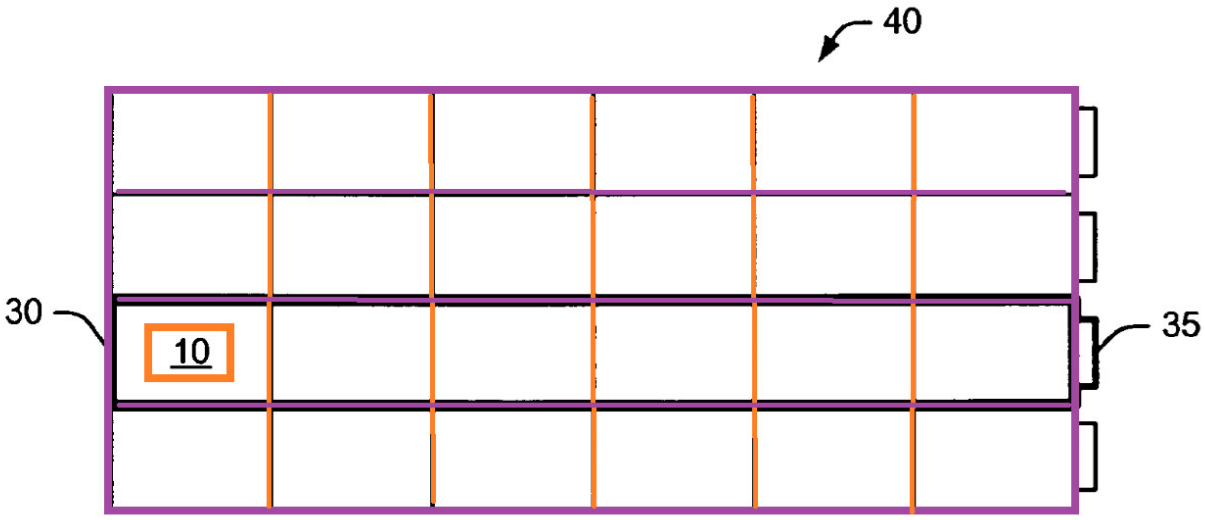


FIGURE 4B

(Ex-1004-Roberts at FIG. 4B, 0013, 0071.)

60. Each ***lighting tile (10)*** is a "functional building block to create a large area planar light source" and includes ***lighting elements (12)***, such as ***LEDs***, and ***contacts***

(14) for facilitating interconnection among ***lighting tiles (10)***:

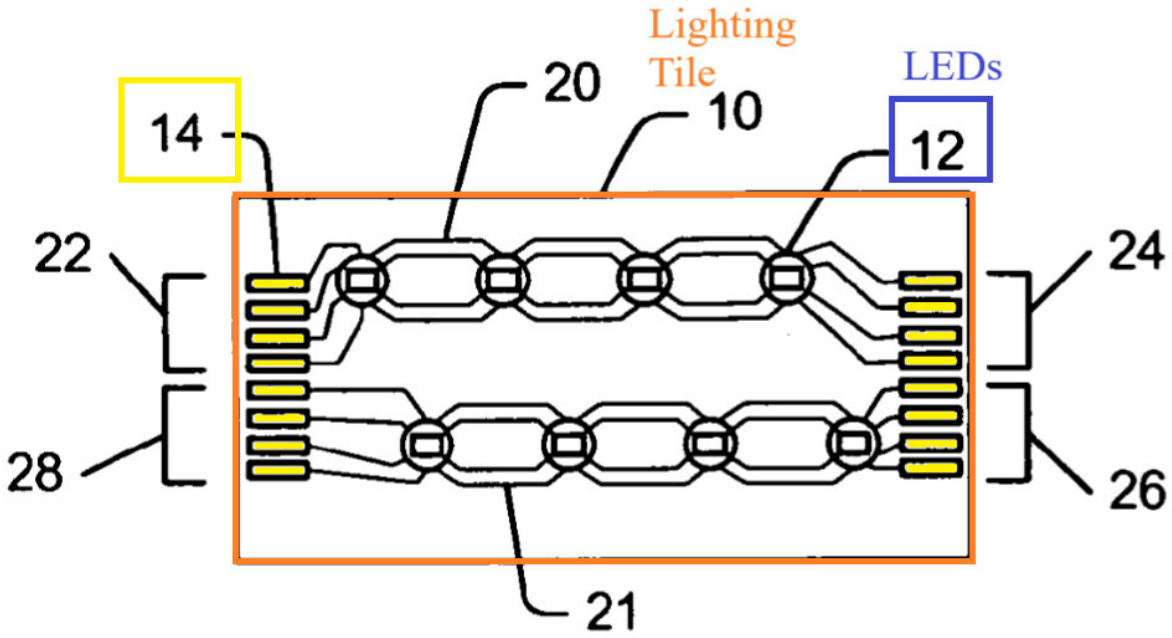


FIGURE 1

(*Id.* at FIG. 1, 0060-62.)

61. An ***edge connector (13)*** may be used to mechanically and/or electrically interconnect the many ***lighting tiles (10)*** of each ***light bar assembly (30)***:

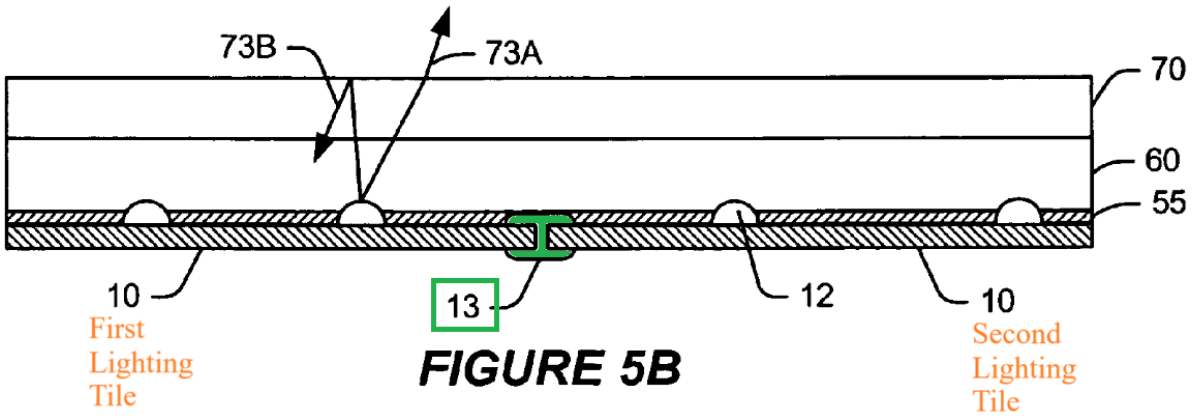


FIGURE 5B

(*Id.* at FIG. 5B, 0082.)

62. Further, a ***loopback connector (35)*** may be included at one end of each ***light bar assembly (30)*** to provide a closed-loop circuit:

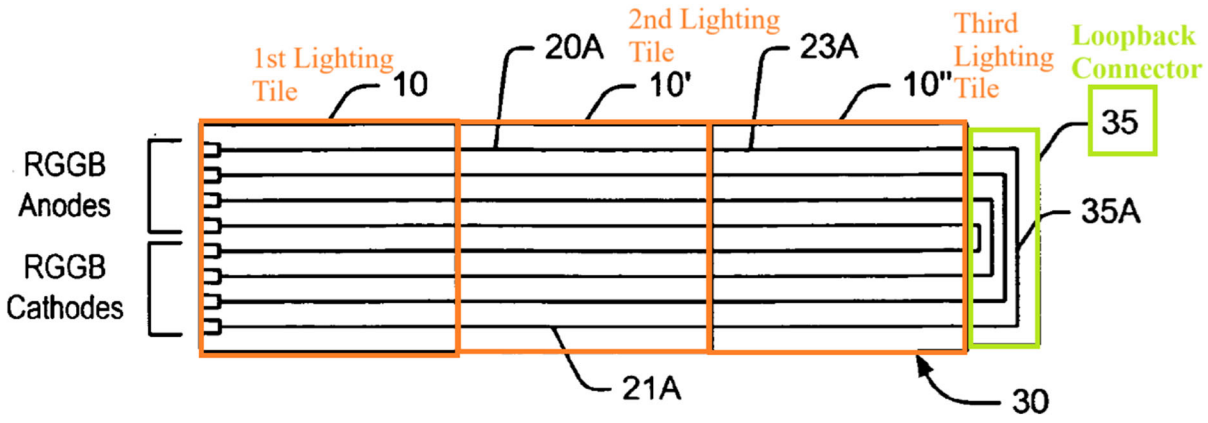


FIGURE 4A

(*Id.* at FIG. 4A, 0020, 0072.)

63. "The ***loopback connector*** 35 may include an edge connector, a flexible wiring board, or any other suitable connector. In addition, the loop connector may include printed traces formed on/in the tile 10." (*Id.* at 0073.)

64. A controller (230) and current driver (220) are used to individually power and control each LED string of the lighting panel:

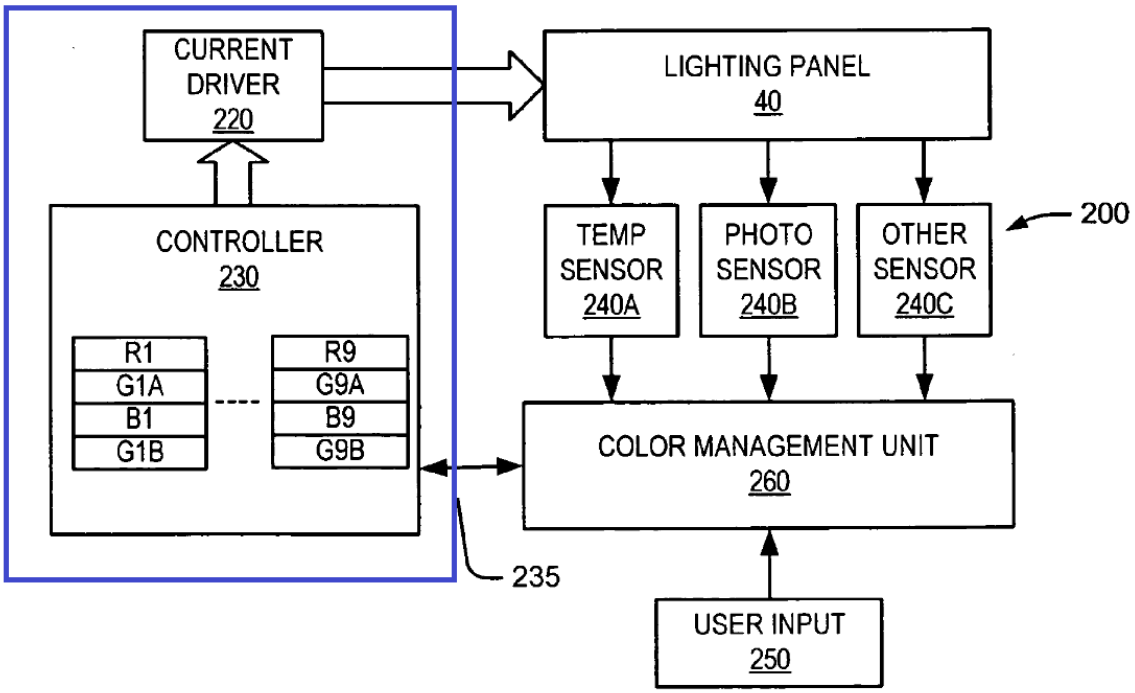


FIGURE 8

(*Id*. at FIG. 8, 0095, 0097.)

65. Roberts is analogous to the '415 patent at least because both relate to light source apparatuses and a liquid crystal display ("LCD") having the same. (Ex-1001 at 1:6-7; Ex-1004-Roberts at 0001, 0003, 0134.)

B. Liu (Ex-1005)

66. Liu is US2006/0187660. I understand that Liu qualifies as prior art.

67. Liu discloses a simple manner of securing lighting boards to a housing using receiving grooves:

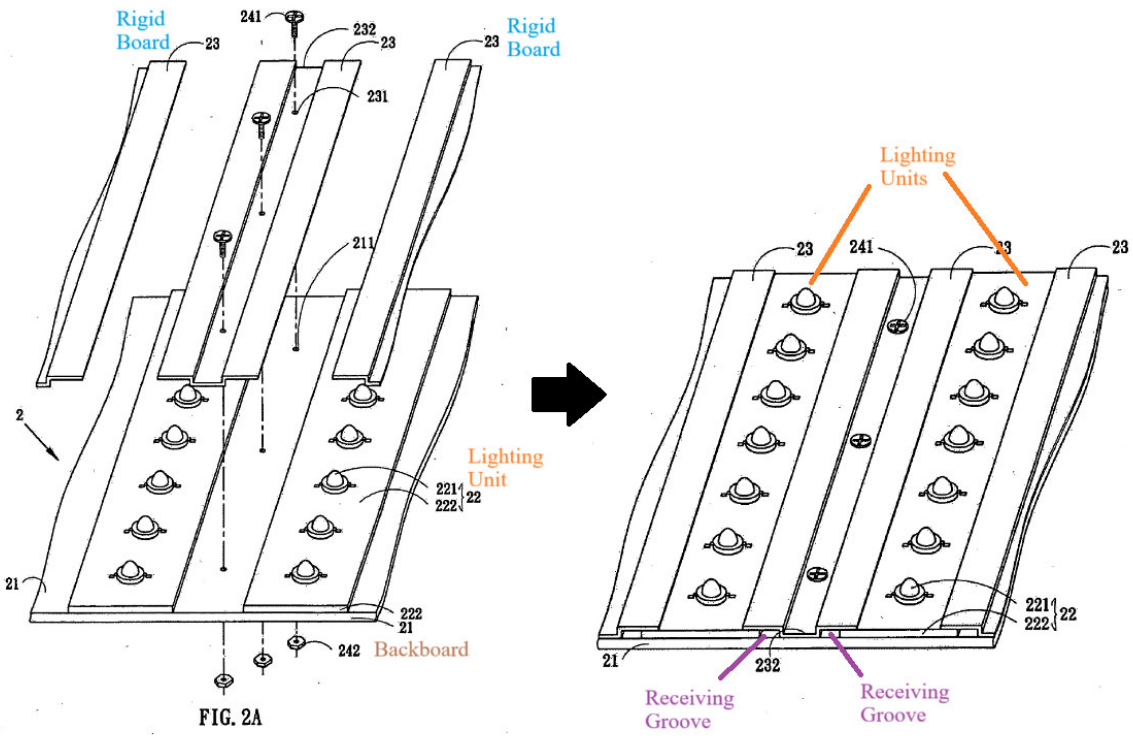


FIG. 2A

(Ex-1005-Liu at FIGS. 2A-2B, 0017-19.)

68. Liu is analogous to the '415 patent at least because both relate to light source apparatuses and an LCD having the same. (Ex-1001 at 1:6-7; Ex-1005-Liu at Abstract, 0002, 0004, 0007-8.)

C. Karlicek (Ex-1006)

69. Karlicek is US2003/0193789. I understand that Karlicek qualifies as prior art.

70. Karlicek discloses various manners of connecting a plurality of LED substrates in series (or parallel) using interconnecting and terminating elements (substrates):

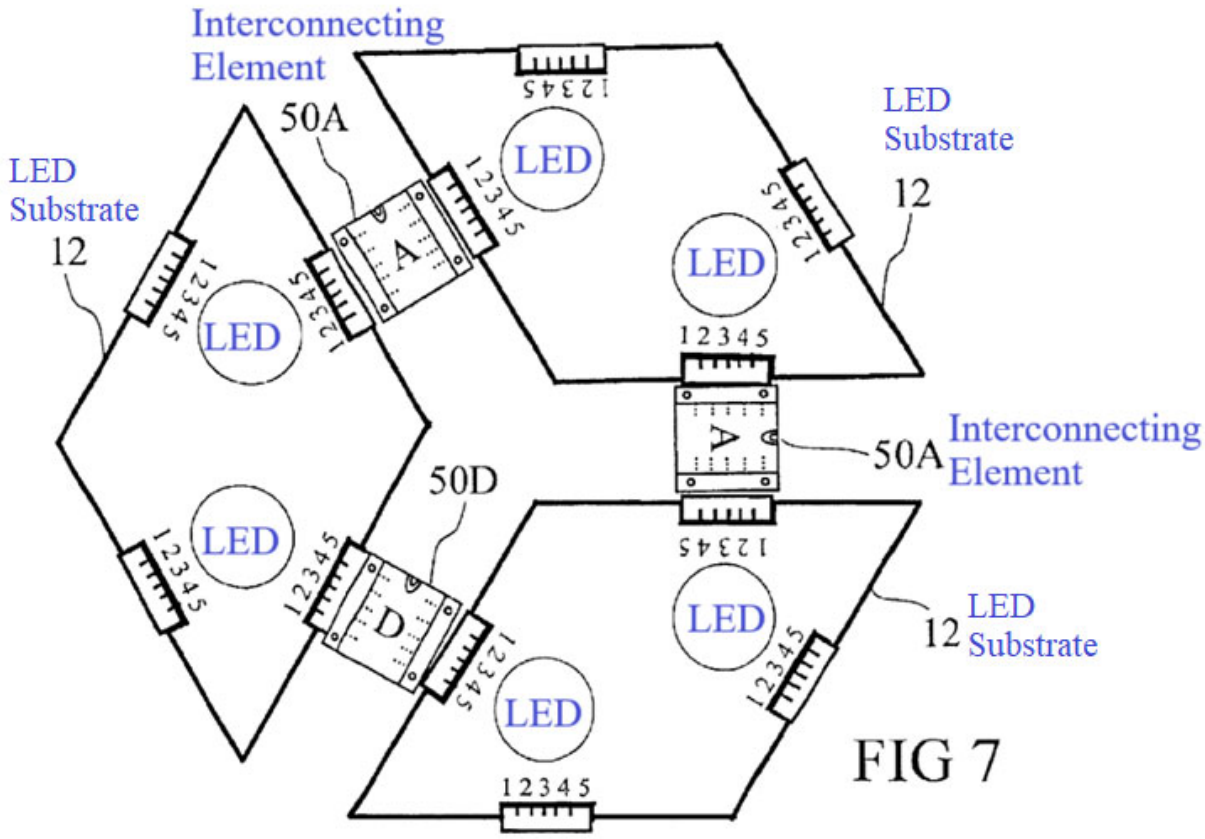


FIG 7

(Ex-1006-Karlicek at FIG. 7, 0055.)

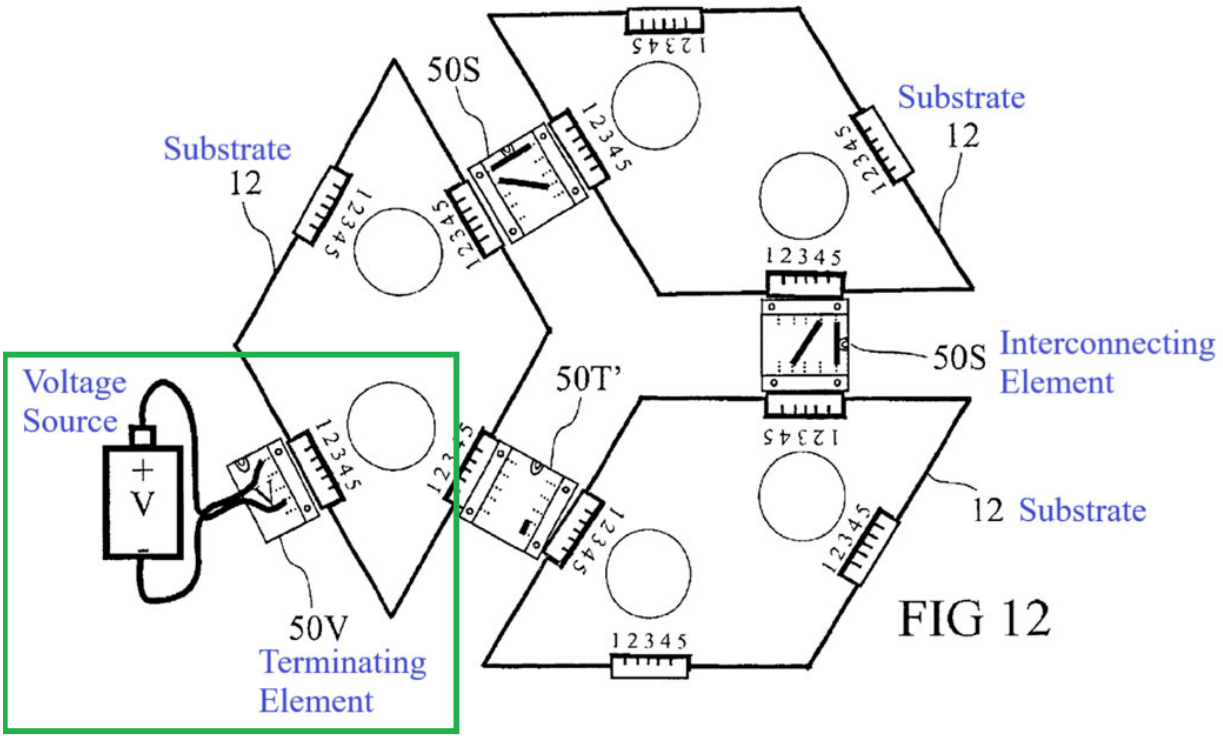


FIG 12

(*Id.* at FIG. 12, 0061.)

71. Karlicek is analogous to the '415 patent at least because both relate to light source apparatuses and an LCD having the same. (Ex-1001 at 1:6-7; Ex-1006-Karlicek at Abstract, 0001-2, 0046.)

D. Nishida (Ex-1009)

72. Nishida is a certified English translation of WO2006/028073A1. I understand that Nishida qualifies as prior art.

73. Nishida discloses conventional features of multi-layer PCB boards, such as multiple copper layers and a silver plating layer. (Ex-1009-Nishida at 0018-20, 0024, 0027, 0029-30.)

74. Nishida is analogous to the '415 patent at least because both relate to light source apparatuses and an LCD having the same. (Ex-1001 at 1:6-7; Ex-1009-Nishida at 0001, 0032, 0034-36.)

E. Newman (Ex-1010)

75. Newman is U.S. Patent No. 4,851,862. I understand that Newman qualifies as prior art.

76. Newman discloses a plurality of LED array modules, each of which comprises an ***LED array chip (16)*** and ***test pads (50)*** for testing the ***LED array chip (16)***. (Ex-1010-Newman at FIGS. 3-4, 2:61-66, 4:43-46, 5:39-44.)

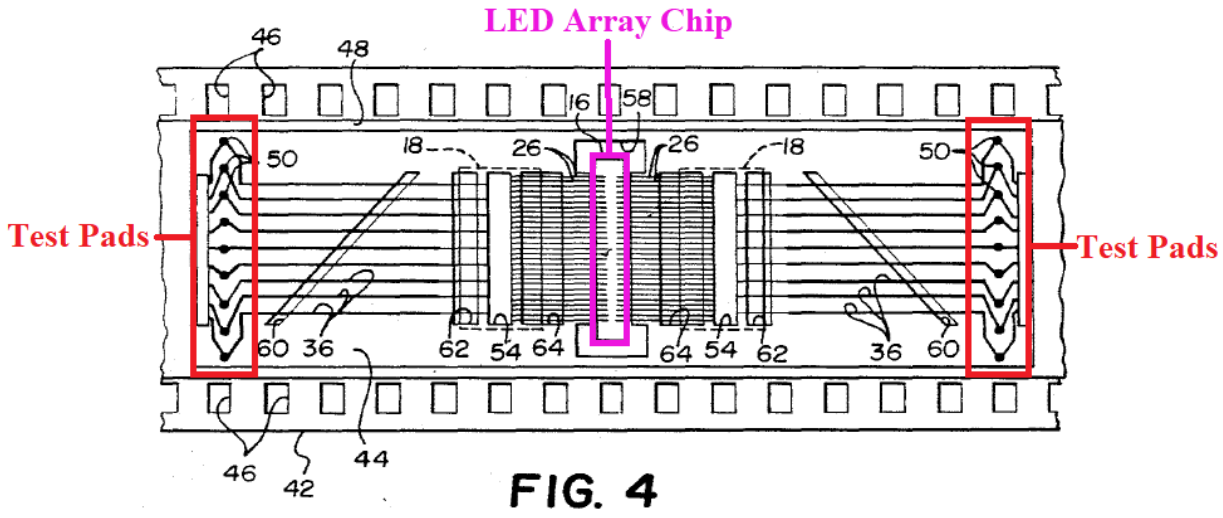


FIG. 4

(*Id*. at FIG. 4.)

77. Newman is analogous to the '415 patent at least because both relate to light source apparatuses. (Ex-1001 at 1:6-7; Ex-1010-Newman at Abstract, 1:6-18, 3:36-62.)

F. Hsiao (Ex-1011)

78. Hsiao is U.S. Patent No. 7,178,951. I understand that Hsiao qualifies as prior art.

79. Hsiao discloses the configuration of a "conventional LCD," including a light unit disposed below a liquid crystal panel. (Ex-1011-Hsiao at FIG. 1, 1:19-60.)

80. Hsiao is analogous to the '415 patent at least because both relate to light source apparatuses and an LCD having the same. (Ex-1001 at 1:6-7; Ex-1011-Hsiao at 1:12-17.)

VIII. GROUND 1: Roberts Renders Obvious Claims 1-2, 7-8, and 11.

A. The Challenged Claims

Claim 1. [1-PRE] A light source apparatus comprising:

81. Regardless of whether the preamble is limiting, Roberts teaches it.

82. Roberts teaches a ***lighting panel (40)*** which serves as a light source for a display:

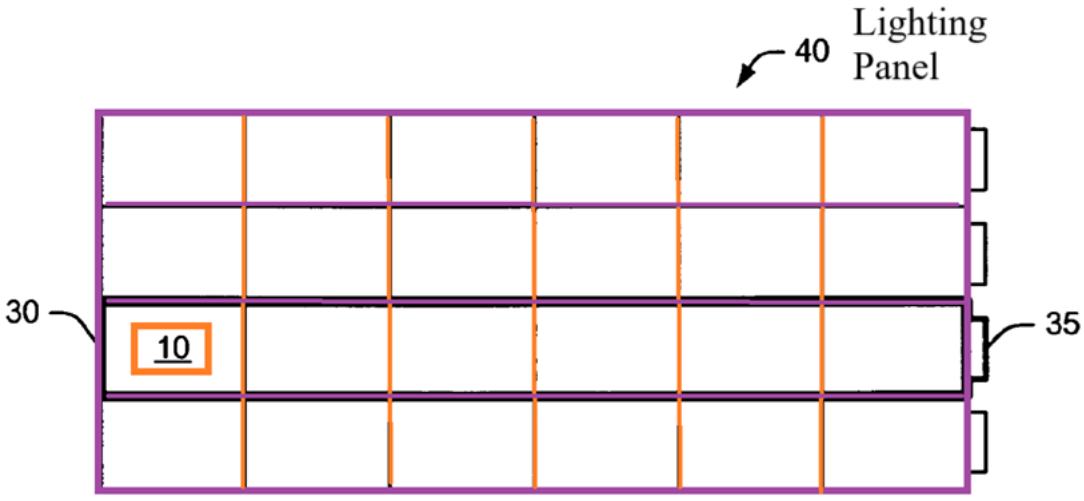


FIGURE 4B

(Ex-1004-Roberts at FIG. 4B, 0013, 0019, 0075-77.)

83. Thus, Roberts teaches the preamble.

[1a] at least one module substrate comprising connecting terminals at both side ends thereof;

84. Roberts teaches limitation [1a].

85. Roberts' lighting panel (40) includes a ***plurality of light bar assemblies (30)***, each of which includes a plurality of ***lighting tiles (10)*** (module substrates):

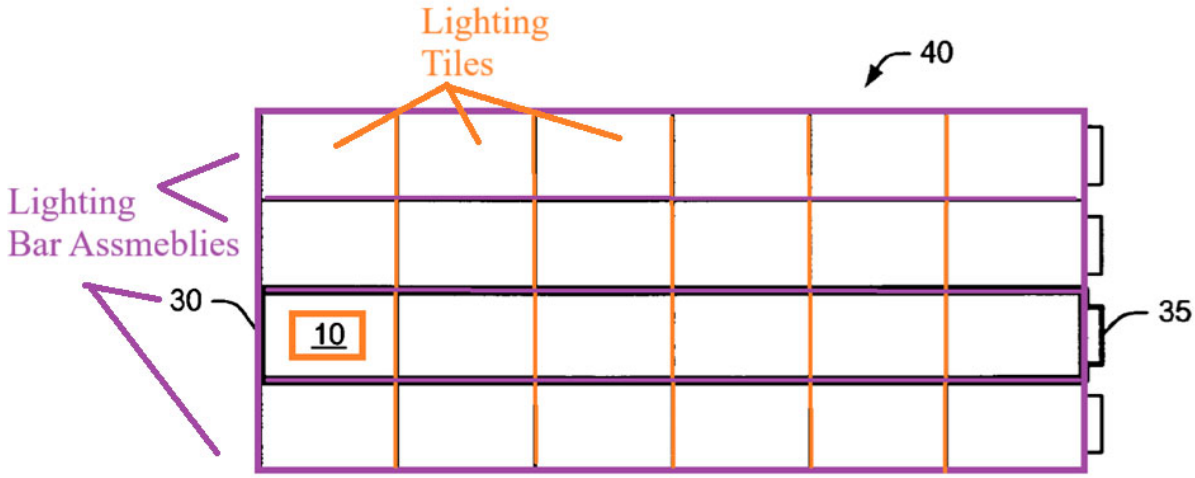


FIGURE 4B

(Ex-1004-Roberts at FIG. 4B, 0075.)

86. Each ***lighting tile (10)*** includes ***connecting terminals (contacts 22, 24, 26, 28)*** at both side ends thereof:

> "In the embodiments illustrated in FIG. 1, the lighting elements 12 are multi-chip clusters of four solid state emitting devices per cluster. In the tile 10, four lighting elements 12 are serially arranged in a first path 20, while four lighting elements 12 are serially arranged in a second path 21. The lighting elements 12 of the first path 20 are connected, for example via printed circuits, to *a set of four anode contacts 22 arranged at a first end of the tile 10, and a set of four cathode contacts 24 arranged at a second end of the tile 10*. The lighting elements 12 of the second path 21 are connected to *a set of four anode contacts 26 arranged at the second end of the tile 10, and a set of four cathode contacts 28 arranged at the first end of the tile 10*."

(*Id.* at 0061.)

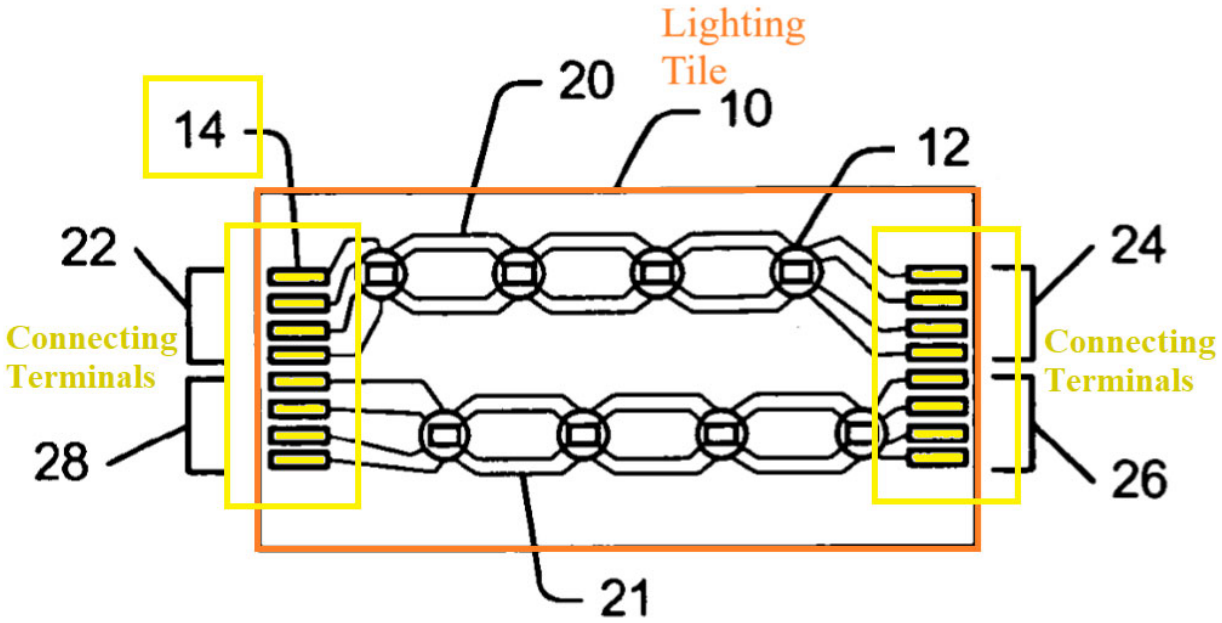


FIGURE 1

(*Id.* at FIG. 1.)

87. Thus, Roberts teaches limitation [1a].

[1b] a light emitting diode on the module substrate; and

88. Roberts teaches limitation [1b].

89. Roberts discloses that each ***lighting tile (10)*** (module substrate) includes ***lighting elements (12)*** thereon, which may be ***LEDs*** (light emitting diodes):

> "A solid state lighting tile 10 may include *thereon* a number of *solid state lighting elements 12* arranged in a regular and/or irregular one- or two-dimensional array."

(Ex-1004-Roberts at 0060.)

> "In some embodiments of the invention, *the lighting elements 12 are chip-on-board clusters including* ***one or more LEDs*** configured to emit

in the *blue* or UV spectrum. A wavelength conversion material is arranged to receive light emitted by the LEDs and to responsively emit a longer wavelength light, such as a *red, green, blue and/or yellow light*."

(*Id.* at 0062.)

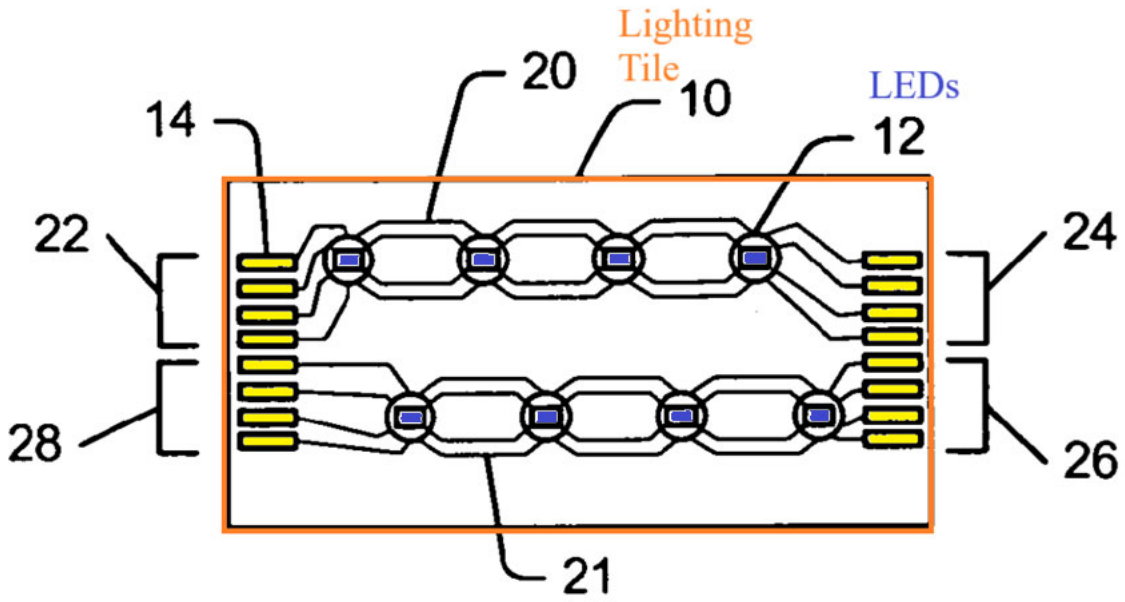


FIGURE 1

(*Id.* at FIG. 1; *see also id.* at 0013.)

90. Thus, Roberts teaches limitation [1b].

[1c] a plurality of connecting substrates connected to the connecting terminals of the module substrate, wherein the connecting substrate comprises a termination connecting substrate, by which the connecting terminal provided at one end of a final module substrate of the module substrates is prepared as a closed loop circuit.

91. Roberts teaches and suggests limitation [1c].

92. Roberts discloses that its ***lighting tiles (10)*** (module substrates) may be "*connected at respective opposing edges by an **edge connector 13** [connecting*

substrate], which may provide an ***electrical*** *and/or mechanical connection between adjacent* ***tiles 10***." (Ex-1004-Roberts at 0082.)

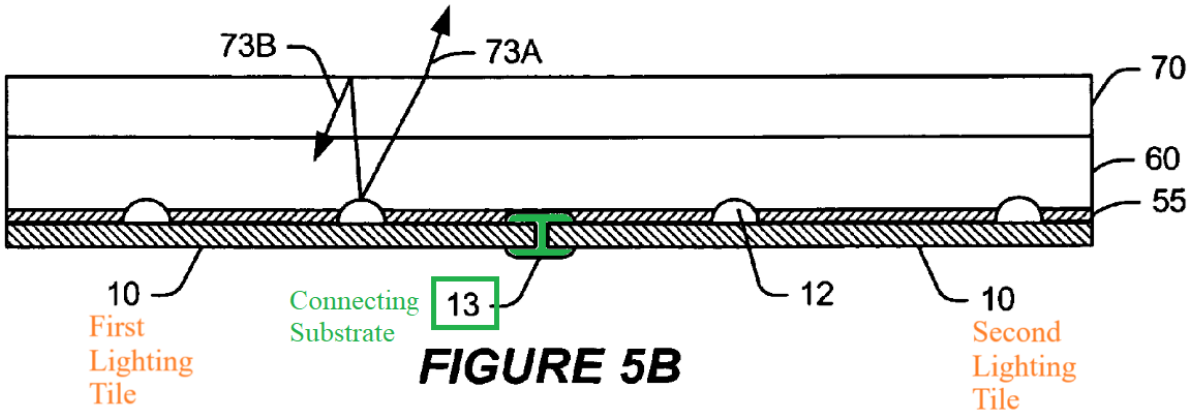


FIGURE 5B

(*Id*. at FIG. 5B.)

93. Roberts does not expressly disclose that its ***edge connectors 13*** (connecting substrates) are "connected to the connecting terminals of the module substrate." However, Roberts teaches and suggests, and a POSITA would have found it obvious, that Roberts' ***edge connectors 13*** are "connected to the connecting terminals of the module substrate." (*Id*. at 0082.)

94. Roberts expressly discloses that its lighting tiles are electrically connected in series using the connecting terminals (*e.g.*, anodes 22, 26 and cathodes 24, 28) and that the ***edge connectors 13*** provide the electrical connection between adjacent ***lighting tiles 10***. (*Id.* at 0071-74, 0082, FIG. 4A.) Thus, Roberts teaches and suggests, and a POSITA would have expected and would have found it obvious, that Roberts' ***edge connectors 13*** are "connected to the connecting terminals of the module substrate" to provide the electrical connection between adjacent tiles 10

(*e.g.*, the electrical connection between the cathode contacts 24 and anode contacts 26 of a first tile 10 and the anode contacts 22 and cathode contacts 28, respectively, of a second tile 10′).

95. Roberts further discloses that its connecting substrates may include ***a loopback connector 35*** (termination connecting substrate). According to Roberts, each ***lighting bar assembly (30)*** may terminate at one end with ***a loopback connector 35***:

> "Furthermore, the cathode contacts 24 of the first path 20 of the rightmost tile 10" may be electrically connected to the anode contacts 26 of the second path 21 of the rightmost tile 10" ***by a loopback connector 35***. For example, ***the loopback connector 35*** *may electrically connect the cathode 24A of the string 20A of blue LED chips 16A of the first path 20 of the rightmost tile 10" with the anode 26A of the string 21A of blue LED chips of the second path 21 of the rightmost tile 10"*. In this manner, the string 20A of the first path 20 may be connected in series with the string 21A of the second path 21 by a conductor 35A of the loopback connector 35 to form a single string 23A of blue LED chips 16. The other strings of the paths 20, 21 of the tiles 10, 10', 10" may be connected in a similar manner."

(Ex-1004-Roberts at 0072.)

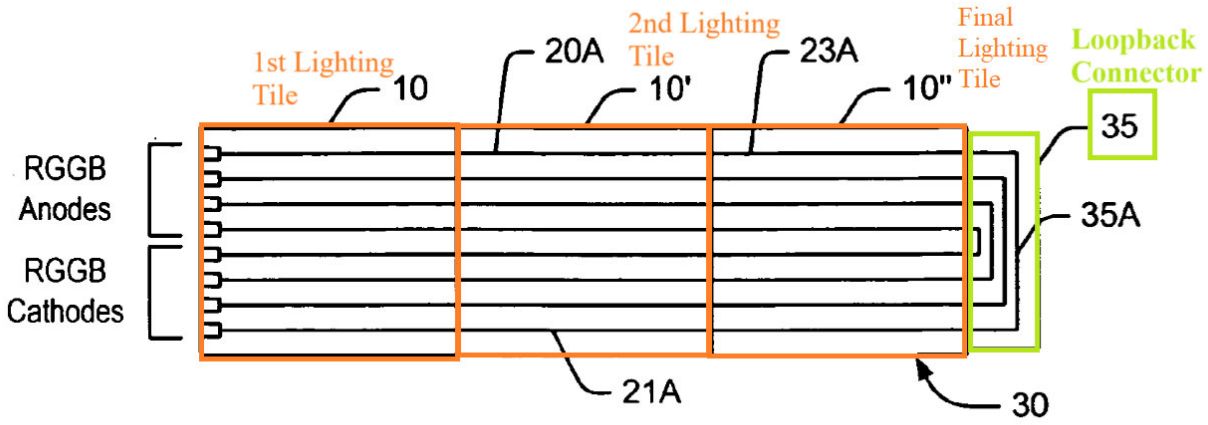


FIGURE 4A

(*Id.* at FIG. 4A.)

96. As Roberts illustrates, each cathode contact 24 at the rightmost end of the final lighting tile 10" is electrically connected to a corresponding anode contact 26 at the rightmost end of the final lighting tile 10" via a conductor 35A of ***the loopback connector 35*** in order to form a single string of individually colored LEDs (*e.g.*, a first blue LED string, a second green LED string, etc.). (*Id.* at 0062, 0072.) In this way, the connecting terminal at the rightmost end of the final lighting tile 10" (the connecting terminal provided at one end of a final module substrate of the module substrates) is prepared, using Roberts' ***loopback connector 35***, as a "closed loop circuit" wherein each LED string is individually powered and controllable.

97. As Roberts explains:

> "***A current driver 220*** *provides independent current control for each of the LED strings 23* of the lighting panel 40. For example, the current

driver 220 may provide *independent current control for 36 separate LED strings in the lighting panel 40*. The current driver 220 may provide a constant current source for each of the 36 separate LED strings of the lighting panel 40 under the control of a controller 230."

(*Id*. at 0097.)

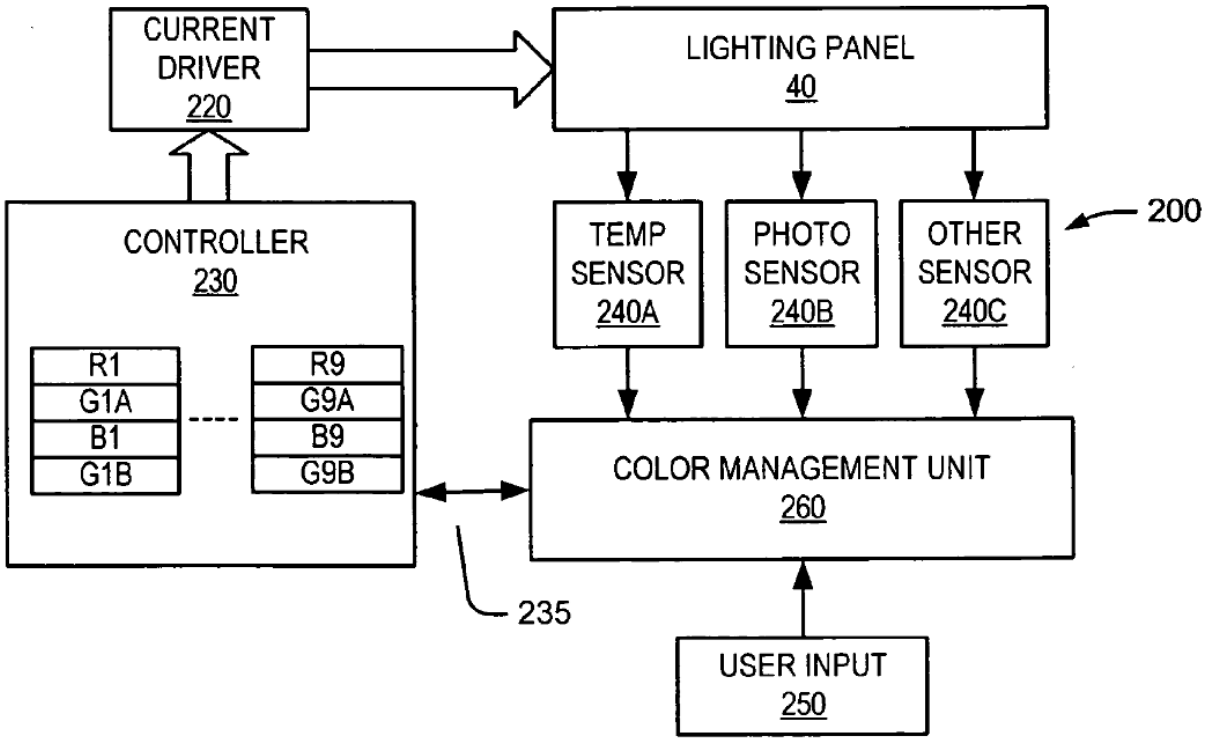


FIGURE 8

(*Id*. at FIG. 8.)

98. Roberts also seeks independent current control of each string in a ***lighting bar assembly***, which a POSITA would have known is facilitated using a closed-loop lighting circuit:

"In order to allow consistent, controllable light output characteristics for a lighting panel, some embodiments of the invention provide *a lighting panel having two or more serial strings of LED chips. An*

> *independent current control circuit is provided for each of the strings of LED chips*. Furthermore, current to each of the strings may be individually controlled, for example, by means of pulse width modulation (PWM) and/or pulse frequency modulation (PFM). The width of pulses applied to a particular string in a PWM scheme (or the frequency of pulses in a PFM scheme) may be based on a pre-stored pulse width (frequency) value that may be modified during operation based, for example, on a user input and/or a sensor input."

(*Id.* at 0094.)

99. Roberts also expressly discloses that its LED strings are prepared as a "closed loop":

> "Same colored LED strings in a lighting panel need not be driven with the same pulse width. For example, a backlight panel 40 may include a plurality of red LED strings 23, each of which may be driven with a different pulse width, resulting in a different average current level. Accordingly, some embodiments of the invention *provide a closed loop* digital control system for a lighting panel, such as an LCD backlight, that includes first and second LED strings 23 that include a plurality of LED chips 16 therein that emit narrow band optical radiation having a first dominant wavelength when energized, and third and fourth LED strings 23 that include a plurality of LED chips 16 that emit narrow band optical radiation having a second dominant wavelength, different from the first dominant wavelength."

(*Id*. at 0134.)

> "The on-state current of the first and second LED strings 23 may be

different than the on-state current of the third and fourth LED strings. For example, the on-state current used to drive red LED strings 23 may be different than the on-state current used to drive green and/or blue LED strings. The average current of a string 23 is proportional to the pulse width of the current through the string 23. The ratio of average current between the first and second LED strings 23 may be maintained relatively constant, and/or the ratio of average current between the third and fourth LED strings 23 may be maintained relatively constant. Furthermore, the ratio of average current between the first and second LED strings 23 compared to the average current of the third and fourth LED strings 23 may be allowed to change *as part of the closed loop control* in order to maintain a desired white point."

(*Id*. at 0136; *see also id*. at 0020, 0033, 0126-27, claims 18 and 33.)

100. An embodiment of Roberts' closed-loop circuit as it relates to the blue LED string (20A, 21A) is illustrated below:

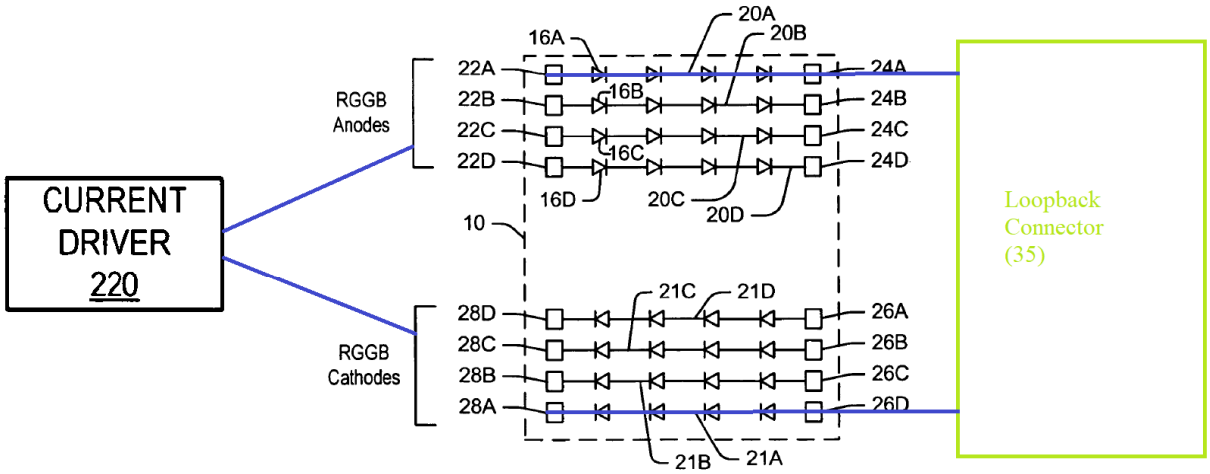


FIGURE 3

(*Id*. at FIG. 3; *see also id*. at 0067-69, 0072, FIGS. 5A and 8.)

101. Accordingly, Roberts teaches "wherein the connecting substrate comprises a termination connecting substrate, by which the connecting terminal provided at one end of a final module substrate of the module substrates is prepared as a closed loop circuit."

102. A POSITA would have understood that Roberts' ***edge connectors 13*** and ***loopback connectors 35*** are "connecting substrates" within the meaning of the Challenged Claims at least because they are physical structures/platforms upon which electrical interconnections between adjacent anode and cathode contacts are built or made. (*Id*. at FIGS. 4A and 5B, 0071-73, 0075, 0082.)

103. Thus, Roberts teaches and suggests limitation [1c].

104. Accordingly, Roberts teaches and renders obvious Claim 1.

Claim 2. The light source apparatus as claimed in claim 1, wherein the connecting substrate comprises an intermediate connecting substrate connecting the connecting terminals of adjacent module substrates to each other.

105. Roberts teaches Claim 2.

106. As explained above relative to limitation [1c], Roberts' ***edge connectors 13*** disclose, teach, and suggest "an intermediate connecting substrate connecting the connecting terminals of adjacent module substrates (***lighting tiles***) to each other." (Ex-1004-Roberts at FIGS. 4A and 5B, 0071-72, 0082.)

107. Thus, Roberts teaches and renders obvious Claim 2.

Claim 7. The light source apparatus as claimed in claim 1, wherein the light emitting diode comprises at least one LED chip having at least one color.

108. Roberts teaches Claim 7.

109. Roberts teaches that the LEDs may comprise at least one LED chip that emits blue, red, green, and/or yellow light. (Ex-1004-Roberts at 0061-62, 0064, 0067.)

110. Thus, Roberts teaches and renders obvious Claim 7.

Claim 8. The light source apparatus as claimed in claim 1, wherein the module substrate comprises a single-layer printed circuit board or a multi-layer printed circuit board.

111. Roberts teaches Claim 8.

112. I note that Claim 8 claims all possible versions of printed circuit boards ("PCBs"): single-layer or multi-layer. Thus, a disclosure of a module substrate comprising a PCB teaches Claim 8.

113. To that end, Roberts teaches that its ***lighting tiles (10)*** (module substrates) may comprise "a printed circuit board (PCB) on which one or more circuit elements, such as discrete light emitting components, may be mounted," such as "a metal core PCB (MCPCB)." (Ex-1004-Roberts at 0060.)

114. Thus, Roberts teaches and renders obvious Claim 8.

Claim 11. The light source apparatus as claimed in claim 1, wherein the module substrate comprises white ink coated on the module substrate, except for a region where the LED chip is mounted.

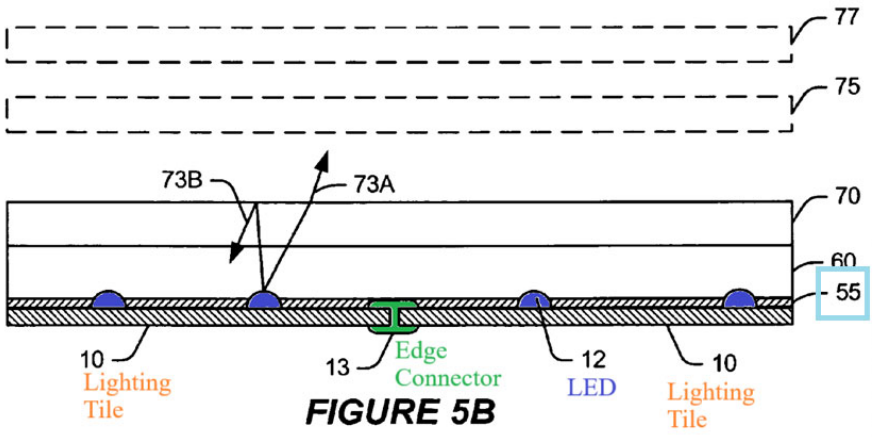
115. Roberts teaches Claim 11.

116. Roberts teaches that a reflective coating, such as a "white paint," may share the "same surface" of the ***lighting tiles 10*** with the LEDs:

> "Additional embodiments of the invention are illustrated in FIG. 5B, in which a pair of tiles 10 are shown. The panels 10 may be connected at respective opposing edges by an edge connector 13, which may provide an electrical and/or mechanical connection between adjacent tiles 10. In the embodiments of FIG. 5B, ***a reflector sheet 55*** is *provided as a reflective coating* ***on the same surface*** *of the tiles 10 as the lighting elements 12*. The coating may include, for example, ***a white paint*** that is configured to reflect and scatter light incident thereon. A diffuser sheet 60 is provided on the reflector sheet 55."

(Ex-1004-Roberts at 0082.)

117. As shown in FIG. 5B, the reflector sheet 55 (white paint) is coated on the ***lighting tile 10*** (module substrate) except in regions where the ***LED chips (12)*** are mounted:



(*Id*. at FIG. 5B.)

118. In my opinion, Roberts' "white paint" teaches and suggests the claimed

"white ink." Roberts and the '415 patent use the terms "white paint" and "white ink," respectively, to refer to the same thing: a high-reflectance white coating applied to surfaces of an LED housing or substrate to enhance luminous efficacy. A POSITA also would have recognized that "white paint" was not limited to liquid architectural paints, but encompassed any high-reflectance coating, including "white ink," because the functional requirement is identical—namely, the deposition of a TiO_2- or similar white-pigment-loaded medium to provide diffuse reflectivity. For example, Weaver described the use of white solder mask coatings containing white fillers to reflect visible light. (Ex-1016-Weaver at 0004.) Likewise, Kawano disclosed white reflective coatings and inks in LED display bodies. (Ex-1017-Kawano at 2:62-67, 13:1-7.) These references show that the terms "white paint," "white ink," and "white coating" were used interchangeably in the field to describe layers reflective to visible light. Accordingly, Roberts' "white paint" would have taught, or at least suggested, "white ink" to a POSITA in this context.

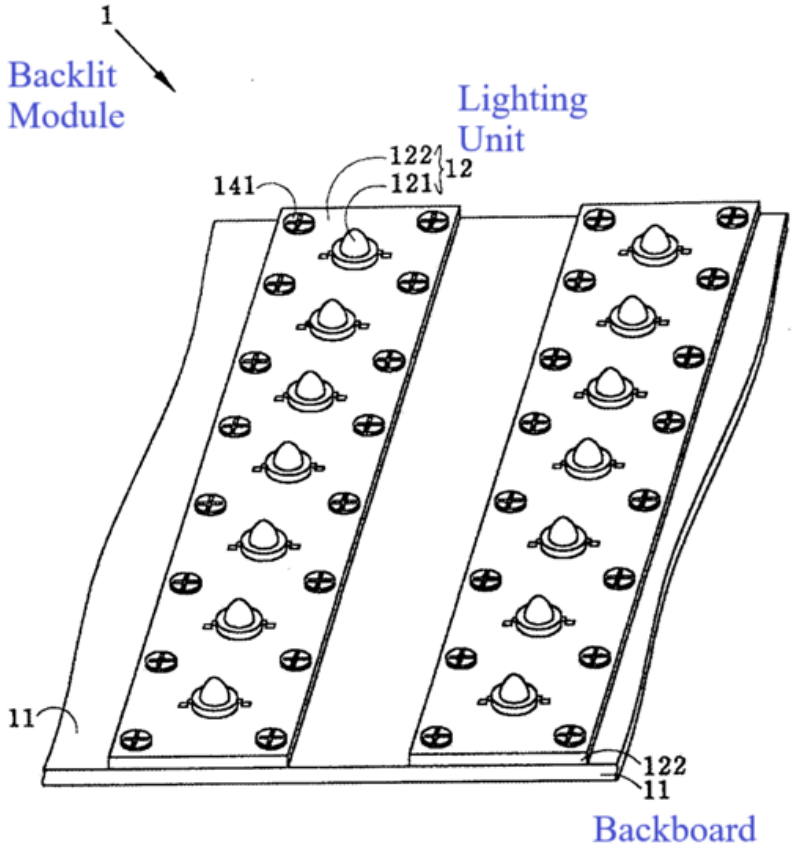
119. Thus, Roberts teaches, suggests, and renders obvious Claim 11.

IX. GROUND 2: Roberts in View of Liu Renders Obvious Claims 12 and 15.

A. Scope, Content, and Motivation to Combine

120. As shown below, Roberts teaches all limitations of the Ground 2 claims except "a housing comprising a receiving groove." Liu, however, discloses this conventional feature.

121. Liu discloses that conventional LCDs included "a backboard 11 and a plurality of lighting units 12 arranged in equal space and in parallel on the backboard 11." (Ex-1005-Liu at 0004.)



(*Id*. at FIG. 1, 0004-6.)

> "Each of the lighting units 12 includes a plurality of lighting elements 121 and an aluminum board 122 carrying the lighting elements 121, wherein the lighting elements 121 are soldered above the aluminum board 122 and connected with the conductive trace (not shown). And, the heat generated by operating the lighting units 12 is dissipated to the backboard 11 through the aluminum board 122."

(*Id.* at 0004.)

122. Liu further discloses that the issue with this arrangement is that "since the material of the aluminum board 122 is not hard enough such that *it is inevitable to have some voids between the aluminum board 122 and the backboard 11 to block [hinder] the thermal dissipation*." (*Id.* at 0006.) Accordingly, Liu seeks "to firmly fasten the lighting units unto the backboard of the backlight module so that the assembling is simplified and the required amount of the nuts and bolts is greatly reduced." (*Id.* at 0007.)

123. Liu proposes a housing (backboard) and rigid board arrangement that securely holds lighting units to the housing, eliminating gaps/voids between the lighting units and the housing. (*Id.* at 0008.) The housing's rigid boards include a groove for receiving the lighting units and securing them to the housing:

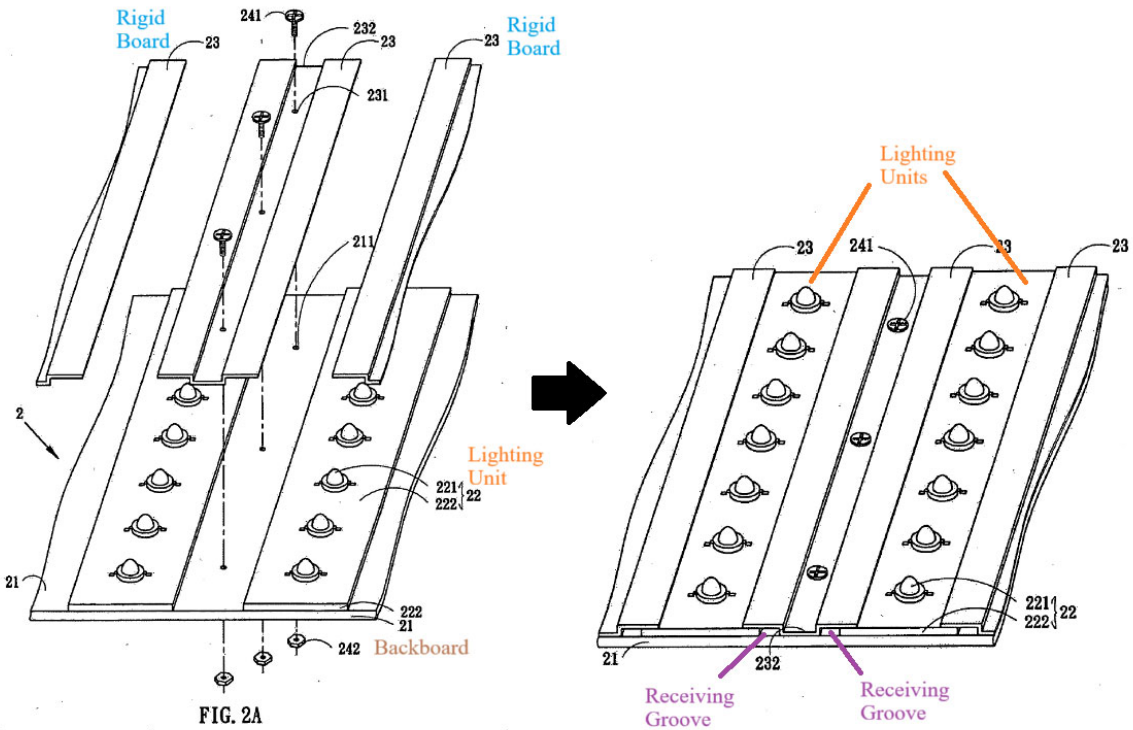


FIG. 2A

(*Id*. at FIGS. 2A-2B.)

124. Liu discloses that this arrangement simplifies assembly while decreasing "the amount of the nuts and bolts required," and improving "thermal dissipation between the lighting units and the backboard." (*Id.* at 0009.)

125. A POSITA would have been motivated to apply Liu's teachings to Roberts. Roberts discloses a lighting display having a plurality of LED bars / lighting tiles that may be used as an LCD backlight. (Ex-1004-Roberts at 0095, 0134.) Roberts does not specifically disclose how to physically mount its lighting tiles / LED bars to a housing to prepare a backlit display. Liu does. According to Liu, mounting lighting boards (*e.g.*, Roberts' lighting tiles / LED bars) for backlit applications is easier, uses less hardware, and facilitates improved heat transfer when a rigid board is used to secure the lighting boards to the housing. A POSITA would have found it obvious and beneficial to apply Liu's teachings to Roberts to ensure Roberts' lighting tiles / LED bars were securely mounted to a housing in a cost-effective manner. Roberts, like Liu, seeks effective heat transfer from the back of its lighting tiles. (Ex-1004-Roberts at 0017, 0066, 0087-88.) Accordingly, a POSITA would have been motivated to apply Liu's light board mounting teachings to Roberts, wherein Liu's rigid boards are used to secure Roberts' lighting tiles / LED lighting bars to a housing.

126. A POSITA also would have had a reasonable expectation of successfully

applying Liu's teachings to Roberts. It would have been straightforward to a POSITA to secure Roberts' lighting tiles / LED bars to a housing using Liu's rigid board teachings in the preparation of Roberts' backlit devices, merely requiring the use of conventional materials (*e.g.*, conventional fasteners, Liu's rigid boards) to secure Roberts' lighting tiles / LED bars to a housing.

B. The Challenged Claims

Claim 12. [12-PRE] A light source apparatus comprising:

127. Roberts teaches limitation [12-PRE] for the same reasons as provided above relative to Ground 1, limitation [1-PRE].

[12a] a housing comprising a receiving groove;

128. Roberts in view of Liu teaches limitation [12a].

129. Liu teaches a backboard (housing) having a rigid board for securing lighting boards thereto:

> "According to the object described above, the present invention discloses a fastening device *utilized in a backlight module* to fasten the lighting units and the resultant backlight module. *A rigid board partially laps over the adjacent lighting unit or units. The rigid board and the backboard have holes respectively such that bolts are passed through the holes and locked on nuts*. Accordingly the rigid board exerts a compressing strength to fasten the adjacent lighting unit or units onto the backboard. In addition to the simplification of the assembling and the decrease of the amount of the nuts and bolts

required, the efficiency of thermal dissipation between the lighting units and the backboard is further improved."

(Ex-1005-Liu at 0008.)

130. Liu's housing (21) and rigid board (23) arrangement defines a groove for receiving a lighting board (22):

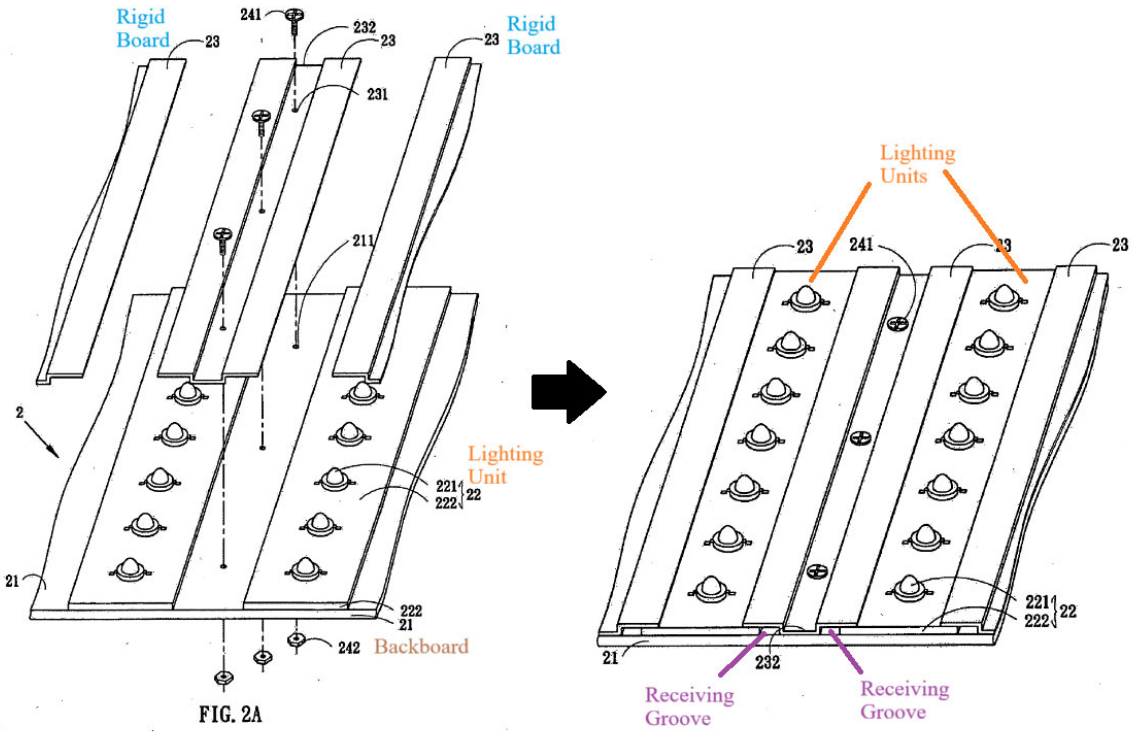


FIG. 2A

(Ex-1005-Liu at FIGS. 2A-2B; 0017-19.)

131. As I explained earlier, a POSITA would have been motivated to combine the teachings of Roberts and Liu with a reasonable expectation of success wherein Roberts' lighting tiles / LED bars are secured to a housing using Liu's rigid boards with a receiving groove. Applying Liu's teaching to Roberts would have resulted in a "housing comprising a receiving groove."

132. Thus, Roberts in view of Liu teaches limitation [12a].

[12b] at least one module substrate which is received in the housing and has connecting terminals mounted at both side ends of the module substrate;

133. For the reasons explained in Ground 1, limitation [1a], Roberts teaches "at least one module substrate" having "connecting terminals mounted at both side ends of the module substrate."

134. Roberts in view of Liu teaches that Robert's lighting tiles (module substrates) are "receiv[ed] in the housing." As I explained earlier, a POSITA would have been motivated to combine the teachings of Roberts and Liu with a reasonable expectation of success wherein Roberts' lighting tiles / LED bars are secured to a housing using Liu's rigid boards. Applying Liu's teaching to Roberts would have resulted in Roberts' lighting tiles being "receiv[ed] in the housing."

135. Thus, Roberts in view of Liu teaches limitation [12b].

[12c] a light emitting diode on the module substrate; and

136. Roberts teaches limitation [12c] for the same reasons as provided above relative to Ground 1, limitation [1b].

[12d] a connecting substrate connected to the connecting terminal of the module substrate, wherein the connecting substrate comprises a termination connecting substrate, which allows a connecting terminal provided at one end of a final module substrate of the module substrates to be feedback in a form of a closed loop.

137. Roberts teaches and suggests limitation [12d] for the same reasons as provided above relative to Ground 1, limitation [1c].

138. There are no material differences between limitations [1c] and [12d]. Because Roberts discloses "a plurality of connecting substrates" [1c], Roberts also discloses "a connecting substrate" [12d]. Roberts also discloses "a connecting terminal provided at one end of a final module substrate of the module substrates to be feedback in a form of a closed loop" [12d]. Claim 12 defines the claimed "feedback" to be in the "form of a closed loop" (*id*.), and Roberts teaches "closed loop" feedback for the same reasons discussed earlier. (Ex-1004-Roberts at FIG. 4A, 0072 (teaching a closed loop); *see also id*. at FIG. 8, 0025, 0033, 0094, 0097, 0099, 0126, 0134, 0136 (teaching closed loop feedback).)

139. Thus, Roberts teaches and suggests limitation [12d].

140. Accordingly, Roberts in view of Liu renders obvious Claim 12.

Claim 15. The light source apparatus as claimed in claim 12, comprising at least one LED bar, on which the module substrates are connected to each other in series by the connecting substrate.

141. Roberts teaches Claim 15.

142. As explained above in Ground 1, limitation [1a], Roberts discloses a ***lighting panel (40)*** having a ***plurality of light bar assemblies (30)*** (LED bars), each comprising multiple ***lighting tiles 10*** (module substrates) that are "connected to each other":

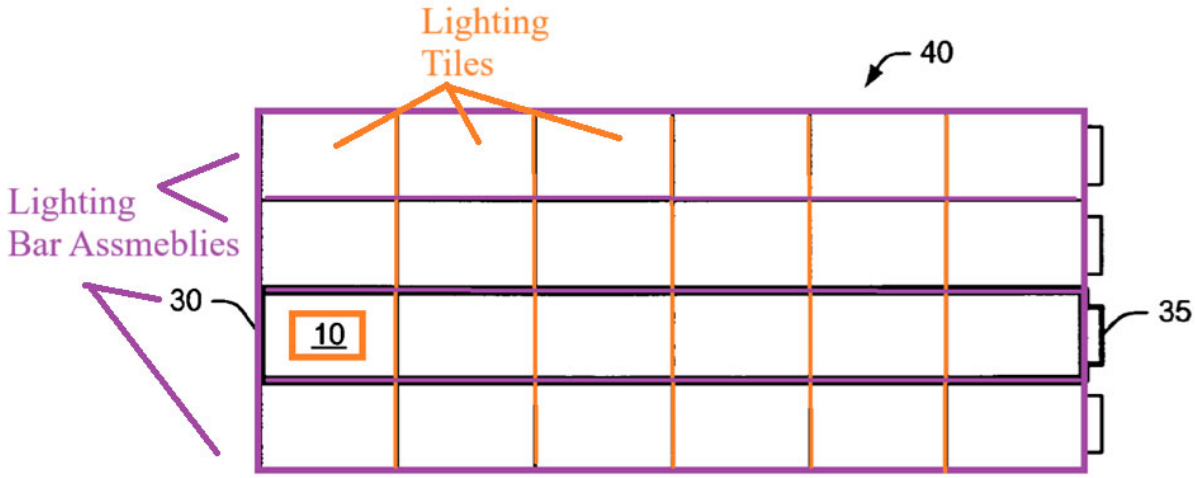


FIGURE 4B

(Ex-1004-Roberts at FIG. 4B, 0075.)

> "*Multiple tiles 10* may be assembled to form a larger *lighting bar assembly 30* as illustrated in FIG. 4A. As shown therein, a bar assembly 30 may include two or more tiles 10, 10', 10" *connected end-to-end*.

(*Id*. at 0071.)

143. Roberts further discloses that the lighting tiles (module substrates) are connected to each other in series:

> "In this manner, the string 20A of the first path 20 may be connected ***in series*** with the string 21A of the second path 21 by a conductor 35A of the loopback connector 35 to form a single string 23A of blue LED chips 16. The other strings of the paths 20, 21 of the tiles 10, 10', 10" may be connected in a similar manner."

(*Id.* at 0072; *see also id*. at 0067.)

144. Roberts thus teaches a "light source apparatus … comprising at least one LED bar, on which the module substrates are connected to each other in series."

145. Roberts also teaches that the module substrates are "connected to each other in series by the connecting substrate." As explained in Ground 1, limitation [1c], the lighting tiles (module substrates) "are connected to each other in series by" "*an edge connector 13 [connecting substrate], which may provide an* ***electrical*** *and/or mechanical connection between adjacent tiles 10*." (Ex-1004-Roberts at 0082.)

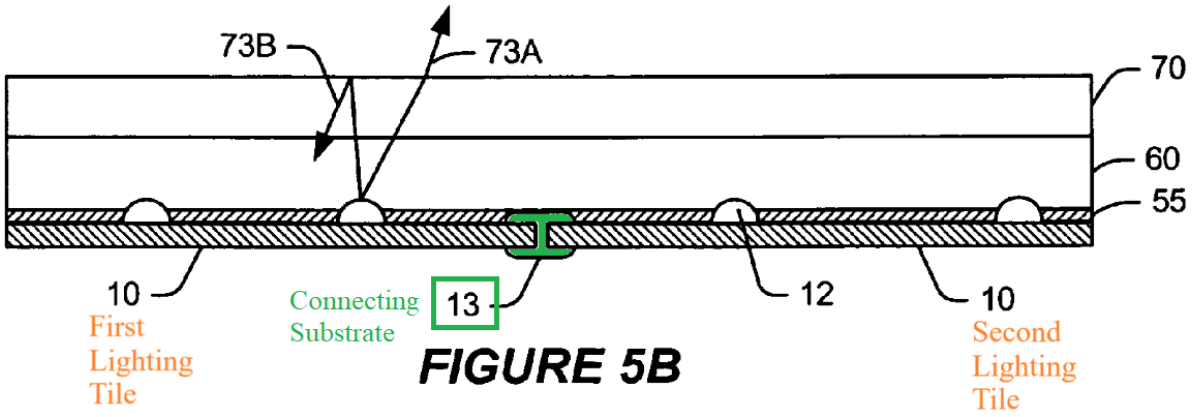


FIGURE 5B

(*Id.* at FIG. 5B.)

146. Thus, Roberts teaches Claim 15, and Roberts in view of Liu renders obvious Claim 15.

X. GROUND 3: Roberts in View of Karlicek Renders obvious Claims 1-8 and 11.

A. Scope, Content, and Motivation to Combine

147. For Ground 3, the art is Roberts in view of Karlicek, wherein Karlicek's "terminating element 50V" is used in addition to or in lieu of Roberts' ***edge connector 13*** to connect Roberts' lighting bar assemblies to an external

power/voltage source.

148. Also, Karlicek's "interconnecting element 50A" is optionally used in lieu of or in addition to Roberts' ***edge connector 13*** to connect adjacent ***lighting tiles 10*** to one another.

149. As shown in Ground 1, Roberts discloses intermediate connecting substrates (***edge connector 13***) and termination connecting substrates (***loopback connector 35***) for connecting its lighting tiles:

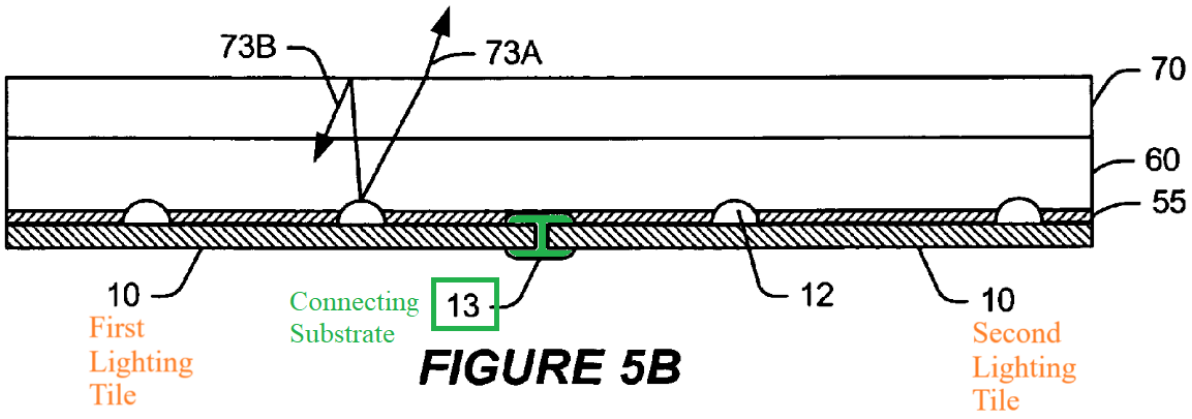


FIGURE 5B

(Ex-1004-Roberts at FIG. 5B.)

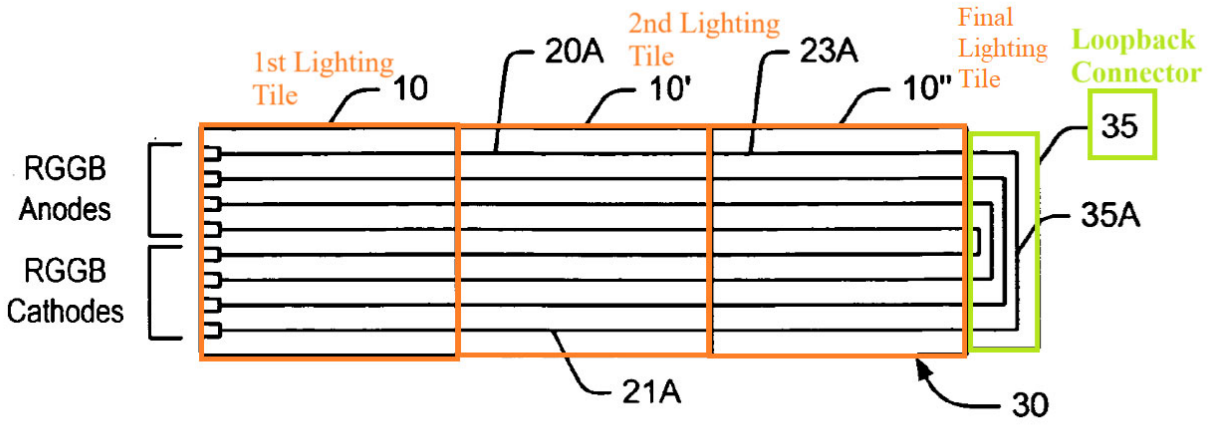


FIGURE 4A

(*Id.* at FIG. 4A.)

150. Roberts also discloses powering and individually controlling each LED string using an external current driver and controller:

> "*A current driver 220 provides independent current control for each of the LED strings 23 of the lighting panel 40*. For example, the current driver 220 may provide independent current control for 36 separate LED strings in the lighting panel 40. *The current driver 220 may provide a constant current source for each of the 36 separate LED strings of the lighting panel 40 under the control of a controller 230*. In some embodiments, the controller 230 may be implemented using an 8-bit microcontroller such as a PIC18F8722 from Microchip Technology Inc., which may be programmed to provide pulse width modulation (PWM) control of 36 separate current supply blocks within the driver 220 for the 36 LED strings 23."

(*Id.* at 0097.)

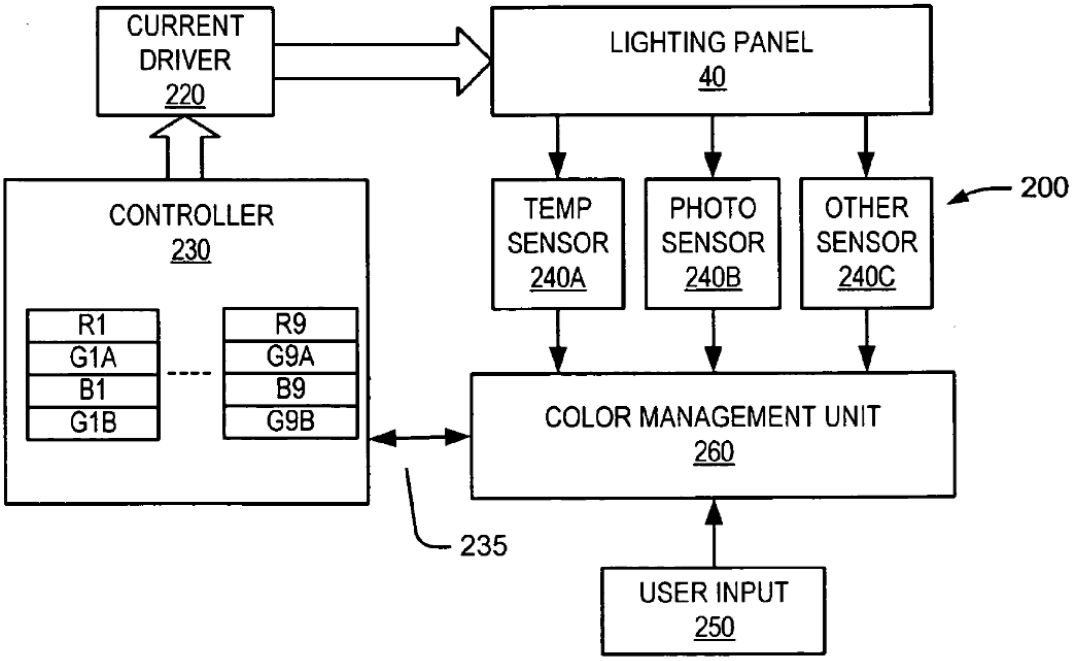


FIGURE 8

(*Id*. at FIG. 8.)

151. Like Roberts, Karlicek discloses a "plurality of substrates 12 each have one or more components 14 arranged thereon," such as "LED components." (Ex-1006-Karlicek at 0046.) Like Roberts, "each substrate 12 includes one or more connectors 16 that effectuate interconnection of the substrates 12" and "to effectuate electrical interconnection of the components 14 across the boundaries of paired substrates 12." (*Id.* at 0049.) Like Roberts, Karlicek employs an "interconnecting element 50A" that "operatively connects to a pair of connectors 16 at mating ports 52 and 54 of the interconnecting element 50A. … The interconnecting element 50A also has a pre-selected electrical configuration that effectuates a desired electrical arrangement of the components of the connected substrates 12, such as a series

connection arrangement, parallel connection arrangement, or the like." (*Id.* at 0055.)

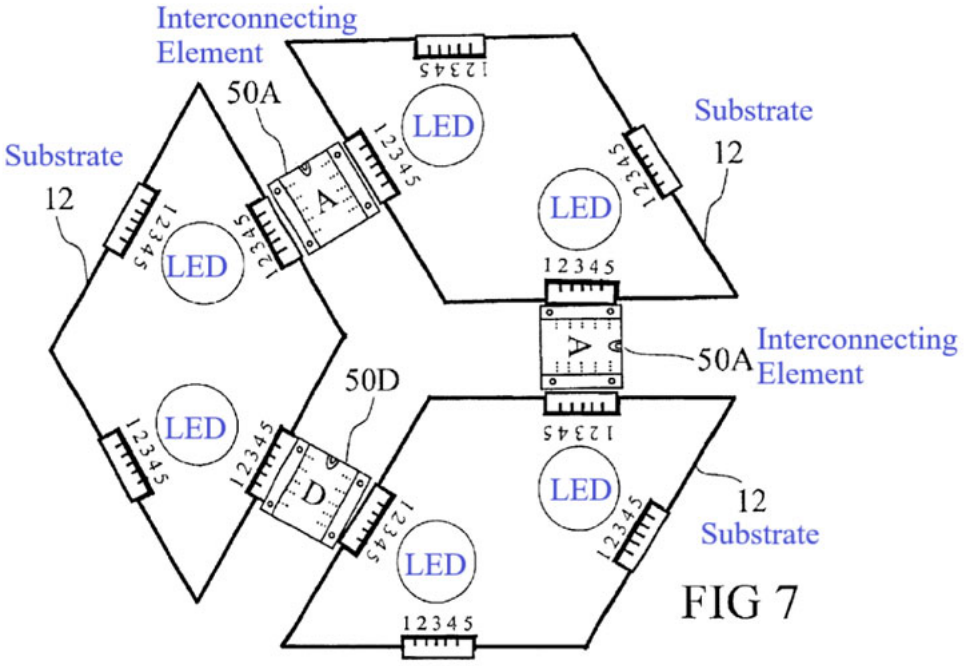


FIG 7

(*Id.* at FIG. 7.)

152. Karlicek further describes and illustrates a convenient manner of connecting an end of a plurality of substrates 12 to a voltage source (V) using a terminating element 50V:

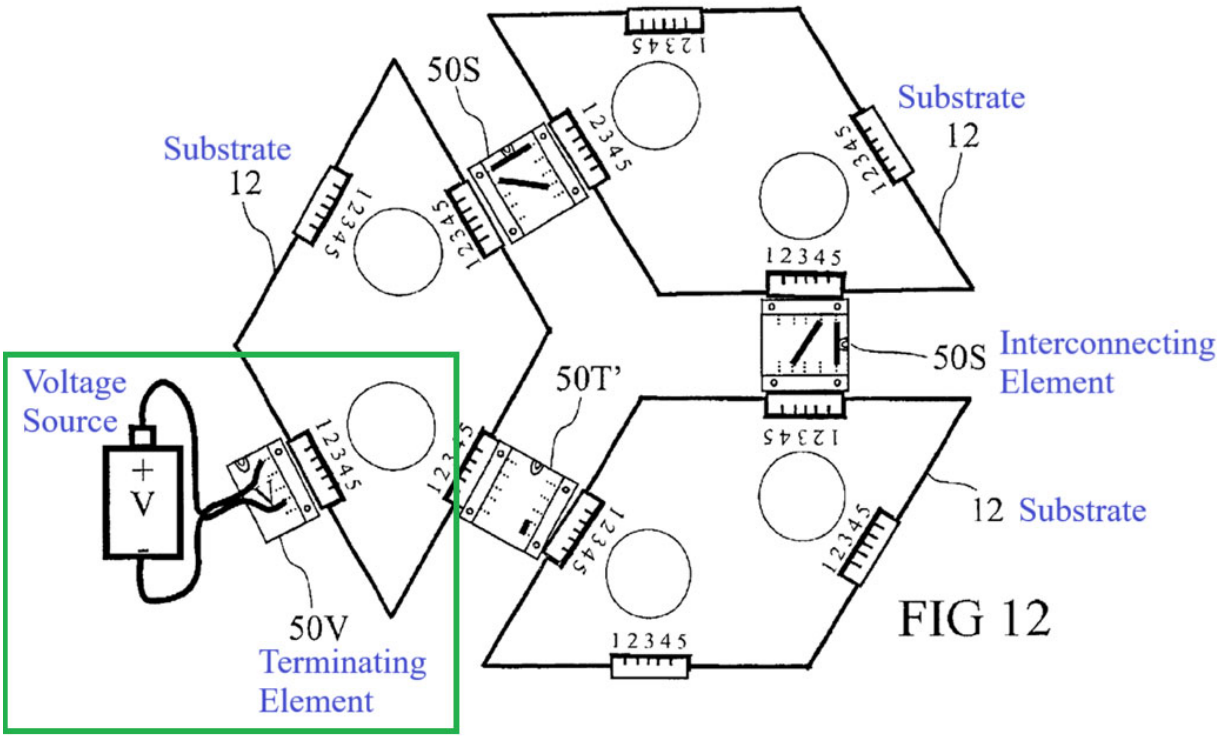


FIG 12

(*Id.* at FIG. 12; 0061.)

153. A POSITA would have been motivated to apply Karlicek's substrate interconnection teachings to Roberts. Like Roberts, Karlicek seeks to connect multiple LED substrates (tiles) in series using connectors to power LEDs:

> "A plurality of PC board traces connect the LEDs 14a, 14b to the connectors 16 and optionally also connect the LEDs 14a, 14b to each another. For example, *a trace 40 can be used to interconnect the LED's 14a, 14b electrically in series*. … In one embodiment, *the connectors 16 are formed into the edges of the PC board 24 so that the traces advantageously directly connect to the electrical conductor members comprising the connectors 16, and the connectors 16 are readily accessible at the edges of the substrate 12*. … In the illustrated

> exemplary embodiment of FIG. 5, the LEDs 14a, 14b are connected in series on the substrate 12."

(*Id*. at 0053.)

154. Also, like Roberts, Karlicek employs intermediate edge connectors to facilitate electrical and mechanical interconnections among the plurality of LED substrates:

> "With reference now to FIGS. 6 and 7, an approach for effectuating the interconnection of pairs of connectors 16 is described. An interconnecting element 50A of a type "A" operatively connects to a pair of connectors 16 at mating ports 52 and 54 of the interconnecting element 50A. The interconnecting element 50A mechanically connects to the two substrates 12 that have the pair of connectors 16 to effectuate structural interconnection between the two substrates 12. The mechanical connection can be by a frictional fit (not shown) or by fastenings 56 which can be screws, rivets, or the like. The interconnecting element 50A also has a pre-selected electrical configuration that effectuates a desired electrical arrangement of the components of the connected substrates 12, such as a series connection arrangement, parallel connection arrangement, or the like."

(*Id.* at 0055 (explaining intermediate edge connectors); *see also id*. at FIGS. 6-7.)

155. Roberts does not expressly disclose how its lighting bars are connected to the external current driver (220) / controller (230), and does not provide specific implementation details for its edge connectors 13. However, a POSITA would have recognized that Karlicek's terminating element (50V) and interconnecting elements

(50A) would have been useful in connecting an end of Roberts' LED bar (30) to Roberts' current driver (220) / controller (230) and for implementing Roberts' edge connectors 13, respectively.

156. Karlicek provides a simple, modular solution for connecting a series of LED tiles to each other and to a power source, which aligns with Roberts' modular approach to preparing a lighting panel having multiple LED bars with any suitable number of lighting tiles. (Ex-1006-Karlicek at 0062-63, 0065-66.) Karlicek's terminating element (50V) would have provided an easy and straightforward manner of connecting Roberts' LED bars to Roberts' current driver (220) / controller (230), merely requiring a properly configured Karlicek terminating element (50V) to be employed with the anode and cathode contacts (22, 24, 26, 28) of a lighting tile 10 located at an end of Roberts' lighting bar 30. Karlicek's interconnecting elements (50A) would have similarly provided an easy and straightforward manner of implementing Roberts' edge connectors 13, merely requiring properly configured Karlicek interconnecting elements (50A) to be employed with the anode and cathode contacts (22, 24, 26, 28) of adjacent lighting tiles 10.

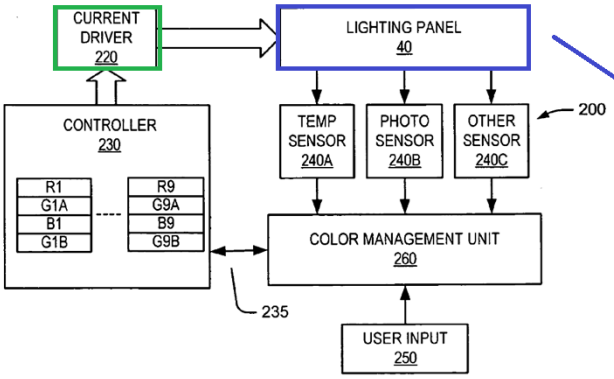


FIGURE 8

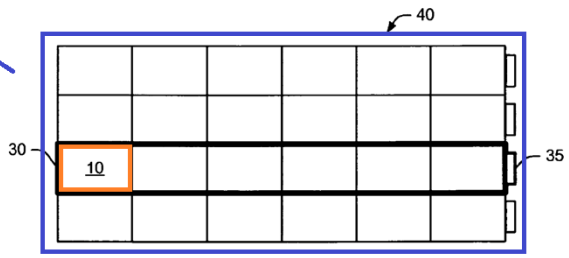


FIGURE 4B

(Ex-1004-Roberts at FIGS. 8, 4B (showing Roberts' current driver (220) is connected to each LED bar (30) of Roberts' lighting panel (40) via a leftmost lighting tile (10).)

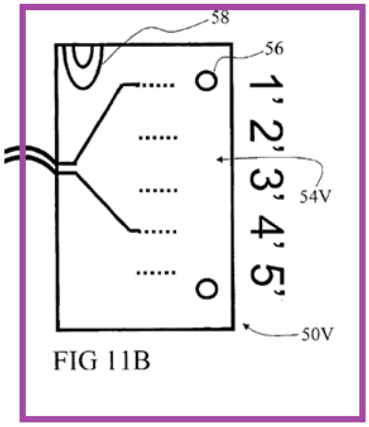


FIG 11B

Karlicek Terminating Element (50V)

Connects to end of a Roberts lighting tile 10

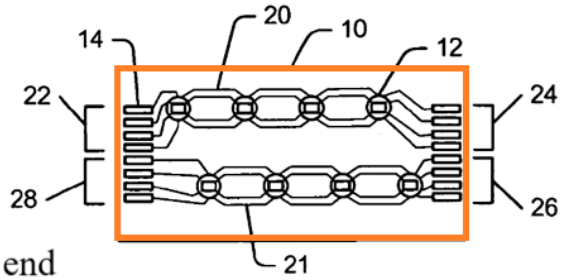


FIGURE 1

(Ex-1006-Karlicek at FIG. 11B; Ex-1004-Roberts at FIG. 1.)

157. As desired by Roberts, Karlicek's terminating element (50V) and interconnecting elements (50A) facilitate independent control of different colored LED strings:

> "With reference now to FIGS. 13 and 14, another embodiment of the modular mounting assembly is described. A substrate 12RGB has six LED components arranged thereon: *a first red LED component 14aR*, *a first green LED component 14aG, and a first blue LED component 14aB* arranged in a first receiving well 22a; and *a second red LED component 14bR, a second green LED component 14bG, and a second blue LED component 14bB* arranged in a second receiving well 22b, as shown. *The first and second LED component of each color is connected in series by PC board traces 40R, 40G, and 40G. In order to accommodate the greater number of anode and cathode terminals in this tri-color substrate 12RGB, connectors 16RGB having seven conductor members each is used. As shown in the electrical schematic of FIG. 14, each of the three colors is independently addressable*: conductor members 1 and 4 connect to the red LED series; conductor members 2 and 5 connect to the green LED series; and conductor members 3 and 6 connect to the blue LED series. The conductor member 1 serves as circuit ground in the substrate 12RGB. For substrates having more complex interconnections such as those shown in FIGS. 13 and 14, two-level or even more complex PC boards can be used to accommodate the larger number of traces involved."

(Ex-1006-Karlicek at 0066.)

158. Karlicek also teaches that its terminating element (50V) and interconnecting elements (50A) are advantageously "standardized," which beneficially allows highly complex modular assemblies to be created in a relatively simple manner:

> "However, it will be appreciated that highly complex modular assemblies including dozens, hundreds, or even greater numbers of LED components having complex spatial arrangements, electrical interconnections, electrical sub-circuits, and the like can be created by appropriate selection and arrangement of a standardized set of substrates, interconnecting elements, and terminating elements. Another advantage of the present invention is that replacement of a failed LED component is greatly simplified, and requires only replacement of the substrate on which the failed LED component is disposed."

(*Id*. at 0065; *see also id*. at 0004-5, 0062.)

159. Additionally, a POSITA would have appreciated that Karlicek's interconnecting elements (50A) are substantially flat and may be located on a single side of an LED tile (*e.g*., a top side of an LED tile). (*Compare* Ex-1004-Roberts at FIG. 5B *with* Ex-1006-Karlicek at FIGS. 6-7.) A POSITA would have recognized that using Karlicek's substantially flat interconnecting elements (50A) to implement Roberts' edge connectors 13 would have beneficially provided an even bottom surface of Roberts' module substrates, which would have facilitated easy mounting of Roberts' module substrates on a housing (*e.g*., the housing of an LCD backlight assembly). A POSITA also would have appreciated that Karlicek's interconnecting elements (50A) provide for a more compact LED bar design, as the volume between adjacent tiles is reduced and/or eliminated since the interconnecting substrates (50A) are entirely located on upper surfaces of Roberts' adjacent tiles.

160. A POSITA also would have had a reasonable expectation of applying Karlicek's substrate interconnection teachings to Roberts. Like Roberts, Karlicek teaches individual power/control of each LED string (blue, red, etc.):

> "In order to accommodate the greater number of anode and cathode terminals in this tri-color substrate 12RGB, connectors 16RGB having seven conductor members each is used. *As shown in the electrical schematic of FIG. 14, each of the three colors is independently addressable*: conductor members 1 and 4 connect to the red LED series; conductor members 2 and 5 connect to the green LED series; and conductor members 3 and 6 connect to the blue LED series."

(Ex-1006-Karlicek at 0066; Ex-1004-Roberts at 0094, 0097.)

161. Further, like Roberts, Karlicek teaches connecting each LED string in series. (Ex-1006-Karlicek at 0053-54, 0058; Ex-1004-Roberts at 0067, 0072.) Implementing Karlicek's terminating element (50V) and interconnecting elements (50A) with Roberts would have been straightforward to a POSITA, merely requiring implementing Karlicek's terminating element (50V) and interconnecting elements (50A) in a form factor and with a wiring scheme that matched Roberts' LED bar requirements.

B. The Challenged Claims

Claims 1-2, 7-8, and 11

162. As discussed above with respect to Ground 1, Roberts renders obvious Claims 1-2, 7-8, and 11, with Roberts' edge connectors 13 disclosing, teaching, and

suggesting the claimed "connecting substrates."

163. To the extent the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Karlicek renders obvious Claims 1-2, 7-8, and 11.

164. Karlicek discloses substantially flat interconnecting elements (50A) that provide an electrical and mechanical connection between adjacent module substrates 12. (Ex-1006-Karlicek at FIGS. 6-7, 0055-56.) A POSITA would have understood that Karlicek's interconnecting elements (50A) are "connecting substrates" within the meaning of the Challenged Claims at least because they are physical structures/platforms upon which electrical interconnections between the conductors of adjacent module substrates are built or made. (Ex-1006-Karlicek at FIGS. 8A-B and 9A-B, 0058-59.) As I explained earlier, a POSITA would have been motivated to implement Roberts' edge connectors 13 using Karlicek's interconnecting elements (50A) with a reasonable expectation of success.

165. Accordingly, even if the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Karlicek renders obvious Claims 1-2, 7-8, and 11 for the reasons provided above in Ground 1, wherein Karlicek's substantially flat interconnecting elements (50A) are used with Roberts' ***lighting bar assemblies 30*** to electrical and mechanically connect adjacent Roberts ***lighting tiles 10***.

Claim 3. The light source apparatus as claimed in claim 1, [3a] wherein the connecting substrate comprises an external connecting substrate which is disposed at a first end of a first module substrate of the module substrates, and

166. Roberts in view of Karlicek teaches limitation [3a].

167. As explained in Ground 1, Claim 1, Roberts teaches ***lighting tiles 10*** (module substrates) having ***contacts (22, 24, 26, 28)*** (connecting terminals) at each end of the tile, and that a series of lighting tiles makes up an individual ***lighting bar assembly 30***:

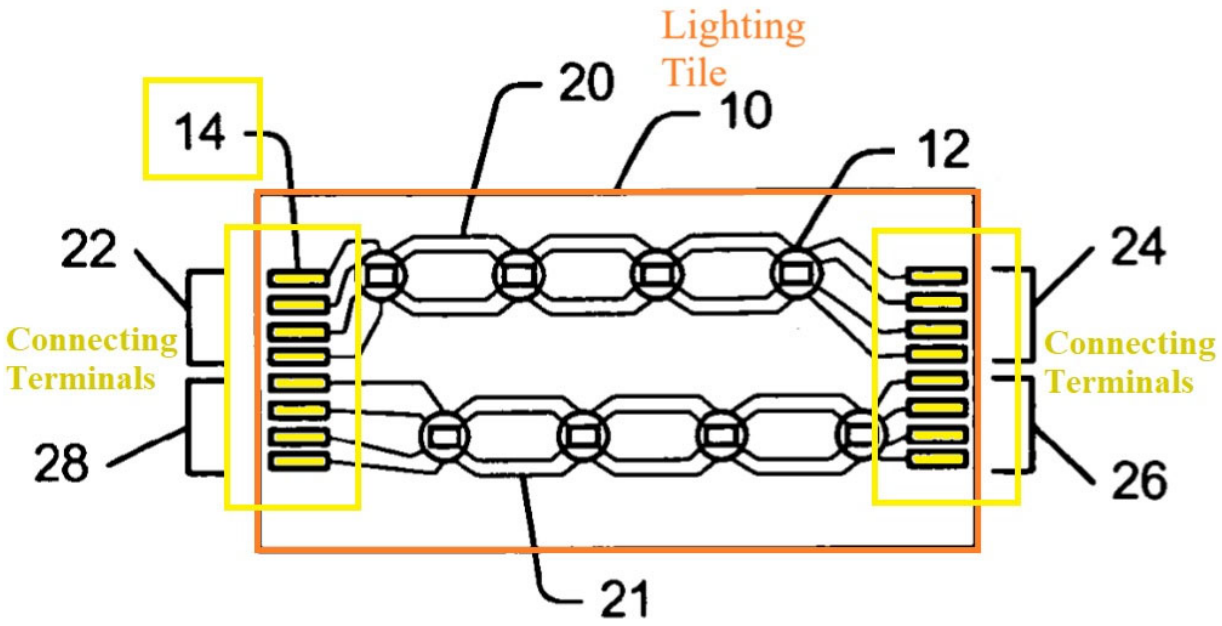


FIGURE 1

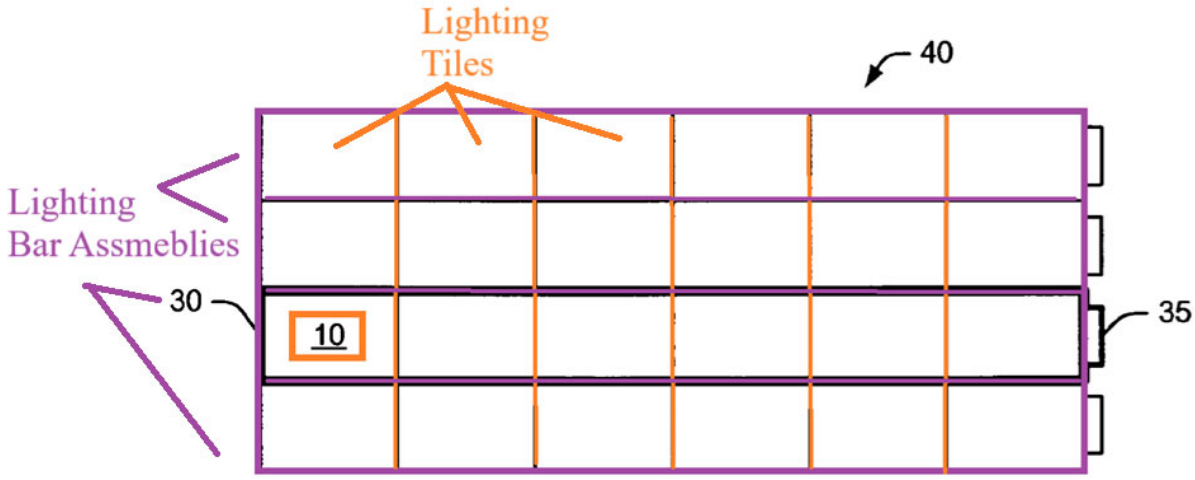


FIGURE 4B

(Ex-1004-Roberts at FIGS. 1, 4B.)

168. As I explained earlier, Roberts teaches that each of its lighting bars should be connected to an external current driver but does not provide conventional implementation details for doing so. Karlicek does.

169. Karlicek teaches the use of a terminating element 50V (external connecting substrate) that connects a first end of the first of a series of lighting tiles (module substrates) to an external voltage source (current driver):

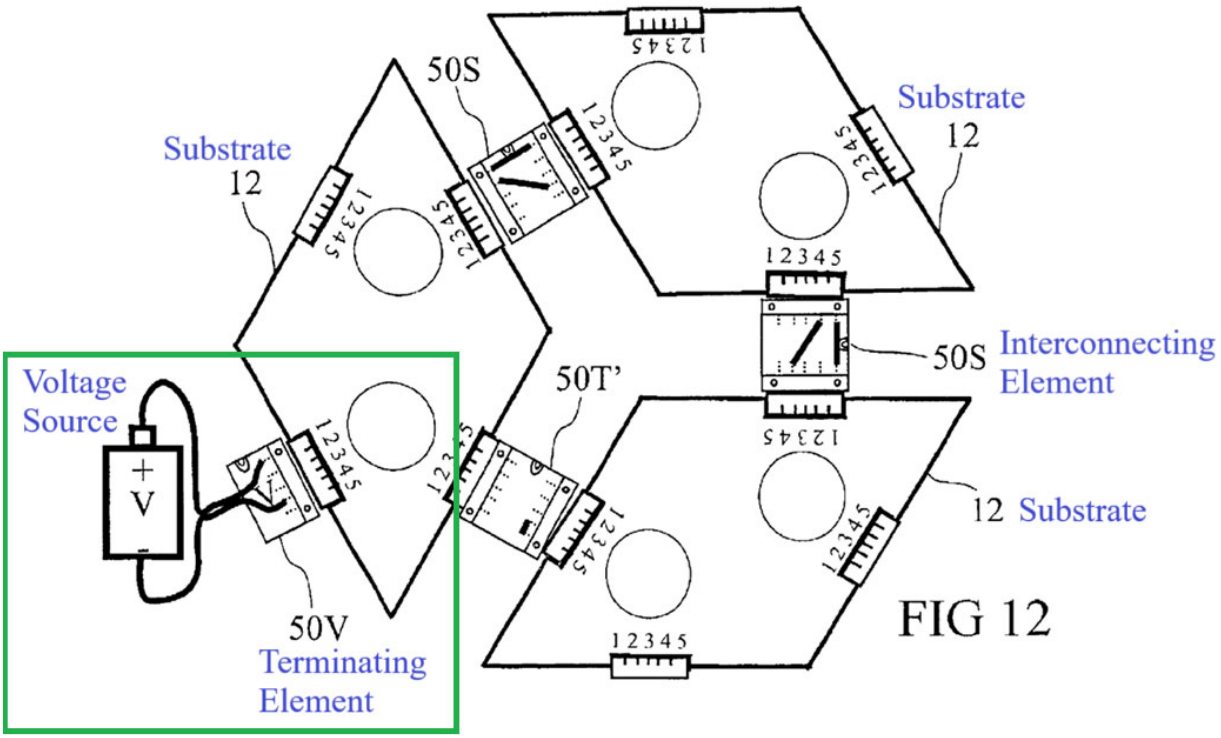


FIG 12

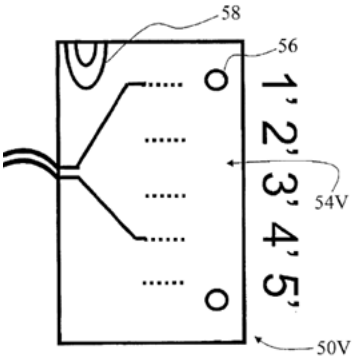


FIG 11B

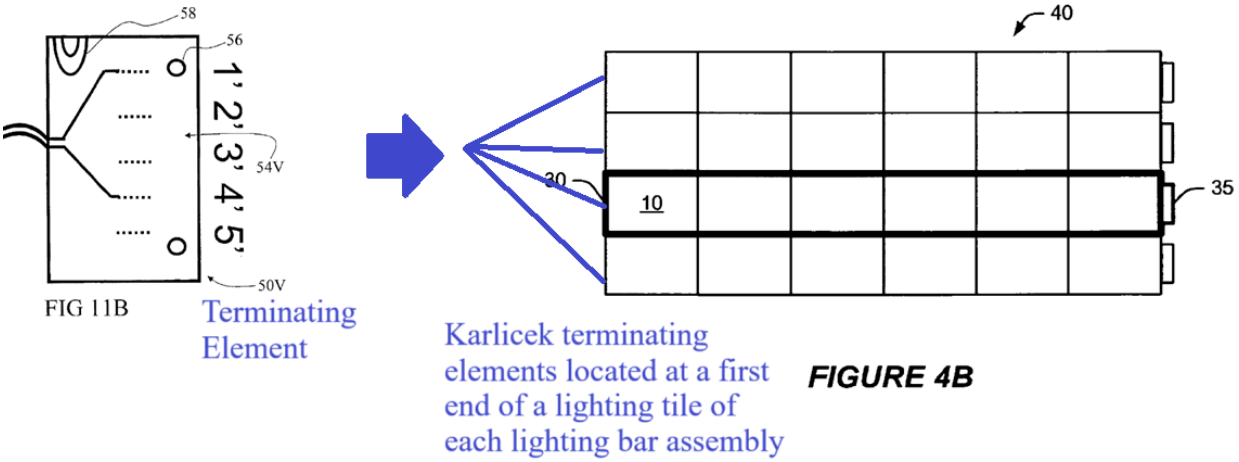
Terminating
Element

(Ex-1006-Karlicek at FIGS. 12, 11B, 0061.)

170. Karlicek's terminating element 50V is configured as a substrate. (*Id.* at FIGS. 11B, 12; 0055, 0061.)

171. As I explained earlier, a POSITA would have been motivated to apply

Karlicek's terminating element teachings to Roberts and with a reasonable expectation of success, wherein each of Roberts' lighting bar assemblies is connected to Roberts' current driver (220) / controller (230) via Karlicek's terminating element (50V) (external connecting substrate), which is disposed at a first end of a first lighting tile (module substrate) of each lighting bar assembly:



(Ex-1006-Karlicek at FIG. 11B, 0061; Ex-1004-Roberts at FIG. 4B, 0075.)

172. Thus, Roberts in view of Karlicek teaches limitation [3a].

[3b] an intermediate connecting substrate which connects the connecting terminal of the first module substrate with the external connecting substrate and/or between the connecting terminal of the module substrates.

173. Roberts teaches limitation [3b].

174. Limitation [3b] has two options. A first option is that an intermediate connecting substrate "connects the connecting terminal of the first module substrate with the external connecting substrate." A second option is that an intermediate connecting substrate provides that connection "between the connecting terminal of

the module substrates." Roberts teaches the second option.

175. Specifically, as explained in Ground 1, limitation [1c] and Claim 2, Roberts' ***edge connector 13*** is "an intermediate connecting substrate" that electrically interconnects the connecting terminals of adjacent lighting tiles (module substrates), *i.e.*, connects "between the connecting terminal of the module substrates."

176. Thus, Roberts teaches limitation [3b], and Roberts in view of Karlicek renders obvious Claim 3.

Claim 4. The light source apparatus as claimed in claim 3, wherein the connecting substrate comprises a connecting terminal, which corresponds to at least one of connecting terminals provided at both side ends of the module substrate.

177. Roberts teaches and suggests Claim 4.

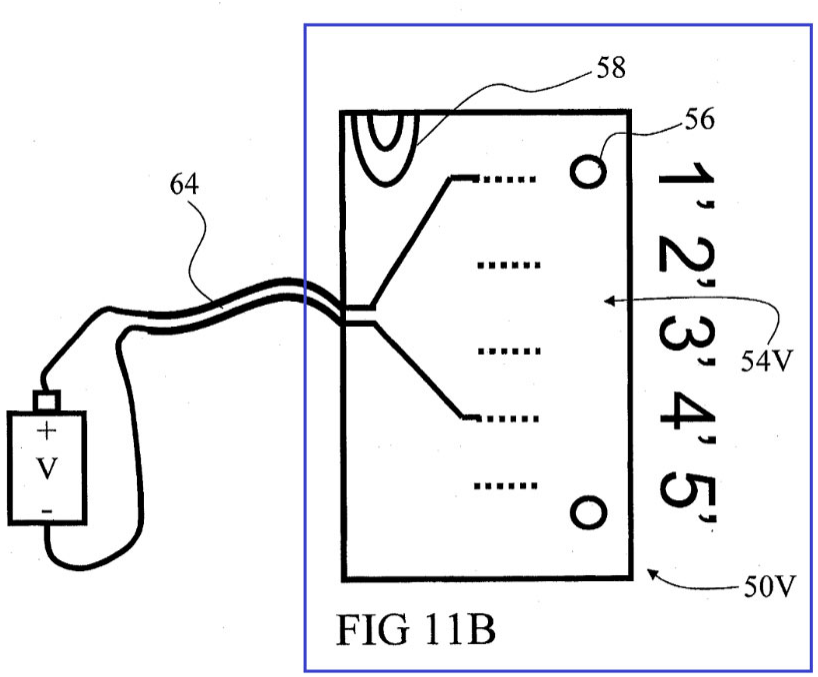
178. Roberts suggests, and a POSITA would have expected and would have found it obvious, that Roberts' ***edge connector 13*** (connecting substrate) would have had a "connecting terminal" that corresponds to the connecting terminal provided at the side end of the ***lighting tile 10*** (module substrate) that the ***edge connector 13*** is connected to. Roberts teaches that its ***edge connectors 13*** are separate components that provide "an electrical and/or mechanical connection between adjacent tiles." (Ex-1004-Roberts at 0082.) A POSITA would have understood that providing such a corresponding "connecting terminal" in the ***edge connector 13*** would have facilitated the electrical interconnection between adjacent tiles.

179. Thus, Roberts teaches and suggests Claim 4, and Roberts in view of Karlicek renders obvious Claim 4.

Claim 5. The light source apparatus as claimed in claim 3, wherein the external connecting substrate comprises an external connector to which a light emitting diode driver is connected.

180. Roberts in view of Karlicek teaches Claim 5.

181. As explained above relative to Claim 3, Karlicek discloses a terminating element (external connecting substrate). Karlicek's terminating element comprises "an external connector to which a light emitting diode driver is connected."



(Ex-1006-Karlicek at FIG. 11B, 0055, 0061.)

182. In the combination of Roberts and Karlicek, each of Roberts' light bar assemblies (30) would have been electrically connected to Roberts' current driver

(220) (light emitting diode driver) via the external connector of Karlicek's terminating element.

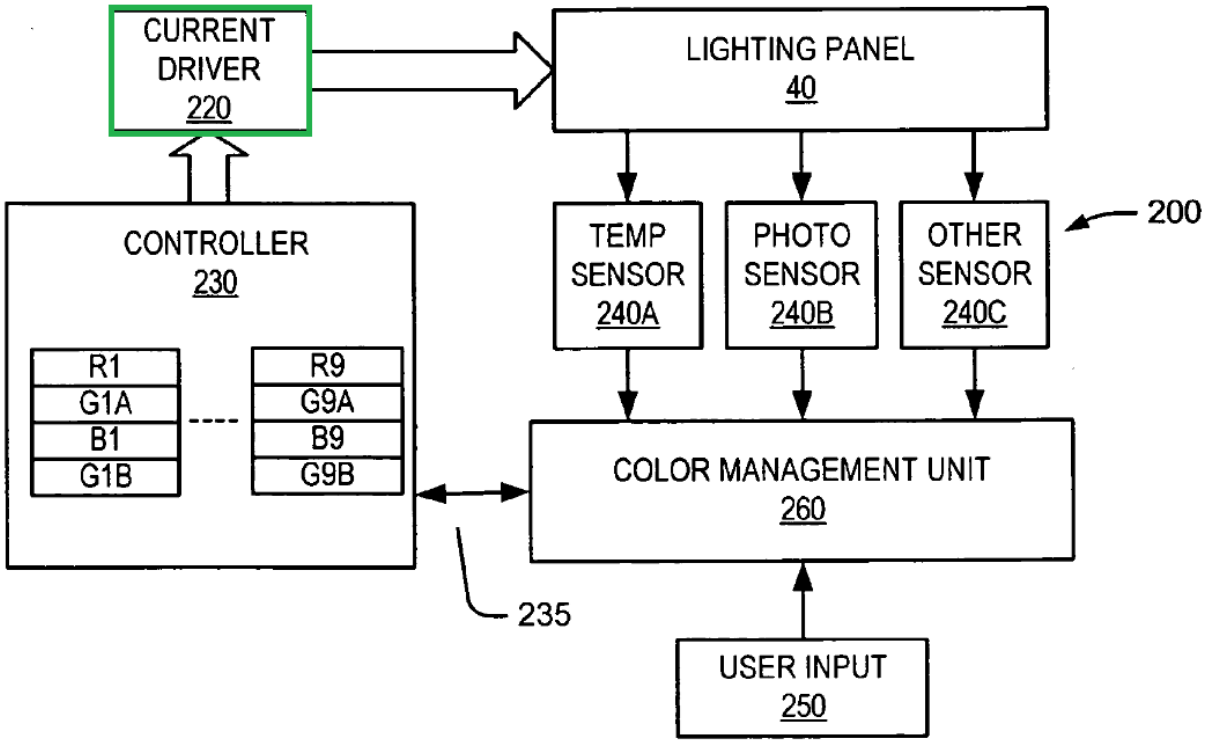


FIGURE 8

(Ex-1004-Roberts at FIG. 8.)

183. Thus, Roberts in view of Karlicek teaches and renders obvious Claim 5.

Claim 6. The light source apparatus as claimed in claim 4, [6a] wherein the connecting terminal is formed on the module substrate or under the module substrate, and

184. Roberts teaches limitation [6a].

185. Roberts' lighting tiles (module substrates) have connecting terminals formed on the substrate:

"In the embodiments illustrated in FIG. 1, the lighting elements 12 are multi-chip clusters of four solid state emitting devices per cluster. In the tile 10, four lighting elements 12 are serially arranged in a first path 20, while four lighting elements 12 are serially arranged in a second path 21. *The lighting elements 12 of the first path 20 are connected, for example via printed circuits, to* ***a set of four anode contacts 22*** *arranged at a first end of the tile 10, and* ***a set of four cathode contacts 24*** *arranged at a second end of the tile 10. The lighting elements 12 of the second path 21 are connected to* ***a set of four anode contacts 26*** *arranged at the second end of the tile 10, and* ***a set of four cathode contacts 28*** *arranged at the first end of the tile 10*."

(Ex-1004-Roberts at 0061.)

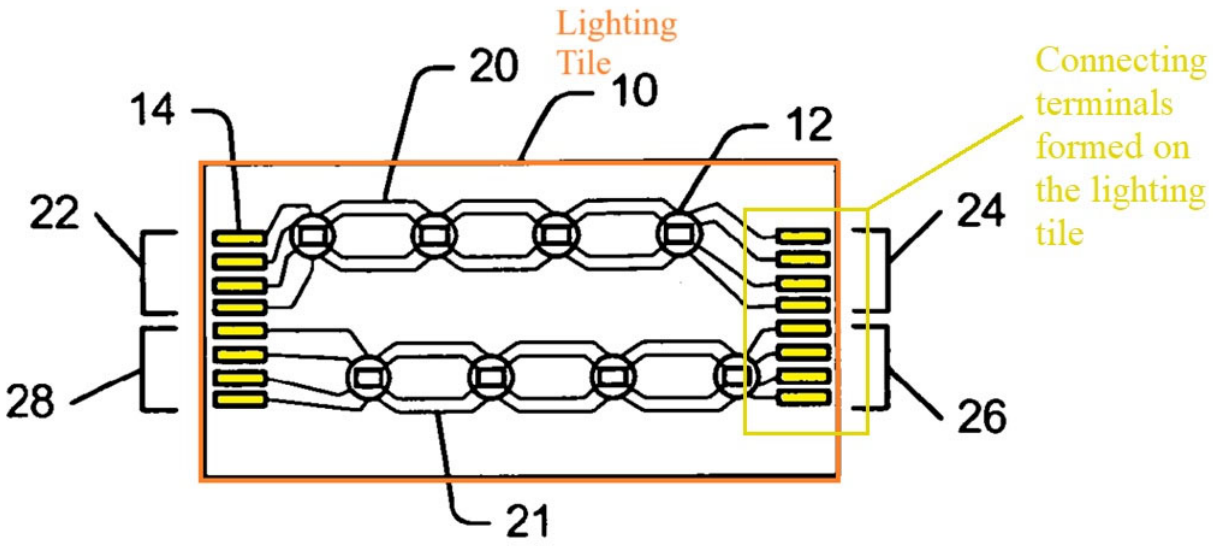


FIGURE 1

(*Id*. at FIG. 1.)

186. Thus, Roberts teaches limitation [6a].

[6b] the intermediate connecting substrate is mounted on the external connecting substrate and on the connecting terminals between plural module substrates.

187. Roberts in view of Karlicek teaches limitation [6b].

188. As explained above in Ground 1, limitation [1c] and Claim 2, Roberts suggests, and a POSITA would have found it obvious, that Roberts' ***edge connector 13*** (intermediate connecting substrate) is mounted "on the connecting terminals between plural module substrates."

189. Roberts illustrates the ***edge connector 13*** as being "mounted on" each lighting tile (module substrate):

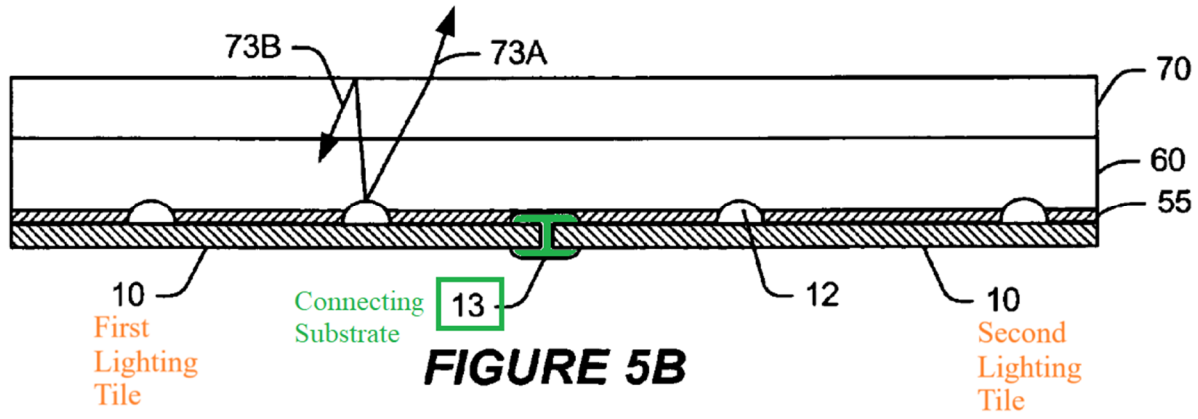


FIGURE 5B

(Ex-1004-Roberts at FIG. 5B.)

190. Moreover, Roberts teaches that its lighting tiles are connected in series via its connecting terminals (*e.g.*, anodes 22, 26 and cathodes 24, 28) and Roberts expressly discloses that the ***edge connector 13*** may provide an electrical connection between adjacent tiles. (*Id.* at 0071-74, FIG. 4A.) Thus, Roberts alone suggests, and a POSITA would have expected and would have found it obvious, that Roberts'

edge connector 13 is "mounted … on the connecting terminals between plural module substrates."

191. Roberts in view of Karlicek also teaches and suggests "the intermediate connecting substrate is mounted … on the connecting terminals between plural module substrates."

192. As explained previously, it was obvious to employ Karlicek's interconnecting element 50A in lieu of or in addition to Roberts ***edge connector 13*** to connect adjacent Roberts ***lighting tiles 10*** to one another, and a POSITA would have had a reasonable expectation of successfully doing so.

193. Karlicek discloses that its interconnecting elements 50A may be ***mounted on*** adjacent tiles:

> "With reference now to FIGS. 6 and 7, an approach for effectuating the interconnection of pairs of connectors 16 is described. An interconnecting element 50A of a type 'A' operatively connects to a pair of connectors 16 at mating ports 52 and 54 of the interconnecting element 50A. The interconnecting element 50A mechanically connects to the two substrates 12 that have the pair of connectors 16 to effectuate structural interconnection between the two substrates 12."

(Ex-1006-Karlicek at 0055.)

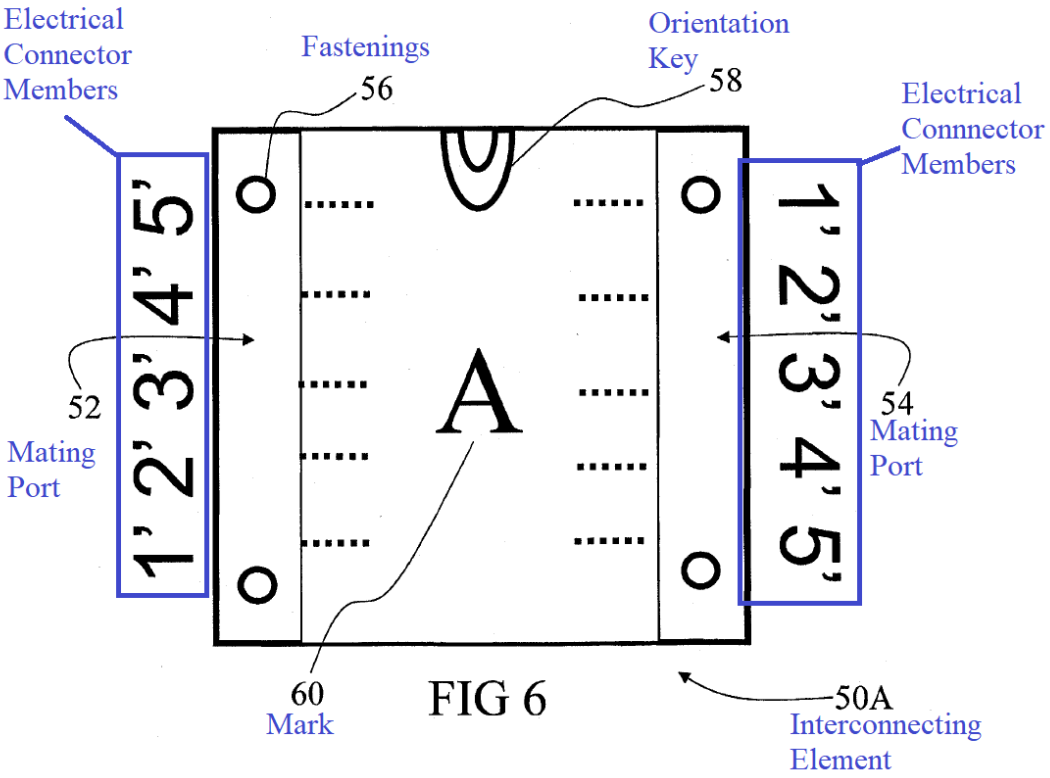


FIG 6

(*Id.* at FIG. 6.)

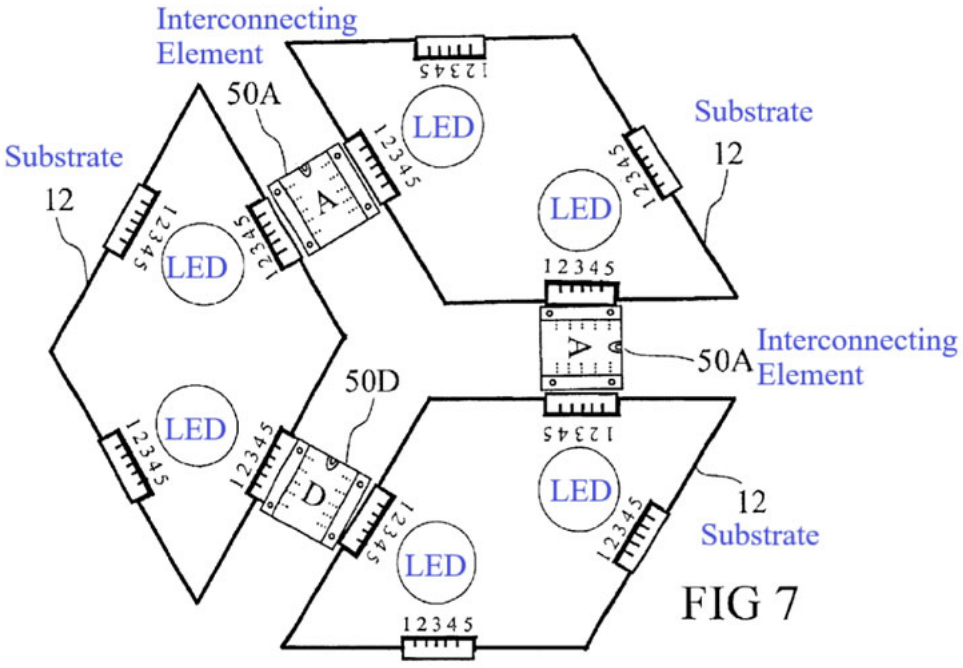


FIG 7

(*Id.* at FIG. 7.)

> "The mechanical connection can be by a frictional fit (not shown) or ***by fastenings 56 which can be screws, rivets, or the like***. … As can be seen in FIG. 6, ***the two mating ports 52, 54*** *each have five electrical connector members 1', 2', 3', 4', 5'* ***that correspond to and electrically connect with*** *the connector members 1, 2, 3, 4, 5 of* ***the connectors 16 of the substrates 12***."

(*Id.* at 0055.)

194. In view of the above figures and disclosures, a POSITA would have understood Karlicek as disclosing, teaching and suggesting that its interconnecting elements 50A are "mounted on" adjacent LED substrates. Thus, A POSITA would have understood Roberts in view of Karlicek as teaching an interconnecting element 50 (intermediate substrate) "mounted on … the connecting terminals between plural module substrates."

195. It also would have been obvious to use Karlicek's terminating element 50V (external connecting substrate) with (i) Roberts' ***edge connector 13*** or (ii) Karlicek's interconnecting element 50A.

196. Both Roberts and Karlicek expressly disclose connectors that provide an electrical and/or mechanical connection between adjacent lighting tiles (substrates). (Ex-1004-Roberts at 0071-74, FIG. 4A; Ex-1006-Karlicek at 0055.) To facilitate increased modularity and ease of manufacturability, it would have been obvious to preinstall Roberts' ***edge connector 13*** at one end of each lighting tile 10 such that

adjacent lighting tiles may be readily connected to form a lighting bar assembly 30. At the closed-loop end, loopback connectors 35 may thus be readily installed since no edge connector is located on that particular end of the lighting bar assembly:

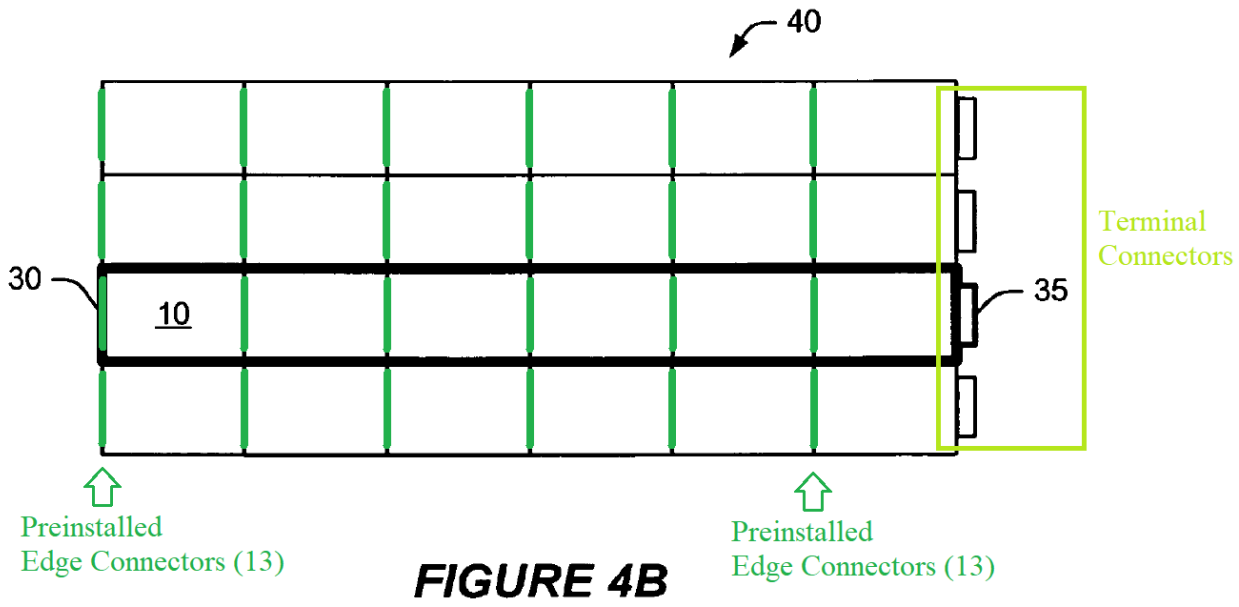


FIGURE 4B

(Ex-1004-Roberts at FIG. 4B, 0072, 0082.)

197. However, on the opposite end of each lighting bar assembly 30, a preinstalled edge connector would already be in place. To facilitate ease of interconnection between a voltage/power source and an end of the lighting bar assembly, a POSITA would have found it obvious to have Roberts' preinstalled edge connector "mounted on" Karlicek's terminating element 50V to facilitate interconnection Roberts' voltage/power source:

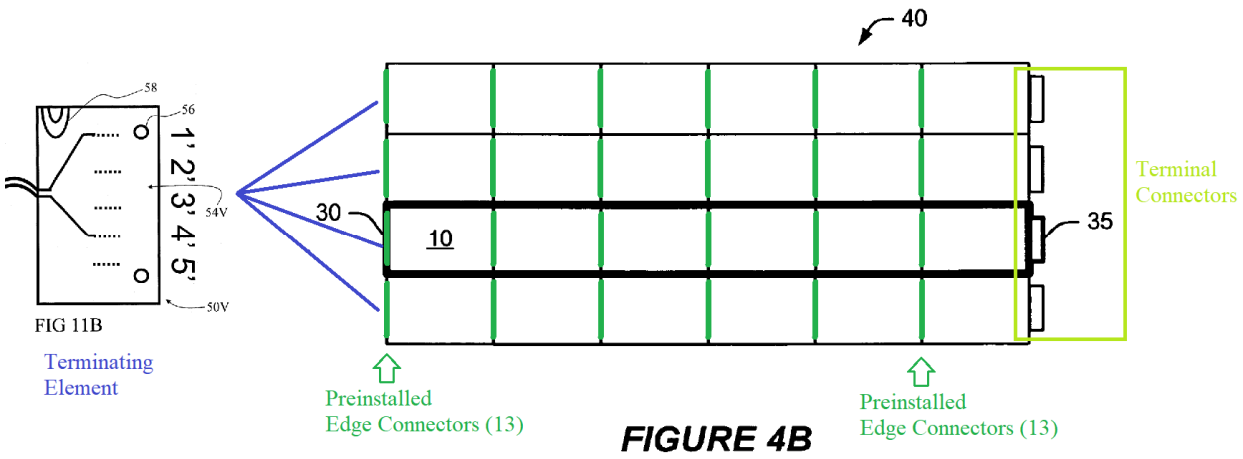


FIG 11B

FIGURE 4B

198. This would have been consistent with the intended function and purpose of Roberts' ***edge connector 13*** and would have beneficially provided uniform electro-mechanical connections between each of the substrates (*e.g.*, module substrates and external connecting substrate) in a lighting bar, which would have been consistent with Roberts' goal of providing a modular system and would have increased system simplicity. For these same reasons, it also would have been obvious to use Karlicek interconnecting elements 50A with the Roberts lighting tiles (instead of Roberts' edge connectors 13), and thus also mount the Karlicek interconnecting elements 50A on a Karlicek terminating element 50V to facilitate ease of construction, modularity and connection to an external voltage/power source.

199. Thus, Roberts in view of Karlicek teaches limitation [6b], and Roberts in view of Karlicek renders obvious Claim 6.

XI. GROUND 4: Roberts in View of Karlicek and Liu Renders Obvious Claims 12-15.

A. Scope, Content, and Motivation to Combine

200. As I explained earlier, a POSITA would have been motivated to apply the teachings of Liu and Karlicek to Roberts with a reasonable expectation of success. The motivations and expectations for Grounds 2-3 remain unchanged when the teachings of both Liu and Karlicek are applied to Roberts because a POSITA would have been motivated to employ a housing comprising a receiving groove per Liu irrespective of whether an external connecting substrate is used per Karlicek, as doing so would have beneficially secured Roberts' lighting bar assemblies to a housing. Likewise, a POSITA would have been motivated to employ an external connecting substrate to connect Roberts' lighting bar assemblies to Roberts' current driver (220) / controller (230) irrespective of whether a housing having a receiving groove was used per Liu, as doing so would have beneficially facilitated electrical connections between Roberts' lighting bar assemblies and Roberts' current driver (220) / controller (230) and in a manner that would have facilitated individual serial control of Roberts' LED strings.

B. The Challenged Claims

Claims 12 and 15

201. As discussed above with respect to Ground 2, Roberts in view of Liu renders obvious Claims 12 and 15.

202. To the extent the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Liu and Karlicek renders obvious Claims 12 and 15 for the same reasons discussed above in Ground 3.

Claim 13. The light source apparatus as claimed in claim 12, wherein the connecting substrate comprises an external connecting substrate, which is provided at one end of a first module substrate of the module substrates to supply a driving power.

203. Roberts in view of Karlicek teaches Claim 13 for the same reasons discussed above relative to Ground 3, Claim 3.

204. More specifically, Karlicek teaches the use of a terminating element 50V (external connecting substrate) that is provided at a first end of a first of a series of lighting tiles (module substrates) to supply a driving power from an external voltage source (current driver):

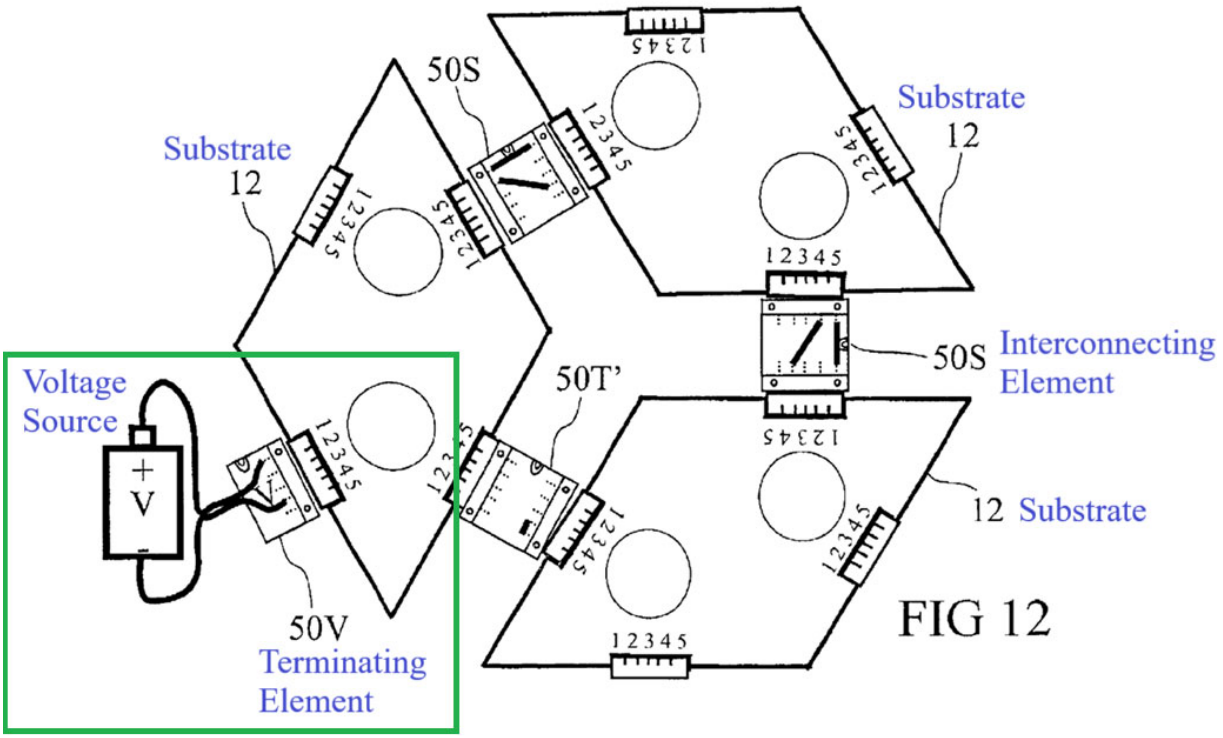


FIG 12

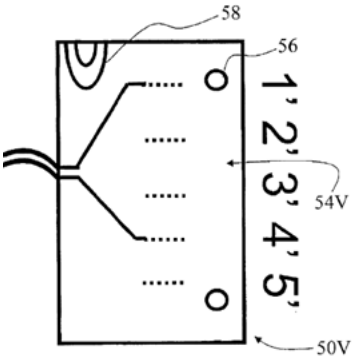


FIG 11B

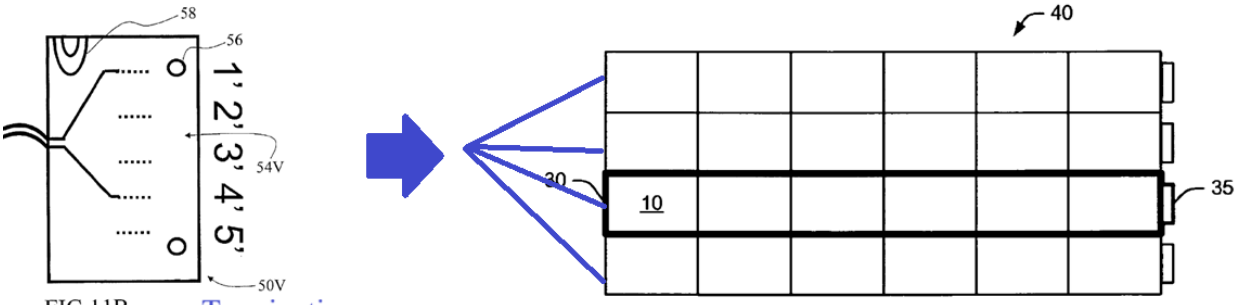
Terminating
Element

(Ex-1006-Karlicek at FIGS. 12, 11B, 0055, 0061.)

205. Karlicek's terminating element 50V is configured as a substrate. (*Id.* at FIGS. 11B, 12.)

206. As I explained earlier, a POSITA would have been motivated to apply

Karlicek's terminating element teachings to Roberts with a reasonable expectation of success, wherein Karlicek's terminating element (50V) (external connecting substrate) is provided at an end of the first lighting tile (module substrate) of each of Roberts' lighting bar assemblies to supply a driving power from Roberts' current driver (220) / controller (230):



(Ex-1006-Karlicek at FIG. 11B, 0061; Ex-1004-Roberts at FIG. 4B, 0075.)

207. Thus, Roberts in view of Karlicek teaches Claim 13, and Roberts in view of Liu and Karlicek renders obvious Claim 13.

Claim 14. The light source apparatus as claimed in claim 13, wherein the connecting substrate comprises a plurality of intermediate connecting substrates which connect both connecting terminals of a plurality of module substrates and/or between the external connecting substrate and the first connecting terminal of the first module substrate.

208. Roberts teaches and suggests Claim 14.

209. As explained relative to Ground 1, limitation [1c] and Claim 2, Roberts discloses that its ***lighting tiles (10)*** (module substrates) may be "*connected at*

*respective opposing edges by an **edge connector 13** [connecting substrate], which may provide an **electrical** and/or mechanical connection between adjacent **tiles 10**.*"

(Ex-1004-Roberts at 0082.)

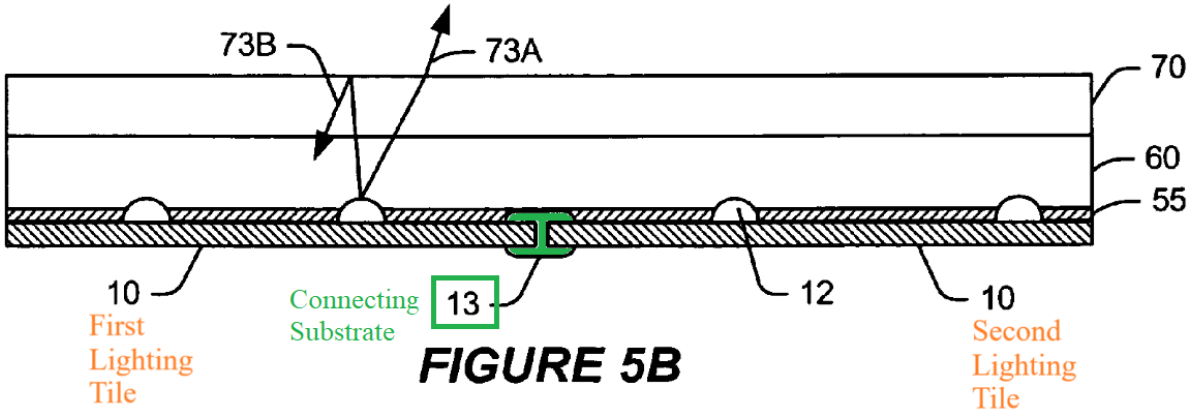


FIGURE 5B

(*Id*. at FIG. 5B.)

210. Roberts suggests, and a POSITA would have found it obvious, that Roberts' ***edge connector 13*** would have "connect[ed] both connecting terminals of a plurality of module substrates" because, as shown above, Roberts' ***edge connector 13*** is mounted on adjacent ***lighting tiles 10*** and Roberts' ***edge connector 13*** is used to provide "an electrical … connection between adjacent tiles 10." (Ex-1004-Roberts at 0071-74, 0082 FIG. 4A.) Thus, Roberts teaches and suggests, and a POSITA would have expected and would have found it obvious, that Roberts' edge connector 13 "connect[s] both connecting terminals of a plurality of module substrates" to facilitate an electrical connection between adjacent tiles.

211. A POSITA also would have found it obvious to use multiple edge connectors 13 (a plurality of intermediate connecting substrates) because Roberts

discloses that numerous ***lighting tiles 10*** "may be connected at respective opposing edges by an edge connector 13, which may provide an electrical and/or mechanical connection between adjacent tiles 10," and Roberts illustrates numerous ***lighting tiles 10*** in a ***lighting bar assembly 30***:

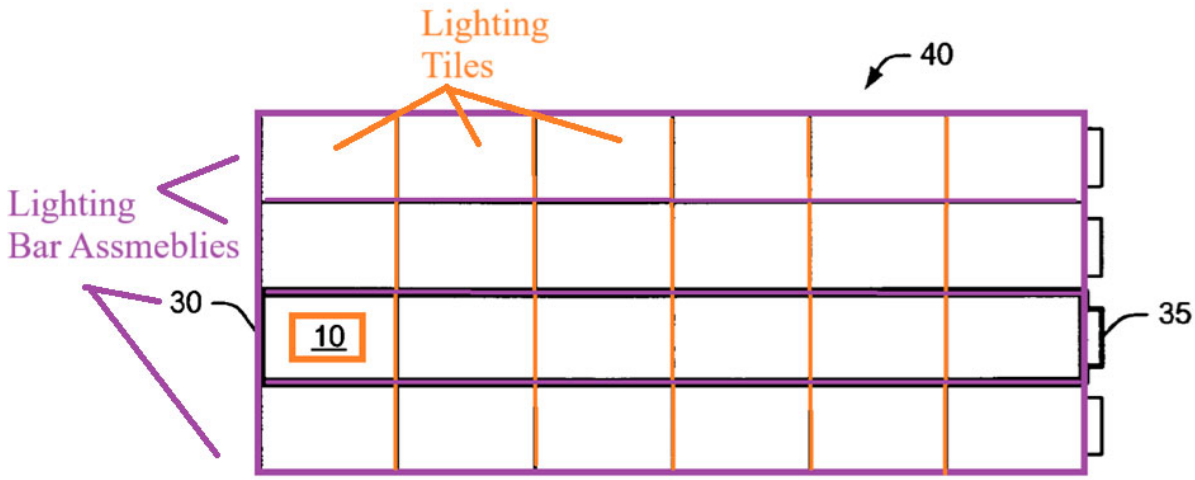


FIGURE 4B

(Ex-1004-Roberts at 4B, 0040, 0071, 0096.)

212. Thus, Roberts teaches and suggests Claim 14, and Roberts in view of Liu and Karlicek renders obvious Claim 14.

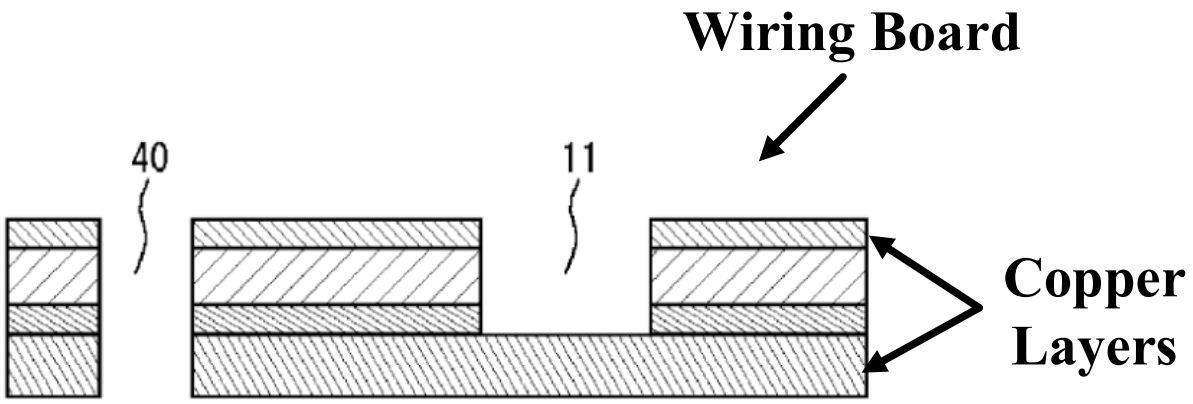
XII. GROUND 5: Roberts in View of Nishida, Optionally in View of Karlicek, Renders Obvious Claim 9.

A. Scope, Content, and Motivation to Combine

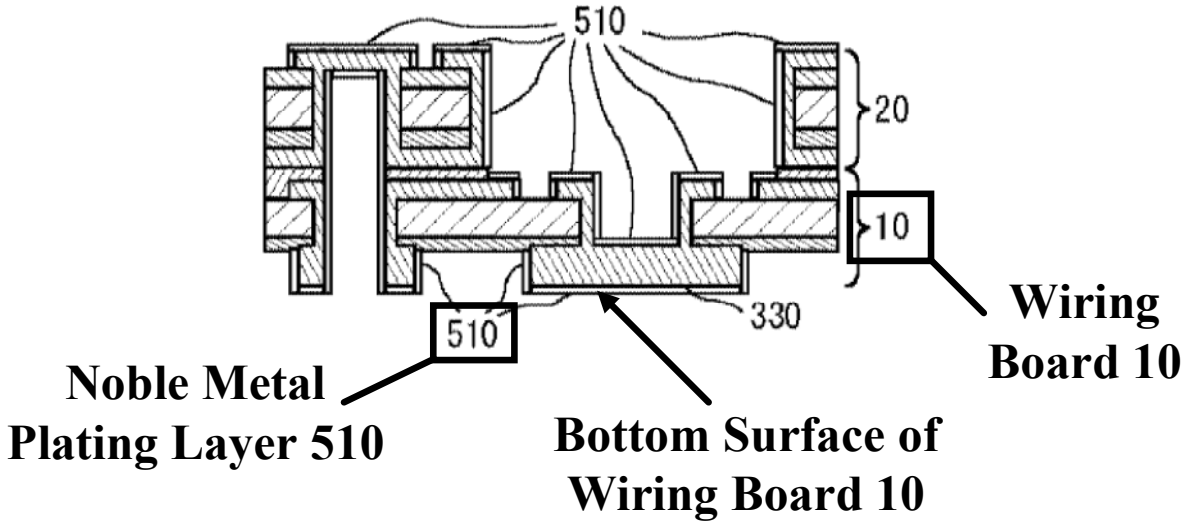
213. Roberts discloses that its lighting tiles 10 may include a PCB, such as a metal core PCB (MCPCB), on which discrete light emitting components may be mounted. (Ex-1004-Roberts at 0060.) But Roberts omits details as to how to

implement its lighting tiles 10 with PCBs. (*Id.*) Nishida provides such details.

214. Nishida discloses a wiring board (base board 10) with a plurality of LEDs 30 that may be used as the backlight of an LCD. (Ex-1009-Nishida at FIG. 2, 0001, 0018-0020, 0029-36.) The wiring board comprises multiple layers of copper 310, 330, 340, and a noble metal plating layer 510 formed on a bottom surface thereof. (*Id*. at FIGS. 3a-3g and 5c, 0018-20, 0024, 0029-30.)

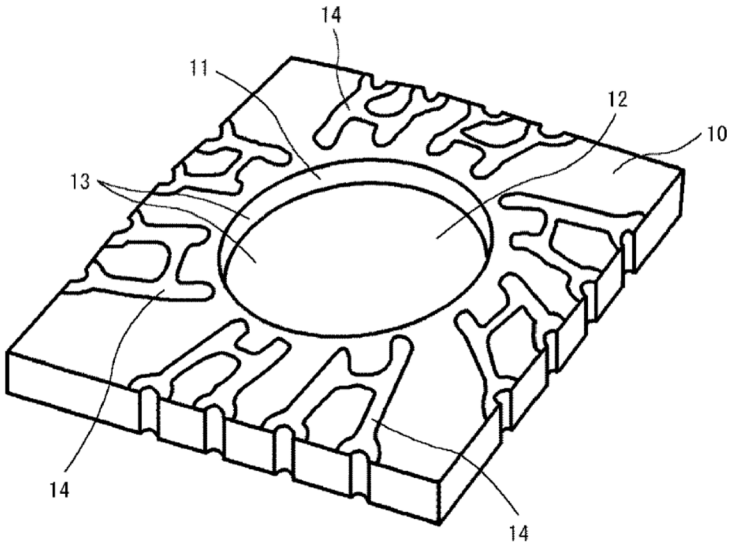


(*Id*. at FIG. 3(d).)



(*Id*. at FIG. 5(c).)

215. A POSITA would have recognized that Nishida's wiring board is a type of PCB. For example, Nishida discloses that its wiring board includes a predetermined circuit pattern 14 formed by etching on a top surface of a substrate. (Ex-1009-Nishida at 0019-20, 0025, 0027, 0029-30.)



(*Id*. at FIG. 2.)

216. A POSITA would have been motivated to apply Nishida's wiring board (PCB) teachings to Roberts' lighting tiles (10). Both Roberts and Nishida are directed to PCBs for LCD backlight panels. (Ex-1004-Roberts at 0134; Ex-1009-Nishida at 0001.) Nishida expressly discloses that its PCB beneficially prevents damage from foreign objects. (Ex-1009-Nishida at 0034.) Nishida also expressly discloses that its PCB beneficially offers "excellent heat dissipation properties," provides "high optical output with good conversion efficiency," and diffuses outputted light prior to emission, thus making Nishida's PCB "particularly suitable

for chip component type light emitting devices that may be used as the light source for display panels," such as Roberts' lighting tiles (10). (*Id.*)

217. Roberts, like Nishida, is also concerned with improving heat dissipation. (Ex-1004-Roberts at 0017-18, 0066, 0087-88.) Indeed, Roberts discloses that the bottom of its tiles 10 may be connected to a heat sink panel 80 with heat sink features:

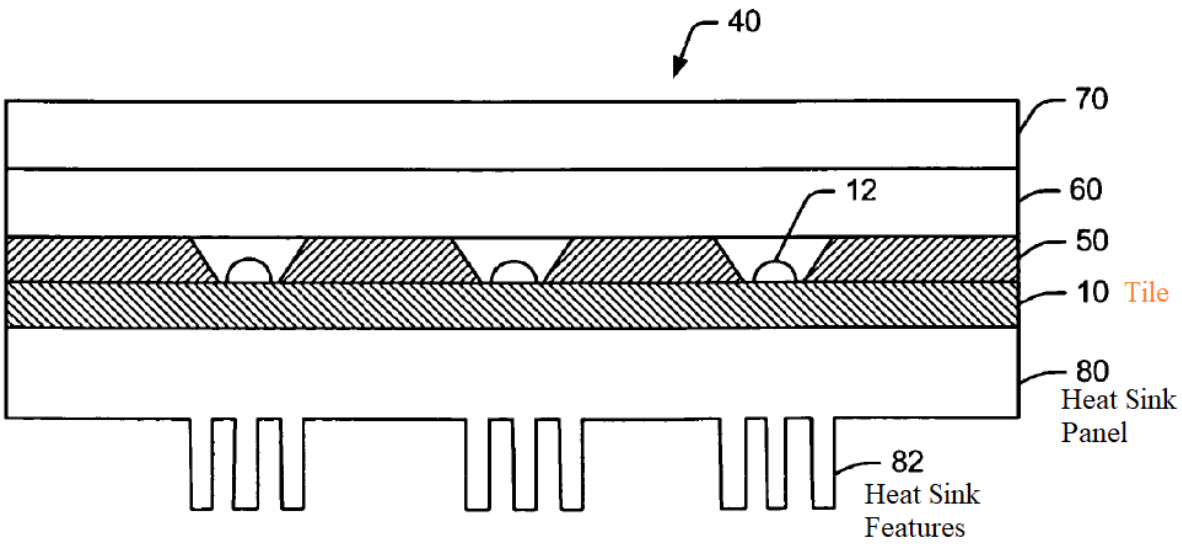


FIGURE 7

(*Id.* at FIG. 7, 0087)

218. A POSITA would have recognized that Nishida's noble metal plating layer would have provided significant thermal management advantages because noble metals (especially silver and gold) have excellent thermal conductivity, allowing the plating material on the bottom of the wiring board (PCB) to efficiently transfer heat to a heat sink or mounting surface. A POSITA would have similarly recognized that

Nishida's multiple copper layers would have provided thermal management advantages, as copper has a high thermal conductivity and using multiple copper layers was a recognized way to spread and dissipate heat evenly and effectively.

219. In view of the above, a POSITA would have found it obvious to apply Nishida's PCB teachings to Roberts. Specifically, a POSITA would have found it obvious to employ PCBs having multiple copper layers and a noble metal plating layer formed on a bottom surface thereof to facilitate improved thermal management. As explained previously, the multiple copper layers facilitate heat dissipation in the lateral direction. Further, applying a noble metal plating layer on the bottom of Roberts' PCB tile 10 would have facilitated enhanced heat transfer to Roberts' heat sink panel 80. Such heat transfer benefits are expressly desired by Roberts. (Ex-1004-Roberts at 0066, 0087, 0088.)

220. A POSITA also would have had a reasonable expectation of successfully applying Nishida's teachings to Roberts. PCBs were well-known and widely used at the time of the alleged invention of the '415 patent, and applying Nishida's PCB teachings to Roberts' lighting tiles (10) would have been straightforward and routine to a POSITA.

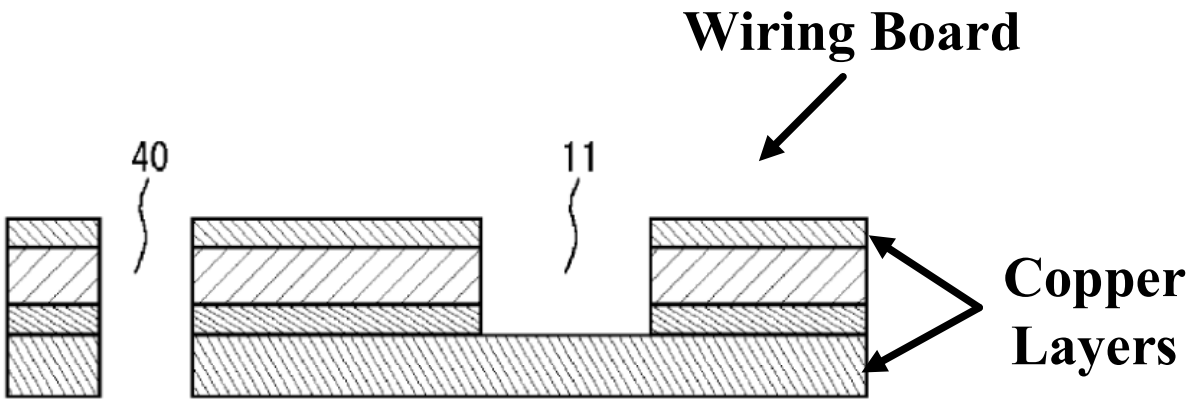
B. The Challenged Claim

Claim 9. The light source apparatus as claimed in claim 1, wherein the module substrate comprises a multi-copper layer and a via hole formed in the module substrate, and a silver plating layer formed on a bottom surface of the module substrate.

221. Roberts in view of Nishida teaches Claim 9.

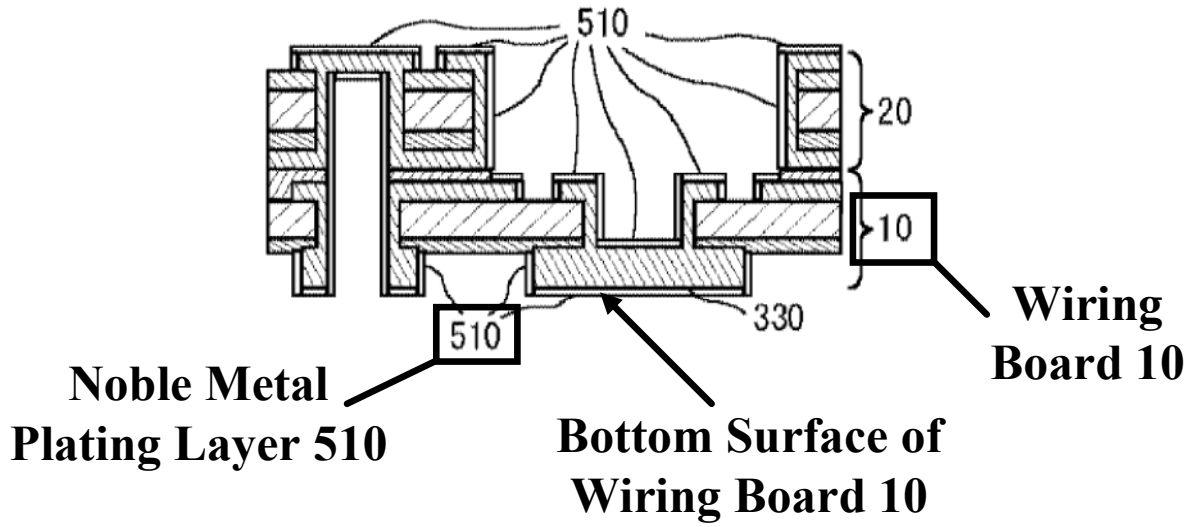
222. Roberts discloses that its lighting tiles (10) (module substrates) may be PCBs with thermal vias (via holes) formed therein. (Ex-1004-Roberts at 0060.) Roberts, however, does not disclose that its lighting tiles (10) (module substrates) comprise a multi-copper layer or a silver plating layer formed on a bottom surface of the substrate. Nishida does.

223. Nishida discloses a wiring board (module substrate) with a plurality of light emitting elements 30 (*e.g.*, LEDs) that may be used as the light source for various types of display panels, such as the backlight of an LCD. (Ex-1009-Nishida at FIG. 2, 0001, 0018-0020, 0029-36.) The wiring board comprises multiple copper layers 310, 330, 340 (a multi-copper layer). (*Id*. at FIGS. 3a-3g and 6-7, 0018-20, 0024, 0029-30.)



(*Id*. at FIG. 3(d).)

224. Nishida further discloses a noble metal plating layer 510 formed on a bottom surface of the wiring board:



(*Id*. at FIG. 5(c), 0029.)

225. A POSITA would have known that silver is a type of noble metal. A POSITA also would have known that silver was commonly used as a plating layer in PCBs due to silver's high thermal and electrical conductivity, oxidation resistance, and relative inexpensiveness compared to other noble metals such as

gold. (*See, e.g.,* Ex-1018-Cowie at Abstract, 1:6-10, 1:62-68, 2:31-38, 3:24, 4:41-57.)

226. As explained earlier, a POSITA would have been motivated to apply Nishida's wiring board teachings with Roberts' lighting tiles (10) (module substrates) to achieve enhanced heat removal and with a reasonable expectation of success. Applying Nishida's teachings to Roberts would thus have resulted in a module substrate that includes "a multi-copper layer and a via hole formed in the module substrate, and a silver plating layer formed on a bottom surface of the module substrate."

227. Thus, Roberts in view of Nishida teaches and renders obvious Claim 9.

228. Further, to the extent the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Nishida and Karlicek renders obvious Claim 9 for the same reasons discussed above in Ground 3.

XIII. GROUND 6: Roberts in View of Newman, Optionally in View of Karlicek, Renders Obvious Claim 10.

A. Scope, Content, and Motivation to Combine

229. As shown in Ground 1, Roberts discloses lighting tiles having a plurality of LEDs but does not specifically disclose test pads for those LEDs. (Ex-1004-Roberts at 0062-72, FIGS. 1-2.) Newman discloses a plurality of LED array modules, each of which comprises an ***LED array chip (16)***. (Ex-1010-Newman at 1:8-10.) The LED array module provides all the wiring for connecting chips together

and testing the module, "thereby protecting the delicate components and allowing the module to be completely tested" prior to final assembly. (*Id*. at Abstract, 1:11-18, 2:47-3:8.) To facilitate this testing, each LED array module includes ***test pads (50)*** for testing the ***LED array chip (16)***. (*Id*. at FIGS. 3-4, 2:61-66, 4:43-46, 5:39-44.)

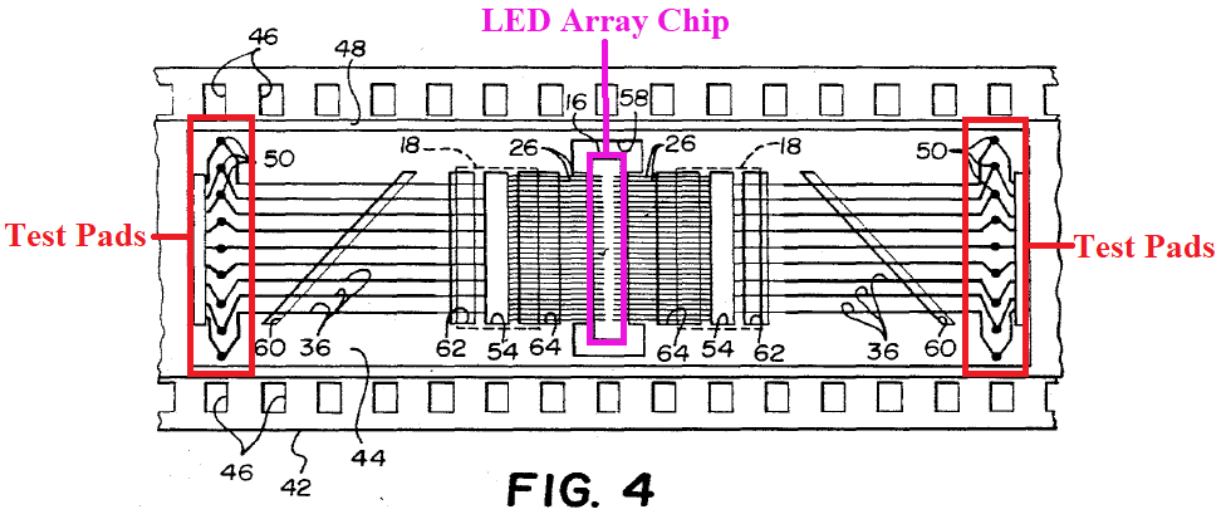


FIG. 4

(*Id*. at FIG. 4.)

230. A POSITA would have been motivated to apply Newman's teachings to Roberts, wherein Roberts' lighting tiles (10) include test pads for testing Roberts' LED chips. Test pads have been routinely used on PCBs (including LED modules) for decades and offer several well-known benefits for manufacturing, quality control, and maintenance. For example, a POSITA would have known that incorporating test pads into an LED module would have beneficially allowed for in-circuit testing to easily verify functionality during production and detect defects

before the module leaves the factory. A POSITA also would have recognized that test pads facilitate easy troubleshooting after deployment. If an LED module fails in the field, a technician can quickly probe the test pads to determine whether the failure is in the LED array, driver circuitry, or power supply.

231. A POSITA also would have had a reasonable expectation of successfully applying Newman's teachings to Roberts. The use of test pads has been a standard practice in electronics manufacturing since at least the 1980s, and incorporating test pads into LED modules, such as Roberts' lighting tiles (10), would have been straightforward and routine task to a POSITA.

B. The Challenged Claim

Claim 10. The light source apparatus as claimed in claim 7, wherein the module substrate includes a test pad terminal for testing the LED chip.

232. Roberts in view of Newman teaches Claim 10.

233. Newman teaches a plurality of LED array modules, each of which comprises an ***LED array chip (16)*** and ***test pads (50)*** (test pad terminals) for testing the ***LED array chip (16)***. (Ex-1010-Newman at FIGS. 3-4, 2:61-66, 4:43-46, 5:39-44.)

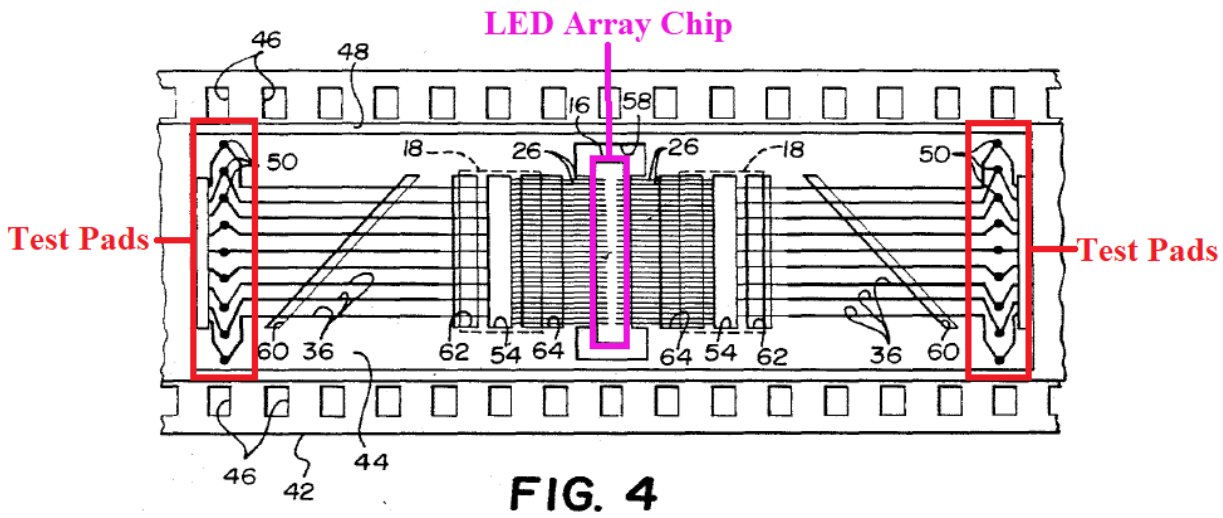


FIG. 4

(*Id*. at FIG. 4.)

234. As I explained earlier, a POSITA would have been motivated to combine the teachings of Roberts and Newman with a reasonable expectation of success, wherein Roberts' lighting tiles (10) (module substrates) are provided with test pad terminals for testing Roberts' LED chips. Applying Newman's teaching to Roberts would have resulted in a module substrate that includes "a test pad terminal for testing the LED chip."

235. Thus, Roberts in view of Newman teaches and renders obvious Claim 10.

236. Further, to the extent the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Newman and Karlicek renders obvious Claim 10 for the same reasons discussed above in Ground 3.

XIV. GROUND 7: Roberts in View of Liu, Karlicek, and Hsiao Renders Obvious Claims 16-18.

A. Scope, Content, and Motivation to Combine

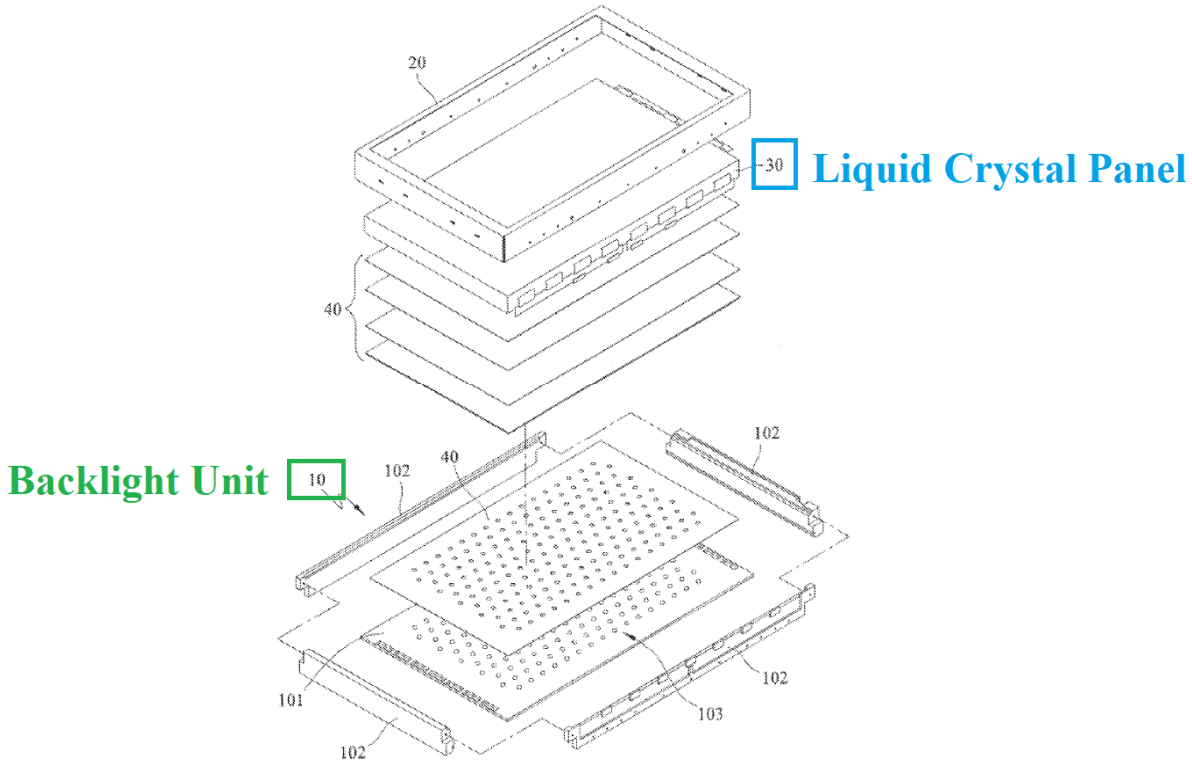
237. As shown below, Roberts in view of Liu and Karlicek teaches all limitations of the Ground 7 claims except "a liquid crystal panel" and "a light unit disposed below the liquid crystal panel." Hsiao, however, discloses that this arrangement was conventional in liquid crystal displays (LCDs).

238. Hsiao describes the arrangement of a "conventional LCD" as follows:

> "FIG. 1 is a perspective view of *a conventional LCD*, which comprises an LCD panel 30, a front frame 20 disposed on the LCD panel 30, a backlight module 10 having an LED array 103 disposed on a back bezel 101, and a frame assembly 102 disposed along the edges of the back bezel 101. The backlight module 10 is a direct type backlight module. There are a plurality of optical films 40 disposed between the LCD panel 30 and the backlight module 10 for enhancing the efficiency of light usage and luminance promotion. The optical films 40 can be diffusing films, prism films, acrylic films and/or light enhancing films.

(Ex-1011-Hsiao at 1:33-43.)

239. Hsiao also provides the following illustration of a conventional LCD showing the ***backlight unit 10*** disposed below the ***liquid crystal panel 30***:



(*Id*. at FIG. 1.)

240. Hsiao further describes how the backlight unit and the liquid crystal panel of a conventional LCD work in conjunction with each other to produce visible images:

> "Liquid crystal displays (LCDs) have become the most popular displays because of the light weight and good displaying quality. The backlight module is an important illumination structure of the LCD. Controlling the transmissive light provided from the backlight module in association with the liquid crystal cells in a matrix of a panel, and appropriately controlling switches, make the brightness and quality of the images presented on the display be determined. Light emitting diodes (LEDs) widely serve as the light source of the backlight module

> because of the low power consumption, light weight and high luminance. Therefore, LEDs have gradually become substitutes for fluorescent lamps when selecting light sources for the backlight module."

(*Id*. at 1:19-32.)

> "Generally, the LCD panel 30 comprises an upper glass substrate, a lower glass substrate, and a liquid crystal layer (not shown) disposed therebetween. The upper glass substrate and the lower glass substrate can be a color filter substrate and an active (or passive) array substrate, respectively. The voltage difference between the upper and the lower glass substrates makes the liquid crystal in the liquid crystal layer rotate or tilt accordingly. Therefore, the light transmitting through the LCD panel 30 will be controlled and will then produce images on the LCD panel 30.

(*Id*. at 1:44-53.)

241. A POSITA would have been motivated to apply the conventional LCD arrangement taught in Hsiao to Roberts. Roberts discloses that its backlight panel 40 may be implemented as an LCD backlight. (Ex-1004-Roberts at 0134; *see also id*. at 0003.) However, Roberts omits conventional details on how to do so. Hsiao provides such details, explaining that a conventional LCD comprises a backlight panel disposed below a liquid crystal panel. (Ex-1011-Hsiao at FIG. 1, 1:33-46.) Hsiao further explains that, by controlling the light provided by the backlight panel and the orientation of the liquid crystals in the liquid crystal panel, this conventional

arrangement allows the LCD to produce images. (*Id*. at 1:19-32, 1:44-53.) A POSITA would have found it obvious and beneficial to apply Hsiao's teachings to Roberts in the conventional manner to create an LCD capable of producing visible pictures.

242. A POSITA also would have had a reasonable expectation of successfully applying Hsiao's teachings to Roberts. Hsiao confirms that disposing a light unit below a liquid crystal panel was conventional (Ex-1011-Hsiao at FIG. 1, 1:19-53), and a POSITA would have found it straightforward to implement this conventional arrangement to produce Roberts' LCD panel.

B. The Challenged Claims

Claim 16. [16-PRE] A liquid crystal display comprising: [16a] a liquid crystal panel; and a light unit disposed below the liquid crystal panel,

243. Roberts in view of Hsiao teaches limitations [16-PRE] and [16a].

244. Robert teaches that its lighting panel 40 (light unit) may be a backlight panel for an LCD (liquid crystal display):

> "[A] backlight panel 40 may include a plurality of red LED strings 23, each of which may be driven with a different pulse width, resulting in a different average current level. Accordingly, some embodiments of the invention provide a closed loop digital control system for a lighting panel, such as an *LCD backlight*…."

(Ex-1004-Roberts at 0134.)

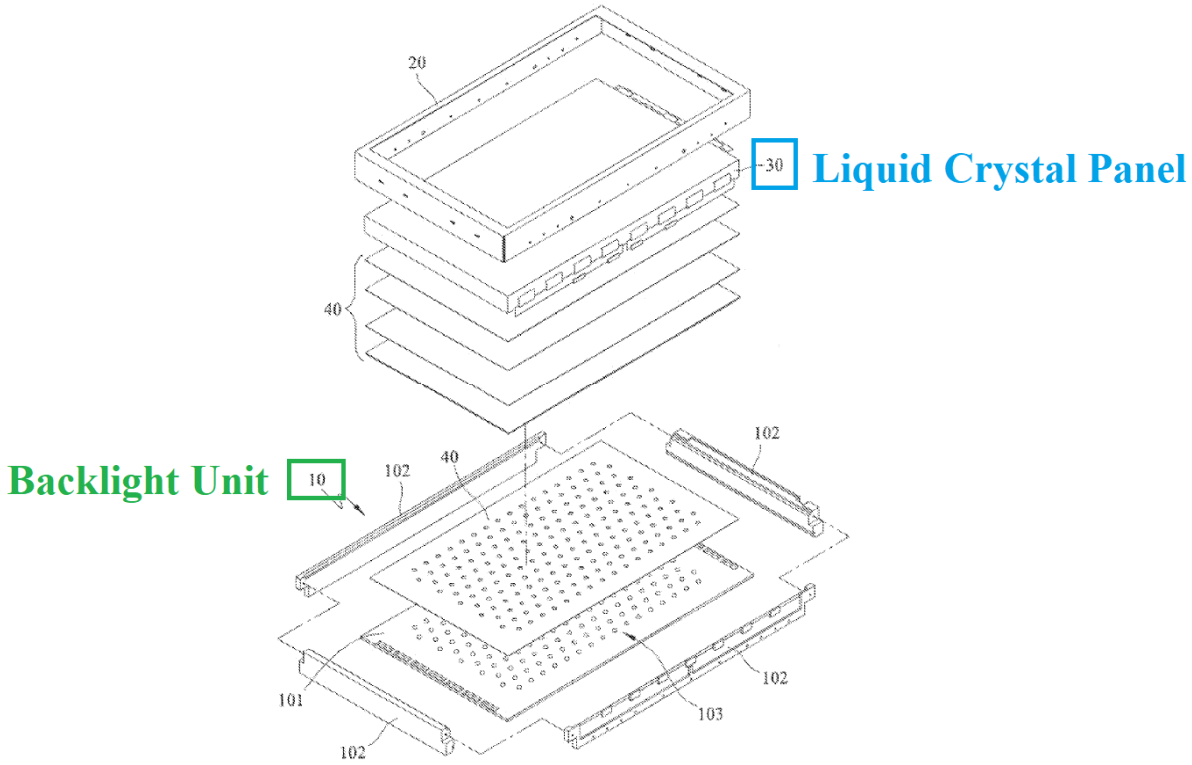
> "The lighting panel 40 may include, for example, a plurality of bar assemblies 30, which, as described above, may include a plurality of tiles 10. However, it will be appreciated that embodiments of the invention may be employed in conjunction with lighting panels formed in *other configurations*. For example, some embodiments of the invention may be employed with *solid state backlight panels* that include a single, large area tile."

(*Id.* at 0095.)

245. Hsiao teaches that a "conventional LCD" includes an ***LCD panel 30*** comprising a liquid crystal layer (liquid crystal panel) and a ***backlight module 10*** (light unit) disposed below the ***LCD panel 30***:

> "FIG. 1 is a perspective view of a conventional LCD, which comprises an LCD panel 30, a front frame 20 disposed on the LCD panel 30, a backlight module 10 having an LED array 103 disposed on a back bezel 101, and a frame assembly 102 disposed along the edges of the back bezel 101. The backlight module 10 is a direct type backlight module. There are a plurality of optical films 40 disposed between the LCD panel 30 and the backlight module 10 for enhancing the efficiency of light usage and luminance promotion. The optical films 40 can be diffusing films, prism films, acrylic films and/or light enhancing films."

(Ex-1011-Hsiao at 1:33-43.)



(*Id*. at FIG. 1.)

246. As I explained earlier, a POSITA would have been motivated to combine the teachings of Roberts and Hsiao with a reasonable expectation of success, wherein Roberts' lighting panel 40 (light unit) is implemented as a backlight panel for an LCD that is disposed below a liquid crystal panel. Applying Hsiao's teaching to Roberts would have resulted in an LCD comprising "a liquid crystal panel" and "a light unit disposed below the liquid crystal panel."

247. Thus, Roberts in view of Hsiao teaches limitations [16-PRE] and [16a].

[16b] wherein the light unit comprises a housing comprising a receiving groove,

248. Roberts in view of Liu teaches limitation [16b] for the same reasons as provided above relative to Ground 2, limitation [12a].

[16c] at least one module substrate which is received in the housing and has a first connecting terminal and a second connecting terminal at both end portions of the module substrate,

249. Roberts in view of Liu teaches limitation [16c] for the same reasons as provided above relative to Ground 2, limitation [12b].

[16d] a light emitting diode on the module substrate, and

250. Roberts teaches limitation [16d] for the same reasons as provided above relative to Ground 1, limitation [1b].

[16e] a connecting substrate which is connected to the first connecting terminal of a first end of the module substrate or the second connecting terminal of a second end of the module substrate, wherein the connecting substrate comprises a termination connecting substrate which comprises a closed loop pattern for forming a second connecting terminal of a second end of a final module substrate as a closed loop circuit.

251. Roberts teaches and suggests limitation [16e] for the same reasons as provided above relative to Ground 1, limitation [1c].

252. As explained above relative to Ground 1, limitation [1c], Roberts teaches and suggests that its ***edge connectors 13*** (connecting substrates) are connected to the first connecting terminal of a first end of a ***lighting tile*** (module substrate) and/or the second connecting terminal of a second end of the ***lighting tile*** (module substrate).

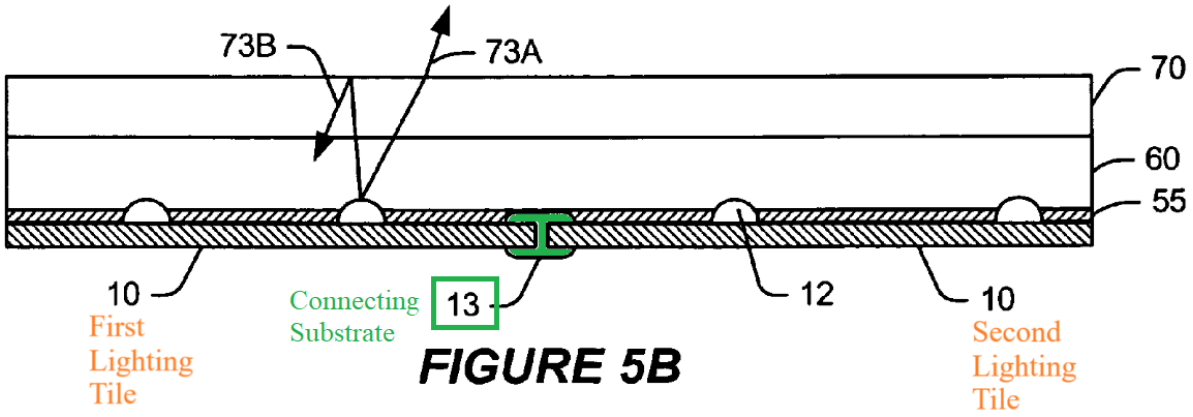


FIGURE 5B

(Ex-1004-Roberts at FIG. 5B; *see also id*. at 0082.)

253. As further explained above relative to Ground 1, limitation [1c], Roberts also teaches that its connecting substrates may include ***a loopback connector 35*** (termination connecting substrate) which comprises a closed loop pattern for forming a connecting terminal at the rightmost end of the final lighting tile 10" (a second connecting terminal of a second end of a final module substrate) as a closed loop circuit.

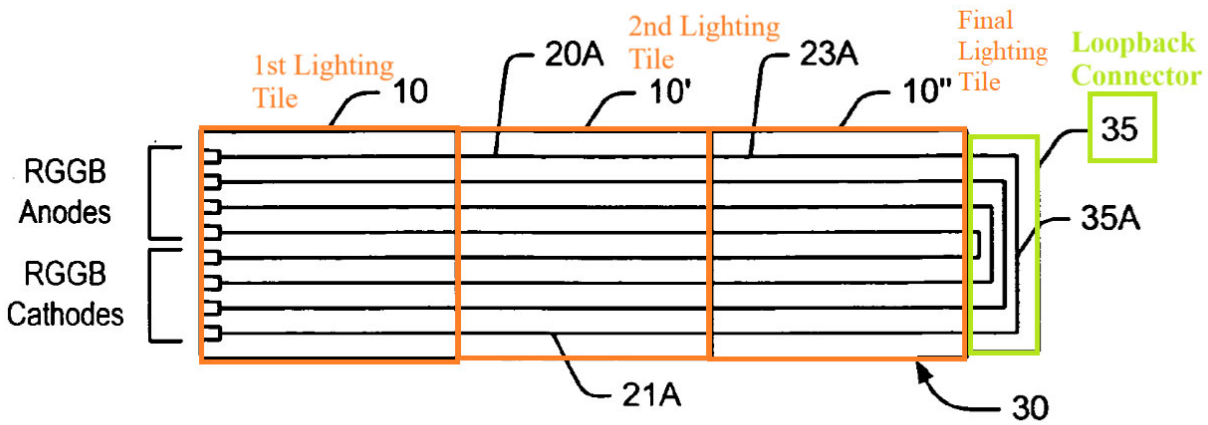


FIGURE 4A

(Ex-1004-Roberts at FIG. 4A; *see also id*. at FIG. 4B, 0071-73, 0075, 0134, 0136.)

254. Thus, Roberts teaches and suggests limitation [16e], and Roberts in view of Liu and Hsiao renders obvious Claim 16.

255. Further, to the extent the term "connecting substrate" is narrowly construed to require a substantially flat substrate, Roberts in view of Liu, Karlicek, and Hsiao renders obvious Claim 16 for the same reasons discussed above in Ground 3.

Claim 17. The liquid crystal display as claimed in claim 16, [17a] wherein the connecting substrate comprises: an external connecting substrate for external connection; and

256. Karlicek teaches limitation [17a] for the same reasons as provided above relative to Ground 3, limitation [3a].

[17b] at least one intermediate connecting substrate comprising a third connecting terminal which connects the external connecting substrate with the first connecting terminal of the first module substrate and/or between the connecting terminals of module substrates.

257. Roberts teaches limitation [17b] for the same reasons as provided above relative to Ground 3, limitation [3b] and Claim 4.

258. Thus, Roberts in view of Liu, Karlicek, and Hsiao renders obvious Claim 17.

18. The liquid crystal display as claimed in claim 17, wherein one of the module substrate, the external connecting substrate, the intermediate substrate and the termination substrate comprises a flexible substrate.

259. Roberts teaches Claim 18.

260. Roberts' loopback connector 35 (termination substrate) may be a flexible

wiring board (flexible substrate):

> "The loopback connector 35 may include an edge connector, *a flexible wiring board*, or any other suitable connector. In addition, the loop connector may include printed traces formed on/in the tile 10."

(Ex-1004-Roberts at 0073.)

261. Thus, Roberts teaches Claim 18, and Roberts in view of Karlicek, Liu, and Hsiao renders obvious Claim 18.

XV. DECLARATION IN LIEU OF OATH

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under § 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon. If called to testify as to the truth of the matters stated herein, I could and would testify competently.

I declare under penalty of perjury that the foregoing is true and correct.

September 19, 2025

Michael Krames

Michael R. Krames, Ph.D.

Appendix A

MICHAEL KRAMES, PHD, NAE, FIEEE, FIES

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C-LEVEL EXECUTIVE IN PHOTONICS AND SEMICONDUCTORS: TECHNOLOGY, PRODUCT, AND GALLIUM NITRIDE EXPERT

Accomplished R&D Professional with 25+ years of experience in photonics including LEDs and wide bandgap semiconductors. Extensive experience in R&D and manufacturing settings, creating some of the most innovative LEDs for solid-state lighting. Tech team builder, overseeing design, fabrication, characterization, and integration. Work in major companies in the opto semiconductor market, including Hewlett-Packard, Philips and innovative start-ups. PhD in Electrical Engineering. Member of the National Academy of Engineering. IEEE and IES Fellow.

Overview

- Recruit top-performing professionals and make critical hires of technology experts.
- Manage large teams of up to 40, including globally distributed teams across the U.S. and Europe.
- Create unique strategic plans and product roadmaps for innovative technologies.
- Maintain strong partnerships with research institutions to develop industry-leading products.
- Oversee intellectual property (IP) portfolios and file dozens of successful patent applications.

Selected Core Competencies

R&D ● Team Leadership ● Strategic Planning ● Photonics Technologies ● Device Design ● Speaker Investment & Fundraising ● Recruitment ● Project Management ● Multimillion USD Budgets ● IP Portfolios

PROFESSIONAL EXPERIENCE

ARKESSO LLC – Palo Alto, CA – 2015-present
President
Strategic technology, investment and intellectual property development and consulting for wide bandgap semiconductor technologies and applications, including expert work in patent litigation.

CURRENT CHEMICALS INC – Cleveland, OH – 2025-present
Board of Directors
Guide strategy and growth for a U.S. manufacturer of critical materials and rare-earth compounds serving industrial, high-tech, and defense markets.

IBEAM MATERIALS INC – Sante Fe, NM – 2019-present
Board of Directors
Guide and govern Los Alamos National Lab start-up for depositing semiconductor grade gallium nitride on large area, flexible amorphous materials with application to flexible lighting systems and displays.

SEABOROUGH RESEARCH BV – Amsterdam, NL – 2015-present
Senior Advisor
Drive materials research and development programs for lighting applications using nano materials, focused on advancing the overall solid-state lighting industry in terms of energy savings and performance capability

PROFESSIONAL EXPERIENCE (CONTINUED)

MOMENTUM CAPITAL BV – Amsterdam, NL – 2016-2019, 2025-present
Principal
Technology scouting, assessment, and due diligence for growth market venture financing with a global view and emphasis on clean technology and energy sectors.

SORAA INC – Fremont, CA – 2009-2015
Chief Technology Officer (CTO)
First Management Team member hired to work with Nobel Prize Winner Shuji Nakamura and other key innovators from the University of California, Santa Barbara, to develop leading LED products for professional directional lighting using a brand-new LED materials platform: GaN-on-GaN. Established the GaN-on-GaN LED technology direction and performance roadmaps. Spearheaded projects to commercialize the technology and built successful LED and Product teams from the ground up to implement these. Directly involved in venture and strategic fundraising including successful Series B & C venture capital funding worth more than $100M.

- Created the world's first LED to surpass halogen and the most efficient light-emitting diodes in the world.
- Built a strong intellectual property portfolio, resulting in more than 140 issued patents for Soraa.
- Developed practical strategies for the use of bulk GaN substrate, improving LED performance 10X.
- Supervised bulk GaN ammonothermal growth team and secured strategic investment to cover burn.
- Recruited a core team of talented technology professionals and made critical hires of senior executives.
- Developed LED roadmaps and oversaw innovation from substrate and epitaxy to fabrication and packaging.
- Established the value of higher color quality in products, including color and whiteness rendering.
- Successful implementation of a research contract with Penn State to advance the state of art for LED lighting.

PHILIPS LUMILEDS / LUMILEDS LIGHTING (Originally an HP-Philips Joint Venture) – San Jose, CA – 1999-2009
Executive Vice President, Advanced Laboratories
Formed and managed an R&D laboratory focused on designing groundbreaking LED technologies. Recruited and hired high-performing team, including employees from HP / Agilent Labs. Managed a 40-member department and a budget of up to $20M. Coordinated with engineering, marketing, product development, and sales teams across the U.S. and Europe. Oversaw technology transfers and managed IP. Developed prototypes for next-generation, solid-state light emitters. Led development of ceramic phosphor technologies.

- Developed the critical LUXEON high power LED platform and managed the technology roadmaps.
- Identified Auger-Meitner recombination as primary loss mechanism in InGaN-based LEDs.
- Designed LED technologies for the iMac, iPhone Flash, digital imaging, and general illumination.
- Created the first automotive LED headlights for the Audi R8, creating new technology breakthroughs.
- Produced a strong intellectually property (IP) portfolio of groundbreaking innovations.
- Oversaw the European phosphor research teams and partners, including nitride-based phosphors
- Spearheaded the creation of thin film flip-chip LED technology and designed new ceramic phosphors.

HEWLETT PACKARD CO, Optoelectronics Division – San Jose, CA – 1995-1999
Design Engineer and Engineering Scientist
Developed innovative, high-energy LED technologies for traffic signal, road lighting, and automotive applications. Developed high-power LED products using novel device structures and epitaxial layer design.

- Worked with teams to develop the world's first high-power LEDs, expanding from milli-Watts to Watt-class.
- Successfully developed the first LED to surpass 100 lumens per Watt.
- Re-engineered LED chip design for red and amber emitters, delivering groundbreaking performance.
- Delivered record-setting performance for visible-spectrum LEDs with 55%+ external quantum efficiency.

MICHAEL KRAMES, PHD, 3 650-823-4007 ▪ mkrames@arkesso.com

EXPERT TESTIFYING EXPERIENCE (LAST 5 YEARS)

Case Description	Role	Jurisdiction	Testimony
SEOUL SEMICONDUCTOR CO., LTD. and SEOUL VIOSYS CO., LTD. (Plaintiffs) vs. TECHNICAL CONSUMER PRODUCTS, INC. (Defendant)	Expert witness for TCP	UNITED STATES DISTRICT COURT FOR THE DISTRICT OF DELAWARE	Deposition testimony Aug 21, 2025
Luminex International Company Ltd. (Petitioner) vs. Signify Holding BV (Patent Owner)	Expert witness for Signify	U.S. PATENT AND TRADEMARK OFFICE BEFORE THE PATENT TRIAL AND APPEAL BOARD	Deposition testimony Mar 13, 2025
Feit Electric Company, Inc. (Plaintiff) vs. LEDVANCE, LLC (Defendant)	Expert witness for LEDVANCE	UNITED STATES DISTRICT COURT EASTERN DISTRICT OF KENTUCKY	Deposition testimony Jan 10, 2025
Signify NA Corp. & Signify Holding BV (Plaintiffs) vs. LEPRO Innovation Inc. et al. (Defendants)	Expert witness for Signify	UNITED STATES DISTRICT COURT DISTRICT OF NEVADA	Deposition testimony Oct 2, 2024
ALSI Holdings, LLC (Plaintiff) vs. Current Lighting Solutions, LLC, and HLI Solutions, Inc. (Defendants)	Expert witness for Current	UNITED STATES DISTRICT COURT WESTERN DISTRICT OF TEXAS WACO DIVISION	Deposition testimony Aug 14, 2023
CAO Lighting, Inc., (Plaintiff) vs. GE Lighting, Inc., General Electric Co., and Consumer Lighting (U.S.), LLC d/b/a GE Lighting (Defendants)	Expert witness for GE	UNITED STATES DISTRICT COURT DISTRICT OF DELAWARE	Trial testimony June 8, 2023
Wolfspeed, Inc. & Ideal Industries Lighting, LLC d/b/a Cree Lighting (Petitioners) v. CAO Lighting, Inc. (Patent Owner)	Expert witness for Wolfspeed	U.S. PATENT AND TRADEMARK OFFICE BEFORE THE PATENT TRIAL AND APPEAL BOARD	Deposition testimony May 15, 2023
CAO Lighting, Inc., (Plaintiff) vs. GE Lighting, Inc., General Electric Co., and Consumer Lighting (U.S.), LLC d/b/a GE Lighting (Defendants)	Expert witness for GE	UNITED STATES DISTRICT COURT DISTRICT OF DELAWARE	Jury trial testimony Feb 16, 2023
CAO Lighting, Inc., (Plaintiff) vs. GE Lighting, Inc., General Electric Co., and Consumer Lighting (U.S.), LLC d/b/a GE Lighting (Defendants)	Expert witness for GE	UNITED STATES DISTRICT COURT DISTRICT OF DELAWARE	Deposition testimony May 25, 2022
Seoul Semiconductor Co., Ltd., and Seoul Viosys Co., Ltd. (Plaintiffs/Counter-Defendants) v. Satco Products, Inc. (Defendant/Counter-Plaintiff)	Expert witness for Satco	UNITED STATES DISTRICT COURT EASTERN DISTRICT OF NEW YORK	Deposition testimony December 2, 2021
Satco Products, Inc. (Petitioner) v. Seoul Semiconductor Co., Ltd. (Patent Owner), IPR2021-00230	Expert witness for Satco	U.S. PATENT AND TRADEMARK OFFICE BEFORE THE PATENT TRIAL AND APPEAL BOARD	Deposition testimony August 20, 2021

Satco Products, Inc. (Petitioner) v. Seoul Viosys Co., Ltd. (Patent Owner), IPR2020-00750	Expert witness for Satco	U.S. PATENT AND TRADEMARK OFFICE BEFORE THE PATENT TRIAL AND APPEAL BOARD	Deposition testimony April 23, 2021
Satco Products, Inc. (Petitioner) v. Seoul Semiconductor Co., Ltd. (Patent Owner), IPR2020-00410	Expert witness for Satco	U.S. PATENT AND TRADEMARK OFFICE BEFORE THE PATENT TRIAL AND APPEAL BOARD	Deposition testimony March 4, 2021

EDUCATION

UNIVERSITY OF ILLINOIS: URBANA-CHAMPAIGN – Urbana, IL
PhD in Electrical Engineering ● Master of Science in Electrical Engineering
Research Assistant ● Solid State Devices Laboratory ● Electro-Optic Systems Laboratory Teaching Assistant ● Department of Electrical and Computer Engineering
PhD.: Native Oxidation of Area-Selective-Disordered AlGaAs-GaAs: Deep Oxide Structures for Device Applications
Master: Volume Holographic and Surface-Relief Transmission Gratings in Wavelength-Division-Multiplexing Receivers

UNIVERSITY OF TEXAS – Austin, TX
Bachelor of Science in Electrical Engineering, with High Honors
Outstanding Student Summer Program (Sandia Nationals Labs, 1988)

MIT Executive Education Courses, 2006

MEMBERSHIPS AND LEADERSHIP

● National Academy of Engineering (2025-)
● IEEE Fellow ● IEEE Consultants Network of Silicon Valley
● Chair, IEEE Nick Holonyak, Jr. Medal (2023-2024)
● IES Fellow ● University of Texas at Austin ECE Academy of Distinguished Alumni
● U.S. Department of Energy Solid-State Lighting Roundtable
● Panelist, Basic Energy Sciences Workshop on Solid-State Lighting
● Chair, SPIE Photonics West conferences on LEDs (2016-)
● Organizing Committee, Phosphor & Quantum Dots Industry Forum (2016-)
● Executive Committee, CS Mantech (2021-)

PUBLICATIONS

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25. ***History of gallium-nitride-based light-emitting diodes for illumination***; Nakamura, S., Krames, M.R.; (2013) Proceedings of the IEEE, 101 (10), art. no. 6582668, pp. 2211-2220.
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31. ***High-performance blue and green laser diodes based on nonpolar/semipolar bulk GaN substrates***; Raring, J.W., Schmidt, M.C., Poblenz, C., Li, B., Chang, Y.-C., Mondry, M.J., Lin, Y.-D., Krames, M.R., Craig, R., Speck, J.S., Denbaars, S.P., Nakamura, S.; (2011) Proceedings of SPIE - The International Society for Optical Engineering, 7939, art. no. 79390Y.
32. ***High-efficiency blue and true-green-emitting laser diodes based on non-c-plane oriented GaN substrates***; Raring, J.W., Schmidt, M.C., Poblenz, C., Chang, Y.-C., Mondry, M.J., Li, B., Iveland, J., Walters, B., Krames, M.R., Craig, R., Rudy, P., Speck, J.S., DenBaars, S.P., Nakamura, S.; (2010) Applied Physics Express, 3 (11), art. no. 112101.
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PRESENTATIONS (RECENT)

1. ***The unspoken challenge for linear fluorescent retrofits - and a solution***, Roy S.; Krames M. R.; 17th Int'l Symposium on Science & Technology of Lighting (LS:17); Toulouse, FR (2022)
2. ***UV-C LEDs for Germicidal/Virucidal Applications***, Krames M. R.; U.S. Dept. of Energy Solid-State Lighting R&D Workshop – GUV Panel; Virtual (2022)
3. ***UV-C Technology Roadmap***, Krames M. R.; Strategies In Light; Virtual (2021)
4. ***UV-C Advancements Enable Innovative Germicidal Uses Displacing Lamps In Some Scenarios***; Krames M. R.; LedsMagazine Webinar; Virtual (2021)
5. ***Ultra-Violet Germicidal Irradiation (UVGI): LEDs vs. Hg Lamps***; Krames M. R.; U.S. Dept. of Energy GUV R&D Discussion; Virtual (2020)
6. ***Converters for Illumination: New Approaches and Applications***; Krames, M.; Phosphors & Quantum Dots Industry Forum; Virtual (2020)
7. ***Gallium Nitride and the Transformation of the Lighting Industry***; Krames, M.; Stanford Optical Society Seminar; Stanford University, Stanford, CA (2020)
8. ***How LEDs are Changing the World***; Krames, M.; UT ECE Colloquia Seminar; University of Texas, Austin, TX (2018)
9. ***Status and Prospects for GaN-based LEDs l Lasers and Their Applications***; Krames, M.; Optics & Photonics International Congress: LEDIA'17; Yokohama, JP (2017)
10. ***Legacy: The Birth of Solid-State Lighting in Silicon Valley***; Krames, M.; Invited Seminar at Lumileds; San Jose, CA (2017)
11. ***The Solid-State Lighting Revolution: Technologies that will Shape the Future of Lighting***; Krames, M.; SPIE Photonics West – Panel Presentation; San Francisco, CA (2017)

12. ***The Challenge for Bulk Nitride Materials***; Krames, M.; Workshop on Ultra-Precision Processing for Wide Bandgap Semiconductors (WUPP); Monterey, CA (2017)
13. ***Status and Future Prospects for Visible-Spectrum LEDs***; Krames, M.; Society for Information Display – Display Week; San Jose, CA (2016)
14. ***LEDs for Lighting Applications: Past, Present, and Future***; Krames, M.; IEEE Photonics Society – Santa Clara Valley Chapter; Santa Clara, CA (2016)
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16. ***Opportunities for Down-Converters – Lighting Device Perspective***; Krames, M.; Phosphor Global Summit & Quantum Dot Forum; Newport Beach, CA (2016)
17. ***Challenges for Power Electronics in Solid-State Lighting***; Krames, M.; ARPA-e CIRCUITS Workshop; Washington, DC (2016)
18. ***Triumph of GaN Lighting***; Krames, M.; UC Berkeley ECE Seminar; Berkeley, CA (2015)

PATENTS (U.S. only)

1)	12,369,438	System and method for providing color light sources …
2)	12,286,576	Luminescent composition
3)	12,107,113	Var. composition ternary compound semi. alloys, structures, and devices
4)	11,879,085	Converter system
5)	RE49,677	Reusable nitride wafer, method of making, and use thereof
6)	11,725,783	Circadian-friendly LED light source
7)	11,662,067	LED lamps with improved quality of light
8)	11,611,023	System and method for selected pump LEDs with multiple phosphors
9)	11,605,618	LED array for in-plane optical interconnects
10)	11,511,071	Circadian-friendly LED light sources
11)	11,287,090	Circadian-friendly LED light source
12)	11,233,181	Converter system
13)	11,162,026	Converter system
14)	11,105,473	LED lamps with improved quality of light
15)	10,955,608	Circadian-friendly LED light sources
16)	10,900,615	Circadian-friendly LED light source
17)	10,847,625	Indium-gallium-nitride structures and devices
18)	10,830,405	Sunlight-based large area light source and large area luminaire
19)	10,700,244	System and method for selected pump LEDs with multiple phosphors
20)	10,693,041	High-performance LED fabrication
21)	10,677,981	Large area light source and large area luminaire
22)	10,557,595	LED lamps with improved quality of light
23)	10,553,754	Power light emitting diode and method with uniform current density
24)	10,529,902	Small LED source with high brightness and high efficiency
25)	10,436,422	Multi-function active accessories for LED lamps
26)	10,324,250	Circadian-friendly LED light sources
27)	10,312,422	Light emitting devices with optical elements and bonding layers
28)	10,312,404	Semi. light emitting device growing active layer on textured surface
29)	10,290,775	Luminescent ceramic for a light emitting device
30)	10,168,009	LED lamps with improved quality of light

31) 10,147,850 System and method for providing color light sources in proximity to predetermined wavelength conversion structures
32) 10,139,056 LED lamps with improved quality of light
33) 10,137,277 Circadian-friendly LED light source
34) 10,115,865 High-performance LED fabrication
35) 10,087,550 Reusable nitride wafer, method of making, and use thereof
36) 10,084,121 Small LED source with high brightness and high efficiency
37) 10,076,633 Circadian-friendly LED light source
38) 9,995,439 Glare reduced compact lens for high intensity light source
39) 9,722,148 Luminescent ceramic for a light emitting device
40) 9,677,723 LED lamps with improved quality of light
41) 9,660,152 System and method for selected pump LEDs with multiple phosphors
42) 9,653,554 Reusable nitride wafer, method of making, and use thereof
43) 9,650,723 Large area seed crystal for ammonothermal crystal growth and method
44) 9,640,724 III-nitride LED with double heterostructure light emitting region
45) 9,618,183 Apportioning optical projection paths in an LED lamp
46) 9,589,792 High quality group-III metal nitride crystals, methods of making, and methods of use
47) 9,583,683 Light emitting devices with optical elements and bonding layers
48) 9,583,678 High-performance LED fabrication
49) 9,564,553 Power LED and method with uniform current density operation
50) 9,435,525 Multi-part heat exchanger for LED lamps
51) 9,419,189 Small LED source with high brightness and high efficiency
52) 9,410,664 Circadian friendly LED light source
53) 9,368,695 LED lamps with improved quality of light
54) 9,360,190 Compact lens for high intensity light source
55) 9,359,260 Luminescent ceramic for a light emitting device
56) 9,293,667 System and method for selected pump LEDs with multiple phosphors
57) 9,293,644 Power LED and method with uniform current density operation
58) 9,267,661 Apportioning optical projection paths in an LED lamp
59) 9,117,944 Semiconductor light emitting devices grown on composite substrates
60) D736,724 LED lamp with accessory
61) D736,723 LED lamp
62) 9,046,227 LED lamps with improved quality of light
63) D730,302 Heat sink
64) 9,000,450 Grown photonic crystals in semiconductor light emitting devices
65) 8,985,794 Providing remote blue phosphors in an LED lamp
66) 8,933,644 LED lamps with improved quality of light
67) 8,911,518 Method and system for dicing substrates containing gallium and nitrogen material with conductive core via structures
68) 8,905,588 System and method for providing color light sources in proximity to predetermined wavelength conversion structures
69) 8,884,517 Illumination sources with thermally-isolated electronics
70) 8,847,252 III-nitride LED with double heterostructure light emitting region
71) 8,846,423 Bonding an optical element to a light emitting device

72) 8,748,923 Wavelength-converted semiconductor light emitting device
73) 8,748,912 Common optical element for an array of phosphor converted LEDs
74) 8,740,413 System and method for providing color light sources in proximity to predetermined wavelength conversion structures
75) 8,729,559 Method of making bulk InGaN substrates and devices thereon
76) 8,686,458 Power light emitting diode and method with current density operation
77) 8,679,869 Contact for a semiconductor light emitting device
78) 8,628,985 Light emitting devices with improved light extraction efficiency
79) 8,597,967 Method and system for dicing substrates containing gallium and nitrogen material
80) 8,502,465 Power light emitting diode and method with current density operation
81) 8,492,244 Methods for relaxation and transfer of strained layers and structures fabricated thereby
82) 8,486,771 Methods of forming relaxed layers of semi. materials, semi. structures, devices and engineered substrates including same
83) 8,482,104 Method for growth of indium-containing nitride films
84) 8,481,408 Relaxation of strained layers
85) 8,471,280 Silicone based reflective underfill and thermal coupler
86) 8,455,913 Package-integrated thin film LED
87) 8,450,754 Series connected flip chip LEDs with growth substrate removed
88) 8,445,929 Wavelength-converted semiconductor light emitting device
89) 8,415,694 Light emitting devices with improved light extraction efficiency
90) 8,334,543 III-V light emitting device including a light extracting structure
91) 8,334,155 Substrate for growing a III-V light emitting device
92) 8,288,186 Substrate for growing a III-V light emitting device
93) 8,278,674 Luminescent ceramic element for a light emitting device
94) 8,203,153 III-V light emitting device including a light extracting structure
95) 8,174,025 Semiconductor light emitting device including porous layer
96) 8,163,575 Grown photonic crystals in semiconductor light emitting devices
97) 8,153,475 Back-end processes for substrates re-use
98) 8,114,692 Light source including a wavelength-converted semi. LED and a filter
99) 8,105,852 Method of forming a composite substrate and growing a III-V light emitting device over the composite substrate
100) 8,080,828 Low profile side emitting LED with window layer and phosphor layer
101) 8,067,254 Common optical element for an array of phosphor converted LED
102) 8,062,916 Series connected flip chip LEDs with growth substrate removed
103) 8,053,905 Compliant bonding structures for semiconductor devices
104) 8,049,234 Light emitting devices with improved light extraction efficiency
105) 8,039,866 Mount for a semiconductor light emitting device
106) 7,981,767 Methods for relaxation and transfer of strained layers and structures fabricated thereby
107) 7,902,564 Multi-grain luminescent ceramics for light emitting devices
108) 7,888,691 Light source including a wavelength-converted semi. LED and a filter
109) 7,880,186 III-nitride light emitting device with DH light emitting region
110) 7,875,984 Complaint bonding structures for semiconductor devices

111)	7,875,533	Package-integrated thin film LED
112)	7,863,631	A1InGaP LED having reduced temperature dependence
113)	7,808,011	Semi. light emitting devices including in-plane light emitting layers
114)	7,804,100	Polarization-reversed III-nitride light emitting device
115)	7,791,096	Mount for a semiconductor light emitting device
116)	7,675,084	Photonic crystal light emitting device
117)	7,663,148	III-nitride light emitting device with reduced strain light emitting layer
118)	7,642,108	LED including photonic crystal structure
119)	7,626,210	Low profile side emitting LED
120)	7,601,989	LED with porous diffusing reflector
121)	7,544,525	AlInGaP LED having reduced temperature dependence
122)	7,514,721	Luminescent ceramic element for a light emitting device
123)	7,491,565	III-nitride light emitting devices fabricated by substrate removal
124)	7,488,621	Package-integrated thin film LED
125)	7,442,965	Photonic crystal light emitting device
126)	7,419,839	Bonding an optical element to a light emitting device
127)	7,408,201	Polarized semiconductor light emitting device
128)	7,402,840	Selective filtering of wavelength-converted semi. light emitting devices
129)	7,361,938	Luminescent ceramic for a light emitting device
130)	7,341,878	Wavelength-converted semiconductor light emitting device
131)	7,294,862	Photonic crystal light emitting device
132)	7,279,718	LED including photonic crystal structure
133)	7,279,345	Method of forming LEDs with improved light extraction efficiency
134)	7,268,371	Light extraction from a semiconductor LED via chip shaping
135)	7,256,483	Package-integrated thin film LED
136)	7,244,630	A1InGaP LED having reduced temperature dependence
137)	7,221,000	Reverse polarization light emitting region for a semiconductor LED
138)	7,122,839	Semiconductor LEDs with graded composition light emitting layers
139)	7,087,941	lll-phosphide light emitting devices with thin active layers
140)	7,064,355	Light emitting diodes with improved light extraction efficiency
141)	7,053,419	Light emitting diodes with improved light extraction efficiency
142)	7,026,663	Selective filtering of wavelength-converted semiconductor LEDs
143)	7,015,054	Semiconductor light emitting device and method
144)	7,012,279	Photonic crystal light emitting device
145)	6,995,389	Heterostructures for III-nitride light emitting devices
146)	6,992,334	Multi-layer highly reflective ohmic contacts for semiconductor devices
147)	6,989,555	Strain-controlled III-nitride light emitting device
148)	6,956,246	Resonant cavity III-nitride LEDs fabricated by growth substrate removal
149)	6,946,309	III-Phosphide and III-Arsenide flip chip light-emitting devices
150)	6,903,376	Selective placement of QWs in flipchip LEDs for improved light extract.
151)	6,849,472	Nitride semiconductor device with reduced polarization fields
152)	6,847,057	Semiconductor light emitting devices
153)	6,844,571	III-nitride light-emitting device with increased light generating capability
154)	6,800,500	III-nitride light emitting devices fabricated by substrate removal
155)	6,784,463	III-Phospide and III-Arsenide flip chip light-emitting devices

156) 6,744,077 Selective filtering of wavelength-converted semi. light emitting devices
157) 6,683,327 Nucleation layer for improved light extract. from light emitting devices
158) 6,649,440 Aluminum indium gallium nitride-based LED having thick epitaxial layer for improved light extraction
159) 6,646,292 Semiconductor light emitting device and method
160) 6,642,652 Phosphor-converted light emitting device
161) 6,576,488 Using electrophoresis to produce a conformally coated phosphor-converted light emitting semi.
162) 6,570,190 LED having angled sides for increased side light extraction
163) 6,525,335 Light emitting semi. devices including wafer bonded heterostructures
164) 6,521,914 III-Nitride LED with increased light generating capability
165) 6,514,782 Method of making a III-N LED with increased light generating capability
166) 6,504,171 Chirped multi-well active region LED
167) 6,486,499 III-nitride light-emitting device with increased light generating capability
168) 6,420,199 Methods for fabricating light emitting devices having aluminum gallium indium nitride structures and mirror stacks
169) 6,323,063 Forming LED having angled sides for increased side light extraction
170) 6,320,206 LEDs having wafer bonded AlGaInN structures and mirror stacks
171) 6,280,523 Thickness tailoring of wfr. bonded AlxGayInzN struct.'s by laser melting
172) 6,229,160 Light extraction from a semi. light-emitting device via chip shaping
173) 6,133,589 AlGaInN-based LED having thick epi layer for improved light extraction
174) 6,046,465 Buried reflectors for light emitters in epi. mat'l & method for producing
175) 5,779,924 Ordered interface texturing for a light emitting device
176) 5,400,354 Laminated upper cladding structure for a light-emitting device