

**IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE**

DELAWARE DISPLAY GROUP LLC §
and INNOVATIVE DISPLAY §
TECHNOLOGIES LLC, §

Plaintiffs, §

v. §

LG ELECTRONICS, INC., §

LG ELECTRONICS U.S.A., INC., §

LG DISPLAY CO., LTD., and §

LG DISPLAY AMERICA, INC., §

Defendants. §

C.A. No. 13-cv-2109-RGA

JURY TRIAL DEMANDED

PLAINTIFFS’ FIRST AMENDED COMPLAINT

Delaware Display Group LLC and Innovative Display Technologies LLC (collectively, “Plaintiffs”) by and through their undersigned counsel, file this First Amended Complaint against LG Electronics, Inc.; LG Electronics U.S.A., Inc.; LG Display Co., Ltd.; and LG Display America, Inc. (collectively, “LG”)

THE PARTIES

1. Delaware Display Group LLC (“DDG”) is a Delaware limited liability company with its principal place of business located at 2400 Dallas Parkway, Suite 200, Plano, Texas 75093.

2. Innovative Display Technologies LLC (“IDT”) is a Texas limited liability company with its principal place of business located at 2400 Dallas Parkway, Suite 200, Plano, Texas 75093.

3. Upon information and belief, LG Electronics, Inc. (“LG Electronics”) is a corporation in South Korea located at LG Twin Towers, 20, Yeouido-dong, Yeongdeungpo-gu, Seoul, 150-721, South Korea. Upon information and belief, LG Electronics may be served with

process in South Korea pursuant to the Hague Convention on the Service Abroad of Judicial and Extrajudicial Documents in Civil or Commercial Matters.

4. Upon information and belief, LG Electronics U.S.A., Inc. (“LG Electronics U.S.A.”) is a Delaware Corporation with offices at 1000 Sylvan Avenue, Englewood Cliffs, New Jersey 07632. Upon information and belief, LG Electronics U.S.A. may be served with process by serving its registered agent, United States Corporation Company, 2711 Centerville Road, Suite 400, Wilmington, Delaware 19808. Upon information and belief, LG Electronics U.S.A. is a subsidiary of LG Electronics.

5. Upon information and belief, LG Display Co., Ltd. (“LG Display”) is a corporation in South Korea located at LG U+ Bldg., Hangang-ro 3-ga, Yongsan-gu, Seoul, Korea. Upon information and belief, LG Display may be served with process in South Korea pursuant to the Hague Convention on the Service Abroad of Judicial and Extrajudicial Documents in Civil or Commercial Matters. Upon information and belief, LG Display is a subsidiary of LG Electronics.

6. Upon information and belief, LG Display America, Inc. (“LG Display America”) is a California Corporation with its principal place of business at 2540 North First Street, Suite 400, San Jose, California 95131. Upon information and belief, LG Display America may be served with process by serving its Agent for Service, Dong Hoon Han, LG Display America, Inc., 2540 North First Street, Suite 400, San Jose, California 95131. Upon information and belief, LG Display America is a subsidiary of LG Display.

7. Upon information and belief, LG has conducted and regularly conducts business within this District, has purposefully availed itself of the privileges of conducting business in this District, and has sought protection and benefit from the laws of the State of Delaware.

JURISDICTION AND VENUE

8. This action arises under the Patent Laws of the United States, 35 U.S.C. § 1, *et seq.*, including 35 U.S.C. §§ 271, 281, 283, 284, and 285. This Court has subject matter jurisdiction over this case for patent infringement under 28 U.S.C. §§ 1331 and 1338(a).

9. As further detailed herein, this Court has personal jurisdiction over LG. LG is amenable to service of summons for this action. Furthermore, personal jurisdiction over LG in this action comports with due process. LG has conducted and regularly conducts business within the United States and this District. LG has purposefully availed itself of the privileges of conducting business in the United States and, more specifically, in this District. LG has sought protection and benefit from the laws of the State of Delaware by incorporating in the state of Delaware, incorporating a subsidiary in the State of Delaware, and/or by placing infringing products into the stream of commerce through an established distribution channel with the expectation and/or knowledge that they will be purchased by consumers in this District. Plaintiffs' causes of action arise directly from LG's business contacts and other activities in this District.

10. LG – directly or through intermediaries (including distributors, retailers, and others), subsidiaries, alter egos, and/or agents – ships, distributes, offers for sale, and/or sells its products in the United States and this District. LG has purposefully and voluntarily placed one or more of its infringing products, as described below, into the stream of commerce with the expectation and/or knowledge that they will be purchased by consumers in this District. LG knowingly and purposefully ships infringing products into and within this District through an established distribution channel. These infringing products have been and continue to be purchased by consumers in this District. Upon information and belief, LG has committed the tort of patent infringement in this District and/or has induced others to commit patent infringement in this District.

11. Venue is proper in this Court under 28 U.S.C. §§ 1391(b), (c), and (d), as well as 28 U.S.C. § 1400(b), in that LG is subject to personal jurisdiction in this District, and therefore is deemed to reside in this District for purposes of venue, and, upon information and belief, LG has committed acts within this judicial District giving rise to this action and does business in this District, including but not limited to making sales in this District, providing service and support to their respective customers in this District, and/or operating an interactive website that is available to persons in this District, which website advertises, markets, and/or offers for sale infringing products.

BACKGROUND

A. The Patents-In-Suit.

12. U.S. Patent No. 7,384,177 titled “Light Emitting Panel Assemblies” (“the ’177 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on June 10, 2008, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the ’177 patent. A true and correct copy of the ’177 patent is attached as **Exhibit A** and made a part hereof.

13. U.S. Patent No. 7,404,660 titled “Light Emitting Panel Assemblies” (“the ’660 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on July 29, 2008, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the ’660 patent. A true and correct copy of the ’660 patent is attached as **Exhibit B** and made a part hereof.

14. U.S. Patent No. 7,434,973 titled “Light Emitting Panel Assemblies” (“the ’973 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on October 14, 2008, after full and fair examination. Jeffery R. Parker, Gregory A. Coghlan, and Robert M. Ezell are the inventors listed on the ’973 patent. A true and correct copy of the ’973 patent is attached as **Exhibit C** and made a part hereof.

15. U.S. Patent No. 7,434,974 titled “Light Emitting Panel Assemblies” (“the ’974 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on October 14, 2008, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the ’974 patent. A true and correct copy of the ’974 patent is attached as **Exhibit D** and made a part hereof.

16. U.S. Patent No. 7,537,370 titled “Light Emitting Panel Assemblies” (“the ’370 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on May 26, 2009, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the ’370 patent. A true and correct copy of the ’370 patent is attached as **Exhibit E** and made a part hereof.

17. U.S. Patent No. 7,914,196 titled “Light Redirecting Film Systems Having Pattern of Variable Optical Elements” (“the ’196 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on March 29, 2011, after full and fair examination. Jeffery R. Parker, Timothy A. McCollum, and Robert M. Ezell are the inventors listed on the ’196 patent. A true and correct copy of the ’196 patent is attached as **Exhibit F** and made a part hereof.

18. U.S. Patent No. 8,215,816 titled “Light Emitting Panel Assemblies” (“the ’816 patent”) was duly and legally issued by the U.S. Patent and Trademark Office on July 10, 2012, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the ’816 patent. A true and correct copy of the ’816 patent is attached as **Exhibit G** and made a part hereof.

19. The ’973 patent and the ’196 patent are collectively referred to as the “DDG patents.”

20. The ’177 patent, the ’660 patent, the ’974 patent, the ’370 patent, and the ’816 patent are collectively referred to as the “IDT patents.” Together, the “DDG patents” and the “IDT patents” are the “patents-in-suit.”

21. On June 26, 2013, IDT was assigned all of the right, title, and interest in the IDT patents, including the exclusive right to sue and collect for its own use and benefit all claims for damages by reason of past infringement or use of the IDT patents.

22. On December 20, 2013, DDG was assigned all of the right, title, and interest in the DDG patent, including the exclusive right to sue and collect for its own use and benefit all claims for damages by reason of past infringement or use of the DDG patent.

23. The patents-in-suit all share the same ultimate parent patent, U.S. Patent No. 5,613,751. The patents-in-suit share inventors, subject matter, and claim terms. The accused products infringe the Patents-in-Suit based on the use of the same technology, *i.e.*, backlights for LCD displays. And IDT and DDG share a common corporate parent.

B. LG's Infringing Conduct.

24. Upon information and belief, LG makes, uses, offers to sell, and/or sells within, and/or imports into the United States display products that use the fundamental technologies covered by the patents-in-suit. Upon information and belief, the infringing display products include, but are not limited to, mobile phones, tablets, televisions, and monitors with an LCD. By way of example only, Plaintiffs identify the Optimus E970 mobile phone as an infringing product of the patents-in-suit.

25. By incorporating the fundamental inventions covered by the patents-in-suit, LG can make improved products, including but not limited to, products with longer displays, thinner displays, and/or displays with a higher light output, a more uniform light output, a lower power requirement, and/or a longer battery life.

26. Upon information and belief, third-party distributors purchase and have purchased LG's infringing display products for sale or importation into the United States, including this

District. Upon information and belief, third-party consumers use and have used LG's infringing display products in the United States, including this District.

27. Upon information and belief, LG has purchased infringing display products that are made, used, offered for sale, sold within, and/or imported into the United States, including this District by third party manufacturers, distributors, and/or importers.

COUNT I

Patent Infringement of U.S. Patent No. 7,384,177

28. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-27 as though fully set forth herein.

29. The '177 patent is valid and enforceable.

30. LG has never been licensed, either expressly or impliedly, under the '177 patent.

31. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, IDT has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, IDT surmises that any express licensees of the '177 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '177 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

32. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '177 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '177 patent, including but not limited to mobile phones,

tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '177 patent.

33. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '177 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '177 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

34. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '177 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '177 patent by making, offering to sell, and/or selling (directly or through intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

35. Upon information and belief, LG had knowledge of the '177 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

36. Upon information and belief, since at least the above-mentioned date when IDT formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '177 patent, including but

not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '177 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '177 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

37. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of IDT and its licensees to practice the '177 patent, for which IDT is entitled to at least a reasonable royalty.

COUNT II

Patent Infringement of U.S. Patent No. 7,404,660

38. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-37 as though fully set forth herein.

39. The '660 patent is valid and enforceable.

40. LG has never been licensed, either expressly or impliedly, under the '660 patent.

41. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, IDT has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, IDT surmises that any express licensees of the '660 patent have complied with the marking requirements of 35

U.S.C. § 287 by placing a notice of the '660 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

42. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '660 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '660 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '660 patent.

43. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '660 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '660 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

44. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '660 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '660 patent by making, offering to sell, and/or selling (directly or through

intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

45. Upon information and belief, LG had knowledge of the '660 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

46. Upon information and belief, since at least the above-mentioned date when IDT formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '660 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '660 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '660 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

47. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of IDT and its licensees to practice the '660 patent, for which IDT is entitled to at least a reasonable royalty.

COUNT III

Patent Infringement of U.S. Patent No. 7,434,973

48. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-47 as though fully set forth herein.

49. The '973 patent is valid and enforceable.

50. LG has never been licensed, either expressly or impliedly, under the '973 patent.

51. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, DDG has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, DDG surmises that any express licensees of the '973 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '973 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

52. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '973 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '973 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '973 patent.

53. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '973 patent,

including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '973 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

54. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '973 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '973 patent by making, offering to sell, and/or selling (directly or through intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

55. Upon information and belief, LG had knowledge of the '973 patent and its infringing conduct at least since the filing of this amended complaint, when LG was formally placed on notice of its infringement.

56. Upon information and belief, since at least the above-mentioned date when DDG formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '973 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '973 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '973 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors,

importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

57. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of DDG and its licensees to practice the '973 patent, for which DDG is entitled to at least a reasonable royalty.

COUNT IV

Patent Infringement of U.S. Patent No. 7,434,974

58. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-57 as though fully set forth herein.

59. The '974 patent is valid and enforceable.

60. LG has never been licensed, either expressly or impliedly, under the '974 patent.

61. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, IDT has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, IDT surmises that any express licensees of the '974 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '974 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

62. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '974 patent by making,

using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '974 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '974 patent.

63. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '974 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '974 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

64. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '974 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '974 patent by making, offering to sell, and/or selling (directly or through intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

65. Upon information and belief, LG had knowledge of the '974 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

66. Upon information and belief, since at least the above-mentioned date when IDT formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '974 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '974 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '974 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

67. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of IDT and its licensees to practice the '974 patent, for which IDT is entitled to at least a reasonable royalty.

COUNT V

Patent Infringement of U.S. Patent No. 7,537,370

68. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-67 as though fully set forth herein.

69. The '370 patent is valid and enforceable.

70. LG has never been licensed, either expressly or impliedly, under the '370 patent.

71. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, IDT has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, IDT surmises that any express licensees of the '370 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '370 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

72. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '370 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '370 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '370 patent.

73. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '370 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '370 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

74. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '370 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '370 patent by making, offering to sell, and/or selling (directly or through intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

75. Upon information and belief, LG had knowledge of the '370 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

76. Upon information and belief, since at least the above-mentioned date when IDT formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '370 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '370 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '370 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these

products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

77. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of IDT and its licensees to practice the '370 patent, for which IDT is entitled to at least a reasonable royalty.

COUNT VI

Patent Infringement of U.S. Patent No. 7,914,196

78. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-77 as though fully set forth herein.

79. The '196 patent is valid and enforceable.

80. LG has never been licensed, either expressly or impliedly, under the '196 patent.

81. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, DDG has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, DDG surmises that any express licensees of the '196 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '196 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

82. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '196 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '196 patent, including but not limited to mobile phones,

tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '196 patent.

83. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '196 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '196 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

84. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '196 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '196 patent by making, offering to sell, and/or selling (directly or through intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

85. Upon information and belief, LG had knowledge of the '196 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

86. Upon information and belief, since at least the above-mentioned date when DDG formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '196 patent, including but

not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '196 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '196 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

87. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of DDG and its licensees to practice the '196 patent, for which DDG is entitled to at least a reasonable royalty.

COUNT VII

Patent Infringement of U.S. Patent No. 8,215,816

88. Plaintiffs repeat and re-allege each and every allegation of paragraphs 1-87 as though fully set forth herein.

89. The '816 patent is valid and enforceable.

90. LG has never been licensed, either expressly or impliedly, under the '816 patent.

91. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, IDT has complied with the requirements of that statute by providing actual or constructive notice to LG of its alleged infringement. Upon information and belief, IDT surmises that any express licensees of the '816 patent have complied with the marking requirements of 35

U.S.C. § 287 by placing a notice of the '816 patent on all goods made, offered for sale, sold within, and/or imported into the United States that embody one or more claims of that patent.

92. Upon information and belief, LG has been and is directly infringing under 35 U.S.C. § 271(a), either literally or under the doctrine of equivalents, and/or indirectly infringing, by way of inducement with specific intent under 35 U.S.C. § 271(b), the '816 patent by making, using, offering to sell, and/or selling to third-party distributors, and/or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, without authority, display products that include all of the limitations of one or more claims of the '816 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, their display components, and/or other products made, used, sold, offered for sale, or imported by LG that include all of the limitations of one or more claims of the '816 patent.

93. Upon information and belief, distributors and consumers that purchase LG's display products that include all of the limitations of one or more claims of the '816 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '816 patent by using, offering to sell, and/or selling to third-party distributors or consumers (directly or through intermediaries and/or subsidiaries) in this District and elsewhere within the United States and/or importing into the United States, those infringing display products.

94. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to LG that include all of the limitations of one or more claims of the '816 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '816 patent by making, offering to sell, and/or selling (directly or through

intermediaries and/or subsidiaries) infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

95. Upon information and belief, LG had knowledge of the '816 patent and its infringing conduct at least since the filing of this lawsuit, when LG was formally placed on notice of its infringement.

96. Upon information and belief, since at least the above-mentioned date when IDT formally placed LG on notice of its infringement, LG has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers that purchase or sell display products that include all of the limitations of one or more claims of the '816 patent, including but not limited to mobile phones, tablets, televisions, and monitors with an LCD, to directly infringe one or more claims of the '816 patent. Since at least the notice provided on the above-mentioned date, LG does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '816 patent. Upon information and belief, LG intends to cause, and has taken affirmative steps to induce, infringement by these third-party manufacturers, distributors, importers, and/or consumers by, *inter alia*, creating advertisements that promote the infringing use of display products, creating established distribution channels for these products into and within the United States, purchasing these products, manufacturing these products in conformity with U.S. laws and regulations, distributing or making available instructions or manuals for these products to purchasers and prospective buyers, and/or providing technical support, replacement parts, or services for these products to these purchasers in the United States.

97. As a direct and proximate result of these acts of patent infringement, LG has encroached on the exclusive rights of IDT and its licensees to practice the '816 patent, for which IDT is entitled to at least a reasonable royalty.

CONCLUSION

98. Plaintiffs are entitled to recover from LG the damages sustained by Plaintiffs as a result of LG's wrongful acts in an amount subject to proof at trial, which, by law, cannot be less than a reasonable royalty, together with interest and costs as fixed by this Court.

99. Plaintiffs have incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and Plaintiffs are entitled to recover their reasonable and necessary attorneys' fees, costs, and expenses.

JURY DEMAND

100. Plaintiffs hereby request a trial by jury pursuant to Rule 38 of the Federal Rules of Civil Procedure.

PRAYER FOR RELIEF

101. Plaintiffs respectfully request that the Court find in its favor and against LG, and that the Court grant Plaintiffs the following relief:

- A. A judgment that LG has infringed the patents-in-suit as alleged herein, directly and/or indirectly by way of inducing infringement of such patents;
- B. A judgment for an accounting of all damages sustained by Plaintiffs as a result of the acts of infringement by LG;
- C. A judgment and order requiring LG to pay Plaintiffs damages under 35 U.S.C. § 284 and any royalties determined to be appropriate;
- D. A permanent injunction enjoining LG and its officers, directors, agents, servants, employees, affiliates, divisions, branches, subsidiaries, parents and all others acting

in concert or privity with them from direct and/or indirect infringement of the patents-in-suit pursuant to 35 U.S.C. § 283;

- E. A judgment and order requiring LG to pay Plaintiffs pre-judgment and post-judgment interest on the damages awarded;
- F. A judgment and order finding this to be an exceptional case and requiring LG to pay the costs of this action (including all disbursements) and attorneys' fees as provided by 35 U.S.C. § 285; and
- G. Such other and further relief as the Court deems just and equitable.

Dated: May 4, 2015

Respectfully submitted,

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EXHIBIT A

(12) **United States Patent**
Parker

(10) **Patent No.:** **US 7,384,177 B2**
(45) **Date of Patent:** **Jun. 10, 2008**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

(75) Inventor: **Jeffery R. Parker**, Richfield, OH (US)

(73) Assignee: **Solid State Opto Limited** (VG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 282 days.

(21) Appl. No.: **11/244,544**

(22) Filed: **Oct. 6, 2005**

(65) **Prior Publication Data**

US 2006/0028817 A1 Feb. 9, 2006

Related U.S. Application Data

(60) Division of application No. 10/784,527, filed on Feb. 23, 2004, now Pat. No. 7,160,015, which is a division of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481, which is a continuation-in-part of application No. 08/778,089, filed on Jan. 2, 1997, now Pat. No. 6,079,838, which is a division of application No. 08/495,176, filed on Jun. 27, 1995, now Pat. No. 5,613,751.

(51) **Int. Cl.**
F21V 7/04 (2006.01)

(52) **U.S. Cl.** **362/601; 362/612; 362/613; 362/623; 362/609; 362/231**

(58) **Field of Classification Search** **362/601, 362/602, 603, 606, 607, 612, 613, 618, 619, 362/620, 623-627, 231, 26, 609**
See application file for complete search history.

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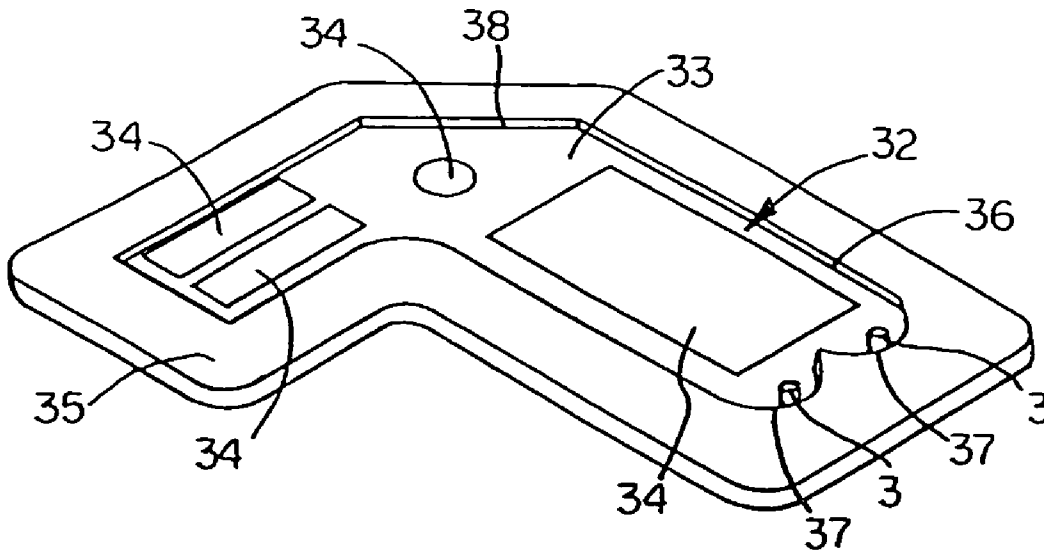
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Primary Examiner—Thomas M. Sember
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

Light emitting assemblies include a tray that forms a cavity or recess containing one or more light sources. A sheet, film or substrate is positioned over the cavity or recess for controlling the light emitted from the assembly. The tray acts as a back, side or edge reflector, and has one or more secondary reflective or refractive surfaces.

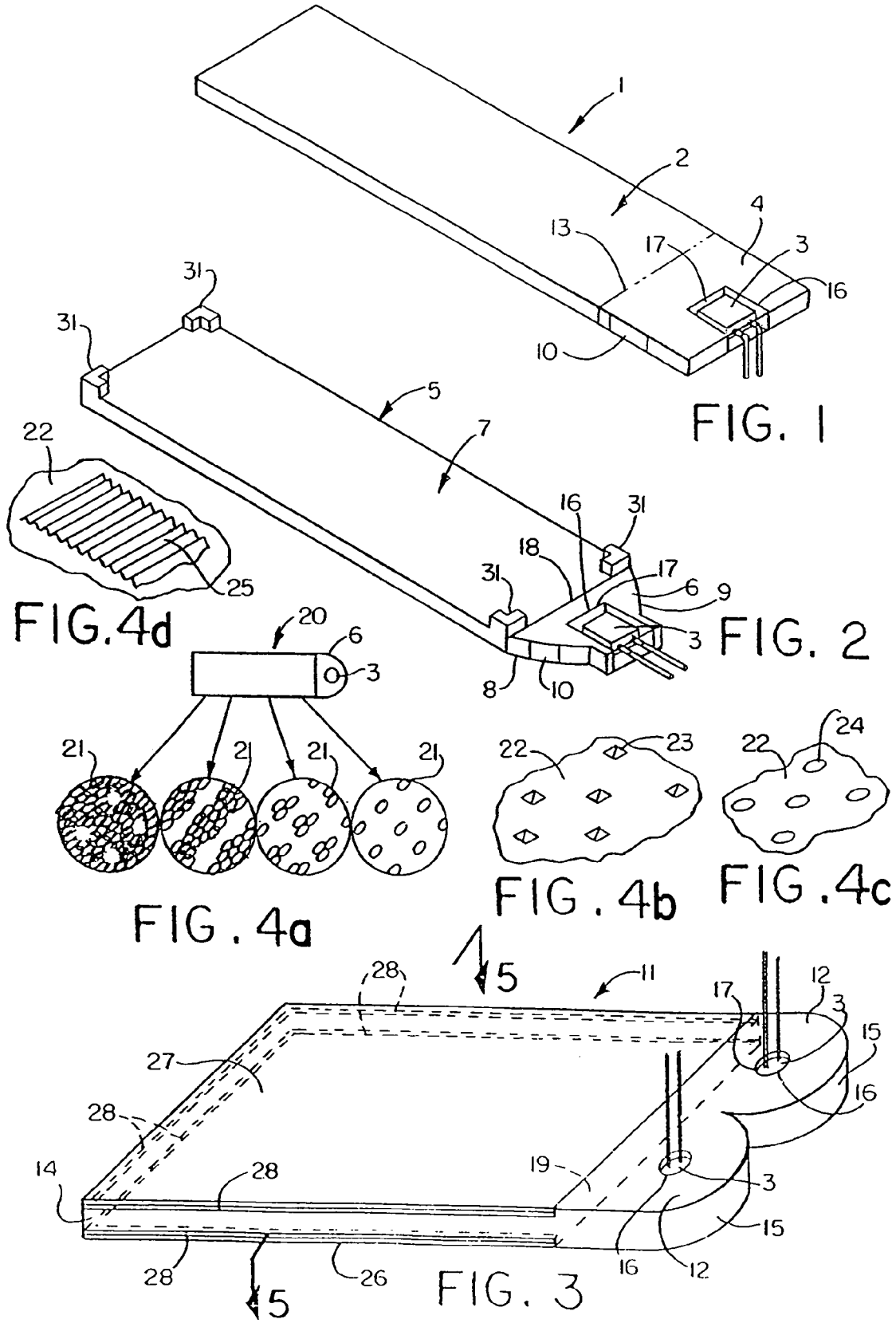
27 Claims, 4 Drawing Sheets

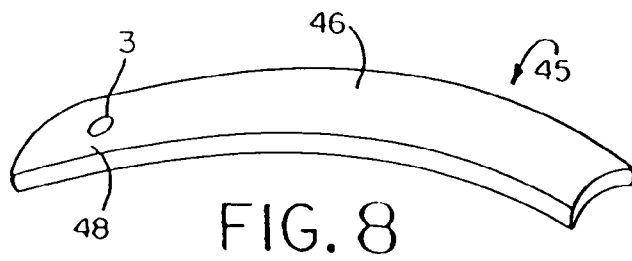
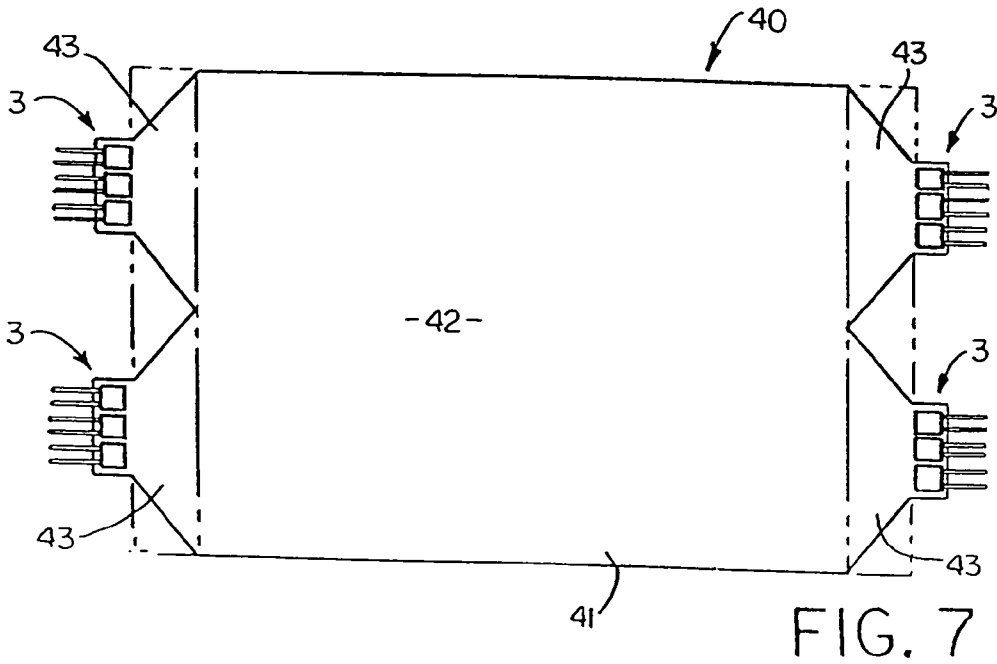
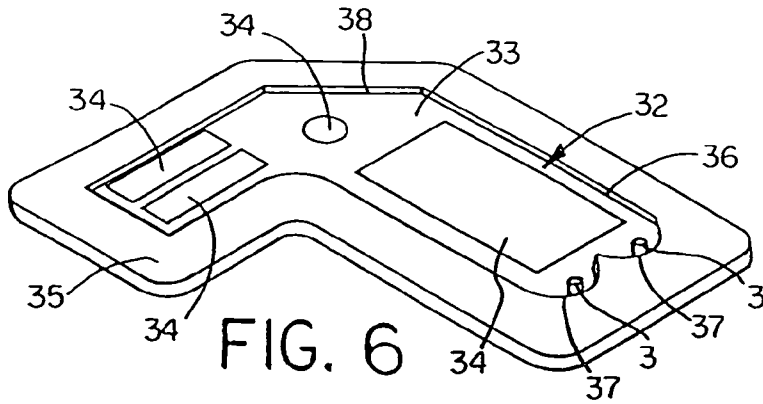
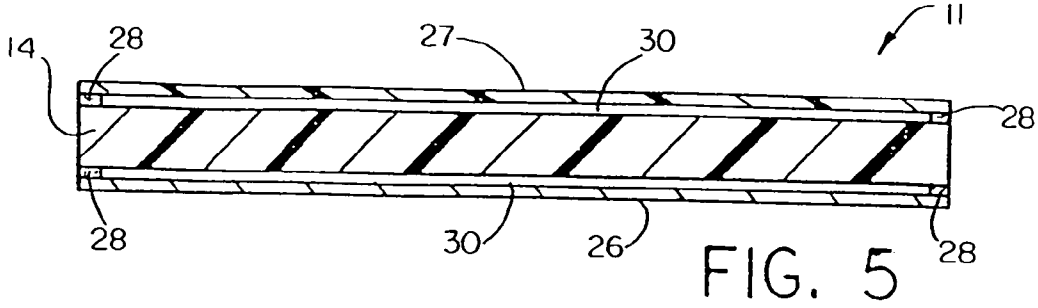


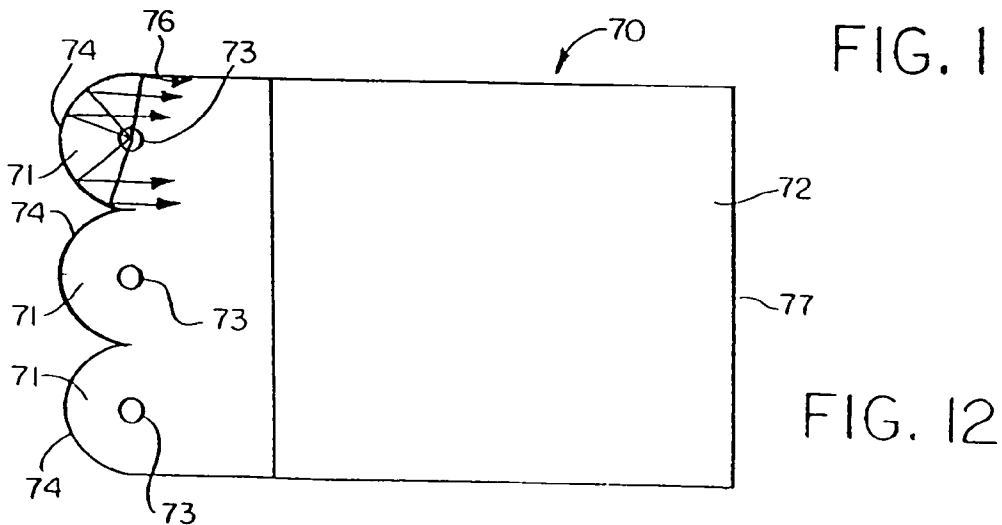
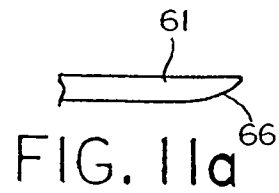
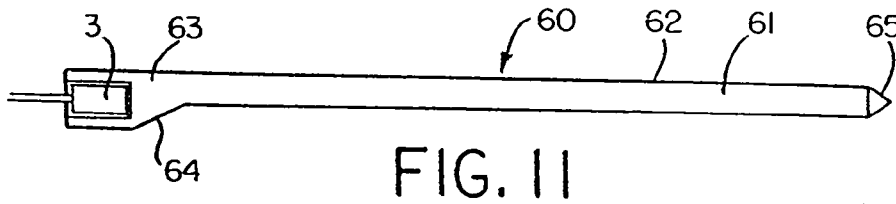
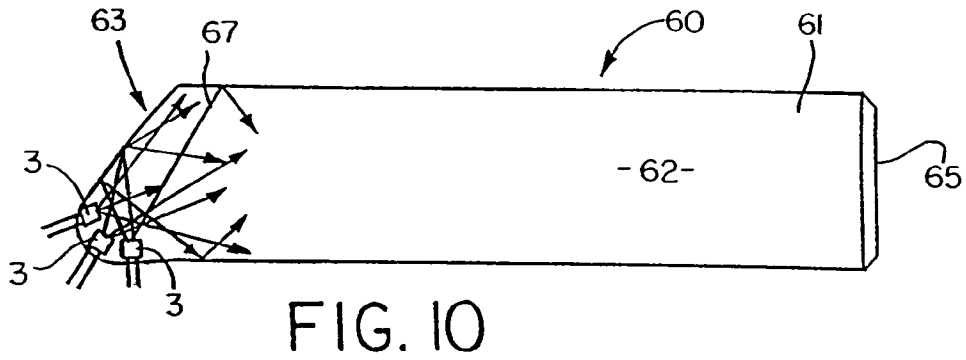
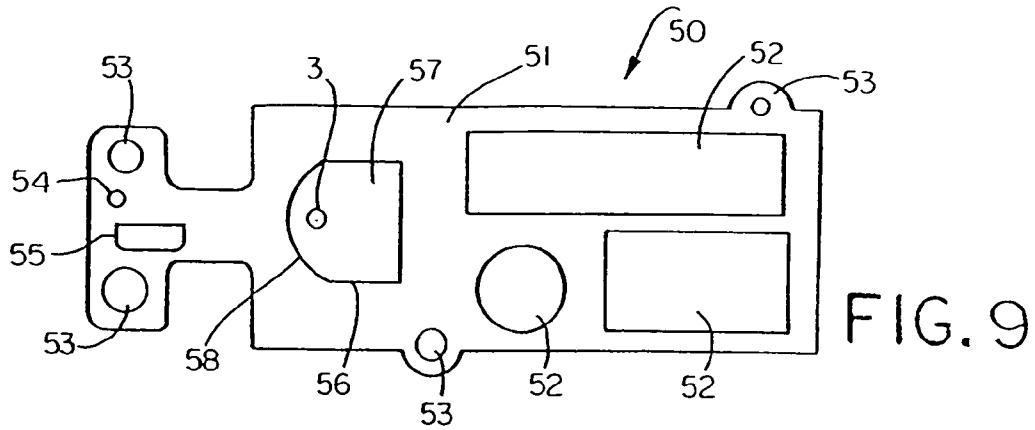
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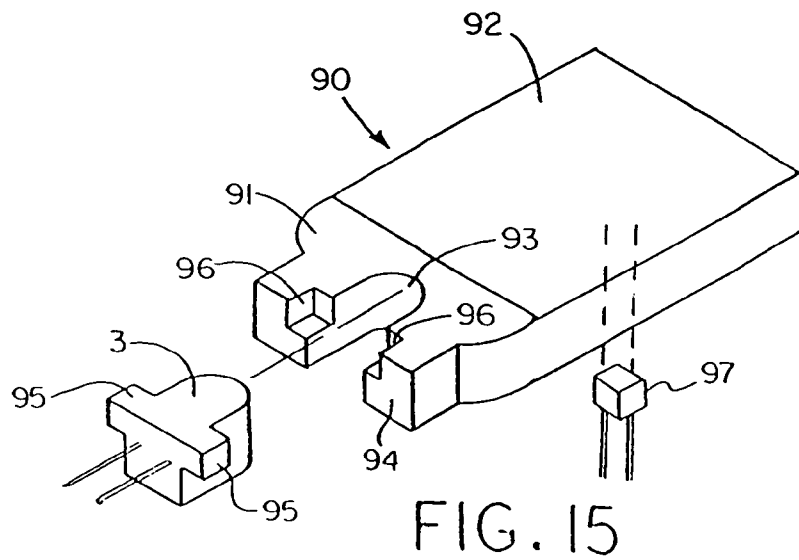
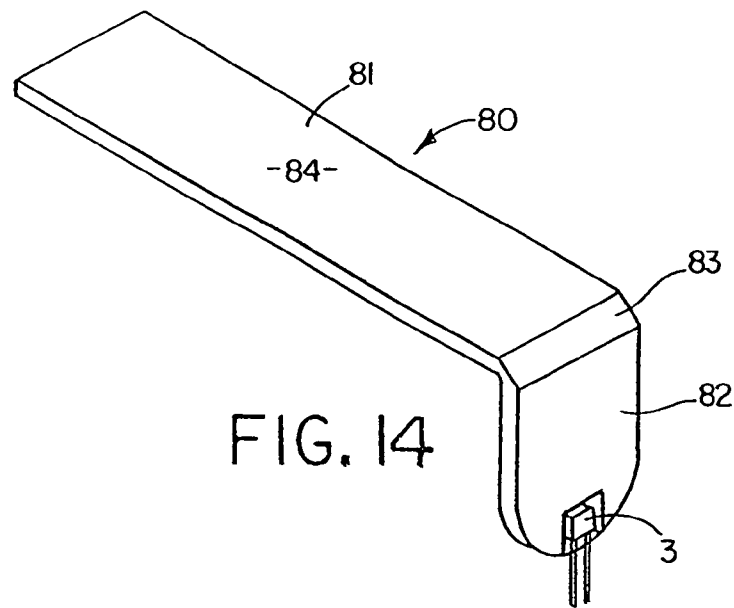
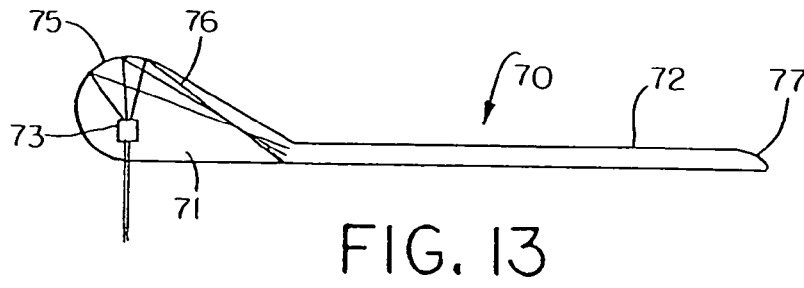
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LIGHT EMITTING PANEL ASSEMBLIES**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a division of U.S. patent application Ser. No. 10/784,527, filed Feb. 23, 2004 now U.S. Pat. No. 7,160,015, which is a division of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 08/778,089, filed Jan. 2, 1997, now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a division of U.S. patent application Ser. No. 08/495,176, filed Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25, 1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emitting panel assemblies each including a transparent panel member for efficiently conducting light, and controlling the light conducted by the panel member to be emitted from one or more light output areas along the length thereof.

Light emitting panel assemblies are generally known. However, the present invention relates to several different light emitting panel assembly configurations which provide for better control of the light output from the panel assemblies and for more efficient utilization of light, which results in greater light output from the panel assemblies.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light emitting panel assemblies include a light emitting panel member having a light transition area in which at least one light source is suitably mounted for transmission of light to the light input surface of the panel member.

In accordance with another aspect of the invention, the light source is desirably embedded, potted or bonded to the light transition area to eliminate any air gaps, decrease surface reflections and/or eliminate any lens effect between the light source and light transition area, thereby reducing light loss and increasing the light output from the panel assembly.

In accordance with another aspect of the invention, the panel assemblies may include reflective or refractive surfaces for changing the path of a portion of the light, emitted from the light source, that would not normally enter the panel members at an acceptable angle that allows the light to remain in the panel members for a longer period of time and/or increase the efficiency of the panel members.

In accordance with another aspect of the invention, the light emitting panel members include a pattern of light extracting deformities or disruptions which provide a desired light output distribution from the panel members by changing the angle of refraction of a portion of the light from one or more light output areas of the panel members.

In accordance with still another aspect of the invention, the light source may include multiple colored light sources for supplying light to one or more light output areas, and for providing a colored or white light output distribution.

In accordance with yet another aspect of the invention, the panel assemblies include a transition area for mixing the multiple colored lights, prior to the light entering the panel members, in order to effect a desired colored or white light output distribution.

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The various light emitting panel assemblies of the present invention are very efficient panel assemblies that may be used to produce increased uniformity and higher light output from the panel members with lower power requirements, and allow the panel members to be made thinner and/or longer, and/or of various shapes and sizes.

To the accomplishment of the foregoing and related ends, the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three different forms of light emitting panel assemblies in accordance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light output area of a panel assembly showing one form of pattern of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views of a portion of a light output area of a panel assembly showing other forms of light extracting deformities formed in or on the light output area;

FIG. 5 is an enlarged transverse section through the light emitting panel assembly of FIG. 3 taken generally on the plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 7 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 9 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of light emitting panel assembly in accordance with this invention;

FIG. 11 is a side elevation view of the light emitting panel assembly of FIG. 10;

FIG. 11a is a fragmentary side elevation view showing a tapered or rounded end on the panel member in place of the prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 13 is a schematic side elevation view of the light emitting panel assembly of FIG. 12; and

FIGS. 14 and 15 are schematic perspective views of still other forms of light emitting panel assemblies in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in detail to the drawings, and initially to FIG. 1, there is schematically shown one form of light emitting panel assembly 1 in accordance with this invention including a transparent light emitting panel 2 and one or

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more light sources 3 which emit light in a predetermined pattern in a light transition member or area 4 used to make the transition from the light source 3 to the light emitting panel 2, as well known in the art. The light that is transmitted by the light transition area 4 to the transparent light emitting panel 2 may be emitted along the entire length of the panel or from one or more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. 1 the light transition area 4 is shown as an integral extension of one end of the light emitting panel 2 and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area 4 may be a separate piece suitably attached to the light input surface 13 of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. 2 shows another form of light emitting panel assembly 5 in accordance with this invention including a panel light transition area 6 at one end of the light emitting panel 7 with sides 8, 9 around and behind the light source 3 shaped to more efficiently reflect and/or refract and focus the light emitted from the light source 3 that impinges on these surfaces back through the light transition area 6 at an acceptable angle for entering the light input surface 18 at one end of the light emitting panel 7. Also, a suitable reflective material or coating 10 may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. 1 and 2 on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

The panel assemblies shown in FIGS. 1 and 2 include a single light source 3, whereas FIG. 3 shows another light emitting panel assembly 11 in accordance with this invention including two light sources 3. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly 11 of FIG. 3 includes a light transition area 12 at one end of the light emitting panel 14 having reflective and/or refractive surfaces 15 around and behind each light source 3. These surfaces 15 may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas 12 into the light input surface 19 of the light emitting panel 14.

The light sources 3 may be mechanically held in any suitable manner in slots, cavities or openings 16 machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources 3 are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bonding the light sources 3 in the slots, cavities

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or openings 16 in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material 17. The slots, cavities or openings 16 may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultrasonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source 3 may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources 3 may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources 3 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. 4a schematically shows one such light surface area 20 on which a pattern of light extracting deformities or disruptions 21 is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities 21 shown in FIG. 4a includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities 21 are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions 21 can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning the sheet or film against one or both sides

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of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformities 21 may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities 21 may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source 3 thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities 21 may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display backlight, the light output will be more efficient if the deformities 21 cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities 21 may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity 21 coverage. Moreover, the pattern of light extracting deformities 21 may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities 21 may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes 21 in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities 21 shown in FIG. 4a, other light extracting

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deformities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. 4b and 4c show panel areas 22 on which prismatic surfaces 23 or depressions 24 are formed in the panel areas, whereas FIG. 4d shows prismatic or other reflective or refractive surfaces 25 formed on the exterior of the panel area. The prismatic surfaces, depressions or raised surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. 5, a back reflector (including trans reflectors) 26 may be attached or positioned against one side of the panel member 14 of FIG. 3 using a suitable adhesive 28 or other method in order to improve light output efficiency of the panel assembly 11 by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities 21, 23, 24 and/or 25 may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate 27 may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive 28 or other method in order to produce a desired effect.

The member 27 may be used to further improve the uniformity of the light output distribution. For example, the member 27 may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive 28 is used to adhere the back reflector 26 and/or film 27 to the panel, the adhesive is preferably applied only along the side edges of the panel, and if desired the end edge opposite the light transition areas 12, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps 30 (see FIG. 5) which are formed between the respective panel surfaces and the back reflector 26 and/or film 27 when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps 30 are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. 2, the panel assembly 5 shown therein also includes molded posts 31 at one or more corners of the panel 7 (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. 6 shows another form of light emitting panel assembly 32 in accordance with this invention including a panel member 33, one or more light sources 3, and one or more light output areas 34. In addition, the panel assembly 32 includes a tray 35 having a cavity or recess 36 in which the panel assembly 32 is received. The tray 35 may act as a back

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reflector as well as end edge and/or side edge reflectors for the panel 33 and side and/or back reflectors 37 for the light sources 3. Additionally, one or more secondary reflective or refractive surfaces 38 may be provided on the panel member 33 and/or tray 35 to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member 33. These secondary reflective/refractive surfaces 38 may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a predetermined pattern. FIG. 6 also shows multiple light output areas 34 on the panel member that emit light from one or more light sources 3.

FIG. 7 is a schematic illustration of still another form of light emitting panel assembly 40 in accordance with this invention including a panel member 41 having one or more light output areas 42 and one or more light transition areas (mixing areas) 43 containing a plurality of light sources 3 at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources 3 desirably employs three colored LEDs (red, blue, green) in each transition mixing area 43 so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area 42. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. 8 shows yet another form of light emitting panel assembly 45 in accordance with this invention including a light emitting panel member 46 and a light source 3 in a light transition area 48 integral with one end of the panel member. In this particular embodiment, the panel member 46 is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. 9 schematically shows another form of light emitting panel assembly 50 in accordance with this invention, including a panel member 51 having multiple light output areas 52, and mounting posts and/or mounting tabs 53. This particular panel assembly 50 may serve as a structural member to support other parts or components as by providing holes or cavities 54, 55 in the panel member 51 which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess 56 may be provided in the panel member 51 for receipt of a correspondingly shaped light transition area 57 having one or more light sources 3 embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface 58 on the transition area 57 and/or wall of the cavity or recess 56 to redirect a portion of the light in a predetermined manner. In this way the light transition area 57 and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector 58 may be placed on the reflective or refractive surface of the cavity or recess 56 or insert 57. Where the reflector 58 is placed on the reflective or refractive surface of the cavity or recess 56, the cavity or recess may act as a mold permitting transparent material from which the transition area 57 is made to be cast around one or more light sources 3.

FIGS. 10 and 11 schematically show another form of light emitting panel assembly 60 in accordance with this inven-

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tion including a panel member 61 having one or more light output areas 62. In this particular embodiment, an off-axis light transition area 63 is provided that is thicker in cross section than the panel member to permit use of one or more light sources 3 embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface 64 (FIG. 11) may be provided on the transition area 63. Moreover, a prism 65 (FIG. 11) or tapered, rounded, or otherwise shaped end 66 (FIG. 11a) may be provided at the end of the panel opposite the light sources 3 to perform the function of an end reflector. The light sources 3 may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays 67 in the transition area 63 as schematically shown in FIG. 10 and/or to permit a shorter length transition area 63 to be used.

FIGS. 12 and 13 schematically show still another form of light emitting panel assembly 70 in accordance with this invention which includes one or more light transition areas 71 at one or both ends of the panel member 72 each containing a single light source 73. The transition area or areas 71 shown in FIGS. 12 and 13 collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area 71 shown in FIGS. 12 and 13 has elliptical and parabolic shape surfaces 74 and 75 in different planes for directing the light rays 76 into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. 14 schematically illustrates still another form of light emitting panel assembly 80 in accordance with this invention including a light emitting panel 81 and one or more light sources 3 positioned, embedded, potted, bonded or otherwise mounted in a light transition area 82 that is at an angle relative to the panel member 81 to permit more efficient use of space. An angled or curved reflective or refractive surface 83 is provided at the junction of the panel member 81 with the transition area 82 in order to reflect/refract light from the light source 3 into the body of the panel member 81 for emission of light from one or more light emitting areas 84 along the length of the panel member.

FIG. 15 schematically illustrates still another form of light emitting panel assembly 90 in accordance with this invention including a light transition area 91 at one or both ends of a light emitting panel member 92 containing a slot 93 for sliding receipt of an LED or other suitable light source 3. Preferably the slot 93 extends into the transition area 91 from the back edge 94, whereby the light source 3 may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source 3 may be provided with wings, tabs or other surfaces 95 for engagement in correspondingly shaped recesses or grooves 96 or the like in the transition area 91 for locating and, if desired, securing the light source in place. Also, the light source 3 may be embedded, potted, bonded or otherwise secured within the slot 93 in the light transition area 91 of the panel member 92. Light from a secondary light source 97 may be projected through the panel member 92 for indication or some other effect.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example LCD back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, membrane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members.

Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting assembly comprising a tray having a back wall and continuous side walls that form a hollow cavity or recess completely surrounded by the side walls, at least one light source located, mounted or positioned in the cavity or recess, and at least one sheet, film or substrate overlying the assembly for controlling the light emitted from the assembly to fit a particular application, wherein the tray acts as at least one of a back, side edge, and end edge reflector and has one or more secondary flat, angled, faceted or curved reflective or refractive surfaces to redirect at least a portion of the light emitted by the light source in a predetermined manner within the cavity or recess.

2. The assembly of claim 1 wherein the refractive or reflective surfaces are flat, planar or curved.

3. The assembly of claim 1 wherein the refractive or reflective surfaces are prismatic or lenticular surfaces.

4. The assembly of claim 1 wherein the refractive or reflective surfaces are quite small compared to the length and width of the tray.

5. The assembly of claim 1 wherein the refractive or reflective surfaces are in close proximity to and around and behind the light source.

6. The assembly of claim 1 wherein there are at least two light sources located, mounted or positioned in the cavity or recess.

7. The assembly of claim 6 wherein each light source is positioned in close proximity to a group of the refractive or reflective surfaces.

8. The assembly of claim 6 wherein the at least two light sources are different color LEDs.

9. The assembly of claim 6 wherein a portion of the light emitted from the light sources mixes in the cavity or recess.

10. The assembly of claim 9 wherein the sheet, film or substrate provides additional light mixing.

11. The assembly of claim 6 wherein the reflective or refractive surfaces promote mixing of the light from two or more light sources.

12. The assembly of claim 6 wherein there is at least one refractive or reflective surface corresponding to each light source.

13. The assembly of claim 1 wherein there is at least one sheet, film or substrate that is a diffuser, colored film or filter, label, transparent or semi-transparent overlay, label or display, reflector, polarizer or reflective polarizer.

14. The assembly of claim 1 wherein the at least one sheet, film or substrate has deformities for controlling the light output ray angle distribution to fit a particular application.

15. A light emitting assembly comprising a tray having a back wall and continuous side walls that form a hollow cavity or recess completely surrounded by the side walls, at least two light sources located, mounted or positioned in the cavity or recess, and at least one sheet, film or substrate overlying the assembly for controlling the light emitted from the assembly to fit a particular application, wherein the tray acts as at least one of a back, side edge and end edge reflector and has at least one secondary flat, angled, faceted or curved reflective or refractive surface to facilitate better mixing of light rays within the cavity or recess to produce a desired light output color or uniformity.

16. The assembly of claim 15 wherein at least some of the light sources are different colored light sources.

17. The assembly of claim 16 wherein the secondary reflective or refractive surface promotes mixing of different color light to make white light.

18. The assembly of claim 15 wherein multiple light sources contain at least one light source of each of the colors red, green and blue.

19. The assembly of claim 15 wherein at least some of the light sources are LEDs.

20. The assembly of claim 19 wherein at least some of the LEDs have multiple chips of different colors.

21. The assembly of claim 15 wherein there is at least one sheet, film or substrate that is a diffuser, colored film or filter, label, transparent or semi-transparent overlay, reflector, polarizer or reflective polarizer.

22. The assembly of claim 15 wherein the sheet, film or substrate is comprised of multiple layers.

23. The assembly of claim 15 wherein there is at least one sheet, film or substrate that has deformities on at least one surface to control the light output ray angle distribution to fit a particular application.

24. The assembly of claim 23 wherein the deformities are depressions or raised surfaces.

25. The assembly of claim 23 wherein the deformities are prismatic or lenticular.

26. The assembly of claim 23 wherein the deformities vary or are random.

27. The assembly of claim 23 wherein at least some of the deformities are paints, inks or coatings.

EXHIBIT B

(12) **United States Patent**
Parker

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(45) **Date of Patent:** **Jul. 29, 2008**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

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(73) Assignee: **Solid State Opto Limited** (VG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Related U.S. Application Data

(60) Division of application No. 10/784,527, filed on Feb. 23, 2004, now Pat. No. 7,160,015, which is a division of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481, which is a continuation-in-part of application No. 08/778,089, filed on Jan. 2, 1997, now Pat. No. 6,079,838, which is a division of application No. 08/495,176, filed on Jun. 27, 1995, now Pat. No. 5,613,751.

(51) **Int. Cl.**

F21V 7/04 (2006.01)

(52) **U.S. Cl.** **362/613**; 362/26; 362/551; 362/606; 362/612

(58) **Field of Classification Search** 362/26, 362/551, 602, 606, 612, 613
See application file for complete search history.

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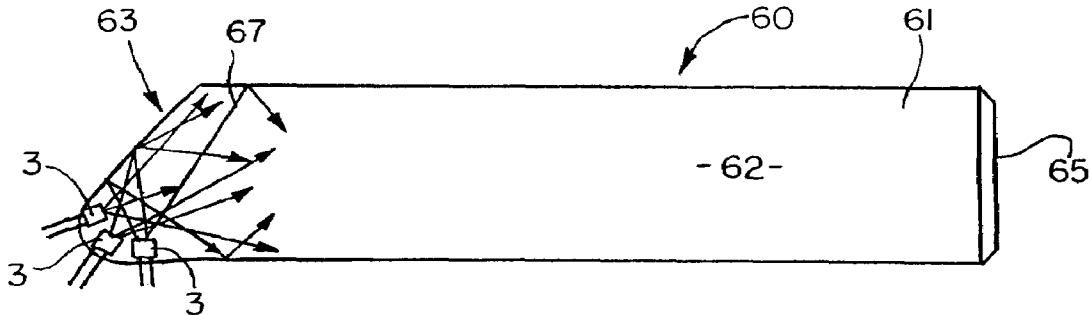
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(57) **ABSTRACT**

Light emitting assemblies include a generally planar optical conductor having at least one input edge with a greater cross-sectional width than thickness and at least one light source having a light output distribution with a greater width component than height component positioned adjacent to the input edge for directing light into the optical conductor and emission of the light from at least one output region of the optical conductor. A transition region is disposed between the light source and output region that is configured to spread and transmit the light by the light source to the output region. A plurality of faceted surfaces in close proximity to the light source maximize or otherwise change the light emitted from the light source.

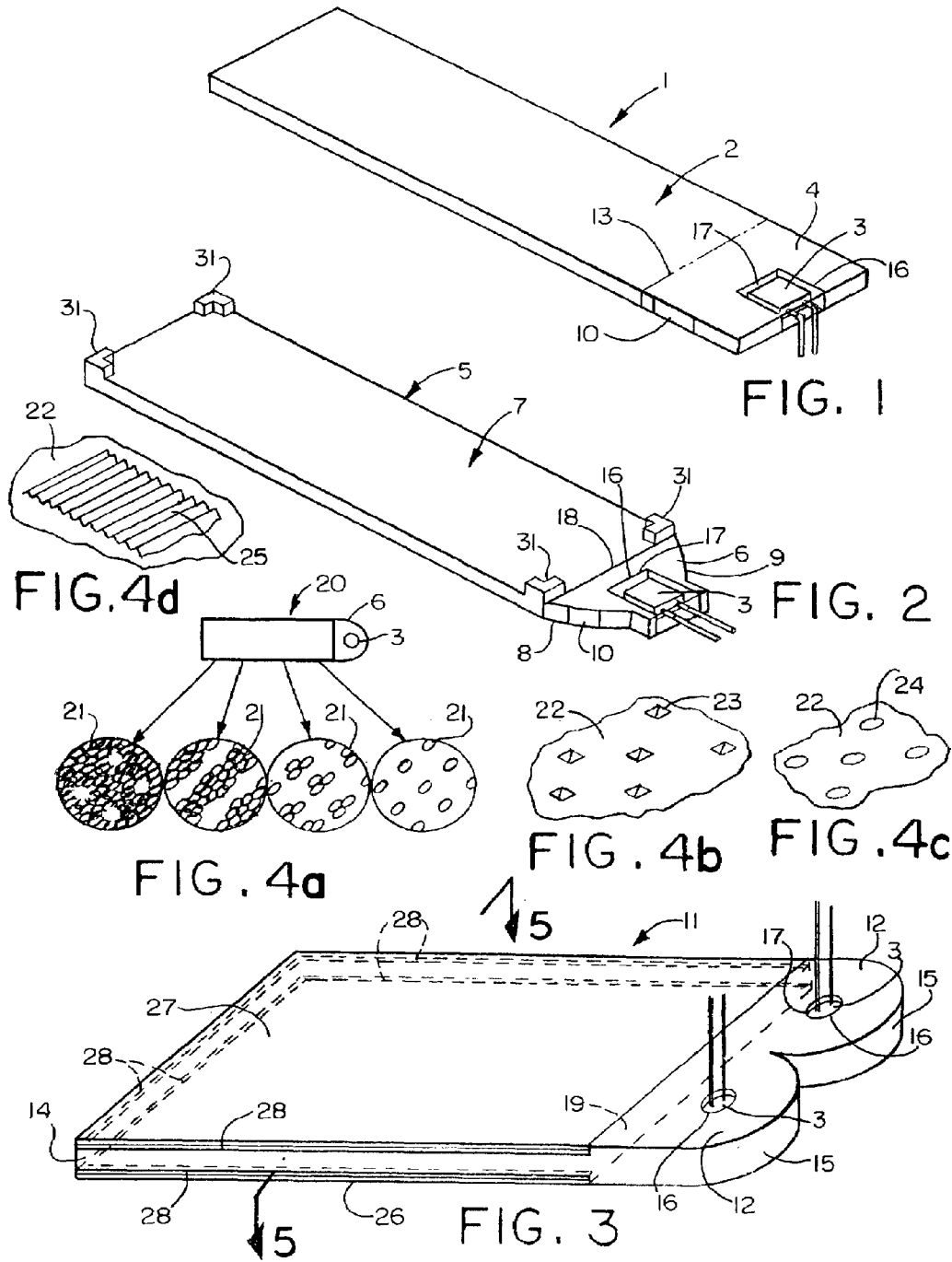
40 Claims, 4 Drawing Sheets

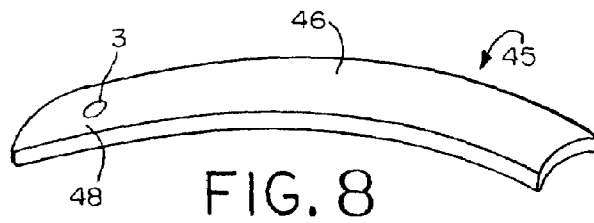
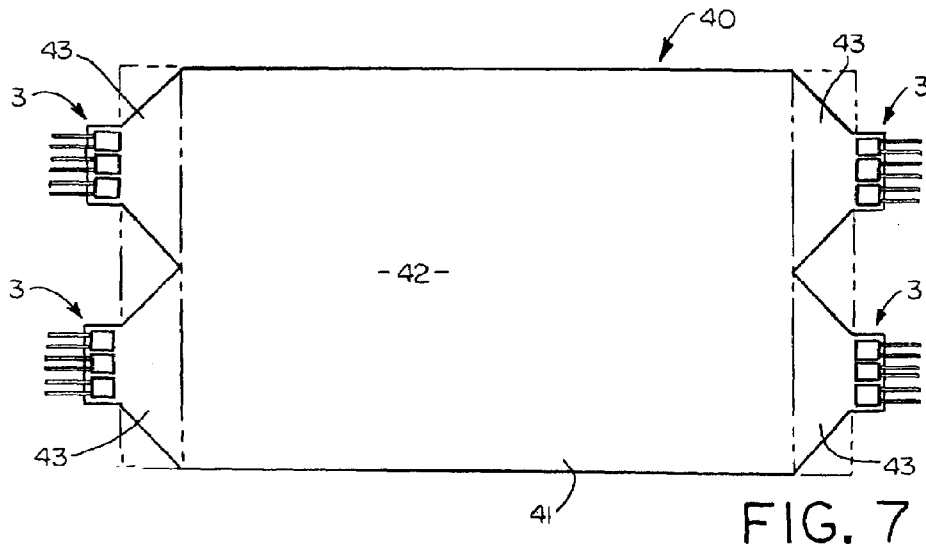
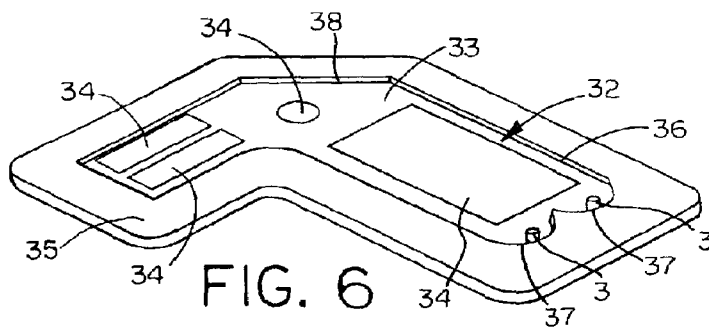
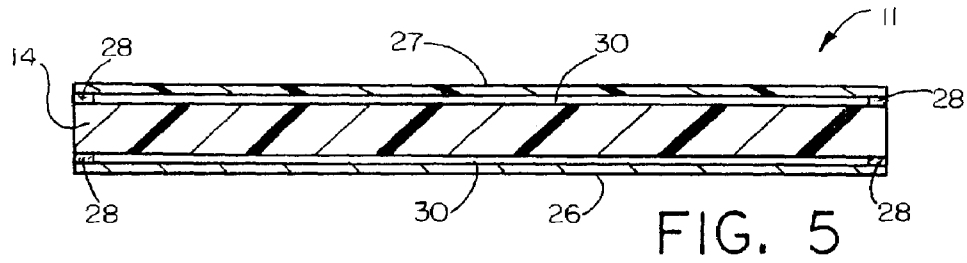


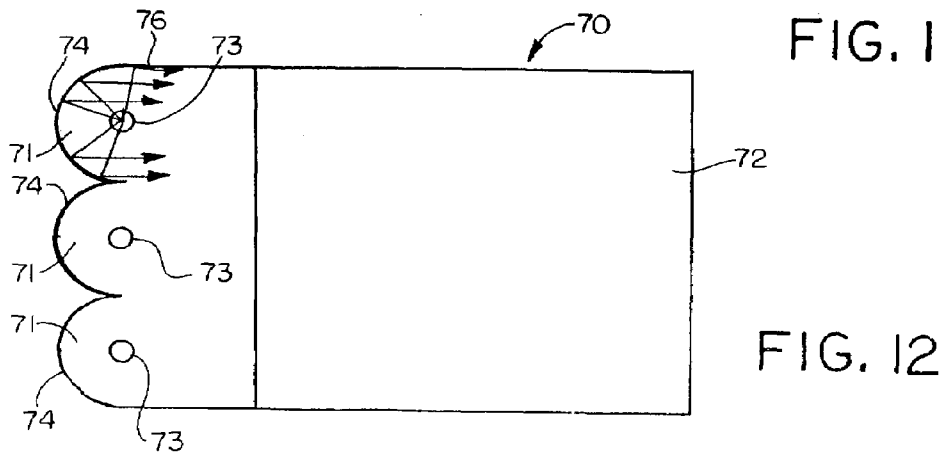
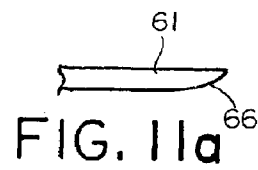
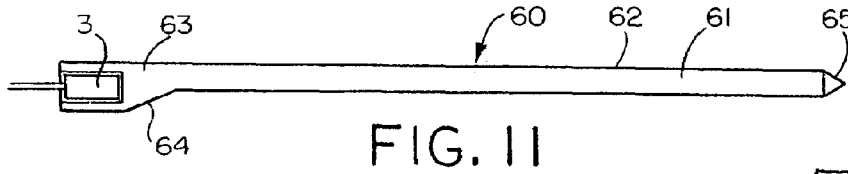
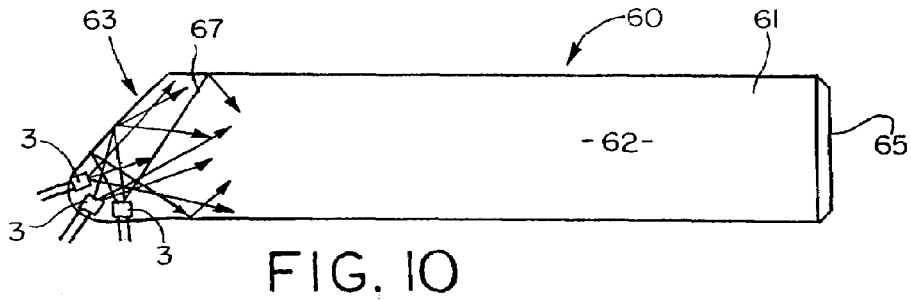
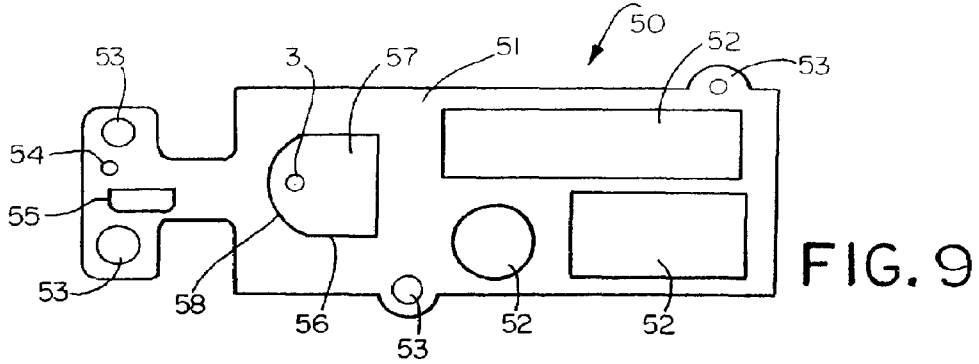
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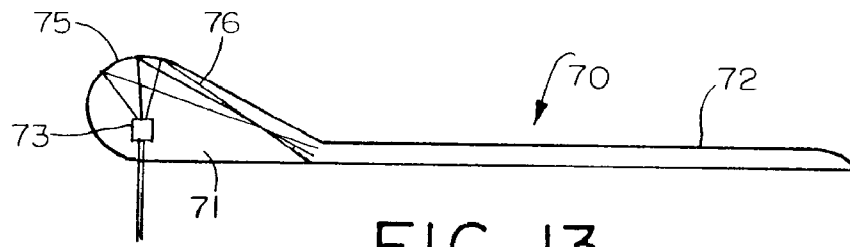


FIG. 13

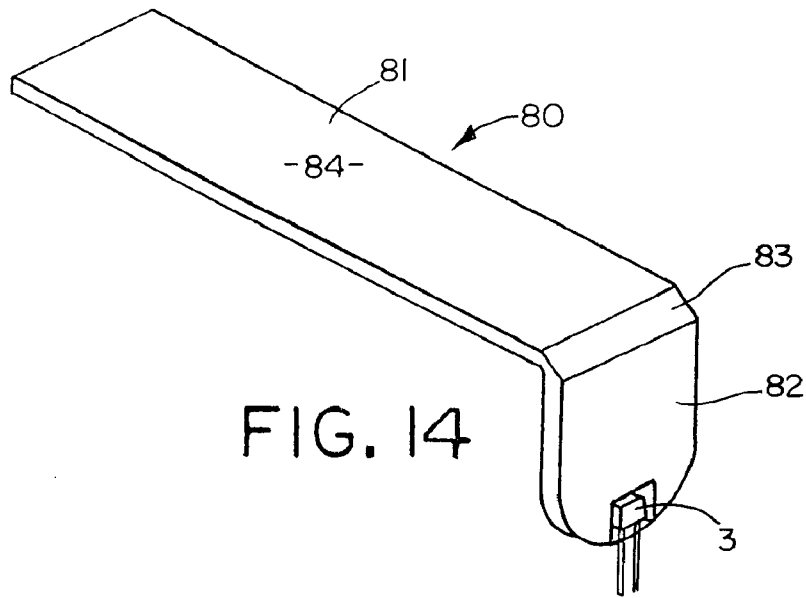


FIG. 14

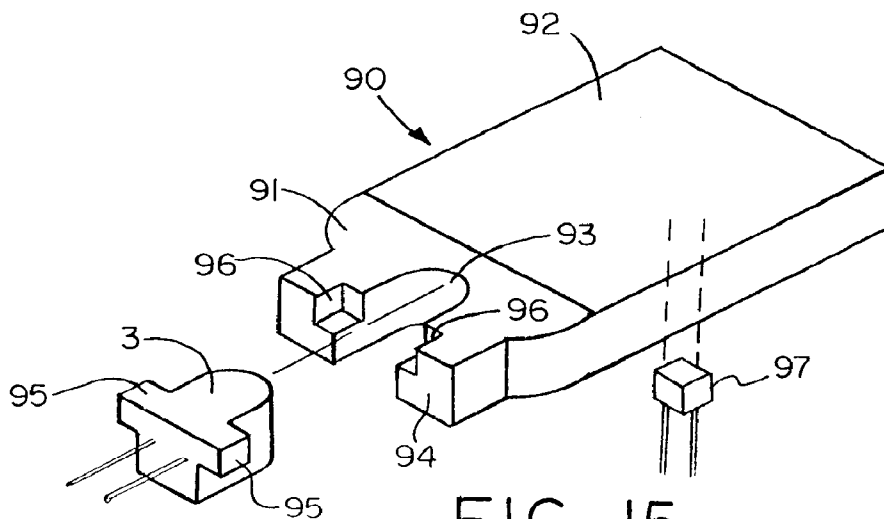


FIG. 15

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LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a division of U.S. patent application Ser. No. 10/784,527, filed Feb. 23, 2004, now U.S. Pat. No. 7,160,015 which is a division of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 08/778,089, filed Jan. 2, 1997, now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a division of U.S. patent application Ser. No. 08/495,176, filed Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25, 1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emitting panel assemblies each including a transparent panel member for efficiently conducting light, and controlling the light conducted by the panel member to be emitted from one or more light output areas along the length thereof.

Light emitting panel assemblies are generally known. However, the present invention relates to several different light emitting panel assembly configurations which provide for better control of the light output from the panel assemblies and for more efficient utilization of light, which results in greater light output from the panel assemblies.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light emitting panel assemblies include a light emitting panel member having a light transition area in which at least one light source is suitably mounted for transmission of light to the light input surface of the panel member.

In accordance with another aspect of the invention, the light source is desirably embedded, potted or bonded to the light transition area to eliminate any air gaps, decrease surface reflections and/or eliminate any lens effect between the light source and light transition area, thereby reducing light loss and increasing the light output from the panel assembly.

In accordance with another aspect of the invention, the panel assemblies may include reflective or refractive surfaces for changing the path of a portion of the light, emitted from the light source, that would not normally enter the panel members at an acceptable angle that allows the light to remain in the panel members for a longer period of time and/or increase the efficiency of the panel members.

In accordance with another aspect of the invention, the light emitting panel members include a pattern of light extracting deformities or disruptions which provide a desired light output distribution from the panel members by changing the angle of refraction of a portion of the light from one or more light output areas of the panel members.

In accordance with still another aspect of the invention, the light source may include multiple colored light sources for supplying light to one or more light output areas, and for providing a colored or white light output distribution.

In accordance with yet another aspect of the invention, the panel assemblies include a transition area for mixing the multiple colored lights, prior to the light entering the panel members, in order to effect a desired colored or white light output distribution.

The various light emitting panel assemblies of the present invention are very efficient panel assemblies that may be used

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to produce increased uniformity and higher light output from the panel members with lower power requirements, and allow the panel members to be made thinner and/or longer, and/or of various shapes and sizes.

To the accomplishment of the foregoing and related ends, the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three different forms of light emitting panel assemblies in accordance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light output area of a panel assembly showing one form of pattern of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views of a portion of a light output area of a panel assembly showing other forms of light extracting deformities formed in or on the light output area;

FIG. 5 is an enlarged transverse section through the light emitting panel assembly of FIG. 3 taken generally on the plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 7 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 9 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of light emitting panel assembly in accordance with this invention;

FIG. 11 is a side elevation view of the light emitting panel assembly of FIG. 10;

FIG. 11a is a fragmentary side elevation view showing a tapered or rounded end on the panel member in place of the prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 13 is a schematic side elevation view of the light emitting panel assembly of FIG. 12; and

FIGS. 14 and 15 are schematic perspective views of still other forms of light emitting panel assemblies in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS

Referring now in detail to the drawings, and initially to FIG. 1, there is schematically shown one form of light emitting panel assembly 1 in accordance with this invention including a transparent light emitting panel 2 and one or more light sources 3 which emit light in a predetermined pattern in a light transition member or area 4 used to make the transition from the light source 3 to the light emitting panel 2, as well known in the art. The light that is transmitted by the light transition area 4 to the transparent light emitting panel 2 may

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be emitted along the entire length of the panel or from one or more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. 1 the light transition area 4 is shown as an integral extension of one end of the light emitting panel 2 and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area 4 may be a separate piece suitably attached to the light input surface 13 of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. 2 shows another form of light emitting panel assembly 5 in accordance with this invention including a panel light transition area 6 at one end of the light emitting panel 7 with sides 8, 9 around and behind the light source 3 shaped to more efficiently reflect and/or refract and focus the light emitted from the light source 3 that impinges on these surfaces back through the light transition area 6 at an acceptable angle for entering the light input surface 18 at one end of the light emitting panel 7. Also, a suitable reflective material or coating 10 may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. 1 and 2 on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

The panel assemblies shown in FIGS. 1 and 2 include a single light source 3, whereas FIG. 3 shows another light emitting panel assembly 11 in accordance with this invention including two light sources 3. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly 11 of FIG. 3 includes a light transition area 12 at one end of the light emitting panel 14 having reflective and/or refractive surfaces 15 around and behind each light source 3. These surfaces 15 may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas 12 into the light input surface 19 of the light emitting panel 14.

The light sources 3 may be mechanically held in any suitable manner in slots, cavities or openings 16 machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources 3 are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bonding the light sources 3 in the slots, cavities or openings 16 in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material 17. The slots, cavities or openings 16 may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultra-

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sonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source 3 may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources 3 may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources 3 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. 4a schematically shows one such light surface area 20 on which a pattern of light extracting deformities or disruptions 21 is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities 21 shown in FIG. 4a includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities 21 are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions 21 can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning the sheet or film against one or both sides of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformi-

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ties **21** may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities **21** may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source **3** thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities **21** may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display backlight, the light output will be more efficient if the deformities **21** cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities **21** may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity **21** coverage. Moreover, the pattern of light extracting deformities **21** may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities **21** may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes **21** in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moire or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities **21** shown in FIG. **4a**, other light extracting deformities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. **4b** and **4c** show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4d** shows prismatic or other reflective or refractive surfaces **25** formed on the exterior of the panel area. The prismatic surfaces, depressions or raised

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surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. **5**, a back reflector (including trans reflectors) **26** may be attached or positioned against one side of the panel member **14** of FIG. **3** using a suitable adhesive **28** or other method in order to improve light output efficiency of the panel assembly **11** by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities **21**, **23**, **24** and/or **25** may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate **27** may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive **28** or other method in order to produce a desired effect.

The member **27** may be used to further improve the uniformity of the light output distribution. For example, the member **27** may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive **28** is used to adhere the back reflector **26** and/or film **27** to the panel, the adhesive is preferably applied only along the side edges of the panel, and if desired the end edge opposite the light transition areas **12**, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps **30** (see FIG. **5**) which are formed between the respective panel surfaces and the back reflector **26** and/or film **27** when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps **30** are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. **2**, the panel assembly **5** shown therein also includes molded posts **31** at one or more corners of the panel **7** (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. **6** shows another form of light emitting panel assembly **32** in accordance with this invention including a panel member **33**, one or more light sources **3**, and one or more light output areas **34**. In addition, the panel assembly **32** includes a tray **35** having a cavity or recess **36** in which the panel assembly **32** is received. The tray **35** may act as a back reflector as well as end edge and/or side edge reflectors for the panel **33** and side and/or back reflectors **37** for the light sources **3**. Additionally, one or more secondary reflective or refractive surfaces **38** may be provided on the panel member **33** and/or tray **35** to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member **33**. These secondary reflective/refractive surfaces **38** may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a prede-

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terminated pattern. FIG. 6 also shows multiple light output areas 34 on the panel member that emit light from one or more light sources 3.

FIG. 7 is a schematic illustration of still another form of light emitting panel assembly 40 in accordance with this invention including a panel member 41 having one or more light output areas 42 and one or more light transition areas (mixing areas) 43 containing a plurality of light sources 3 at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources 3 desirably employs three colored LEDs (red, blue, green) in each transition mixing area 43 so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area 42. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. 8 shows yet another form of light emitting panel assembly 45 in accordance with this invention including a light emitting panel member 46 and a light source 3 in a light transition area 48 integral with one end of the panel member. In this particular embodiment, the panel member 46 is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. 9 schematically shows another form of light emitting panel assembly 50 in accordance with this invention, including a panel member 51 having multiple light output areas 52, and mounting posts and/or mounting tabs 53. This particular panel assembly 50 may serve as a structural member to support other parts or components as by providing holes or cavities 54, 55 in the panel member 51 which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess 56 may be provided in the panel member 51 for receipt of a correspondingly shaped light transition area 57 having one or more light sources 3 embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface 58 on the transition area 57 and/or wall of the cavity or recess 56 to redirect a portion of the light in a predetermined manner. In this way the light transition area 57 and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector 58 may be placed on the reflective or refractive surface of the cavity or recess 56 or insert 57. Where the reflector 58 is placed on the reflective or refractive surface of the cavity or recess 56, the cavity or recess may act as a mold permitting transparent material from which the transition area 57 is made to be cast around one or more light sources 3.

FIGS. 10 and 11 schematically show another form of light emitting panel assembly 60 in accordance with this invention including a panel member 61 having one or more light output areas 62. In this particular embodiment, an off-axis light transition area 63 is provided that is thicker in cross section than the panel member to permit use of one or more light sources 3 embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface 64 (FIG. 11) may be provided on the transition area 63. Moreover, a prism 65 (FIG. 11) or tapered, rounded, or otherwise shaped end 66 (FIG. 11a) may be provided at the end of the panel opposite the light sources 3 to perform the function of an end reflector.

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The light sources 3 may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays 67 in the transition area 63 as schematically shown in FIG. 10 and/or to permit a shorter length transition area 63 to be used.

FIGS. 12 and 13 schematically show still another form of light emitting panel assembly 70 in accordance with this invention which includes one or more light transition areas 71 at one or both ends of the panel member 72 each containing a single light source 73. The transition area or areas 71 shown in FIGS. 12 and 13 collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area 71 shown in FIGS. 12 and 13 has elliptical and parabolic shape surfaces 74 and 75 in different planes for directing the light rays 76 into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. 14 schematically illustrates still another form of light emitting panel assembly 80 in accordance with this invention including a light emitting panel 81 and one or more light sources 3 positioned, embedded, potted, bonded or otherwise mounted in a light transition area 82 that is at an angle relative to the panel member 81 to permit more efficient use of space. An angled or curved reflective or refractive surface 83 is provided at the junction of the panel member 81 with the transition area 82 in order to reflect/refract light from the light source 3 into the body of the panel member 81 for emission of light from one or more light emitting areas 84 along the length of the panel member.

FIG. 15 schematically illustrates still another form of light emitting panel assembly 90 in accordance with this invention including a light transition area 91 at one or both ends of a light emitting panel member 92 containing a slot 93 for sliding receipt of an LED or other suitable light source 3. Preferably the slot 93 extends into the transition area 91 from the back edge 94, whereby the light source 3 may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source 3 may be provided with wings, tabs or other surfaces 95 for engagement in correspondingly shaped recesses or grooves 96 or the like in the transition area 91 for locating and, if desired, securing the light source in place. Also, the light source 3 may be embedded, potted, bonded or otherwise secured within the slot 93 in the light transition area 91 of the panel member 92. Light from a secondary light source 97 may be projected through the panel member 92 for indication or some other effect.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example LCD back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, membrane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members.

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Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting panel assembly comprising:
 - a generally planar optical conductor having at least one input edge with a greater cross-sectional width than thickness; and
 - a plurality of light sources configured to generate light having an output distribution defined by a greater width component than height component, the light sources positioned adjacent to the input edge, thereby directing light into the optical conductor;
 - the optical conductor having at least one output region and a predetermined pattern of deformities configured to cause light to be emitted from the output region,
 - the optical conductor having a transition region disposed between the light source and the output region.
2. The assembly of claim 1 wherein the transition region is configured to spread and transmit the light generated by the light sources to the output region.
3. The assembly of claim 1 wherein the transition region is integral with the optical conductor.
4. The assembly of claim 1 wherein a portion of the assembly has faceted surfaces in close proximity to the light sources for maximizing or otherwise changing the light emitted from the light sources.
5. The assembly of claim 1 wherein the light sources are LEDs.
6. The assembly of claim 5 wherein at least one of the LEDs has at least two different color chips.
7. The assembly of claim 6 wherein the light from the different color chips mixes and spreads within the transition region to produce a desired light output color.
8. The assembly of claim 1 wherein the transition region is dimensionally thicker in cross section than the output region.
9. The assembly of claim 8 wherein the transition region gradually decreases in thickness from the input edge to the output region.
10. The assembly of claim 1 wherein the transition region and the output region of the optical conductor have substantially the same thickness.
11. The assembly of claim 1 wherein the optical conductor gradually decreases in thickness along its length in a direction away from the input edge.
12. The assembly of claim 1 wherein the optical conductor includes a proximal edge and a distal edge, and wherein the distal edge of the optical conductor includes a reflector associated therewith.
13. The assembly of claim 1 wherein the optical conductor has side edges, and wherein at least one of the side edges includes a reflector associated therewith.
14. The assembly of claim 1 wherein the optical conductor includes a proximal edge, a distal edge, and a plurality of slots extending inward from the proximal edge of the optical conductor that are configured to receive the light sources therein, and wherein the slots define inner edges that are oriented substantially parallel to and spaced inward from the proximal edge of the optical conductor, such that the inner edges operate as the input edge of the optical conductor.

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15. The assembly of claim 14 wherein a portion of the assembly has faceted surfaces in close proximity to the light sources for maximizing or otherwise changing the light emitted from the light sources.

16. The assembly of claim 1 wherein the light sources are focused light sources.

17. The assembly of claim 16 wherein the focused light sources are LEDs.

18. The assembly of claim 1 wherein the light sources are configured to focus the light on the input edge in a direction substantially perpendicular thereto.

19. The assembly of claim 1 wherein at least some of the plurality of light sources are different color LEDs.

20. The assembly of claim 19 wherein the light from the different color LEDs mixes and spreads within the transition region to produce a desired light output color.

21. The assembly of claim 1 wherein the optical conductor includes a plurality of input edges each configured to receive light from one of the light sources.

22. The assembly of claim 21 wherein a group of faceted surfaces is associated with each of the light sources for maximizing or otherwise changing the light emitted from the light sources.

23. The assembly of claim 21 wherein the optical conductor includes a proximal edge, a distal edge, and a plurality of slots extending inward from the proximal edge of the optical conductor, each slot being configured to receive one of the light sources therein, each slot defining an inner edge that is oriented substantially parallel to and spaced inward from the proximal edge of the optical conductor, such that each inner edge operates as one of the input edges of the optical conductor.

24. The assembly of claim 23 wherein a group of faceted surfaces is associated with each of the light sources for maximizing or otherwise changing the light emitted from the light sources.

25. The assembly of claim 1 further comprising a tray in which the optical conductor is received.

26. The assembly of claim 25 wherein the tray acts as a pair of reflectors, each associated with side edges of the optical conductor.

27. The assembly of claim 25 wherein the tray acts as a reflector associated with a distal edge of the optical conductor.

28. The assembly of claim 25 wherein the tray includes a reflector associated with a bottom surface of the optical conductor.

29. The assembly of claim 25 wherein the tray houses a reflector associated with a bottom surface of the optical conductor.

30. The assembly of claim 1 wherein at least one reflective surface is provided on the transition region in close proximity to the light sources for causing internal reflection of a portion of the light generated by the light sources back through the transition region into the optical conductor at an acceptable angle.

31. The assembly of claim 30 wherein the reflective surface is located on the transition region on opposite sides of the light sources.

32. The assembly of claim 30 wherein the reflective surface includes faceted surfaces in close proximity to the light sources for maximizing or otherwise changing the light emitted from the light sources.

33. A light emitting panel assembly comprising:

- a generally planar optical conductor having at least one input edge with a greater cross-sectional width than thickness; and

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a plurality of LED light sources each having a greater width than height positioned adjacent to the input edge, thereby directing light into the optical conductor, each light source being configured to generate light having an output distribution defined by a greater width component than height component;

the optical conductor having at least one output region and a predetermined pattern of deformities configured to cause light to be emitted from the output region,

the optical conductor having a transition region disposed between the light source and the output region.

34. The assembly of claim 33 wherein each light source has a light output distribution with a greater width component than height component.

35. The assembly of claim 33 wherein the transition region is configured to spread and transmit the light generated by the light sources to the output region.

36. The assembly of claim 33 wherein at least a portion of the assembly has faceted reflective or refractive surfaces in close proximity to the light sources for maximizing or otherwise changing the light emitted from the light sources.

37. The assembly of claim 33 wherein at least one of the light sources has at least two different color chips, and

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wherein the light from the different color chips mixes and spreads within the transition region to produce a desired light output color.

38. The assembly of claim 33 wherein the optical conductor includes a proximal edge, a distal edge, and a plurality of slots extending inward from the proximal edge of the optical conductor that are configured to receive the light sources therein, and wherein each of the slots defines an inner edge that is oriented substantially parallel to and spaced inward from the proximal edge of the optical conductor, such that the inner edge operates as the input edge of the optical conductor.

39. The assembly of claim 38 wherein at least a portion of the assembly has faceted reflective or refractive surfaces in close proximity to the light sources for maximizing or otherwise changing the light emitted from the light sources.

40. The assembly of claim 33 wherein at least a portion of the assembly has groups of faceted reflective or refractive surfaces in close proximity to each light source for maximizing or otherwise changing the light emitted from each light source.

* * * * *

EXHIBIT C

(12) **United States Patent**
Parker et al.

(10) **Patent No.:** **US 7,434,973 B2**
(45) **Date of Patent:** ***Oct. 14, 2008**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

(75) Inventors: **Jeffery R. Parker**, Strongsville, OH (US); **Gregory A. Coghlan**, Olmsted Falls, OH (US); **Robert M. Ezell**, Copley, OH (US)

(73) Assignee: **Solid State Opto Limited** (VG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/673,302**

(22) Filed: **Feb. 9, 2007**

(65) **Prior Publication Data**

US 2007/0147087 A1 Jun. 28, 2007

Related U.S. Application Data

(60) Continuation of application No. 10/619,815, filed on Jul. 15, 2003, now Pat. No. 7,195,389, which is a continuation of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481, which is a continuation-in-part of application No. 08/778,089, filed on Jan. 2, 1997, now Pat. No. 6,079,838, which is a division of application No. 08/495,176, filed on Jun. 27, 1995, now Pat. No. 5,613,751.

(51) **Int. Cl.**
F21V 7/00 (2006.01)

(52) **U.S. Cl.** **362/606**; 362/613; 362/618;
362/619

(58) **Field of Classification Search** 362/800,
362/606-610, 612-613, 617-620, 615, 623-629;
349/65, 63, 62

See application file for complete search history.

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Primary Examiner—Sandra O’Shea

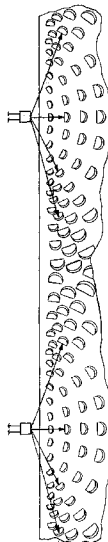
Assistant Examiner—Bao Q Truong

(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

Light emitting panel assemblies include a light emitting panel member having at least one light source optically coupled to a portion of an input edge of the panel member. A plurality of individual light extracting deformities on or in at least one panel surface of the panel member are of well defined shape and have a length and width substantially smaller than the length and width of the panel surface. At least some of the deformities have at least one surface that is angled at different orientations relative to the input edge depending on the location of the deformities on the panel surface to face a portion of the input edge to which a light source is optically coupled.

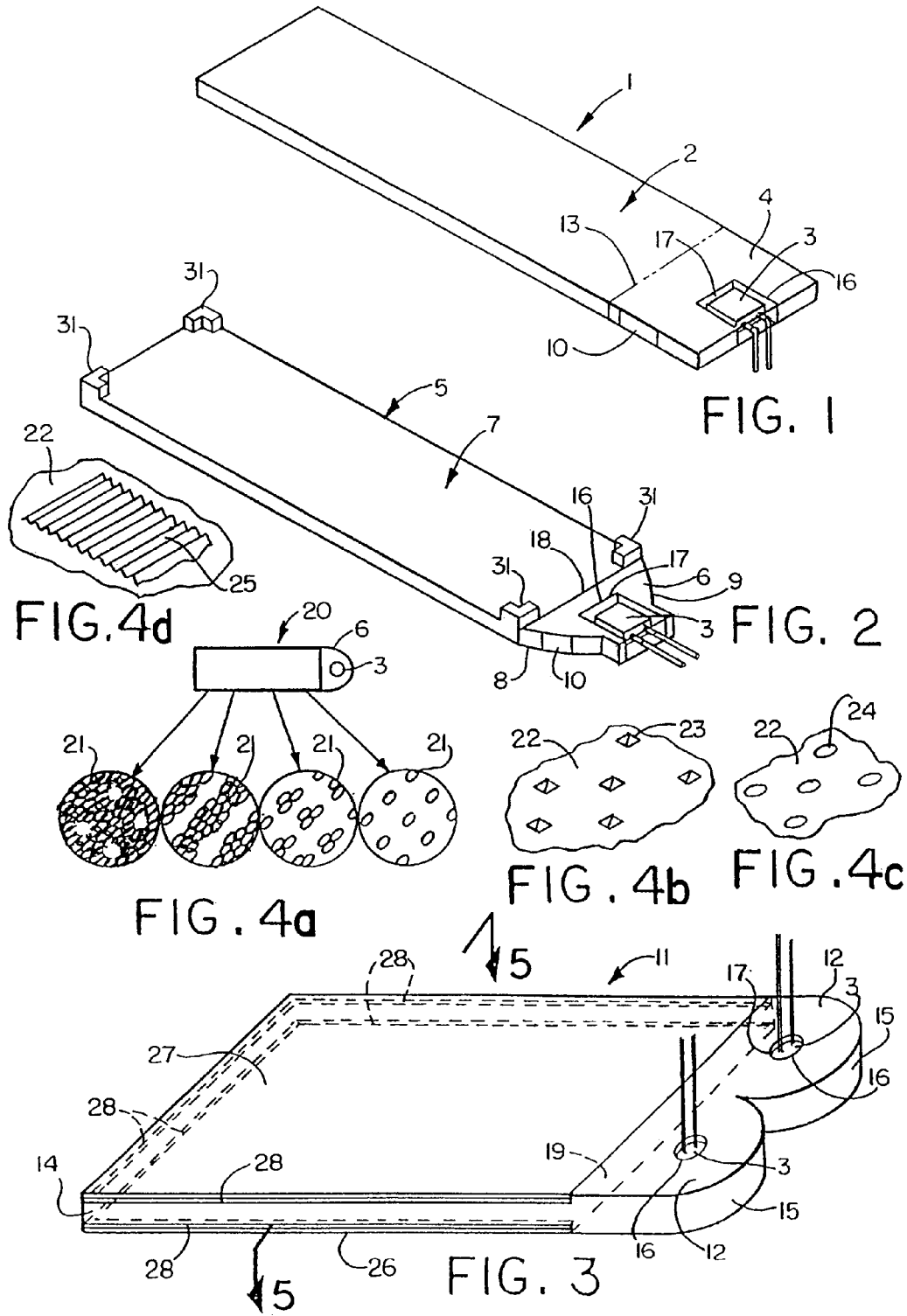
14 Claims, 14 Drawing Sheets

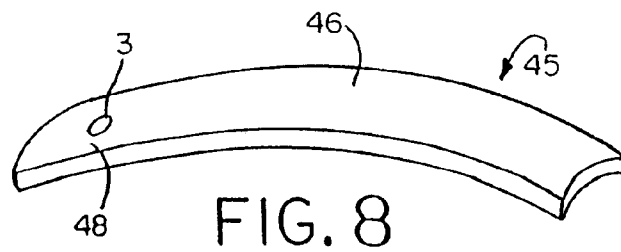
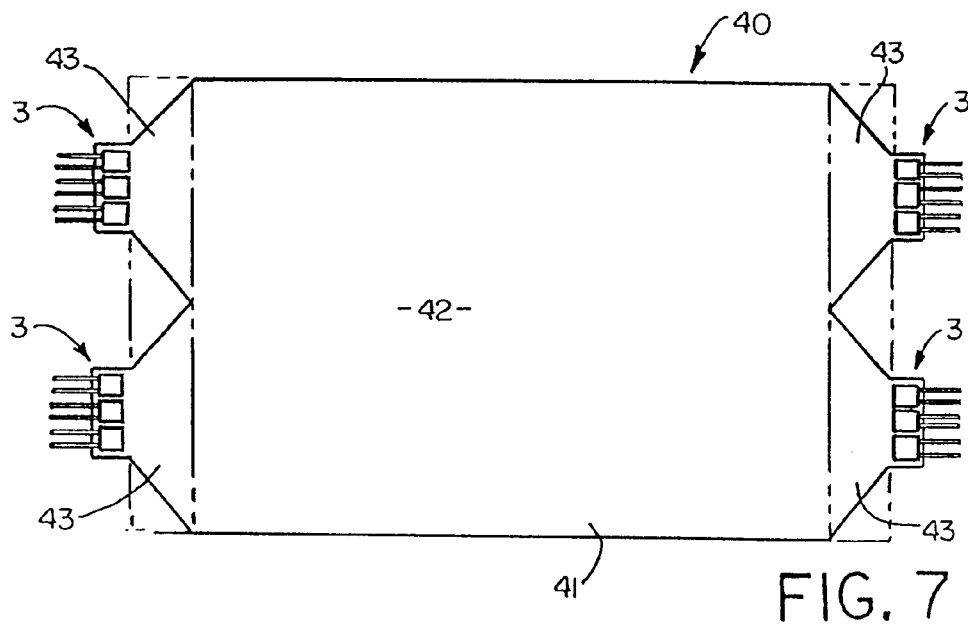
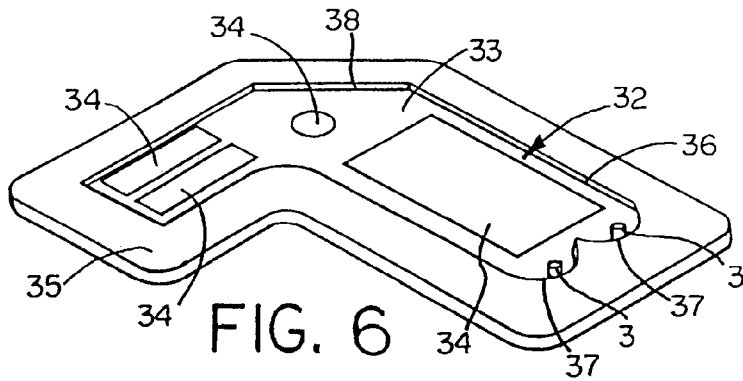
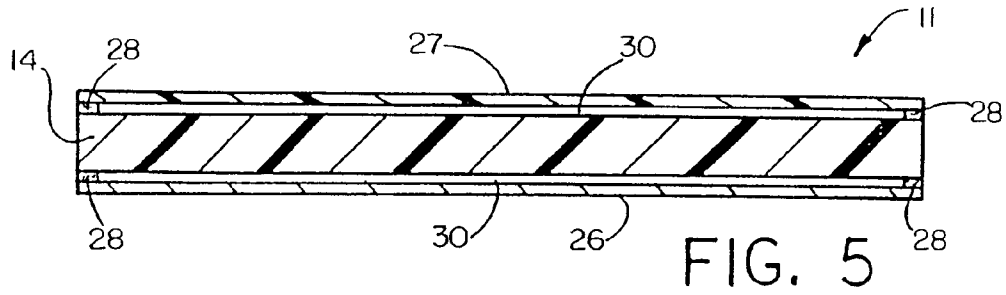


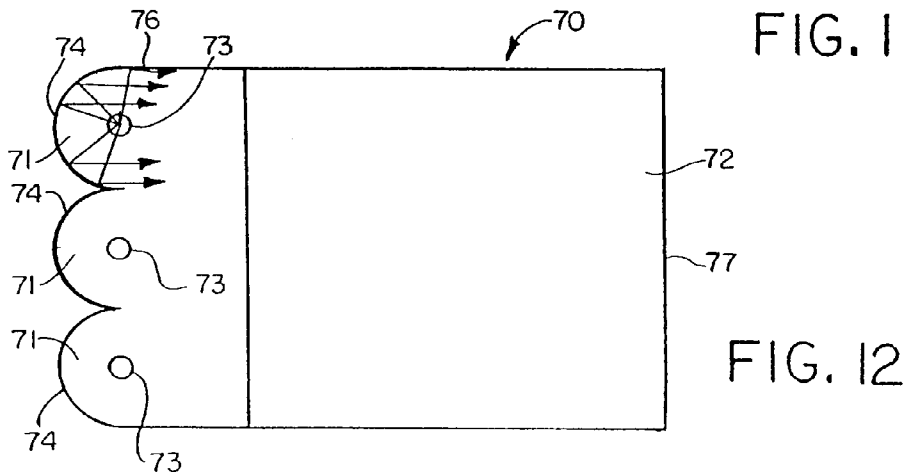
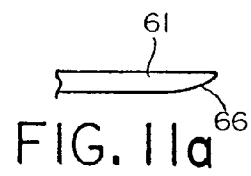
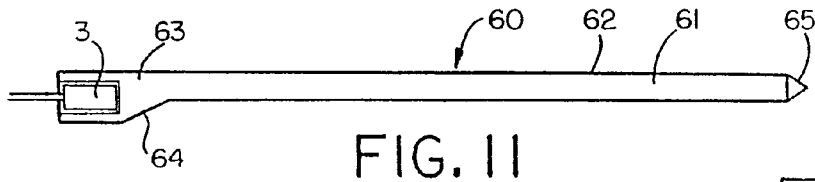
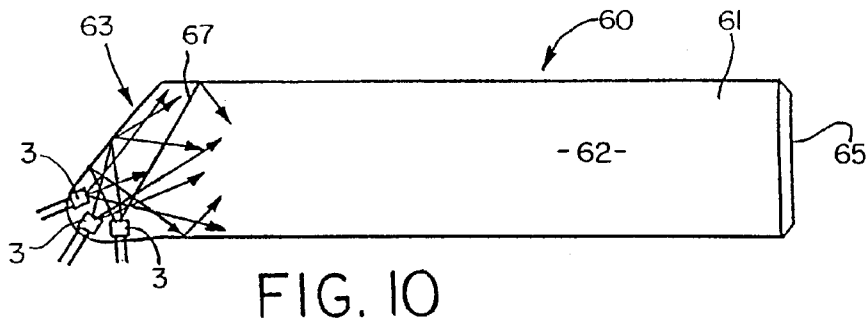
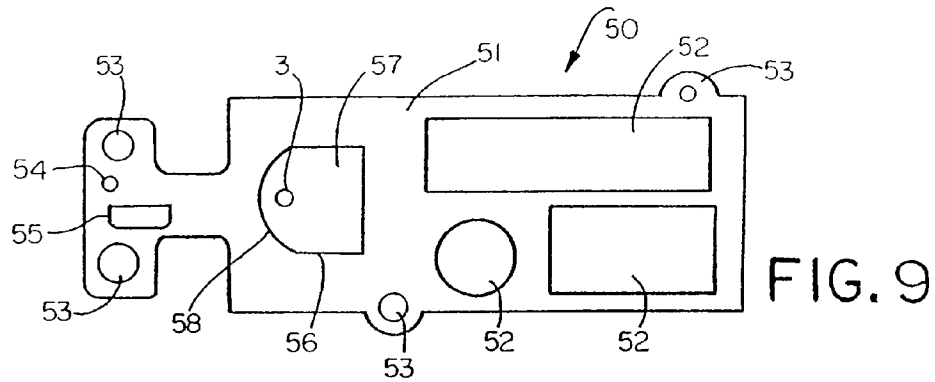
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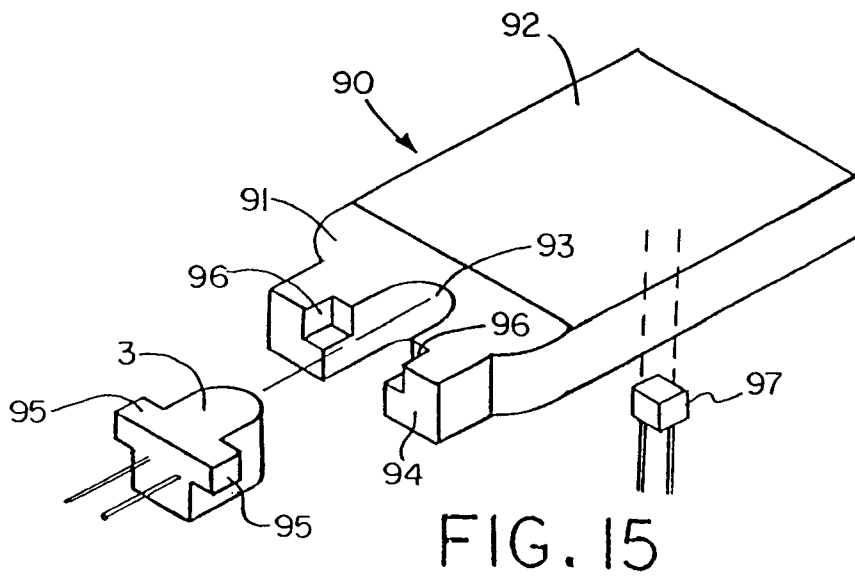
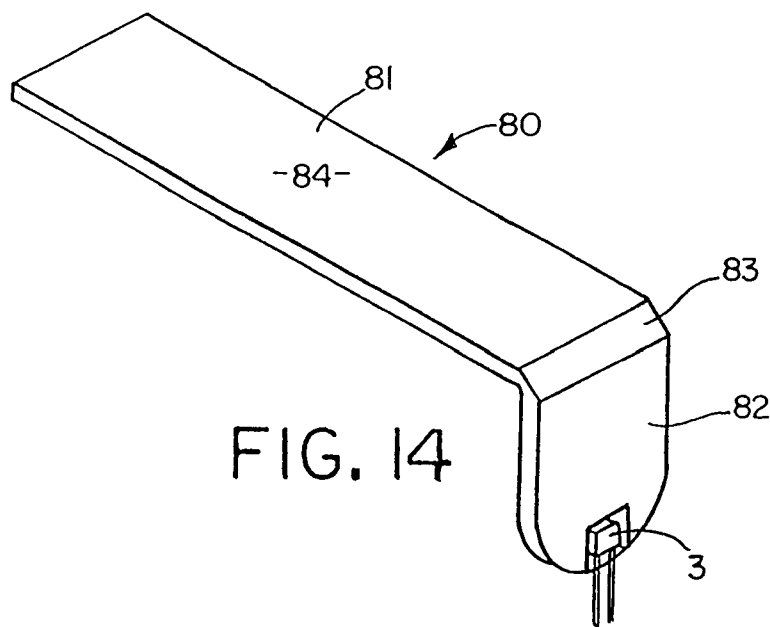
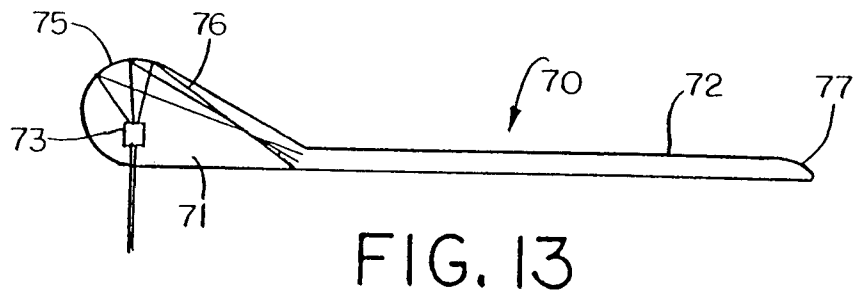
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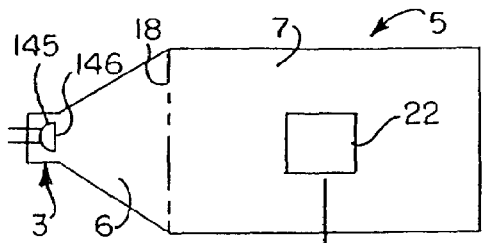


FIG. 16

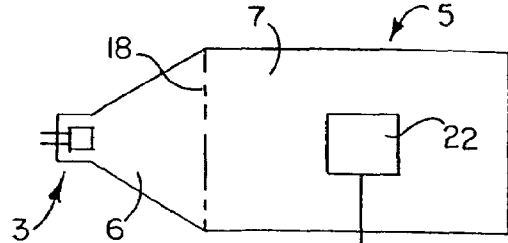


FIG. 17

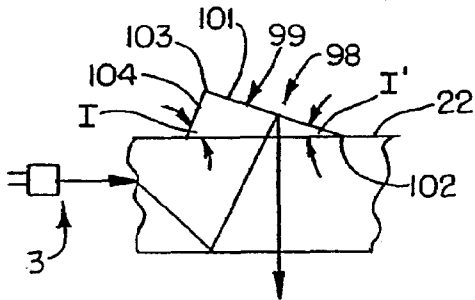
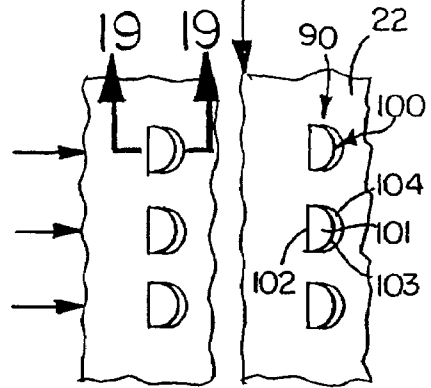
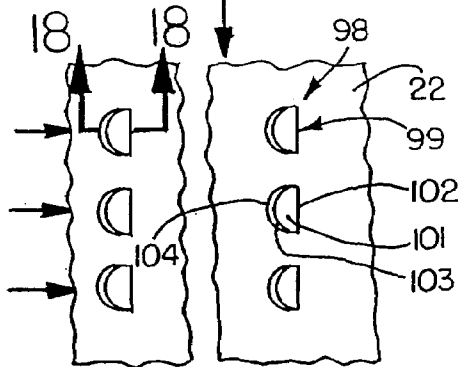


FIG. 18

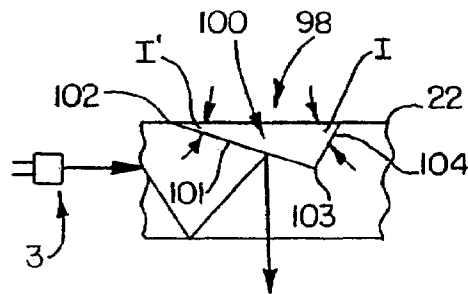


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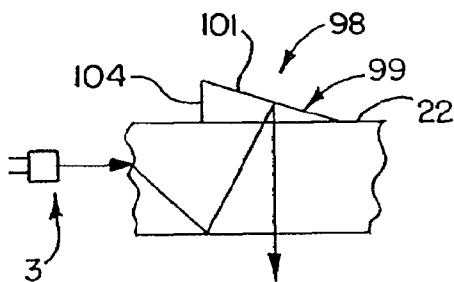


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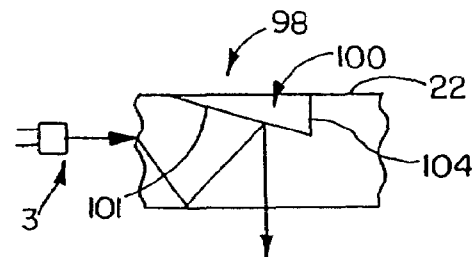


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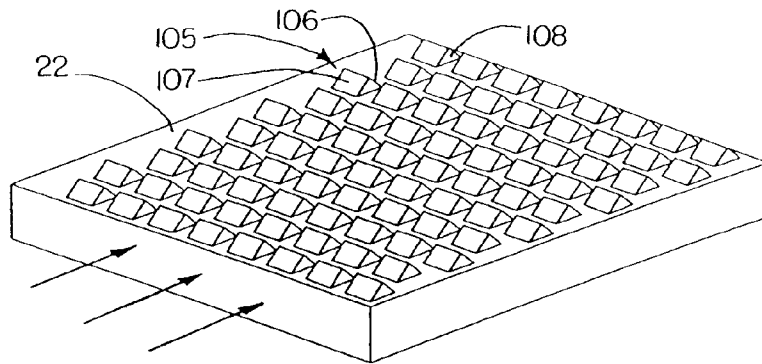


FIG. 22

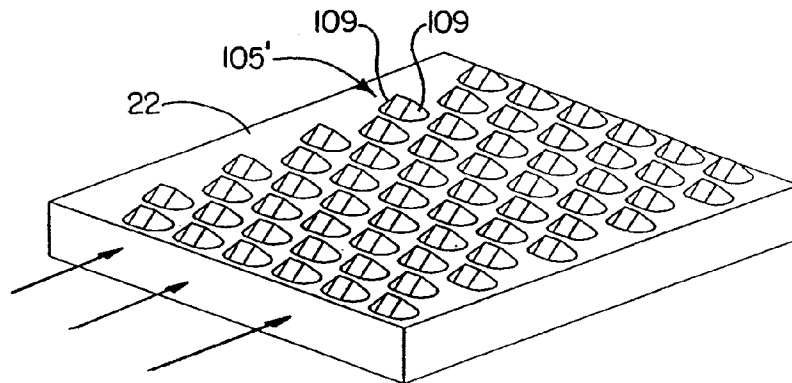


FIG. 23

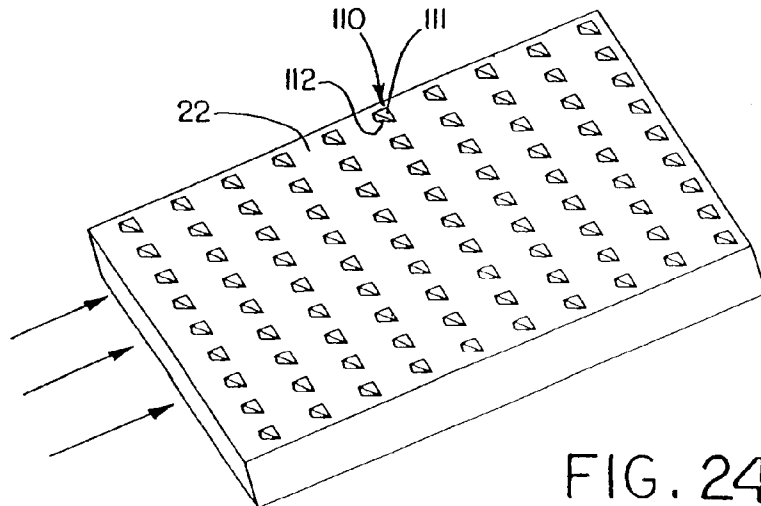


FIG. 24

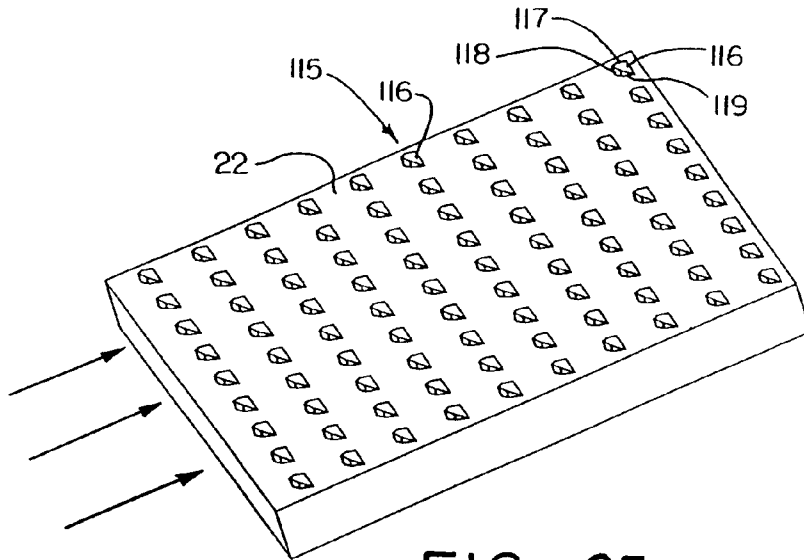


FIG. 25

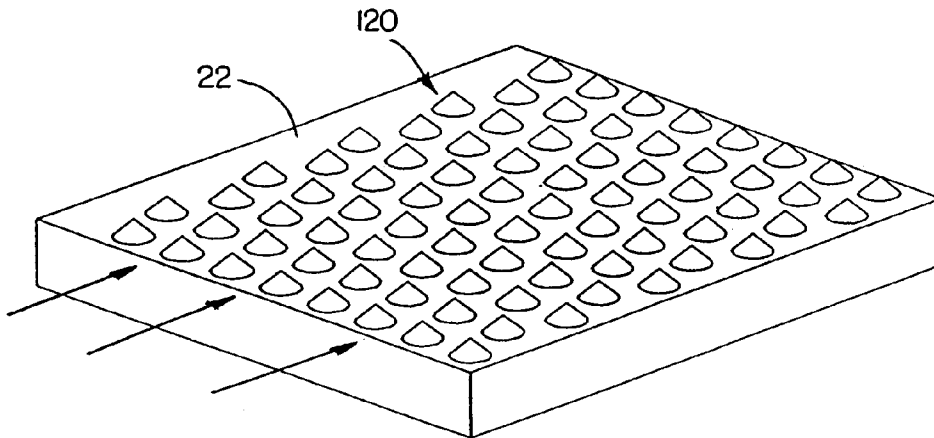


FIG. 26

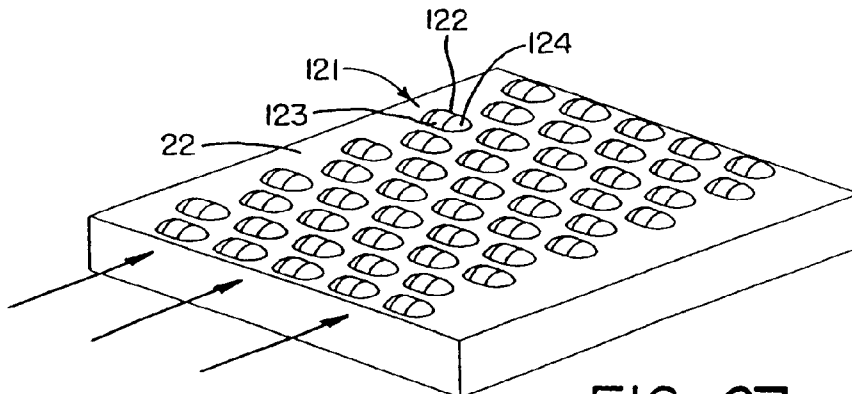


FIG. 27

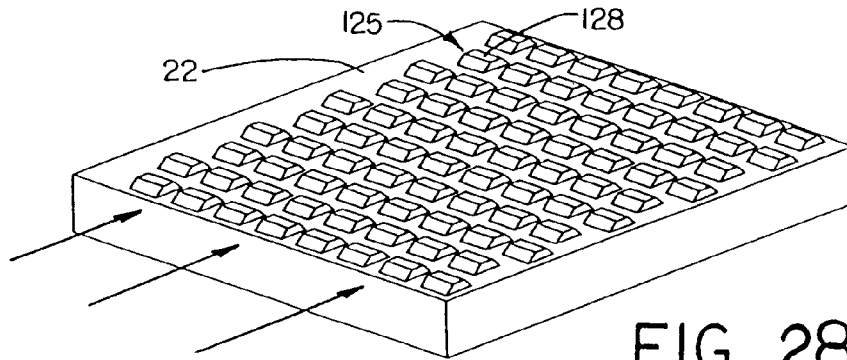


FIG. 28

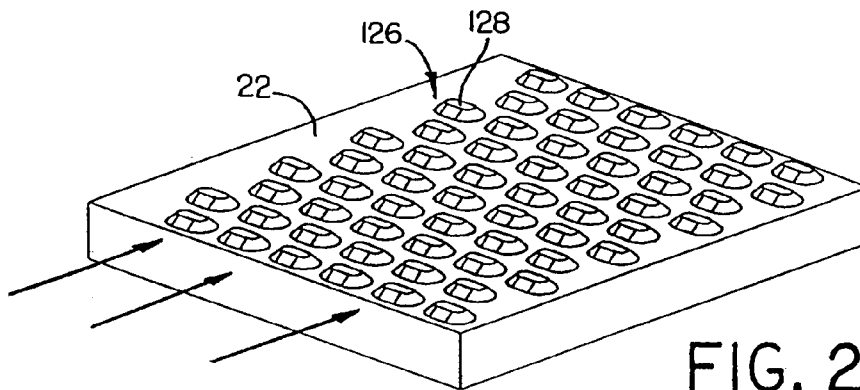


FIG. 29

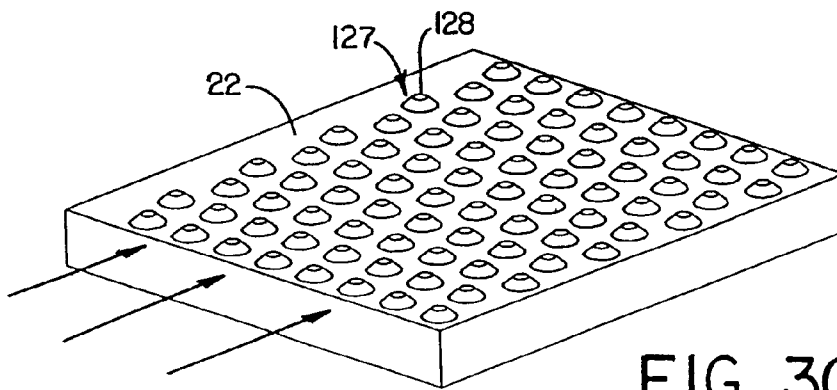


FIG. 30

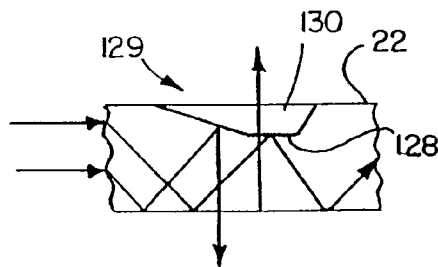


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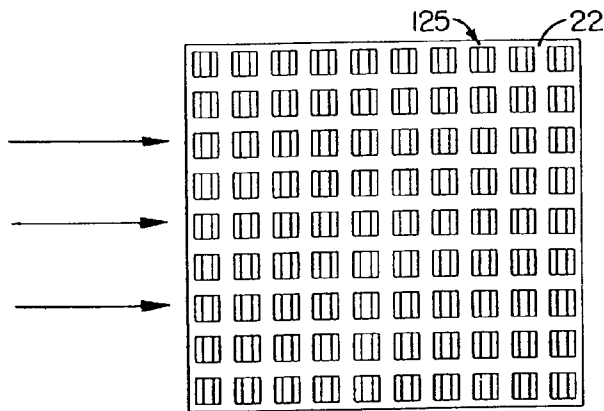


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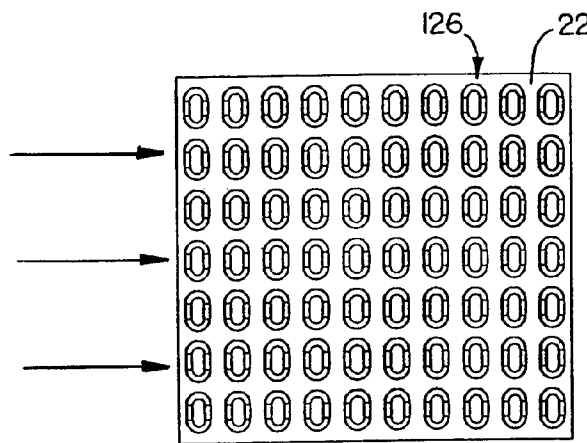


FIG. 33

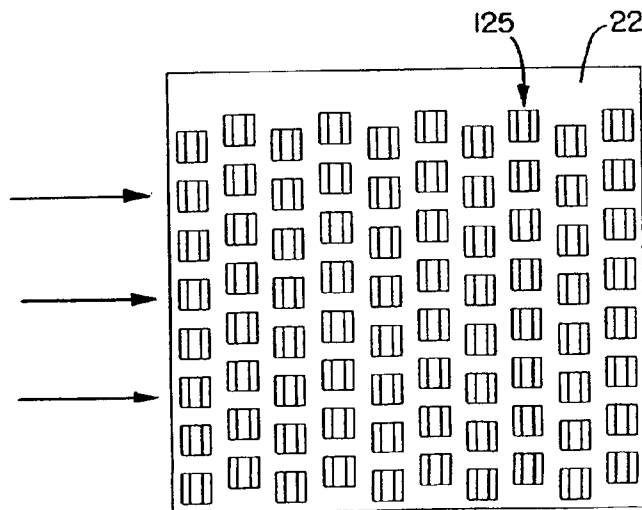


FIG. 34

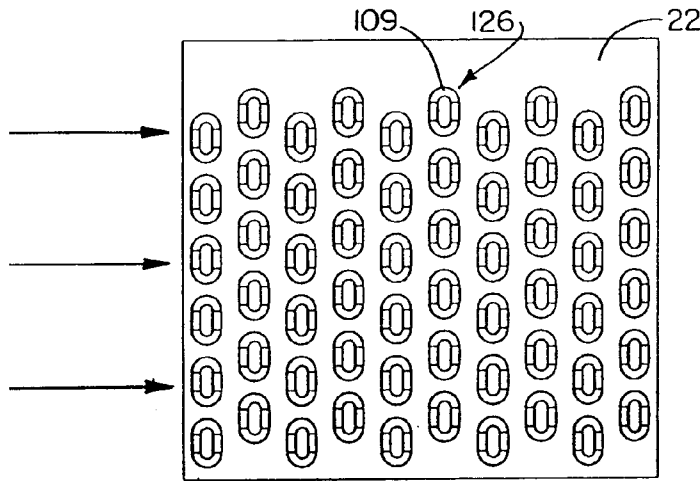


FIG. 35

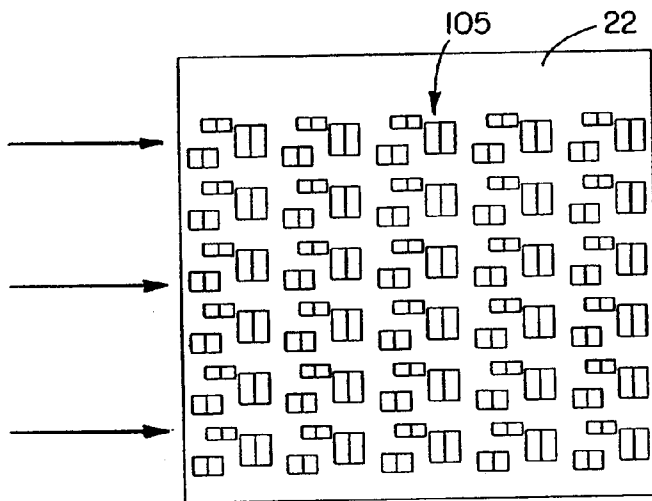


FIG. 36

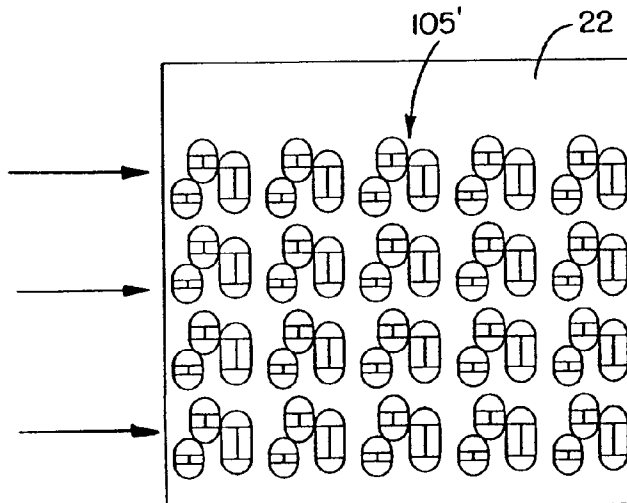


FIG. 37

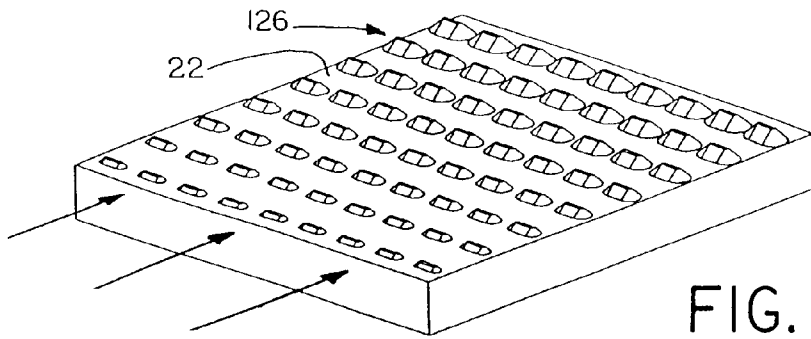


FIG. 38

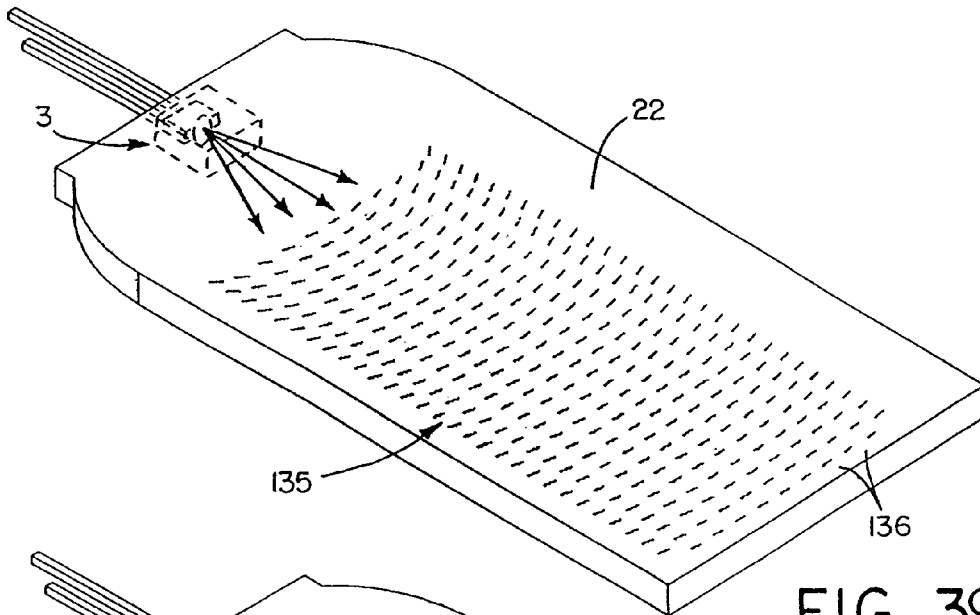


FIG. 39

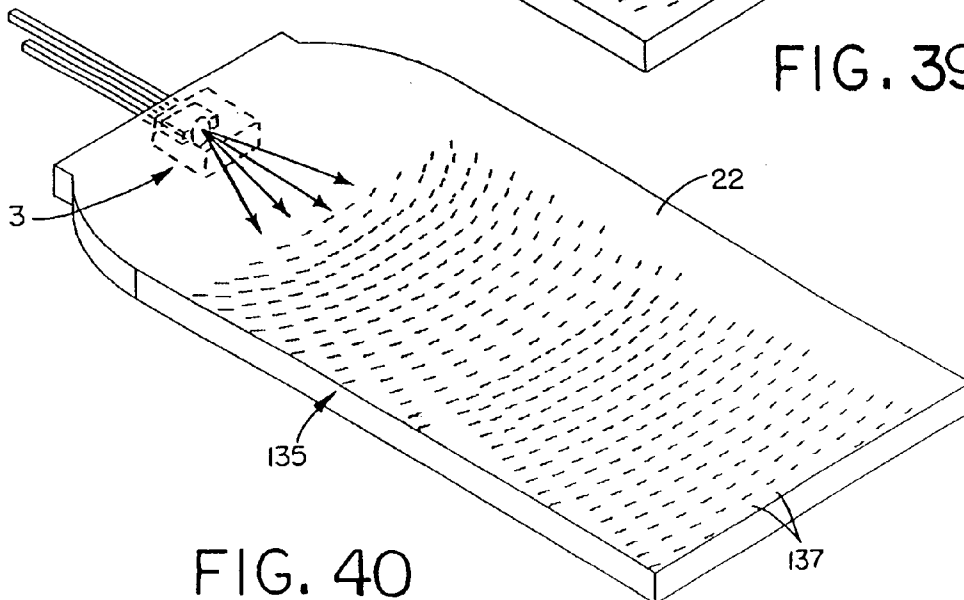


FIG. 40

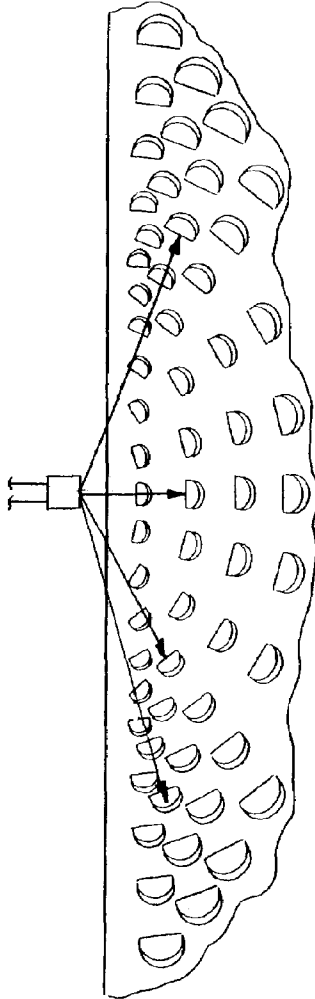


FIG. 39A

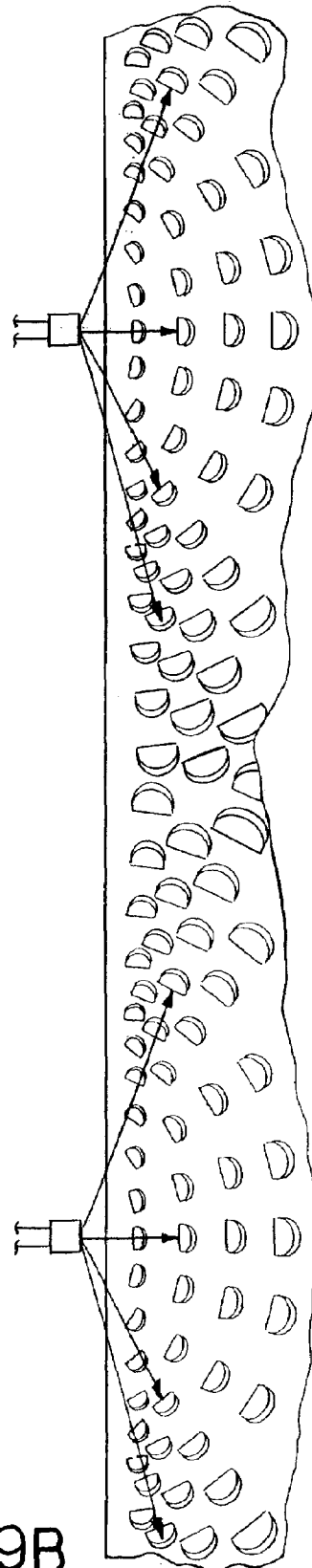


FIG. 39B

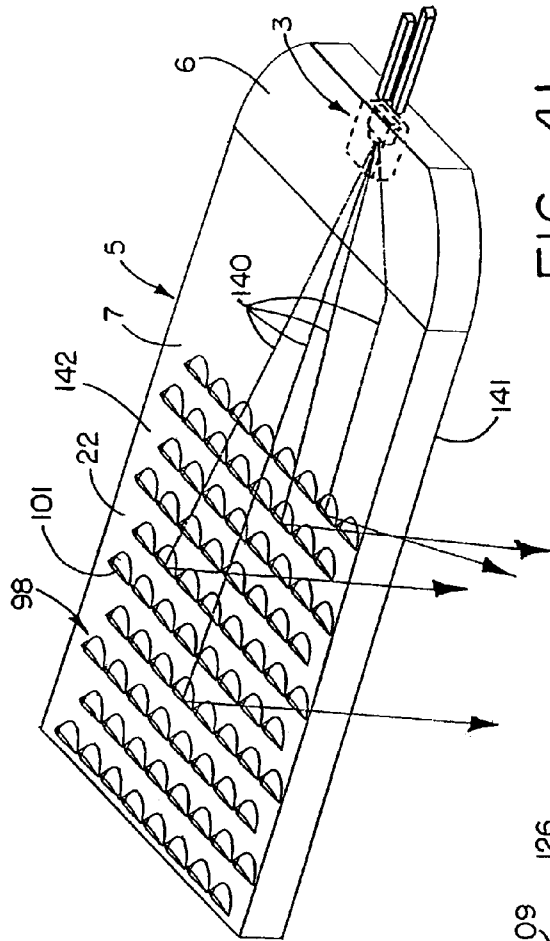


FIG. 41

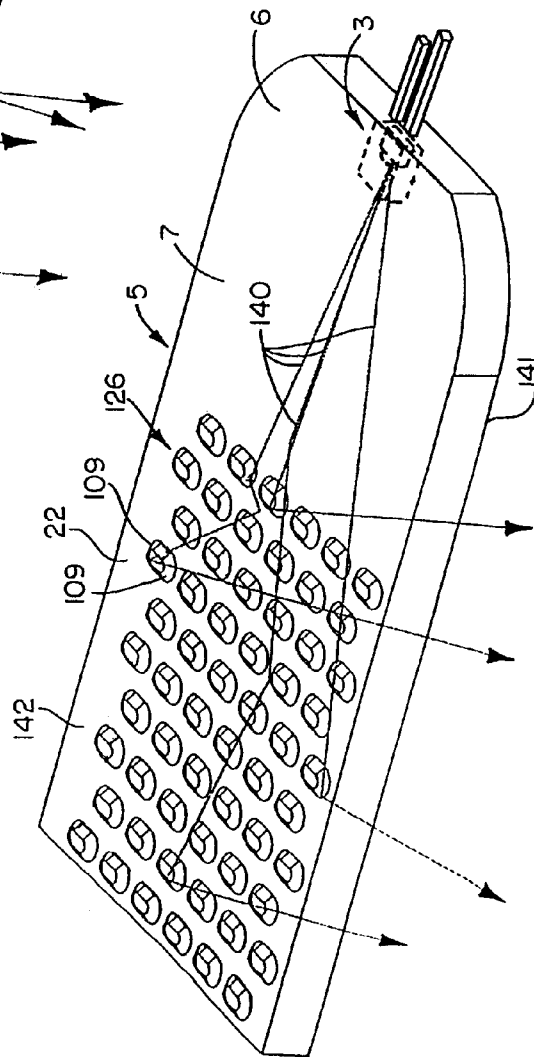


FIG. 42

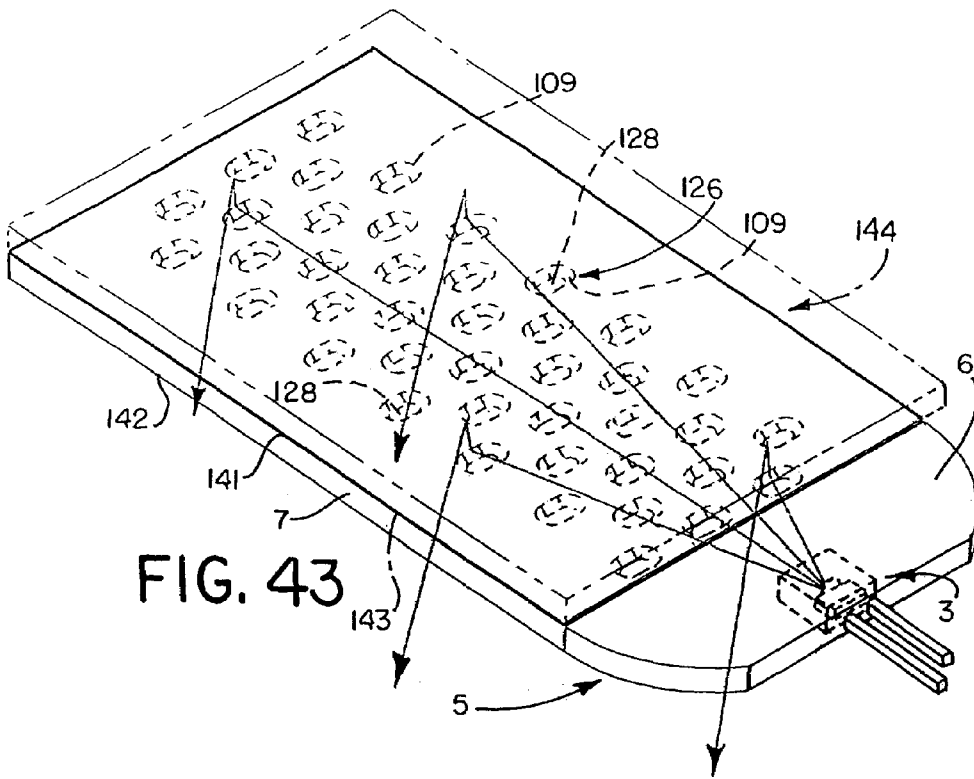


FIG. 43

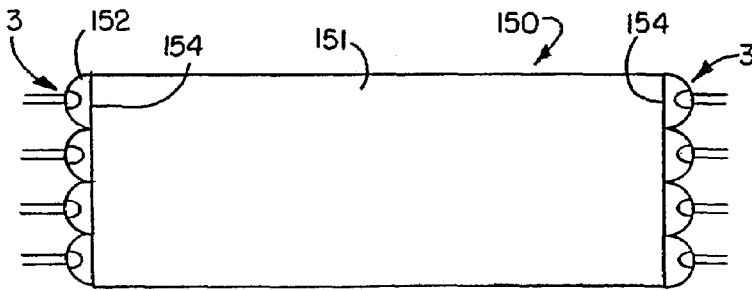


FIG. 44

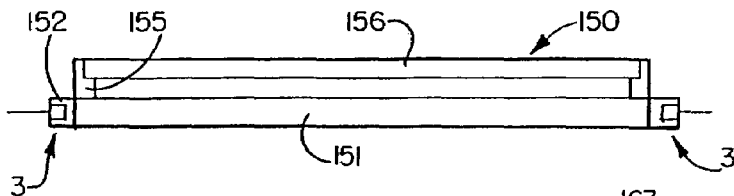


FIG. 45

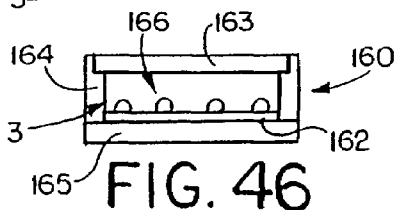


FIG. 46

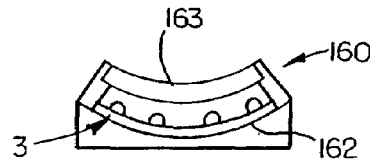


FIG. 47

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LIGHT EMITTING PANEL ASSEMBLIES**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application is a continuation of U.S. patent application Ser. No. 10/619,815, filed Jul. 15, 2003 now U.S. Pat. No. 7,195,389, which is a continuation of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 08/778,089, filed Jan. 2, 1997, now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a division of U.S. patent application Ser. No. 08/495,176, filed Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25, 1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emitting panel assemblies.

Light emitting panel assemblies are generally known. However, the present invention relates to several different light emitting panel assembly configurations which provide for better control of the light output from the panel assemblies and more efficient utilization of light to suit a particular application.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light emitting panel assemblies include a light emitting panel member having a pattern of individual light extracting deformities of well defined shapes on or in one or more surface areas of the light emitting panel member.

In accordance with another aspect of the invention, each of the light extracting deformities includes a reflective or refractive surface of a predetermined slope for more precisely controlling the emission of light by each of said deformities.

In accordance with another aspect of the invention, each of the light extracting deformities has an end wall that produces a relatively small projected surface area on the panel surface area to allow the number of deformities on or in the panel surface areas to be increased.

In accordance with another aspect of the invention, the light extracting deformities have straight side walls.

In accordance with another aspect of the invention, the light extracting deformities have rounded side walls.

In accordance with another aspect of the invention, the light extracting deformities have planar surfaces in parallel spaced relation to the panel surface areas.

In accordance with another aspect of the invention, the panel member is transparent and includes one or more panel portions having opposite sides that are free of any reflective material, whereby light is free to pass through such opposite sides.

In accordance with another aspect of the invention, deformities on or in one or more of the panel portions are shaped to cause more of the light entering the panel member through an input edge to be emitted from one of the sides of the panel portions than the other side.

In accordance with another aspect of the invention, the one side of the panel portion through which more of the light is emitted may be placed in close proximity to a front face of a display for front lighting the display.

In accordance with another aspect of the invention, the light emitting deformities have planar surfaces through which light from the display passes with minimal optical distortion.

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In accordance with another aspect of the invention, the pattern of light extracting deformities may be uniform or variable as desired to obtain a desired light output distribution from the panel surface areas.

5 In accordance with another aspect of the invention, the size and shape as well as the depth or height and angular orientation and location of the light extracting deformities may vary along the length and/or width of any given panel surface area to obtain a desired light output distribution from the panel member.

10 In accordance with yet another aspect of the invention, a focused light source may be insert molded or cast within a light transition area of the light emitting panel member.

In accordance with still another aspect of the invention, 15 molded supports may be provided on the panel member for supporting other parts or components in spaced relation from the panel member.

In accordance with another aspect of the invention, an array of light sources may be mounted on a printed circuit board for 20 directing light through a diffuser or lens mounted in spaced relation to the light sources for use in phototherapy treatment and the like.

The various light emitting panel assemblies of the present invention are relatively efficient panel assemblies that may be 25 used to produce increased uniformity and higher light output from the panel members with lower power requirements, and allow the panel members to be made thinner and/or longer, and/or of various shapes and sizes.

To the accomplishment of the foregoing and related ends, 30 the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three different forms of light emitting panel assemblies in accordance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light output area of a panel assembly showing one form of pattern of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views of a portion of a light output area of a panel assembly showing other forms of light extracting deformities formed in or on the light output area;

FIG. 5 is an enlarged transverse section through the light emitting panel assembly of FIG. 3 taken generally on the plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 7 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 9 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of light emitting panel assembly in accordance with this invention;

FIG. 11 is a side elevation view of the light emitting panel assembly of FIG. 10;

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FIG. 11*a* is a fragmentary side elevation view showing a tapered or rounded end on the panel member in place of the prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 13 is a schematic side elevation view of the light emitting panel assembly of FIG. 12;

FIGS. 14 and 15 are schematic perspective views of still other forms of light emitting panel assemblies in accordance with this invention;

FIGS. 16 and 17 are enlarged schematic fragmentary plan views of a surface area of a light panel assembly showing still other forms of light extracting deformities in accordance with this invention formed on or in a surface of the panel member;

FIGS. 18 and 19 are enlarged longitudinal sections through one of the light extracting deformities of FIGS. 16 and 17, respectively;

FIGS. 20 and 21 are enlarged schematic longitudinal sections through light extracting deformities similar to FIGS. 18 and 19, respectively, except that the deformity end walls are shown extending substantially perpendicular to the panel surface instead of perpendicular to their respective reflective/refractive surfaces as shown in FIGS. 18 and 19;

FIGS. 22 through 30 are enlarged schematic perspective views of panel surface areas containing various patterns of individual light extracting deformities of other well defined shapes in accordance with this invention;

FIG. 31 is an enlarged schematic longitudinal section through another form of light extracting deformity in accordance with this invention;

FIGS. 32 and 33 are enlarged schematic top plan views of panel surface areas containing light extracting deformities similar in shape to those shown in FIGS. 28 and 29 arranged in a plurality of straight rows along the length and width of the panel surface area;

FIGS. 34 and 35 are enlarged schematic top plan views of panel surface areas containing light extracting deformities also similar in shape to those shown in FIGS. 28 and 29 arranged in staggered rows along the length of the panel surface areas;

FIGS. 36 and 37 are enlarged schematic top plan views of panel surface areas containing a random or variable pattern of different sized light emitting deformities on the panel surface areas;

FIG. 38 is an enlarged schematic perspective view of a panel surface area showing light extracting deformities in accordance with this invention increasing in size as the distance of the deformities from the light source increases or intensity of the light increases along the length of the panel surface area;

FIGS. 39 and 40 are schematic perspective views showing different angular orientations of the light extracting deformities along the length and width of a panel surface area;

FIG. 39A is an enlarged schematic top plan view of the panel surface area of FIG. 39 showing the reflective or refractive surfaces of the light extracting deformities oriented to face the portion of the width of the input edge to which the light source is optically coupled across the width of the panel surface and the deformities in close proximity to the input edge increasing in density, size and depth or height as the distance of the deformities from the light source increases across the width of the panel surface.

FIG. 39B is an enlarged fragmentary top plan view similar to FIG. 39A but showing a plurality of light sources optically coupled to different portions of the width of the input edge of the panel surface with the reflective or refractive light extract-

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ing surfaces of the deformities at different locations across the width of the panel surface oriented to face the different portions of the width of the input edge to which the different light sources are optically coupled and the deformities in close proximity to the input edge increasing in density, size and depth or height as the distance of the deformities from the respective light sources increases across the width of the panel surface.

FIGS. 41 and 42 are enlarged perspective views schematically showing how exemplary light rays emitted from a focused light source are reflected or refracted by different individual light extracting deformities of well defined shapes in accordance with this invention;

FIG. 43 is a schematic perspective view showing a light emitting panel assembly similar to FIG. 42 placed on a front face of a display to provide front lighting for the display;

FIG. 44 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention for use in phototherapy treatment and the like; and

FIGS. 45 through 47 are schematic side elevation views of still other forms of light emitting panel assemblies in accordance with this invention for use in phototherapy treatment and the like.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in detail to the drawings, and initially to FIG. 1, there is schematically shown one form of light emitting panel assembly 1 in accordance with this invention including a transparent light emitting panel 2 and one or more light sources 3 which emit light in a predetermined pattern in a light transition member or area 4 used to make the transition from the light source 3 to the light emitting panel 2, as well known in the art. The light that is transmitted by the light transition area 4 to the transparent light emitting panel 2 may be emitted along the entire length of the panel or from one or more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. 1 the light transition area 4 is shown as an integral extension of one end of the light emitting panel 2 and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area 4 may be a separate piece suitably attached to the light input surface 13 of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. 2 shows another form of light emitting panel assembly 5 in accordance with this invention including a panel light transition area 6 at one end of the light emitting panel 7 with sides 8, 9 around and behind the light source 3 shaped to more efficiently reflect and/or refract and focus the light emitted from the light source 3 that impinges on these surfaces back through the light transition area 6 at an acceptable angle for entering the light input surface 18 at one end of the light emitting panel 7. Also, a suitable reflective material or coating 10 may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. 1 and 2 on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

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The panel assemblies shown in FIGS. 1 and 2 include a single light source 3, whereas FIG. 3 shows another light emitting panel assembly 11 in accordance with this invention including two light sources 3. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly 11 of FIG. 3 includes a light transition area 12 at one end of the light emitting panel 14 having reflective and/or refractive surfaces 15 around and behind each light source 3. These surfaces 15 may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas 12 into the light input surface 19 of the light emitting panel 14.

The light sources 3 may be mechanically held in any suitable manner in slots, cavities or openings 16 machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources 3 are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bonding the light sources 3 in the slots, cavities or openings 16 in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material 17. The slots, cavities or openings 16 may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultrasonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source 3 may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources 3 may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources 3 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

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A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. 4a schematically shows one such light surface area 20 on which a pattern of light extracting deformities or disruptions 21 is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities 21 shown in FIG. 4a includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities 21 are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions 21 can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning the sheet or film against one or both sides of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformities 21 may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities 21 may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source 3 thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities 21 may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display back light, the light output will be more efficient if the deformities 21 cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities 21 may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the

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deformity **21** coverage. Moreover, the pattern of light extracting deformities **21** may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities **21** may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes **21** in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities **21** shown in FIG. **4a**, other light extracting deformities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. **4b** and **4c** show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4d** shows prismatic or other reflective or refractive surfaces **25** formed on the exterior of the panel area. The prismatic surfaces, depressions or raised surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. **5**, a back reflector (including trans reflectors) **26** may be attached or positioned against one side of the panel member **14** of FIG. **3** using a suitable adhesive **28** or other method in order to improve light output efficiency of the panel assembly **11** by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities **21**, **23**, **24** and/or **25** may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate **27** may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive **28** or other method in order to produce a desired effect.

The member **27** may be used to further improve the uniformity of the light output distribution. For example, the member **27** may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive **28** is used to adhere the back reflector **26** and/or film **27** to the panel, the adhesive is preferably applied only

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along the side edges of the panel, and if desired the end edge opposite the light transition areas **12**, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps **30** (see FIG. **5**) which are formed between the respective panel surfaces and the back reflector **26** and/or film **27** when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps **30** are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. **2**, the panel assembly **5** shown therein also includes molded posts **31** at one or more corners of the panel **7** (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. **6** shows another form of light emitting panel assembly **32** in accordance with this invention including a panel member **33**, one or more light sources **3**, and one or more light output areas **34**. In addition, the panel assembly **32** includes a tray **35** having a cavity or recess **36** in which the panel assembly **32** is received. The tray **35** may act as a back reflector as well as end edge and/or side edge reflectors for the panel **33** and side and/or back reflectors **37** for the light sources **3**. Additionally, one or more secondary reflective or refractive surfaces **38** may be provided on the panel member **33** and/or tray **35** to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member **33**. These secondary reflective/refractive surfaces **38** may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a predetermined pattern. FIG. **6** also shows multiple light output areas **34** on the panel member that emit light from one or more light sources **3**.

FIG. **7** is a schematic illustration of still another form of light emitting panel assembly **40** in accordance with this invention including a panel member **41** having one or more light output areas **42** and one or more light transition areas (mixing areas) **43** containing a plurality of light sources **3** at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources **3** desirably employs three colored LEDs (red, blue, green) in each transition mixing area **43** so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area **42**. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. **8** shows yet another form of light emitting panel assembly **45** in accordance with this invention including a light emitting panel member **46** and a light source **3** in a light transition area **48** integral with one end of the panel member. In this particular embodiment, the panel member **46** is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. **9** schematically shows another form of light emitting panel assembly **50** in accordance with this invention, including a panel member **51** having multiple light output areas **52**,

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and mounting posts and/or mounting tabs **53**. This particular panel assembly **50** may serve as a structural member to support other parts or components as by providing holes or cavities **54**, **55** in the panel member **51** which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess **56** may be provided in the panel member **51** for receipt of a correspondingly shaped light transition area **57** having one or more light sources **3** embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface **58** on the transition area **57** and/or wall of the cavity or recess **56** to redirect a portion of the light in a predetermined manner. In this way the light transition area **57** and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector **58** may be placed on the reflective or refractive surface of the cavity or recess **56** or insert **57**. Where the reflector **58** is placed on the reflective or refractive surface of the cavity or recess **56**, the cavity or recess may act as a mold permitting transparent material from which the transition area **57** is made to be cast around one or more light sources **3**.

FIGS. **10** and **11** schematically show another form of light emitting panel assembly **60** in accordance with this invention including a panel member **61** having one or more light output areas **62**. In this particular embodiment, an off-axis light transition area **63** is provided that is thicker in cross section than the panel member to permit use of one or more light sources **3** embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface **64** (FIG. **11**) may be provided on the transition area **63**. Moreover, a prism **65** (FIG. **11**) or tapered, rounded, or otherwise shaped end **66** (FIG. **11a**) may be provided at the end of the panel opposite the light sources **3** to perform the function of an end reflector. The light sources **3** may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays **67** in the transition area **63** as schematically shown in FIG. **10** and/or to permit a shorter length transition area **63** to be used.

FIGS. **12** and **13** schematically show still another form of light emitting panel assembly **70** in accordance with this invention which includes one or more light transition areas **71** at one or both ends of the panel member **72** each containing a single light source **73**. The transition area or areas **71** shown in FIGS. **12** and **13** collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area **71** shown in FIGS. **12** and **13** has elliptical and parabolic shape surfaces **74** and **75** in different planes for directing the light rays **76** into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. **14** schematically illustrates still another form of light emitting panel assembly **80** in accordance with this invention including a light emitting panel **81** and one or more light sources **3** positioned, embedded, potted, bonded or otherwise mounted in a light transition area **82** that is at an angle relative to the panel member **81** to permit more efficient use of space. An angled or curved reflective or refractive surface **83** is

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provided at the junction of the panel member **81** with the transition area **82** in order to reflect/refract light from the light source **3** into the body of the panel member **81** for emission of light from one or more light emitting areas **84** along the length of the panel member.

FIG. **15** schematically illustrates still another form of light emitting panel assembly **90** in accordance with this invention including a light transition area **91** at one or both ends of a light emitting panel member **92** containing a slot **93** for sliding receipt of an LED or other suitable light source **3**. Preferably the slot **93** extends into the transition area **91** from the back edge **94**, whereby the light source **3** may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source **3** may be provided with wings, tabs or other surfaces **95** for engagement in correspondingly shaped recesses or grooves **96** or the like in the transition area **91** for locating and, if desired, securing the light source in place. Also, the light source **3** may be embedded, potted, bonded or otherwise secured within the slot **93** in the light transition area **91** of the panel member **92**. Light from a secondary light source **97** may be projected through the panel member **92** for indication or some other effect.

FIG. **16** through **19** show other light extracting deformities **98** in accordance with this invention which may either be individual projections **99** on the respective panel surface areas **22** or individual depressions **100** in such panel surface areas. In either case, the light extracting deformities **98** differ from the light extracting deformities shown in FIGS. **4a**, **4b**, **4c** and **4d** in that each of the deformities **98** has a well defined shape including a reflective or refractive surface **101** that intersects the respective panel surface area **22** at one edge **102** and has a uniform slope throughout its length for more precisely controlling the emission of light by each of the deformities. Along a peripheral edge portion **103** of each reflective/refractive surface **101** is an end wall **104** of each deformity **98** that intersects the respective panel surface area at a greater included angle **I** than the included angle **I'** between the reflective/refractive surfaces **101** and the panel surface area **22** (see FIGS. **18** and **19**) to minimize the projected surface area of the end walls on the panel surface area. This allows more deformities **98** to be placed on or in the panel surface areas than would otherwise be possible if the projected surface areas of the end walls **104** were substantially the same as or greater than the projected surface areas of the reflective/refractive surfaces **101**.

In FIGS. **16** and **17** the peripheral edge portions **103** of the reflective/refractive surfaces **101** and associated end walls **104** are curved in the transverse direction. Also, in FIGS. **18** and **19** the end walls **104** of the deformities **98** are shown extending substantially perpendicular to the reflective/refractive surfaces **101** of the deformities. Alternatively, such end walls **104** may extend substantially perpendicular to the panel surface areas **22** as schematically shown in FIGS. **20** and **21**. This virtually eliminates any projected surface area of the end walls **104** on the panel surface areas **22** whereby the density of the deformities on the panel surface areas may be even further increased.

The light extracting deformities may also be of other well defined shapes to obtain a desired light output distribution from a panel surface area. FIG. **22** shows individual light extracting deformities **105** on a panel surface area **22** each including a generally planar, rectangular reflective/refractive surface **106** and associated end wall **107** of a uniform slope throughout their length and width and generally planar side

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walls **108**. Alternatively, the deformities **105'** may have rounded or curved side walls **109** as schematically shown in FIG. **23**.

FIG. **24** shows individual light extracting deformities **110** on a panel surface area **22** each including a planar, sloping triangular shaped reflective/refractive surface **111** and associated planar, generally triangularly shaped side walls or end walls **112**. FIG. **25** shows individual light extracting deformities **115** each including a planar sloping reflective/refractive surface **116** having angled peripheral edge portions **117** and associated angled end and side walls **118** and **119**.

FIG. **26** shows individual light extracting deformities **120** which are generally conically shaped, whereas FIG. **27** shows individual light extracting deformities **121** each including a rounded reflective/refractive surface **122** and rounded end wall **123** and rounded or curved side walls **124** all blended together.

Regardless of the particular shape of the reflective/refractive surfaces and end and side walls of the individual deformities, such deformities may also include planar surfaces intersecting the reflective/refractive surfaces and end and/or side walls in parallel spaced relation to the panel surface areas **22**. FIGS. **28** through **30** show deformities **125**, **126** and **127** in the form of individual projections on a panel surface area **22** having representative shapes similar to those shown in FIGS. **22**, **23** and **26**, respectively, except that each deformity is intersected by a planar surface **128** in parallel spaced relation to the panel surface area **22**. In like manner, FIG. **31** shows one of a multitude of deformities **129** in the form of individual depressions **130** in a panel surface area **22** each intersected by a planar surface **128** in parallel spaced relation to the general planar surface of the panel surface area **22**. Any light rays that impinge on such planar surfaces **128** at internal angles less than the critical angle for emission of light from the panel surface area **22** will be internally reflected by the planar surfaces **128**, whereas any light rays impinging on such planar surfaces **128** at internal angles greater than the critical angle will be emitted by the planar surfaces with minimal optical discontinuities as schematically shown in FIG. **31**.

Where the deformities are projections on the panel surface area **22**, the reflective/refractive surfaces extend at an angle away from the panel in a direction generally opposite to that in which the light rays from the light source **3** travel through the panel as schematically shown in FIGS. **18** and **20**. Where the deformities are depressions in the panel surface area, the reflective/refractive surfaces extend at an angle into the panel in the same general direction in which the light rays from the light source **3** travel through the panel member as schematically shown in FIGS. **19** and **21**.

Regardless of whether the deformities are projections or depressions on or in the panel surface areas **22**, the slopes of the light reflecting/refractive surfaces of the deformities may be varied to cause the light rays impinging thereon to be either refracted out of the light emitting panel or reflected back through the panel and emitted out the opposite side of the panel which may be etched to diffuse the light emitted therefrom or covered by a transparent film, sheet or plate similar to the film **27** shown in FIGS. **3** and **5** to produce a desired effect.

Also, the pattern of light extracting deformities on the panel surface areas may be uniform or variable as desired to obtain a desired light output distribution from the panel surface areas. FIGS. **32** and **33** show deformities **125** and **126** similar in shape to those shown in FIGS. **28** and **29** arranged in a plurality of generally straight uniformly spaced apart rows along the length and width of a panel surface area **22**,

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whereas FIGS. **34** and **35** show such deformities **125** and **126** arranged in staggered rows along the length of a panel surface area.

Also, the size, including the width, length and depth or height as well as the angular orientation and position or location of the light extracting deformities may vary along the length and/or width of any given panel surface area to obtain a desired light output distribution from the panel surface area. FIGS. **36** and **37** show a random or variable pattern of different sized deformities **105** and **105'** similar in shape to those shown in FIGS. **22** and **23**, respectively, arranged in staggered rows on a panel surface area **22**, whereas FIG. **38** shows deformities **126** similar in shape to those shown in FIG. **29** increasing in size as the distance of the deformities from the light source increases or intensity of the light decreases along the length and/or width of the panel surface area **22**.

FIGS. **39** and **40** schematically show different angular orientations of light extracting deformities **135** of any desired shape along the length and width of a panel surface area **22**. For example the deformities **135** may be of the shape shown in FIGS. **16-21** each including a reflective or refractive light emitting surface **101'** and an end wall surface **104'**, both of which intersect the panel surface **22** and intersect each other to form a ridge **136** as shown in FIGS. **39A** and **39B**. In FIG. **39** the light extracting deformities **135** are arranged in straight rows **136** along the length of the panel surface area but the reflective or refractive surfaces **101'** of the deformities in each of the rows are oriented to face the light source **3** so that the reflective or refractive surfaces **101'** of all of the deformities are substantially in line with the light rays being emitted from the light source **3** across the width and length of the panel surface as schematically shown in FIG. **39A**. Also FIG. **39A** shows the deformities **135** in close proximity to the input edge increasing in density, size and depth or height as the distance of the deformities from the light source increases across the width of the panel surface. In FIG. **40** the deformities **135** are also oriented so that the reflective or refractive surfaces of the deformities face the light source **3** across the width and length of the panel surface similar to FIG. **39**. In addition, the rows **137** of deformities in FIG. **40** are in substantial radial alignment with the light source.

FIG. **39B** shows a plurality of light sources **3** optically coupled to different portions of the width of the input edge of the panel surface area **22** and the reflective or refractive light extracting surfaces **101'** of different ones of the deformities **135** at different locations across the panel surface area oriented at different angles to face different portions of the input edge to which the respective light sources are optically coupled. Also FIG. **39B** shows the deformities in close proximity to the input edge increasing in density, size and depth or height as the distance of the deformities from the respective light sources increases across the width of the panel surface.

FIGS. **41** and **42** schematically show how exemplary light rays **140** emitted from a focused light source **3** insert molded or cast within a light transition area **6** of a light emitting panel assembly **5** in accordance with this invention are reflected during their travel through the light emitting panel member **7** until they impinge upon individual light extracting deformities **98**, **126** of well defined shapes on or in a panel surface area **22** causing more of the light rays to be reflected or refracted out of one side **141** of the panel member than the other side **142**. In FIG. **41** the exemplary light rays **140** are shown being reflected by the reflective/refractive surfaces **101** of the deformities **98** in the same general direction out through the same side **141** of the panel member, whereas in FIG. **42** the light rays **140** are shown being scattered in different directions within the panel member **7** by the rounded

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side walls **109** of the deformities **126** before the light rays are reflected/refracted out of the same side **141** of the panel member. Such a pattern of individual light extracting deformities of well defined shapes in accordance with the present invention can cause 60 to 70% or more of the light received through the input edge **18** of the panel member to be emitted from the same side of the panel member.

FIG. **43** schematically shows the side **141** of the light emitting panel assembly **5** of FIG. **42** from which a majority of the light is emitted placed against the front face **143** of a liquid crystal display or other signage **144** for front lighting the display/signage when the ambient light is not sufficient for proper illumination. The portions of the panel member **7** overlying the display/signage **144** are transparent without any back reflector, whereby when the light source **3** is energized, light will be emitted from the side **141** of the panel member **7** contacting the front face **143** of the display/signage **144** and then reflected back out through the panel member **7** including particularly the planar surfaces **128** on the deformities.

By selecting the optical index of refraction of the panel member **7** to closely match the substrate of the display/signage **144**, the light reflected by the display/signage will pass through the planar surfaces **128** of the deformities with minimal optical discontinuities for ease of viewing the display/signage. Also, providing a random or variable pattern of light extracting deformities on the panel member insures that the spacing of the light extracting deformities does not match the pixel spacing of the display so as not to produce a headlight effect.

Because the light extracting deformities are of well defined shapes, the size, shape, location and orientation of each light extracting deformity can be individually adjusted or randomly varied at any given surface area of the panel member to spread the light output distribution uniformly across each panel surface area or obtain any other desired light output distribution at each panel surface area. Also, such light extracting deformities may be formed in or on any surface area of the panel member in any desired manner, such as by machining using a milling or laser cutter, or by molding or stamping or the like.

The light source **3** for the panel assemblies shown in FIGS. **16**, **17** and **39** through **43** may be of any suitable type as previously described. However, preferably such light source is a focused light source such as a lens end bulb, a chip from an LED, or a laser or laser diode. Alternatively such light source may be an LED, incandescent lamp or other light source having an integral collector **145** (see FIG. **16**) that collects the light from the light source and focuses the light. In either case the light from the light source is preferably focused in a predetermined pattern on the input surface **146** of the light transition area **6** which directs the light at an acceptable angle for entering the light input edge **18** of the light emitting panel **7** over a substantial portion of the cross sectional area of the panel.

FIG. **44** schematically illustrates still another form of light emitting panel assembly **150** in accordance with this invention which is particularly adapted to be used for different types of phototherapy treatment by exposing various portions of the skin or eyes of a person to light being emitted from the panel assembly to treat such conditions as neonatal hyperbilirubinemia, insomnia, sleep disorders or tiredness associated with jet lag or shift work, certain types of psychiatric disorders such as seasonal affective disorder (SAD) and depression and so on. To that end, the light emitting panel assembly **150** includes a light emitting panel member **151** which may be in the shape of a pad or blanket. At one or both ends of the panel member **151** are one or more light transition areas **152**

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containing one or more LEDs or other light sources **3** for uniformly supplying light of any desired wavelength to the panel input edge **154** at one or both ends of the panel member. If desired, the light sources may be different colored LEDs so that the light from the LEDs can be mixed to produce virtually any desired colored light output distribution including white light from the panel member. Also, white LEDs may be used for producing a white light output distribution from the panel member.

On one or more selected panel surface areas on one or both sides of the panel member **151** are a pattern of light extracting deformities or disruptions which are not shown in FIG. **44** but may be of any of the types previously described for producing a desired light output distribution from the panel surface areas. The portion of the body of a person to receive phototherapy treatment may be placed in close association with or directly against the light emitting surface areas of the panel. Alternatively, the panel assembly **150** may be provided with molded portions **155** at strategic locations on the panel member **151** (for example at all four corners) for providing structural support for locating other parts or components such as a diffuser or lens **156** as schematically shown in FIG. **45**.

FIG. **46** shows still another form of light emitting panel assembly **160** in accordance with this invention for use in phototherapy treatment or other applications in which an array of LEDs or other light sources **3** are mounted on a printed circuit board **162** for directing light through a transparent member **163** which may be a diffuser or lens. The transparent member **163** is maintained in spaced apart relation from the printed circuit board **162** and light sources **3** mounted thereon by a plurality of upstanding supports **164** on a base **165** for the circuit board. Not only does this protect the circuit board **162** and light sources **3** against damage, but also provides an air gap **166** between the light sources **3** and transparent member **163** to facilitate dissipation of any heat that is produced by the light sources.

In FIG. **46** the circuit board **162** and transparent member **163** are shown as being substantially flat. However, it will be appreciated that such circuit board **162** and transparent member **163** may also be curved as schematically shown in FIG. **47** for supporting a body part such as an arm, leg or neck of a person receiving phototherapy treatment.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example liquid crystal display (LCD) or other signage back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, membrane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members in the manner previously described.

Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting panel assembly comprising a light emitting panel member having at least one input edge, a plurality of light sources optically coupled to different portions of the width of the input edge, and a pattern of individual light

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extracting deformities associated with respective light sources, wherein the deformities are projections or depressions on or in at least one surface of the panel member for producing a desired light output from the panel member, wherein each of the deformities has a length and width substantially smaller than the length and width of the panel surface, wherein the deformities that are in close proximity to the input edge increase in density, size, depth and/or height as the distance of the deformities from the respective light sources increases across the width of the panel member, and wherein the density, size, depth and/or height of the deformities in close proximity to the input edge is greatest at approximate midpoints between adjacent pairs of the light sources.

2. The assembly of claim 1 wherein the light sources are light emitting diodes.

3. The assembly of claim 1 wherein different ones of at least some of the deformities have at least one light extracting surface that is oriented to face the respective light sources depending on the location of the deformities across the width of the panel member.

4. The assembly of claim 1 wherein at least some of the deformities have two or more intersecting surfaces that intersect the panel surface and intersect each other.

5. The assembly of claim 4 wherein the surfaces of at least some of the deformities are multi-segment, curved or flat.

6. A light emitting panel assembly comprising a light emitting panel member having at least one input edge, a plurality of light sources optically coupled to different portions of the width of the input edge, and a pattern of individual light extracting deformities associated with respective light sources, wherein the deformities are projections or depressions on or in at least one surface of the panel member for producing a desired light output from the panel member, wherein each of the deformities has a length and width substantially smaller than the length and width of the panel surface, wherein the deformities that are in close proximity to the input edge increase in density, size, depth and/or height as the distance of the deformities from the respective light sources increases across the width of the panel member, wherein at least some of the deformities have two or more intersecting surfaces that intersect the panel surface and intersect each other, and wherein at least some of the deformities only have two surfaces.

7. The assembly of claim 6 wherein the light sources are light emitting diodes.

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8. The assembly of claim 6 wherein different ones of at least some of the deformities have at least one light extracting surface that is oriented to face different light sources depending on the location of the deformities across the width of the panel member.

9. The assembly of claim 6 wherein at least some of the deformities at different locations across the width of the panel surface have at least one light extracting surface that is oriented in a width or length direction of the light extracting surface at different orientations relative to the input edge and relative to each other depending on the location of the deformities on the panel surface to face the portion of the width of the input edge to which the different light sources are optically coupled.

10. The assembly of claim 9 wherein substantially all of the deformities across the width of the panel member have at least one light extracting surface that is oriented in the width or length direction of the light extracting surface to face the portion of the width of the input edge to which the different light sources are optically coupled.

11. The assembly of claim 9 wherein at least one of the intersecting surfaces of at least some of the deformities comprises the light extracting surface of the deformities that is oriented in the width or length direction of the light extracting surface to face the portion of the width of the input edge to which the different light sources are optically coupled.

12. The assembly of claim 9 wherein the two surfaces of at least some of the deformities come together to form ridges, and at least one of the surfaces of at least some of the deformities at different locations across the width of the panel surface is oriented at different orientations in a width or length direction of the at least one surface relative to the input edge and relative to each other to face the portion of the width of the input edge to which the different light sources are optically coupled.

13. The assembly of claim 12 wherein at least some of the deformities vary in at least one of the following characteristics for controlling an output ray angle distribution or uniformity of the light emitted by the panel member to serve a particular application: density, size, depth and/or height.

14. The assembly of claim 12 wherein at least some of the deformities are random in at least one of the following characteristics for controlling an output ray angle distribution or uniformity of the light emitted by the panel member to suit a particular application: density, size, depth and/or height.

* * * * *

EXHIBIT D

(12) **United States Patent
Parker**

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(45) **Date of Patent:** Oct. 14, 2008

(54) **LIGHT EMITTING PANEL ASSEMBLIES**
(75) Inventor: **Jeffery R. Parker**, Richfield, OH (US)
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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 103 days.
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(65) **Prior Publication Data**
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Related U.S. Application Data

(60) Continuation of application No. 10/784,527, filed on Feb. 23, 2004, now Pat. No. 7,160,015, which is a division of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481, which is a continuation-in-part of application No. 08/778,089, filed on Jan. 2, 1997, now Pat. No. 6,079,838, which is a division of application No. 08/495,176, filed on Jun. 27, 1995, now Pat. No. 5,613,751.

(Continued)

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362/800, 27, 619, 613, 612, 620, 608, 609,
362/621, 600, 632, 634, 26
See application file for complete search history.

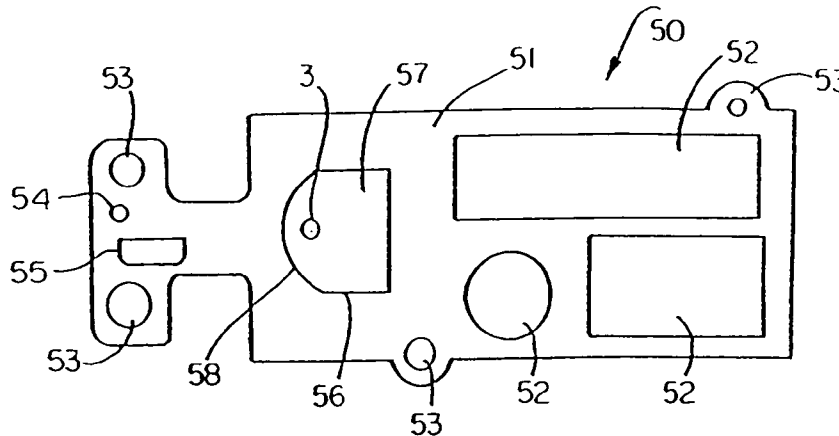
(57) **ABSTRACT**

Light emitting panel assembly includes a light emitting panel member received in a cavity or recess in a tray or housing. The panel member has a pattern of light extracting deformities on or in at least one surface of the panel member to cause light received from at least one LED light source positioned near or against the light entrance surface of the panel member to be emitted from a light emitting surface of the panel member. The tray or housing acts as an end edge and/or side edge reflector for the panel member to reflect light that would otherwise exit the panel member through the end edge and/or side edge back into the panel member for causing additional light to be emitted from the panel member.

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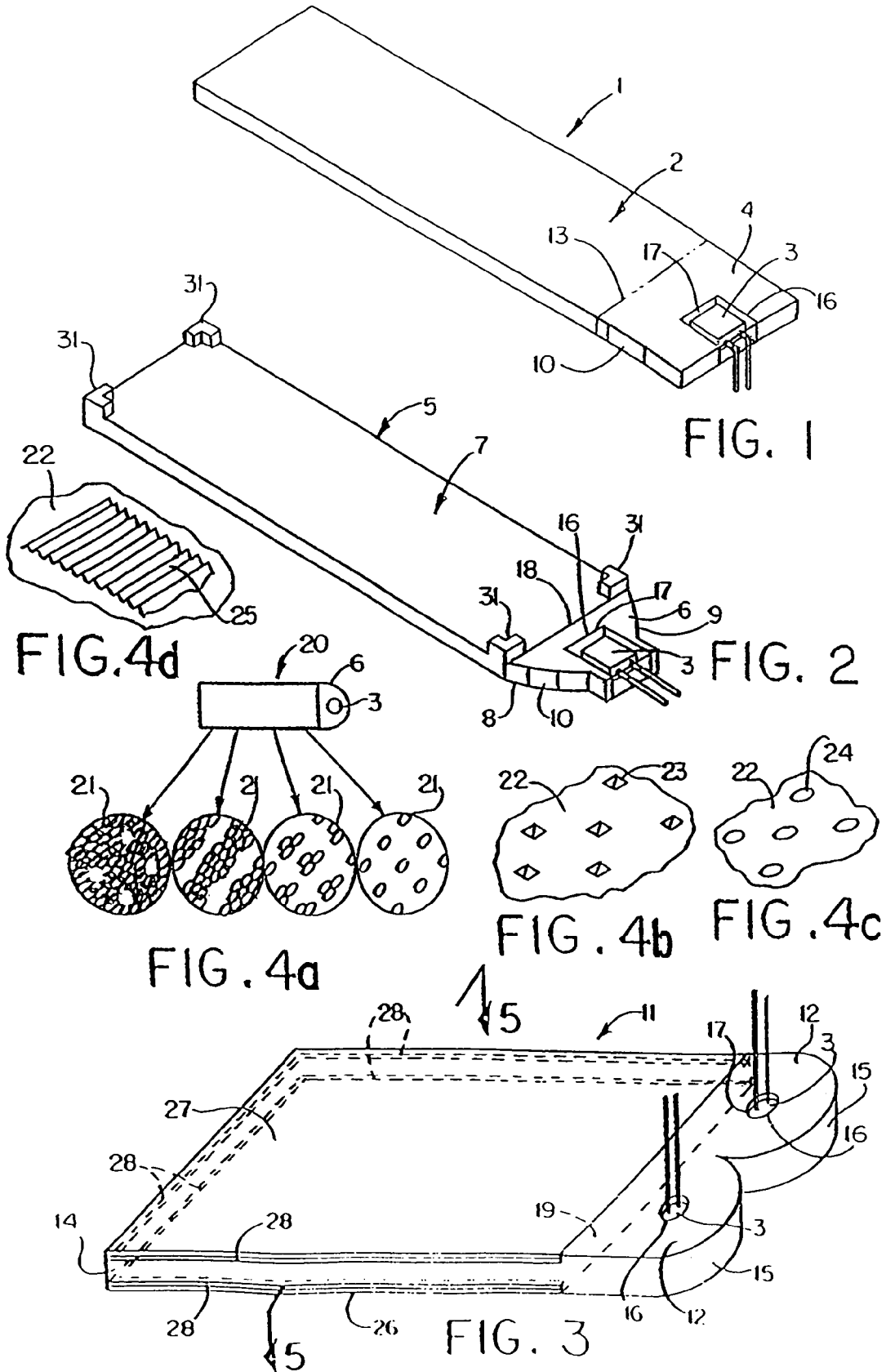
24 Claims, 4 Drawing Sheets

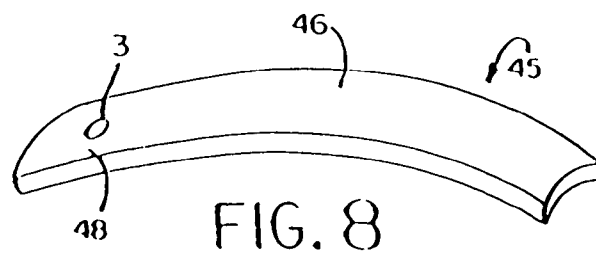
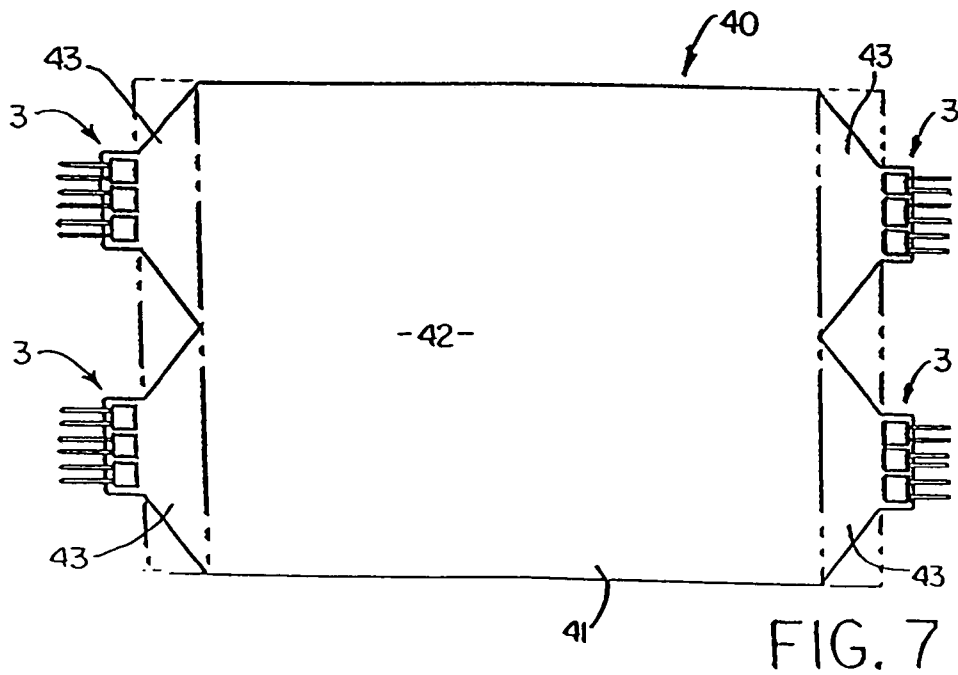
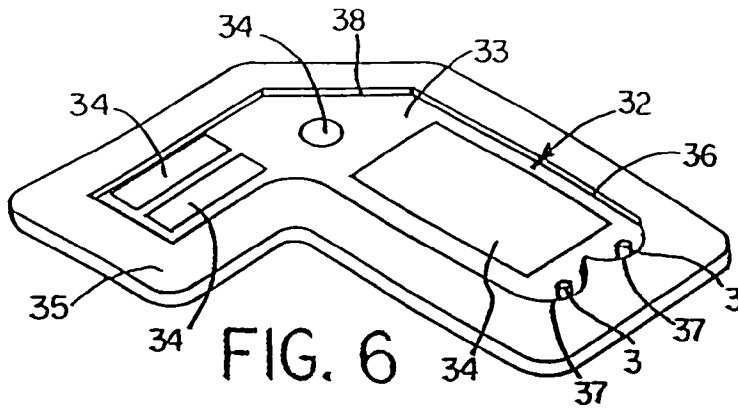
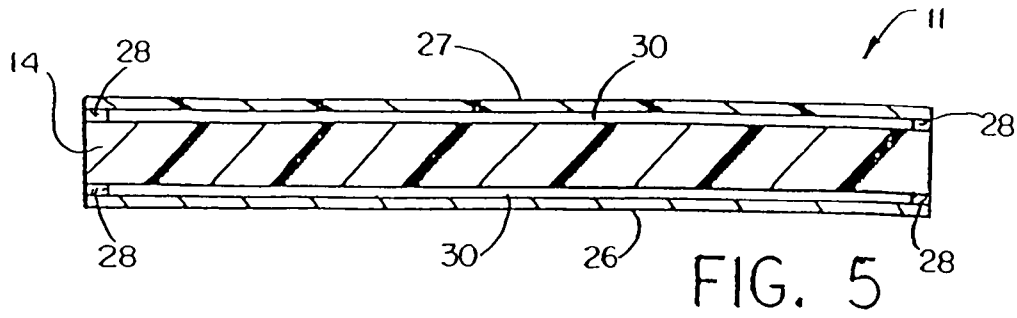


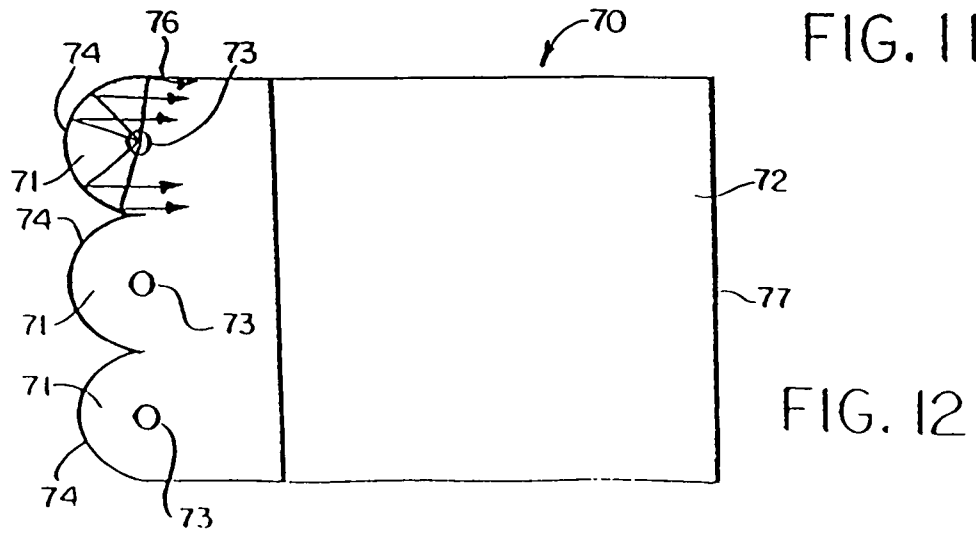
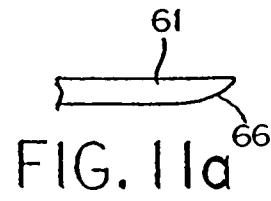
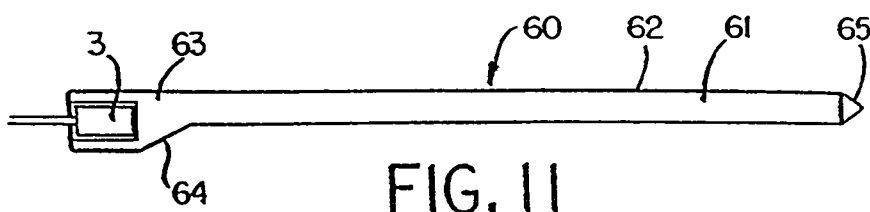
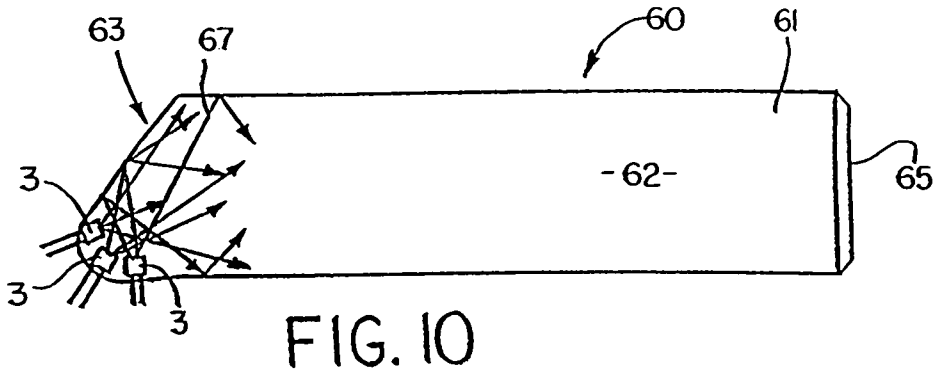
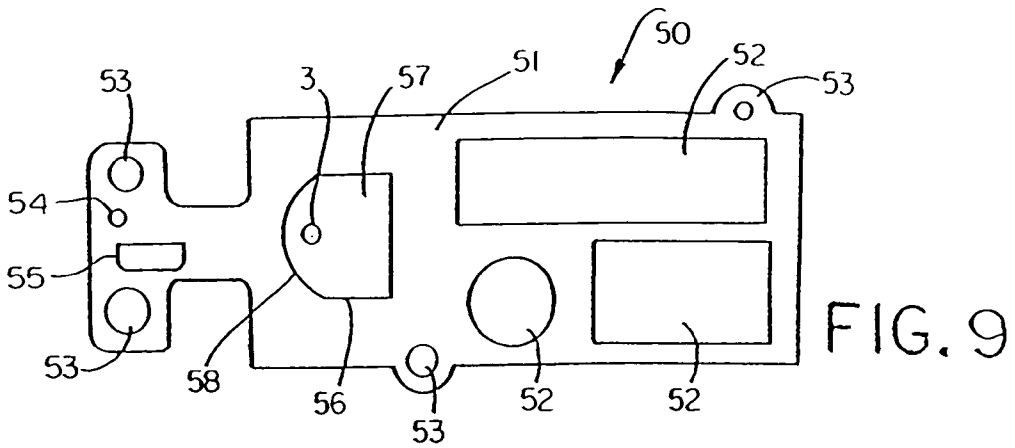
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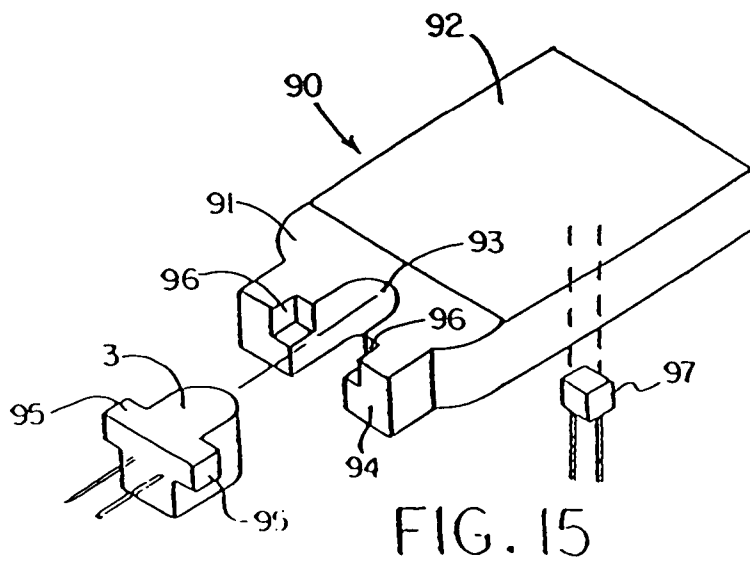
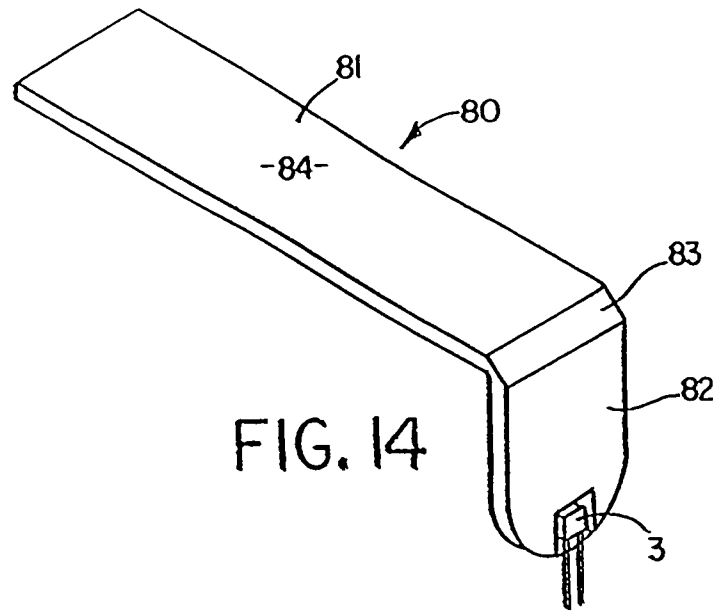
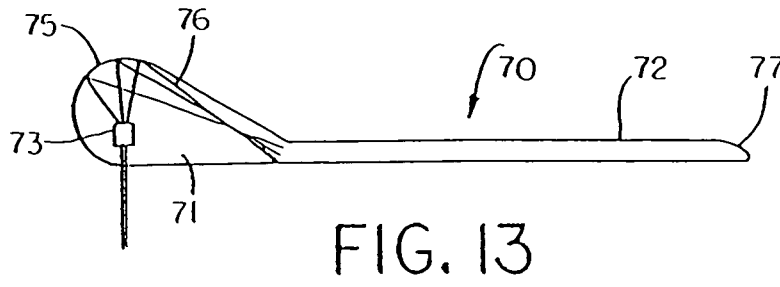
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LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 10/784,527, filed Feb. 23, 2004, which is a division of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 08/778,089, filed Jan. 2, 1997, now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a division of U.S. patent application Ser. No. 08/495,176, filed Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25, 1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emitting panel assemblies each including a transparent panel member for efficiently conducting light, and controlling the light conducted by the panel member to be emitted from one or more light output areas along the length thereof.

Light emitting panel assemblies are generally known. However, the present invention relates to several different light emitting panel assembly configurations which provide for better control of the light output from the panel assemblies and for more efficient utilization of light, which results in greater light output from the panel assemblies.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light emitting panel assemblies include a light emitting panel member having a light transition area in which at least one light source is suitably mounted for transmission of light to the light input surface of the panel member.

In accordance with another aspect of the invention, the light source is desirably embedded, potted or bonded to the light transition area to eliminate any air gaps, decrease surface reflections and/or eliminate any lens effect between the light source and light transition area, thereby reducing light loss and increasing the light output from the panel assembly.

In accordance with another aspect of the invention, the panel assemblies may include reflective or refractive surfaces for changing the path of a portion of the light, emitted from the light source, that would not normally enter the panel members at an acceptable angle that allows the light to remain in the panel members for a longer period of time and/or increase the efficiency of the panel members.

In accordance with another aspect of the invention, the light emitting panel members include a pattern of light extracting deformities or disruptions which provide a desired light output distribution from the panel members by changing the angle of refraction of a portion of the light from one or more light output areas of the panel members.

In accordance with still another aspect of the invention, the light source may include multiple colored light sources for supplying light to one or more light output areas, and for providing a colored or white light output distribution.

In accordance with yet another aspect of the invention, the panel assemblies include a transition area for mixing the multiple colored lights, prior to the light entering the panel members, in order to effect a desired colored or white light output distribution.

The various light emitting panel assemblies of the present invention are very efficient panel assemblies that may be used to produce increased uniformity and higher light output from

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the panel members with lower power requirements, and allow the panel members to be made thinner and/or longer, and/or of various shapes and sizes.

To the accomplishment of the foregoing and related ends, the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three different forms of light emitting panel assemblies in accordance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light output area of a panel assembly showing one form of pattern of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views of a portion of a light output area of a panel assembly showing other forms of light extracting deformities formed in or on the light output area;

FIG. 5 is an enlarged transverse section through the light emitting panel assembly of FIG. 3 taken generally on the plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 7 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 9 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of light emitting panel assembly in accordance with this invention;

FIG. 11 is a side elevation view of the light emitting panel assembly of FIG. 10;

FIG. 11a is a fragmentary side elevation view showing a tapered or rounded end on the panel member in place of the prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 13 is a schematic side elevation view of the light emitting panel assembly of FIG. 12; and

FIGS. 14 and 15 are schematic perspective views of still other forms of light emitting panel assemblies in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS

Referring now in detail to the drawings, and initially to FIG. 1, there is schematically shown one form of light emitting panel assembly 1 in accordance with this invention including a transparent light emitting panel 2 and one or more light sources 3 which emit light in a predetermined pattern in a light transition member or area 4 used to make the transition from the light source 3 to the light emitting panel 2, as well known in the art. The light that is transmitted by the light transition area 4 to the transparent light emitting panel 2 may be emitted along the entire length of the panel or from one or

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more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. 1 the light transition area 4 is shown as an integral extension of one end of the light emitting panel 2 and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area 4 may be a separate piece suitably attached to the light input surface 13 of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. 2 shows another form of light emitting panel assembly 5 in accordance with this invention including a panel light transition area 6 at one end of the light emitting panel 7 with sides 8, 9 around and behind the light source 3 shaped to more efficiently reflect and/or refract and focus the light emitted from the light source 3 that impinges on these surfaces back through the light transition area 6 at an acceptable angle for entering the light input surface 18 at one end of the light emitting panel 7. Also, a suitable reflective material or coating 10 may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. 1 and 2 on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

The panel assemblies shown in FIGS. 1 and 2 include a single light source 3, whereas FIG. 3 shows another light emitting panel assembly 11 in accordance with this invention including two light sources 3. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly 11 of FIG. 3 includes a light transition area 12 at one end of the light emitting panel 14 having reflective and/or refractive surfaces 15 around and behind each light source 3. These surfaces 15 may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas 12 into the light input surface 19 of the light emitting panel 14.

The light sources 3 may be mechanically held in any suitable manner in slots, cavities or openings 16 machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources 3 are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bonding the light sources 3 in the slots, cavities or openings 16 in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material 17. The slots, cavities or openings 16 may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultra-

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sonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source 3 may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources 3 may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources 3 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. 4a schematically shows one such light surface area 20 on which a pattern of light extracting deformities or disruptions 21 is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities 21 shown in FIG. 4a includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities 21 are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions 21 can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning the sheet or film against one or both sides of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformi-

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ties **21** may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities **21** may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source **3** thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities **21** may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display backlight, the light output will be more efficient if the deformities **21** cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities **21** may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity **21** coverage. Moreover, the pattern of light extracting deformities **21** may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities **21** may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes **21** in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities **21** shown in FIG. **4a**, other light extracting deformities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. **4b** and **4c** show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4d** shows prismatic or other reflective or refractive surfaces **25** formed on the exterior of the panel area. The prismatic surfaces, depressions or raised

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surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. **5**, a back reflector (including trans reflectors) **26** may be attached or positioned against one side of the panel member **14** of FIG. **3** using a suitable adhesive **28** or other method in order to improve light output efficiency of the panel assembly **11** by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities **21**, **23**, **24** and/or **25** may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate **27** may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive **28** or other method in order to produce a desired effect.

The member **27** may be used to further improve the uniformity of the light output distribution. For example, the member **27** may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive **28** is used to adhere the back reflector **26** and/or film **27** to the panel, the adhesive is preferably applied only along the side edges of the panel, and if desired the end edge opposite the light transition areas **12**, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps **30** (see FIG. **5**) which are formed between the respective panel surfaces and the back reflector **26** and/or film **27** when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps **30** are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. **2**, the panel assembly **5** shown therein also includes molded posts **31** at one or more corners of the panel **7** (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. **6** shows another form of light emitting panel assembly **32** in accordance with this invention including a panel member **33**, one or more light sources **3**, and one or more light output areas **34**. In addition, the panel assembly **32** includes a tray **35** having a cavity or recess **36** in which the panel assembly **32** is received. The tray **35** may act as a back reflector as well as end edge and/or side edge reflectors for the panel **33** and side and/or back reflectors **37** for the light sources **3**. Additionally, one or more secondary reflective or refractive surfaces **38** may be provided on the panel member **33** and/or tray **35** to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member **33**. These secondary reflective/refractive surfaces **38** may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a prede-

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terminated pattern. FIG. 6 also shows multiple light output areas 34 on the panel member that emit light from one or more light sources 3.

FIG. 7 is a schematic illustration of still another form of light emitting panel assembly 40 in accordance with this invention including a panel member 41 having one or more light output areas 42 and one or more light transition areas (mixing areas) 43 containing a plurality of light sources 3 at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources 3 desirably employs three colored LEDs (red, blue, green) in each transition mixing area 43 so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area 42. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. 8 shows yet another form of light emitting panel assembly 45 in accordance with this invention including a light emitting panel member 46 and a light source 3 in a light transition area 48 integral with one end of the panel member. In this particular embodiment, the panel member 46 is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. 9 schematically shows another form of light emitting panel assembly 50 in accordance with this invention, including a panel member 51 having multiple light output areas 52, and mounting posts and/or mounting tabs 53. This particular panel assembly 50 may serve as a structural member to support other parts or components as by providing holes or cavities 54, 55 in the panel member 51 which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess 56 may be provided in the panel member 51 for receipt of a correspondingly shaped light transition area 57 having one or more light sources 3 embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface 58 on the transition area 57 and/or wall of the cavity or recess 56 to redirect a portion of the light in a predetermined manner. In this way the light transition area 57 and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector 58 may be placed on the reflective or refractive surface of the cavity or recess 56 or insert 57. Where the reflector 58 is placed on the reflective or refractive surface of the cavity or recess 56, the cavity or recess may act as a mold permitting transparent material from which the transition area 57 is made to be cast around one or more light sources 3.

FIGS. 10 and 11 schematically show another form of light emitting panel assembly 60 in accordance with this invention including a panel member 61 having one or more light output areas 62. In this particular embodiment, an off-axis light transition area 63 is provided that is thicker in cross section than the panel member to permit use of one or more light sources 3 embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface 64 (FIG. 11) may be provided on the transition area 63. Moreover, a prism 65 (FIG. 11) or tapered, rounded, or otherwise shaped end 66 (FIG. 11a) may be provided at the end of the panel opposite the light sources 3 to perform the function of an end reflector.

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The light sources 3 may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays 67 in the transition area 63 as schematically shown in FIG. 10 and/or to permit a shorter length transition area 63 to be used.

FIGS. 12 and 13 schematically show still another form of light emitting panel assembly 70 in accordance with this invention which includes one or more light transition areas 71 at one or both ends of the panel member 72 each containing a single light source 73. The transition area or areas 71 shown in FIGS. 12 and 13 collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area 71 shown in FIGS. 12 and 13 has elliptical and parabolic shape surfaces 74 and 75 in different planes for directing the light rays 76 into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. 14 schematically illustrates still another form of light emitting panel assembly 80 in accordance with this invention including a light emitting panel 81 and one or more light sources 3 positioned, embedded, potted, bonded or otherwise mounted in a light transition area 82 that is at an angle relative to the panel member 81 to permit more efficient use of space. An angled or curved reflective or refractive surface 83 is provided at the junction of the panel member 81 with the transition area 82 in order to reflect/refract light from the light source 3 into the body of the panel member 81 for emission of light from one or more light emitting areas 84 along the length of the panel member.

FIG. 15 schematically illustrates still another form of light emitting panel assembly 90 in accordance with this invention including a light transition area 91 at one or both ends of a light emitting panel member 92 containing a slot 93 for sliding receipt of an LED or other suitable light source 3. Preferably the slot 93 extends into the transition area 91 from the back edge 94, whereby the light source 3 may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source 3 may be provided with wings, tabs or other surfaces 95 for engagement in correspondingly shaped recesses or grooves 96 or the like in the transition area 91 for locating and, if desired, securing the light source in place. Also, the light source 3 may be embedded, potted, bonded or otherwise secured within the slot 93 in the light transition area 91 of the panel member 92. Light from a secondary light source 97 may be projected through the panel member 92 for indication or some other effect.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example LCD back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, membrane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members.

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Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting panel assembly comprising at least a light emitting panel member having a light entrance surface and a light emitting surface, at least one LED light source positioned near or against the light entrance surface, and a tray or housing having a cavity or recess in which the panel member is entirely received, wherein the panel member has a pattern of light extracting deformities on or in at least one surface to cause light to be emitted from the light emitting surface of the panel member, and the tray or housing includes end walls and side walls that act as end edge reflectors and side edge reflectors for the panel member to reflect light that would otherwise exit the panel member through an end edge and/or side edge back into the panel member and toward the pattern of light extracting deformities for causing additional light to be emitted from the light emitting surface of the panel member, wherein the tray or housing provides structural support to the panel member and has posts, tabs, or other structural features that provide a mount for mounting of the assembly into a larger assembly or device.

2. The assembly of claim 1 wherein the tray or housing includes a bottom wall that acts as a back reflector for the panel member.

3. The assembly of claim 1 wherein the tray or housing provides a support for supporting and/or positioning a film near the panel member.

4. The assembly of claim 3 wherein the film is at least one of a diffuser and a brightness enhancing film.

5. The assembly of claim 1 further comprising a film positioned near the light emitting surface of the panel member for changing the output ray angle distribution of the emitted light to fit a particular application.

6. The assembly of claim 1 wherein the light entrance surface is faceted to alter the light output distribution of the LED as the light enters the panel member.

7. A light emitting panel assembly comprising at least a light emitting panel member having a light entrance surface and a light emitting surface, at least one LED light source positioned near or against the light entrance surface, and a tray or housing having a cavity or recess in which the panel member is entirely received, wherein the panel member has a pattern of light extracting deformities on or in at least one surface to cause light to be emitted from the light emitting surface of the panel member, and the tray or housing includes end walls and side walls that act as end edge reflectors and side edge reflectors for the panel member to reflect light that would otherwise exit the panel member through an end edge and/or side edge back into the panel member and toward the pattern of light extracting deformities for causing additional light to be emitted from the light emitting surface of the panel member, wherein the tray or housing has posts, tabs or other structural features that provide a mount or structural support for at least one other part or component, and the tray or housing provides structural support to the panel member.

8. The assembly of claim 7 wherein the other part or component is a liquid crystal display.

9. The assembly of claim 7 wherein the other part or component is a printed circuit.

10. The assembly of claim 7 wherein the film is at least one of a diffuser and a brightness enhancing film.

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11. The assembly of claim 7 further comprising a film positioned near the light emitting surface of the panel member for changing the output ray angle distribution of the emitted light to fit a particular application.

12. The assembly of claim 7 wherein the light entrance surface is faceted to alter the light output distribution of the LED as the light enters the panel member.

13. A light emitting panel assembly comprising at least a light emitting panel member having a light entrance surface and a light emitting surface, at least one LED light source positioned near or against the light entrance surface, and a tray or housing having a cavity or recess in which the panel member is entirely received, wherein the panel member has a pattern of light extracting deformities on or in at least one surface to cause light to be emitted from the light emitting surface of the panel member, and the tray or housing includes end walls and side walls that act as end edge reflectors and side edge reflectors for the panel member to reflect light that would otherwise exit the panel member through an end edge and/or side edge back into the panel member and toward the pattern of light extracting deformities for causing additional light to be emitted from the light emitting surface of the panel member, and an additional component overlaying the panel member, the panel member having at least one of a tab, hole, cavity, or protrusion that positions the tray or housing relative to the panel member.

14. The assembly of claim 13 wherein the tray or housing includes at least one of a recess or cavity for positioning the panel member entirely within the recess or cavity.

15. The assembly of claim 13 wherein the additional component is a display panel.

16. The assembly of claim 13 wherein the additional component is a film or substrate.

17. A light emitting panel assembly comprising at least a light emitting panel member having a light entrance surface and a light emitting surface, at least one LED light source positioned near or against the light entrance surface, and a tray or housing having a cavity or recess in which the panel member is entirely received, wherein the panel member has a pattern of light extracting deformities on or in at least one surface to cause light to be emitted from the light emitting surface of the panel member, and the tray or housing includes end walls and side walls that act as end edge reflectors and side edge reflectors for the panel member to reflect light that would otherwise exit the panel member through an end edge and/or side edge back into the panel member and toward the pattern of light extracting deformities for causing additional light to be emitted from the light emitting surface of the panel member, and an additional component overlying the panel member, the panel member having at least one of a tab, hole, cavity or protrusion that positions the additional component relative to the panel member, wherein the at least one of a tab, hole, cavity, or protrusion holds the additional component away from the panel member to create an air gap between the panel member and the additional component.

18. The assembly of claim 17 wherein the protrusion is molded into the panel member and extends outward therefrom.

19. The assembly of claim 18 wherein the protrusion comprises a post extending outward from the panel member.

20. The assembly of claim 18 wherein the additional component is a film or substrate.

21. The assembly of claim 17 wherein the light source is positioned relative to the panel member by the at least one of a tab, hole, cavity, or protrusion.

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22. The assembly of claim **21** wherein the light source has a tab and the panel member has a recess to receive the tab of the light source.

23. The assembly of claim **17** wherein the tray includes at least one of a recess or cavity for positioning the panel member entirely within the recess or cavity.

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24. The assembly of claim **17** wherein the additional component is a display panel.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,434,974 B2
APPLICATION NO. : 11/378080
DATED : October 14, 2008
INVENTOR(S) : Jeffery R. Parker

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 9,
Line 66, replace "7" with --11--.

Signed and Sealed this

Second Day of December, 2008

A handwritten signature in black ink that reads "Jon W. Dudas". The signature is written in a cursive style with a large, looped initial "J".

JON W. DUDAS
Director of the United States Patent and Trademark Office

EXHIBIT E

(12) **United States Patent**
Parker

(10) **Patent No.:** **US 7,537,370 B2**
(45) **Date of Patent:** ***May 26, 2009**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

(75) Inventor: **Jeffery R. Parker**, Richfield, OH (US)

(73) Assignee: **Solid State Opto Limited** (VG)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/548,330**

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(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Division of application No. 10/784,527, filed on Feb. 23, 2004, now Pat. No. 7,160,015, which is a division of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481, which is a continuation-in-part of application No. 08/778,089, filed on Jan. 2, 1997, now Pat. No. 6,079,838, which is a division of application No. 08/495,176, filed on Jun. 27, 1995, now Pat. No. 5,613,751.

(51) **Int. Cl.**
F21V 8/00 (2006.01)

(52) **U.S. Cl.** **362/607**; 362/618; 362/619; 362/620

(58) **Field of Classification Search** 362/603, 362/606-609, 617-621, 623-628
See application file for complete search history.

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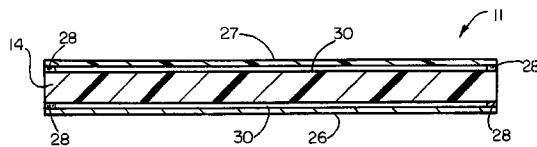
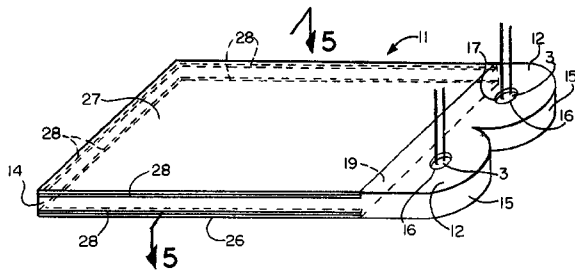
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(57) **ABSTRACT**

Light emitting panel assemblies include an optical panel member having a pattern of light extracting deformities on or in one or both sides to cause light to be emitted in a predetermined output distribution. The pattern of light extracting deformities on or in one side may have two or more different types or shapes of deformities and at least one of the types or shapes may vary along the length or width of the panel member. Where the light extracting deformities are on or in both sides, at least some of the deformities on or in one side may be of a different type or shape or vary in a different way or manner than the deformities on or in the other side.

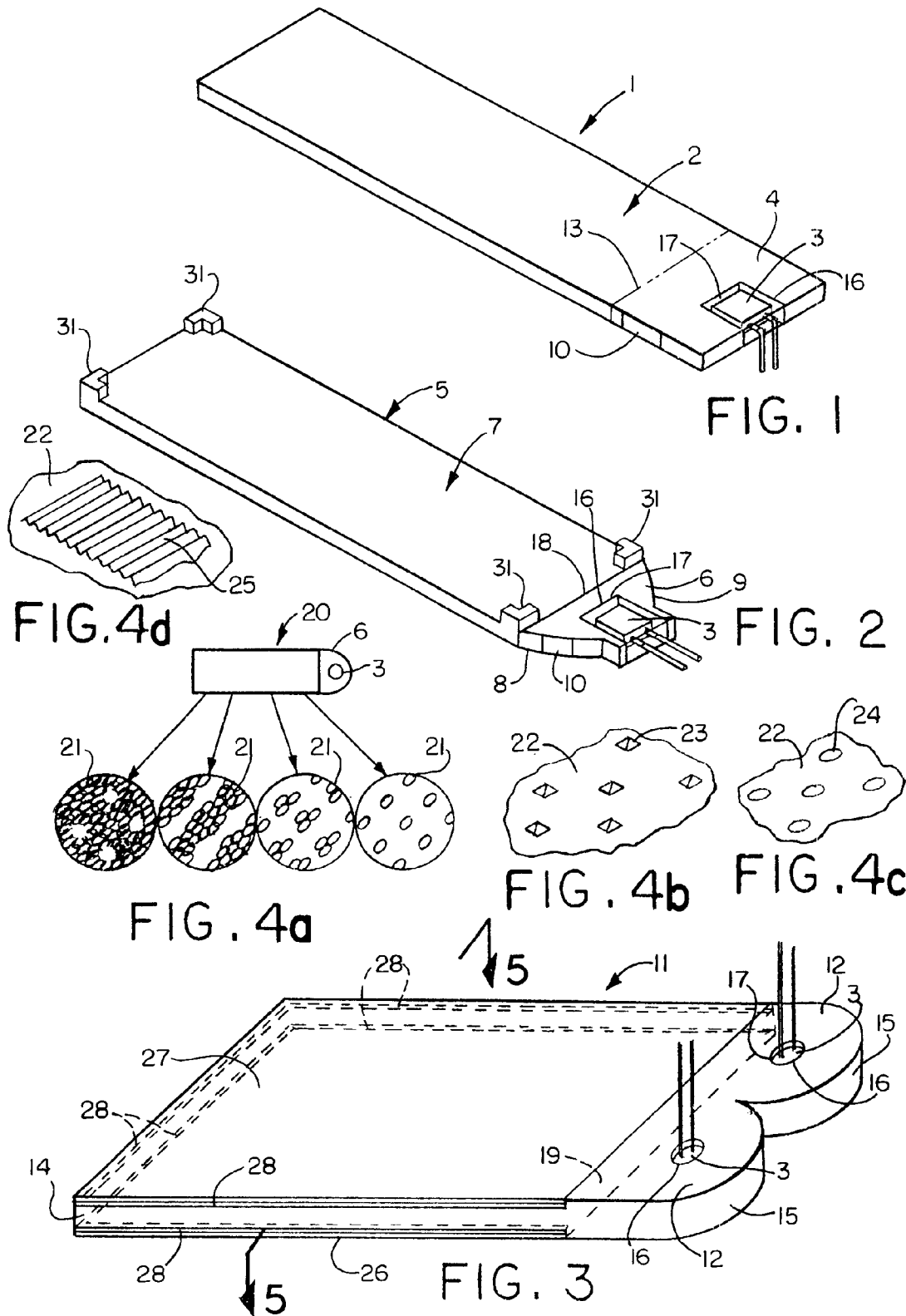
48 Claims, 4 Drawing Sheets

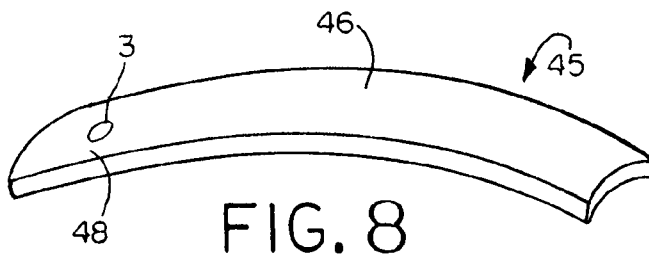
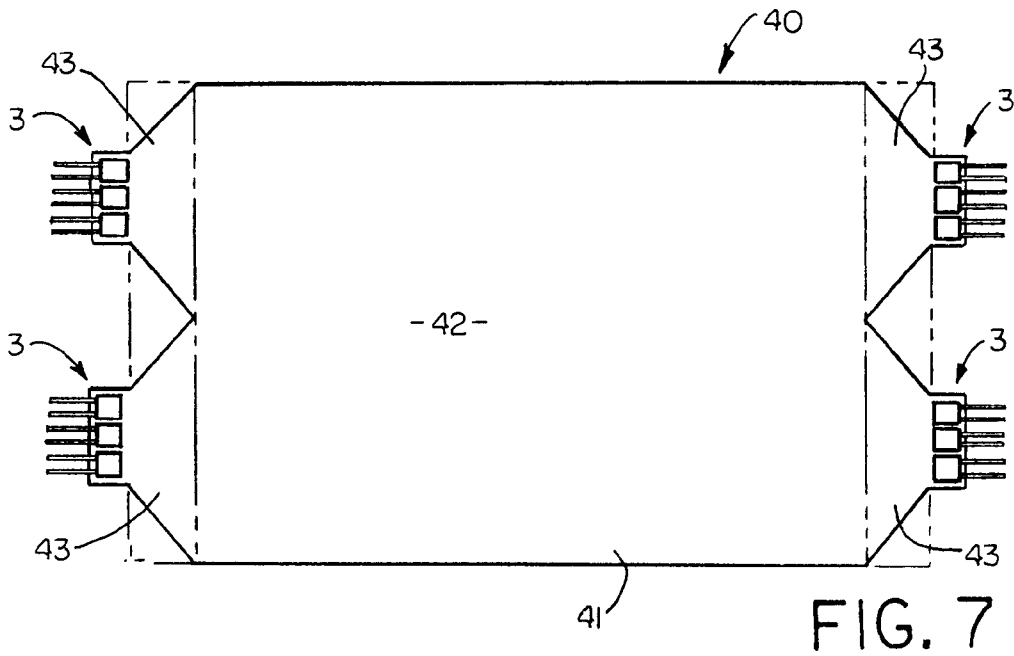
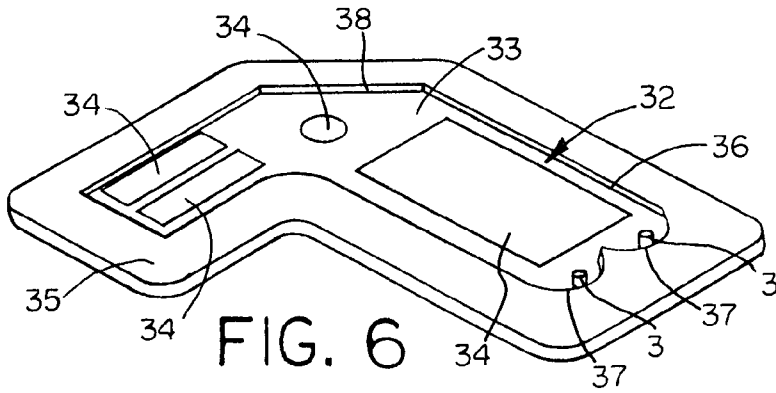
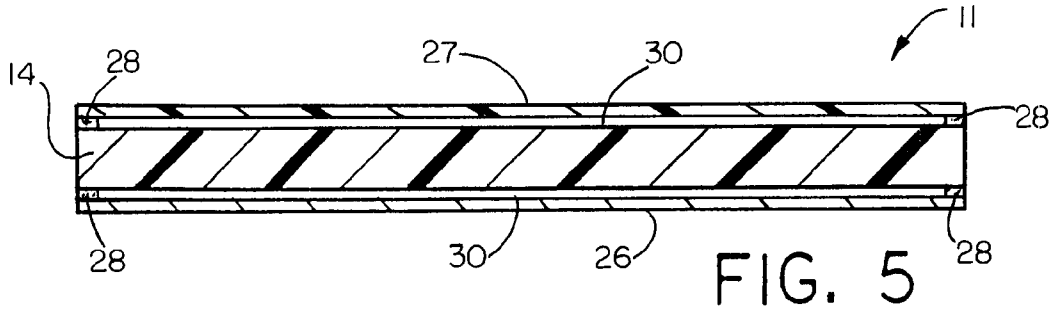


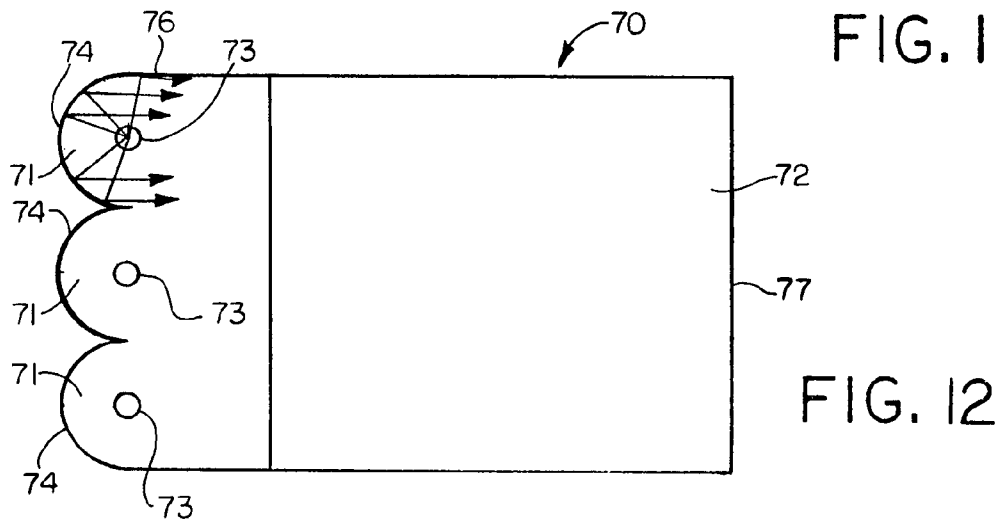
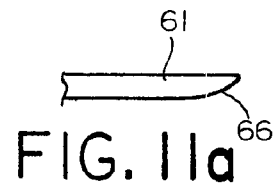
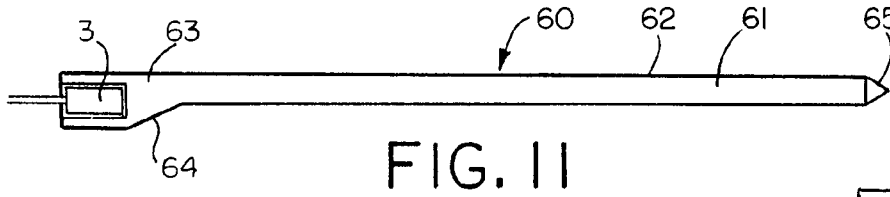
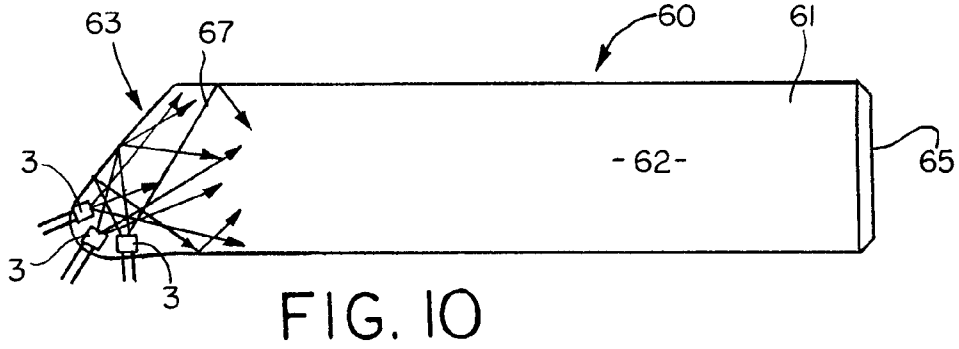
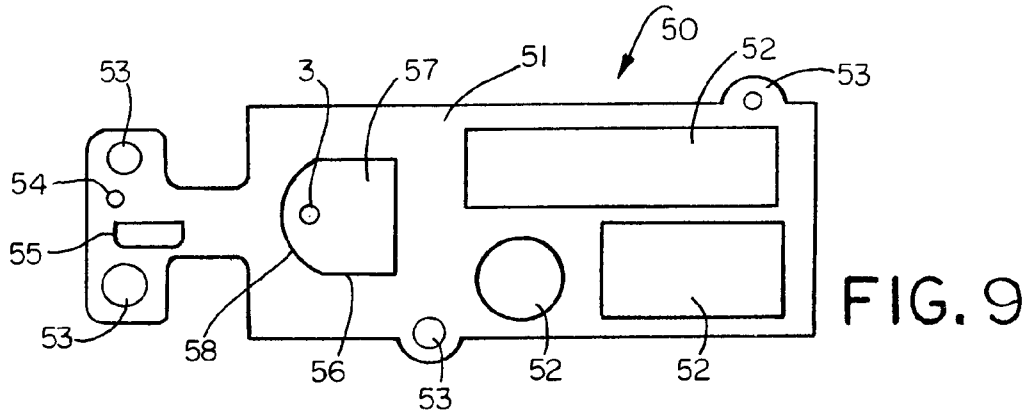
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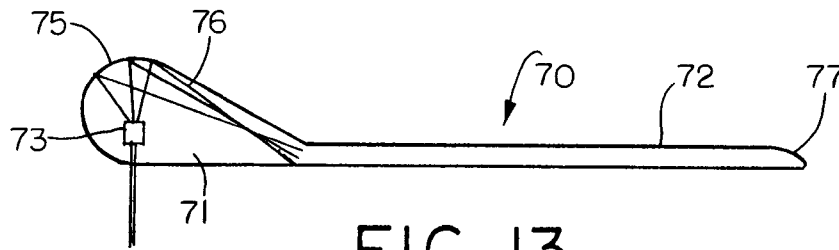


FIG. 13

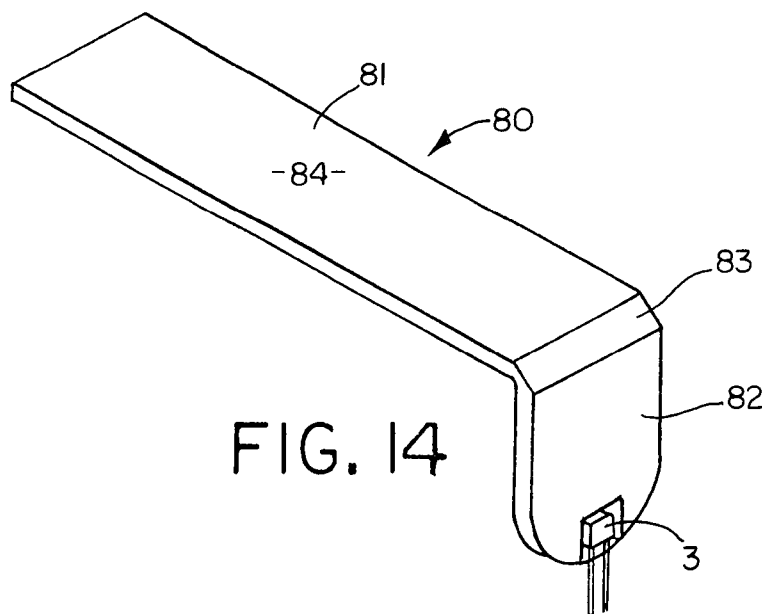


FIG. 14

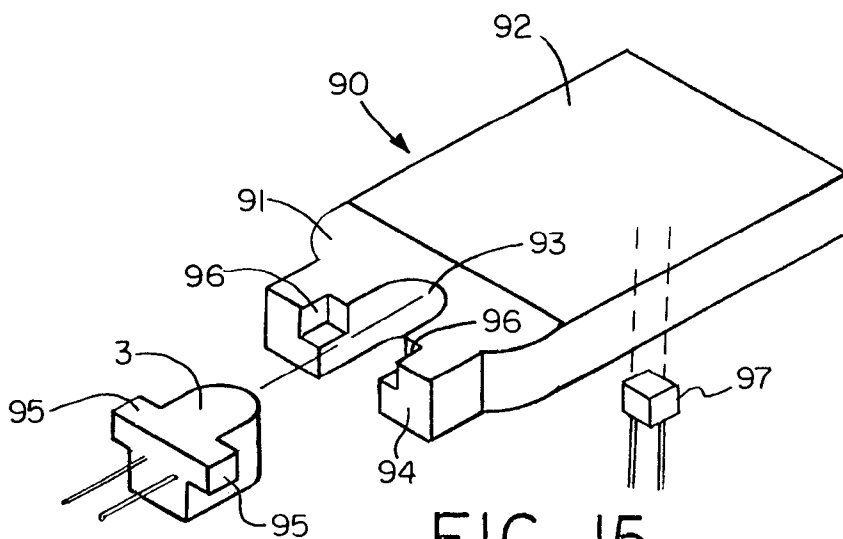


FIG. 15

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LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a division of U.S. patent application Ser. No. 10/784,527, filed Feb. 23, 2004, which is a division of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, dated Mar. 30, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 08/778,089, filed Jan. 2, 1997, now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a division of U.S. patent application Ser. No. 08/495,176, filed Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25, 1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emitting panel assemblies each including a transparent panel member for efficiently conducting light, and controlling the light conducted by the panel member to be emitted from one or more light output areas along the length thereof.

Light emitting panel assemblies are generally known. However, the present invention relates to several different light emitting panel assembly configurations which provide for better control of the light output from the panel assemblies and for more efficient utilization of light, which results in greater light output from the panel assemblies.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light emitting panel assemblies include a light emitting panel member having a light transition area in which at least one light source is suitably mounted for transmission of light to the light input surface of the panel member.

In accordance with another aspect of the invention, the light source is desirably embedded, potted or bonded to the light transition area to eliminate any air gaps, decrease surface reflections and/or eliminate any lens effect between the light source and light transition area, thereby reducing light loss and increasing the light output from the panel assembly.

In accordance with another aspect of the invention, the panel assemblies may include reflective or refractive surfaces for changing the path of a portion of the light, emitted from the light source, that would not normally enter the panel members at an acceptable angle that allows the light to remain in the panel members for a longer period of time and/or increase the efficiency of the panel members.

In accordance with another aspect of the invention, the light emitting panel members include a pattern of light extracting deformities or disruptions which provide a desired light output distribution from the panel members by changing the angle of refraction of a portion of the light from one or more light output areas of the panel members.

In accordance with still another aspect of the invention, the light source may include multiple colored light sources for supplying light to one or more light output areas, and for providing a colored or white light output distribution.

In accordance with yet another aspect of the invention, the panel assemblies include a transition area for mixing the multiple colored lights, prior to the light entering the panel members, in order to effect a desired colored or white light output distribution.

The various light emitting panel assemblies of the present invention are very efficient panel assemblies that may be used to produce increased uniformity and higher light output from

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the panel members with lower power requirements, and allow the panel members to be made thinner and/or longer, and/or of various shapes and sizes.

To the accomplishment of the foregoing and related ends, the invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three different forms of light emitting panel assemblies in accordance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light output area of a panel assembly showing one form of pattern of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views of a portion of a light output area of a panel assembly showing other forms of light extracting deformities formed in or on the light output area;

FIG. 5 is an enlarged transverse section through the light emitting panel assembly of FIG. 3 taken generally on the plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 7 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of light emitting panel assembly in accordance with this invention;

FIG. 9 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of light emitting panel assembly in accordance with this invention;

FIG. 11 is a side elevation view of the light emitting panel assembly of FIG. 10;

FIG. 11a is a fragmentary side elevation view showing a tapered or rounded end on the panel member in place of the prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of light emitting panel assembly in accordance with this invention;

FIG. 13 is a schematic side elevation view of the light emitting panel assembly of FIG. 12; and

FIGS. 14 and 15 are schematic perspective views of still other forms of light emitting panel assemblies in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS

Referring now in detail to the drawings, and initially to FIG. 1, there is schematically shown one form of light emitting panel assembly 1 in accordance with this invention including a transparent light emitting panel 2 and one or more light sources 3 which emit light in a predetermined pattern in a light transition member or area 4 used to make the transition from the light source 3 to the light emitting panel 2, as well known in the art. The light that is transmitted by the light transition area 4 to the transparent light emitting panel 2 may be emitted along the entire length of the panel or from one or

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more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. 1 the light transition area 4 is shown as an integral extension of one end of the light emitting panel 2 and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area 4 may be a separate piece suitably attached to the light input surface 13 of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. 2 shows another form of light emitting panel assembly 5 in accordance with this invention including a panel light transition area 6 at one end of the light emitting panel 7 with sides 8, 9 around and behind the light source 3 shaped to more efficiently reflect and/or refract and focus the light emitted from the light source 3 that impinges on these surfaces back through the light transition area 6 at an acceptable angle for entering the light input surface 18 at one end of the light emitting panel 7. Also, a suitable reflective material or coating 10 may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. 1 and 2 on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

The panel assemblies shown in FIGS. 1 and 2 include a single light source 3, whereas FIG. 3 shows another light emitting panel assembly 11 in accordance with this invention including two light sources 3. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly 11 of FIG. 3 includes a light transition area 12 at one end of the light emitting panel 14 having reflective and/or refractive surfaces 15 around and behind each light source 3. These surfaces 15 may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas 12 into the light input surface 19 of the light emitting panel 14.

The light sources 3 may be mechanically held in any suitable manner in slots, cavities or openings 16 machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources 3 are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bonding the light sources 3 in the slots, cavities or openings 16 in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material 17. The slots, cavities or openings 16 may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultra-

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sonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source 3 may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources 3 may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources 3 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. 4a schematically shows one such light surface area 20 on which a pattern of light extracting deformities or disruptions 21 is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities 21 shown in FIG. 4a includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities 21 are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions 21 can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning the sheet or film against one or both sides of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformi-

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ties **21** may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities **21** may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source **3** thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities **21** may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display backlight, the light output will be more efficient if the deformities **21** cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities **21** may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity **21** coverage. Moreover, the pattern of light extracting deformities **21** may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities **21** may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes **21** in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities **21** shown in FIG. **4a**, other light extracting deformities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. **4b** and **4c** show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4d** shows prismatic or other reflective or refractive surfaces **25** formed on the exterior of the panel area. The prismatic surfaces, depressions or raised

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surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. **5**, a back reflector (including trans reflectors) **26** may be attached or positioned against one side of the panel member **14** of FIG. **3** using a suitable adhesive **28** or other method in order to improve light output efficiency of the panel assembly **11** by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities **21**, **23**, **24** and/or **25** may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate **27** may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive **28** or other method in order to produce a desired effect.

The member **27** may be used to further improve the uniformity of the light output distribution. For example, the member **27** may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive **28** is used to adhere the back reflector **26** and/or film **27** to the panel, the adhesive is preferably applied only along the side edges of the panel, and if desired the end edge opposite the light transition areas **12**, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps **30** (see FIG. **5**) which are formed between the respective panel surfaces and the back reflector **26** and/or film **27** when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps **30** are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. **2**, the panel assembly **5** shown therein also includes molded posts **31** at one or more corners of the panel **7** (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. **6** shows another form of light emitting panel assembly **32** in accordance with this invention including a panel member **33**, one or more light sources **3**, and one or more light output areas **34**. In addition, the panel assembly **32** includes a tray **35** having a cavity or recess **36** in which the panel assembly **32** is received. The tray **35** may act as a back reflector as well as end edge and/or side edge reflectors for the panel **33** and side and/or back reflectors **37** for the light sources **3**. Additionally, one or more secondary reflective or refractive surfaces **38** may be provided on the panel member **33** and/or tray **35** to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member **33**. These secondary reflective/refractive surfaces **38** may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a prede-

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terminated pattern. FIG. 6 also shows multiple light output areas 34 on the panel member that emit light from one or more light sources 3.

FIG. 7 is a schematic illustration of still another form of light emitting panel assembly 40 in accordance with this invention including a panel member 41 having one or more light output areas 42 and one or more light transition areas (mixing areas) 43 containing a plurality of light sources 3 at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources 3 desirably employs three colored LEDs (red, blue, green) in each transition mixing area 43 so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area 42. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. 8 shows yet another form of light emitting panel assembly 45 in accordance with this invention including a light emitting panel member 46 and a light source 3 in a light transition area 48 integral with one end of the panel member. In this particular embodiment, the panel member 46 is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. 9 schematically shows another form of light emitting panel assembly 50 in accordance with this invention, including a panel member 51 having multiple light output areas 52, and mounting posts and/or mounting tabs 53. This particular panel assembly 50 may serve as a structural member to support other parts or components as by providing holes or cavities 54, 55 in the panel member 51 which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess 56 may be provided in the panel member 51 for receipt of a correspondingly shaped light transition area 57 having one or more light sources 3 embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface 58 on the transition area 57 and/or wall of the cavity or recess 56 to redirect a portion of the light in a predetermined manner. In this way the light transition area 57 and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector 58 may be placed on the reflective or refractive surface of the cavity or recess 56 or insert 57. Where the reflector 58 is placed on the reflective or refractive surface of the cavity or recess 56, the cavity or recess may act as a mold permitting transparent material from which the transition area 57 is made to be cast around one or more light sources 3.

FIGS. 10 and 11 schematically show another form of light emitting panel assembly 60 in accordance with this invention including a panel member 61 having one or more light output areas 62. In this particular embodiment, an off-axis light transition area 63 is provided that is thicker in cross section than the panel member to permit use of one or more light sources 3 embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface 64 (FIG. 11) may be provided on the transition area 63. Moreover, a prism 65 (FIG. 11) or tapered, rounded, or otherwise shaped end 66 (FIG. 11a) may be provided at the end of the panel opposite the light sources 3 to perform the function of an end reflector.

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The light sources 3 may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays 67 in the transition area 63 as schematically shown in FIG. 10 and/or to permit a shorter length transition area 63 to be used.

FIGS. 12 and 13 schematically show still another form of light emitting panel assembly 70 in accordance with this invention which includes one or more light transition areas 71 at one or both ends of the panel member 72 each containing a single light source 73. The transition area or areas 71 shown in FIGS. 12 and 13 collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area 71 shown in FIGS. 12 and 13 has elliptical and parabolic shape surfaces 74 and 75 in different planes for directing the light rays 76 into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. 14 schematically illustrates still another form of light emitting panel assembly 80 in accordance with this invention including a light emitting panel 81 and one or more light sources 3 positioned, embedded, potted, bonded or otherwise mounted in a light transition area 82 that is at an angle relative to the panel member 81 to permit more efficient use of space. An angled or curved reflective or refractive surface 83 is provided at the junction of the panel member 81 with the transition area 82 in order to reflect/refract light from the light source 3 into the body of the panel member 81 for emission of light from one or more light emitting areas 84 along the length of the panel member.

FIG. 15 schematically illustrates still another form of light emitting panel assembly 90 in accordance with this invention including a light transition area 91 at one or both ends of a light emitting panel member 92 containing a slot 93 for sliding receipt of an LED or other suitable light source 3. Preferably the slot 93 extends into the transition area 91 from the back edge 94, whereby the light source 3 may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source 3 may be provided with wings, tabs or other surfaces 95 for engagement in correspondingly shaped recesses or grooves 96 or the like in the transition area 91 for locating and, if desired, securing the light source in place. Also, the light source 3 may be embedded, potted, bonded or otherwise secured within the slot 93 in the light transition area 91 of the panel member 92. Light from a secondary light source 97 may be projected through the panel member 92 for indication or some other effect.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example LCD back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, membrane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members.

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Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, both the front and back sides having a pattern of light extracting deformities that are projections or depressions on or in the sides to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in at least one of the sides varies along at least one of the length and width of the panel member and at least some of the light extracting deformities on or in one of the sides are of a different type than the light extracting deformities on or in the other side of the panel member, and at least one film, sheet or substrate overlying at least a portion of one of the sides of the panel member to change the output distribution of the emitted light such that the light will pass through a liquid crystal display with low loss.

2. The assembly of claim 1 wherein the deformities on or in one of the sides are prismatic.

3. The assembly of claim 1 wherein the deformities on or in one of the sides are lenticular.

4. The assembly of claim 1 wherein the deformities on or in one of the sides run the full length or width of the one side.

5. The assembly of claim 1 wherein the deformities on or in one of the sides are quite small in relation to the length and width of the panel member.

6. The assembly of claim 1 wherein the deformities on or in one of the sides have at least one diffuse surface.

7. The assembly of claim 1 wherein the deformities on or in one of the sides are etched dots.

8. The assembly of claim 1 wherein the deformities on or in one of the sides vary randomly.

9. The assembly of claim 1 wherein the panel member is flat.

10. The assembly of claim 1 wherein the panel member is tapered.

11. The assembly of claim 1 wherein the deformities on or in one of the sides vary in at least one of the following characteristics: slope angle, density, orientation, height or depth, and size.

12. The assembly of claim 1 wherein at least one side of the sheet, film or substrate has deformities or optical elements.

13. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, both the front and back sides having a pattern of light extracting deformities that are projections or depressions on or in the sides to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in at least one of the sides varies along at least one of the length and width of the panel member and at least some of the light extracting deformities on or in one of the sides are of a different type than the light extracting deformities on or in the other side of the panel member, wherein the panel member has a transition region between the at least one input edge and the patterns of light extracting

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deformities to allow the light from the at least one light source to mix and spread, and at least one side of the transition region contains optical elements for reflecting or refracting light from the at least one light source.

14. The assembly of claim 13 wherein the optical elements are faceted.

15. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, at least one of the sides having a pattern of light extracting deformities that are projections or depressions on or in the at least one side to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in the at least one side has at least two different types of light extracting deformities and at least one of the types of deformities on or in the at least one side varies along at least one of the length and width of the panel member, and at least one film, sheet or substrate overlying at least a portion of one of the sides of the panel member to change the output distribution of the emitted light such that the light will pass through a liquid crystal display with low loss.

16. The assembly of claim 15 wherein at least one of the types of deformities is prismatic.

17. The assembly of claim 15 wherein at least one of the types of deformities is lenticular.

18. The assembly of claim 15 wherein the deformities on or in the one side run the full length or width of the one side.

19. The assembly of claim 15 wherein at least one of the types of deformities is quite small in relation to the length and width of the panel member.

20. The assembly of claim 15 wherein at least one of the types of deformities has at least one diffuse surface.

21. The assembly of claim 15 wherein at least one of the types of deformities is etched dots.

22. The assembly of claim 15 wherein at least one of the types of deformities varies randomly.

23. The assembly of claim 15 wherein the panel member is flat.

24. The assembly of claim 15 wherein the panel member is tapered.

25. The assembly of claim 15 wherein at least one of the types of deformities varies in at least one of the following characteristics: slope angle, density, orientation, height or depth, and size.

26. The assembly of claim 15 wherein at least one side of the film, sheet or substrate has deformities or optical elements.

27. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, at least one of the sides having a pattern of light extracting deformities that are projections or depressions on or in the at least one side to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in the at least one side has at least two different types of light extracting deformities and at least one of the types of deformities on or in the at least one side varies alone at least one of the length and width of the panel member, wherein the panel member has a transition region between the at least one input edge and the patterns of light extracting deformities to allow the light from the at least one light source to mix and spread, and at least one side of the

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transition region contains optical elements for reflecting or refracting light from the at least one light source.

28. The assembly of claim 27 wherein the optical elements are faceted.

29. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, both the front and back sides having a pattern of light extracting deformities that are projections or depressions on or in the sides to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in at least one of the sides varies along at least one of the length and width of the panel member and at least some of the light extracting deformities on or in one of the sides vary in a different way or manner than the light extracting deformities on or in the other side of the panel member, and at least one film, sheet or substrate overlying at least a portion of one of the sides of the panel member to change the output distribution of the emitted light such that the light will pass through a liquid crystal display with low loss.

30. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in density.

31. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in slope angle relative to one another.

32. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in position.

33. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in angle of orientation relative to one another.

34. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in height or depth.

35. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary in size.

36. The assembly of claim 29 wherein at least some of the deformities on or in at least one side do not vary.

37. The assembly of claim 29 wherein at least some of the deformities on or in at least one side vary randomly.

38. The assembly of claim 29 wherein at least some of the deformities are prismatic.

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39. The assembly of claim 29 wherein at least some of the deformities are lenticular.

40. The assembly of claim 29 wherein the deformities on or in one of the sides run the full length or width of the one side.

41. The assembly of claim 29 wherein at least some of the deformities are quite small in relation to the length and width of the panel member.

42. The assembly of claim 29 wherein at least some of the deformities have at least one diffuse surface.

43. The assembly of claim 29 wherein at least some of the deformities are etched dots.

44. The assembly of claim 29 wherein the panel member is flat.

45. The assembly of claim 29 wherein the panel member is tapered.

46. The assembly of claim 29 wherein at least one side of the sheet, film or substrate has deformities or optical elements.

47. A light emitting panel assembly comprising at least one light source, an optical panel member having at least one input edge for receiving light from the at least one light source, the panel member having front and back sides and a greater cross sectional width than thickness, both the front and back sides having a pattern of light extracting deformities that are projections or depressions on or in the sides to cause light to be emitted from the panel member in a predetermined output distribution, where the pattern of light extracting deformities on or in at least one of the sides varies along at least one of the length and width of the panel member and at least some of the light extracting deformities on or in one of the sides vary in a different way or manner than the light extracting deformities on or in the other side of the panel member, wherein the panel member has a transition region between the at least one input edge and the patterns of light extracting deformities to allow the light from the at least one light source to mix and spread, and at least one side of the transition region contains optical elements for reflecting or refracting light from the at least one light source.

48. The assembly of claim 47 wherein the optical elements are faceted.

* * * * *

EXHIBIT F



US007914196B2

(12) **United States Patent**
Parker et al.

(10) **Patent No.:** **US 7,914,196 B2**
(45) **Date of Patent:** ***Mar. 29, 2011**

(54) **LIGHT REDIRECTING FILM SYSTEMS HAVING PATTERN OF VARIABLE OPTICAL ELEMENTS**

(58) **Field of Classification Search** 362/615, 362/618, 619, 620, 624, 625, 626, 606, 608, 362/627; 385/131; 349/65, 69, 70
See application file for complete search history.

(75) Inventors: **Jeffery R. Parker**, Richfield, OH (US);
Timothy A. McCollum, Avon Lake, OH (US); **Robert M. Ezell**, Brunswick, OH (US)

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(74) *Attorney, Agent, or Firm* — Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

Light redirecting film systems comprise a backlight having deformities that cause a majority of the light entering the input edge of the backlight to be emitted from a light output surface of the backlight. In close proximity to the light output surface is a light redirecting film that has a pattern of individual optical elements of well-defined shape to redistribute the light emitted by the light output surface toward a direction normal to the film.

25 Claims, 18 Drawing Sheets

(73) Assignee: **Rambus International Ltd.** (KY)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 306 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/054,680**

(22) Filed: **Mar. 25, 2008**

(65) **Prior Publication Data**

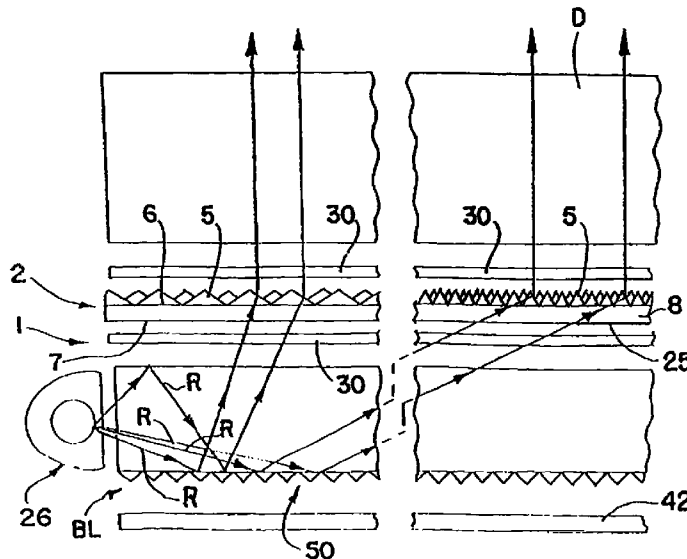
US 2008/0239755 A1 Oct. 2, 2008

Related U.S. Application Data

(60) Division of application No. 11/484,063, filed on Jul. 11, 2006, now Pat. No. 7,364,342, which is a division of application No. 10/729,113, filed on Dec. 5, 2003, now Pat. No. 7,090,389, which is a division of application No. 09/909,318, filed on Jul. 19, 2001, now Pat. No. 6,752,505, and a continuation-in-part of application No. 09/256,275, filed on Feb. 23, 1999, now Pat. No. 6,712,481.

(51) **Int. Cl.**
F21V 7/04 (2006.01)

(52) **U.S. Cl.** **362/618; 362/627; 362/624; 349/65; 385/131**



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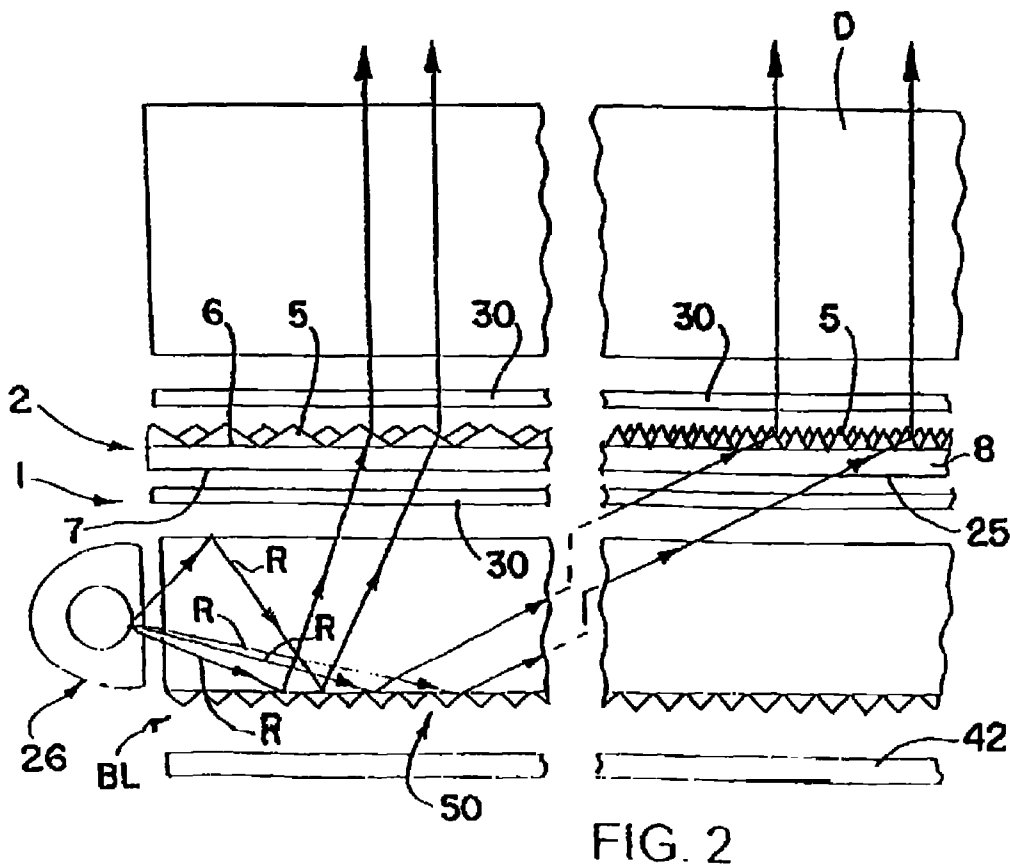
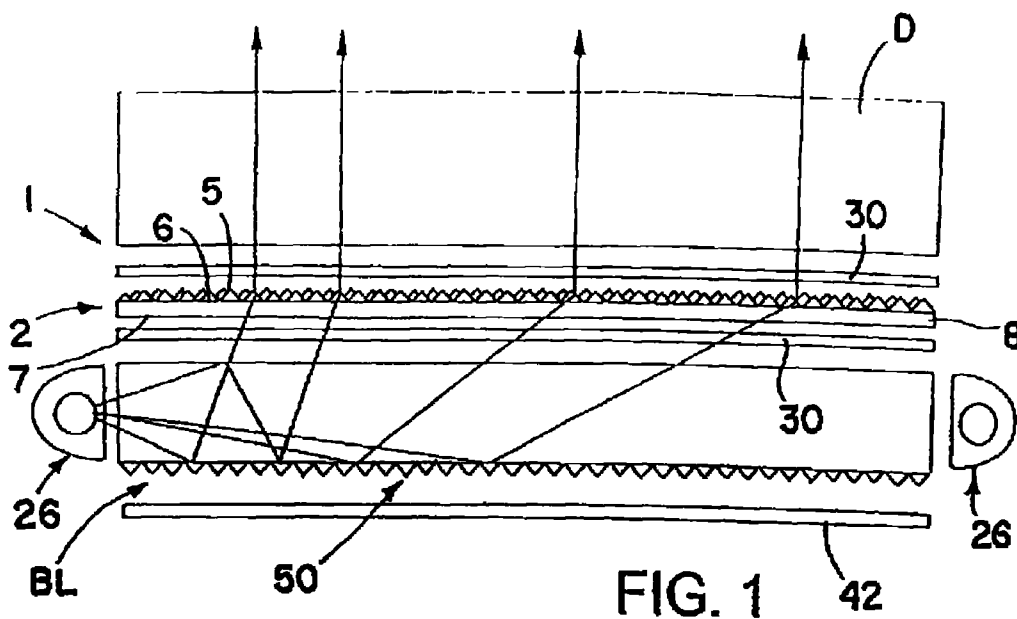
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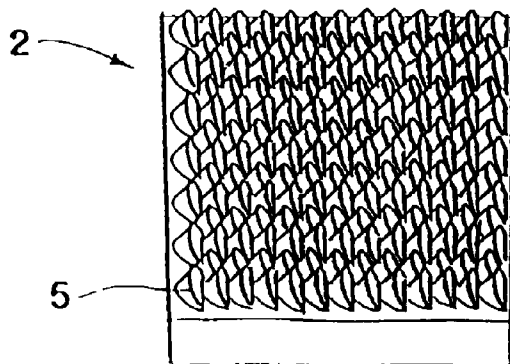
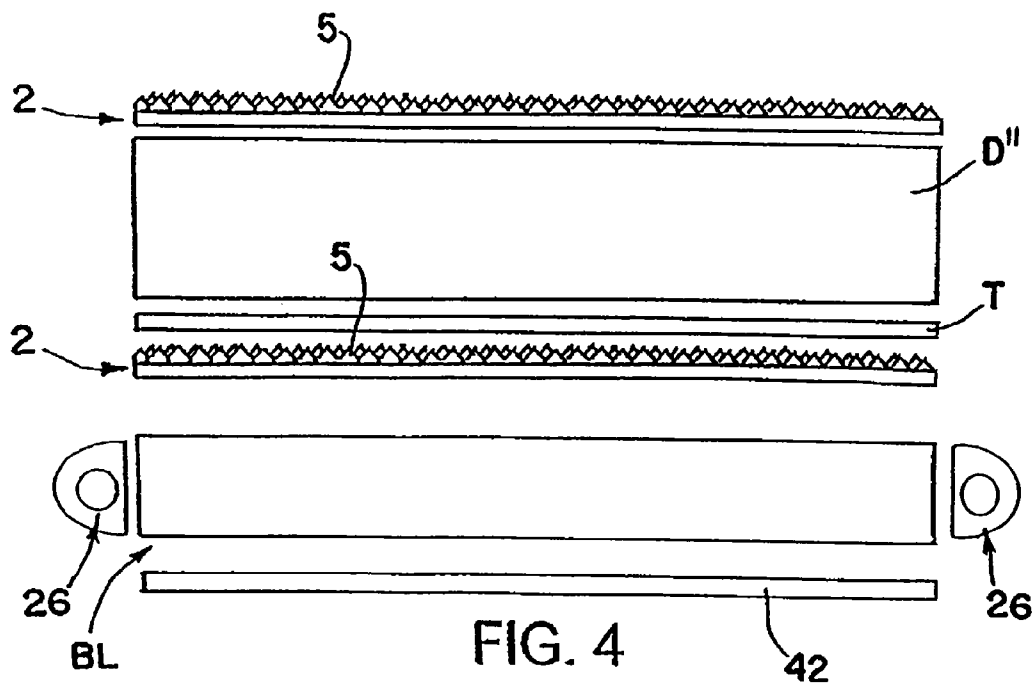
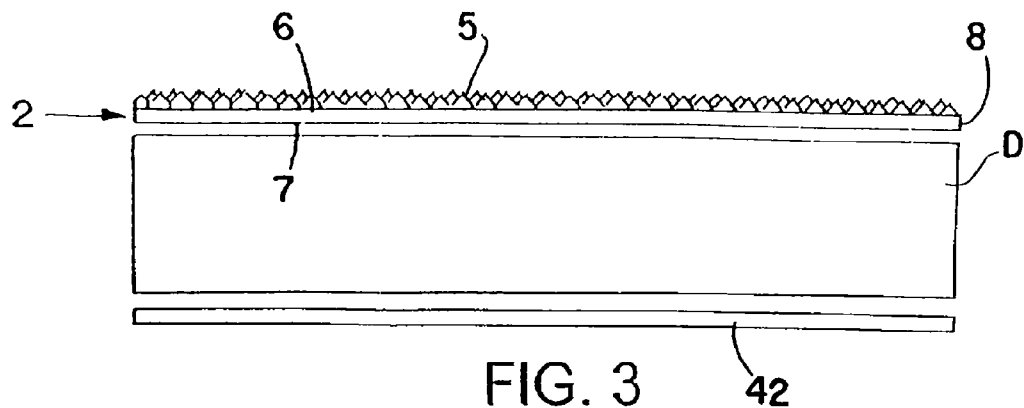


FIG. 5

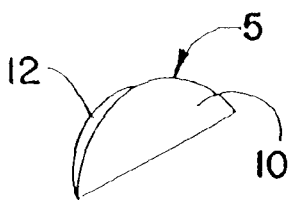


FIG. 5a

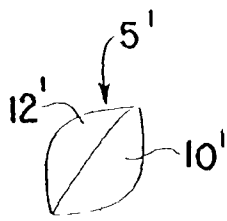


FIG. 5b

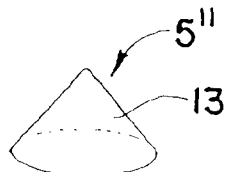


FIG. 5c

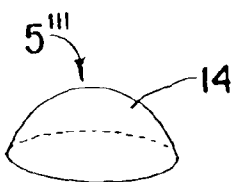


FIG. 5d

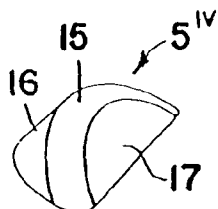


FIG. 5e



FIG. 5f

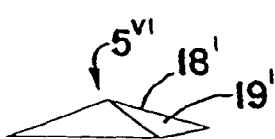


FIG. 5g

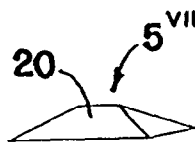


FIG. 5h

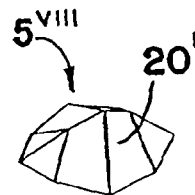


FIG. 5i

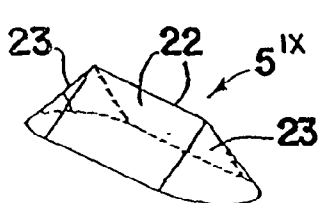


FIG. 5j

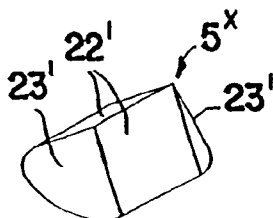


FIG. 5k

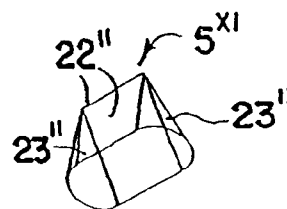


FIG. 5l

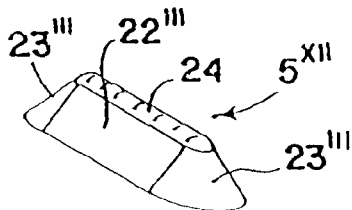


FIG. 5m

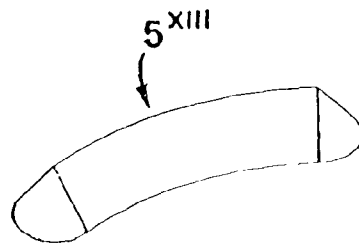


FIG. 5n

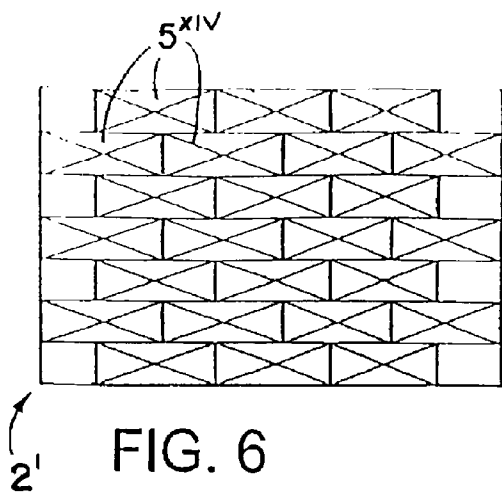


FIG. 6

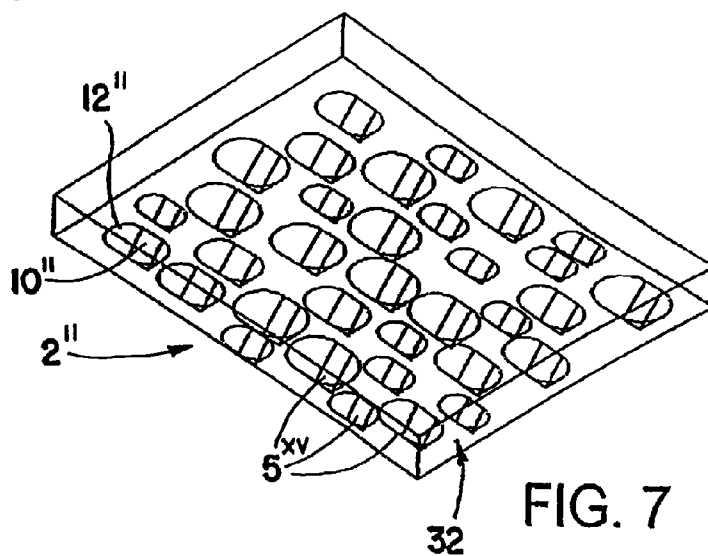


FIG. 7

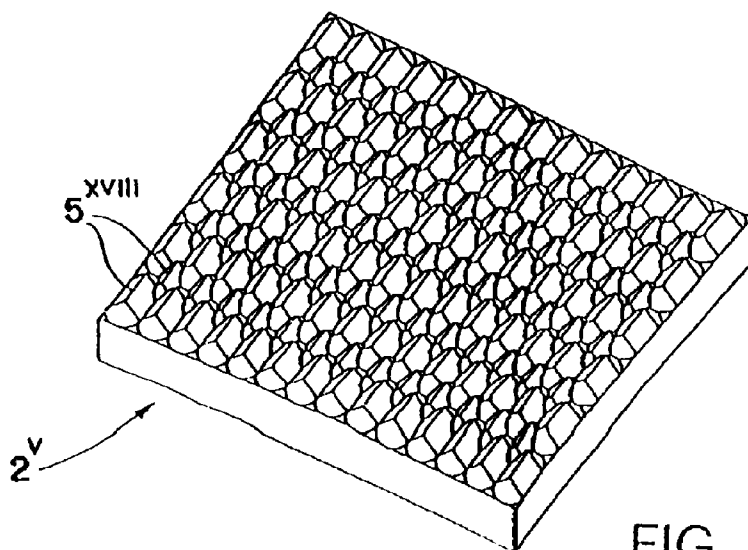


FIG. 8

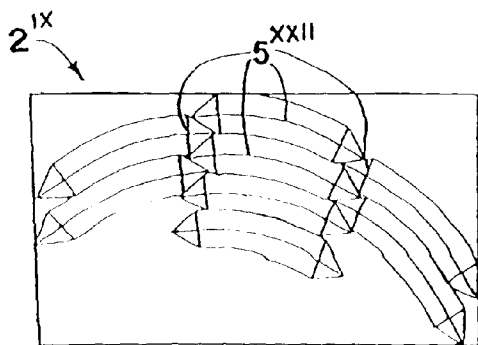
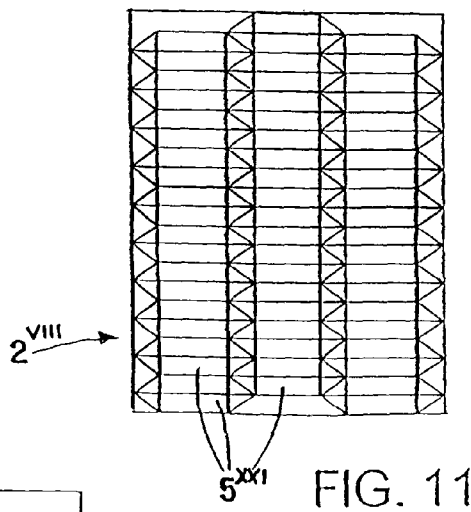
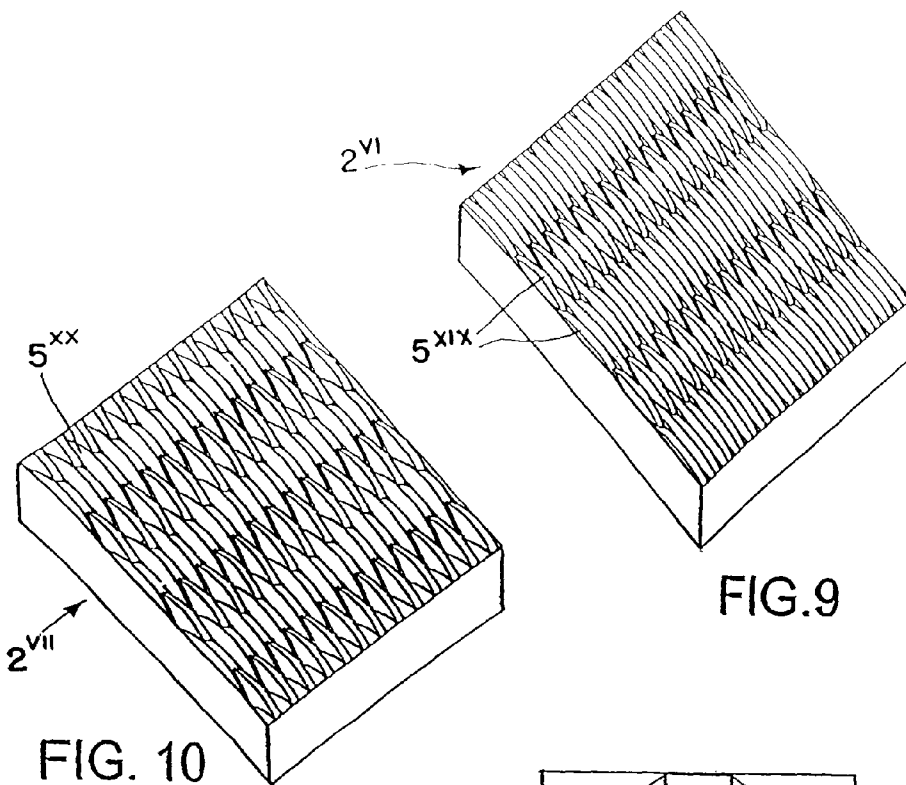
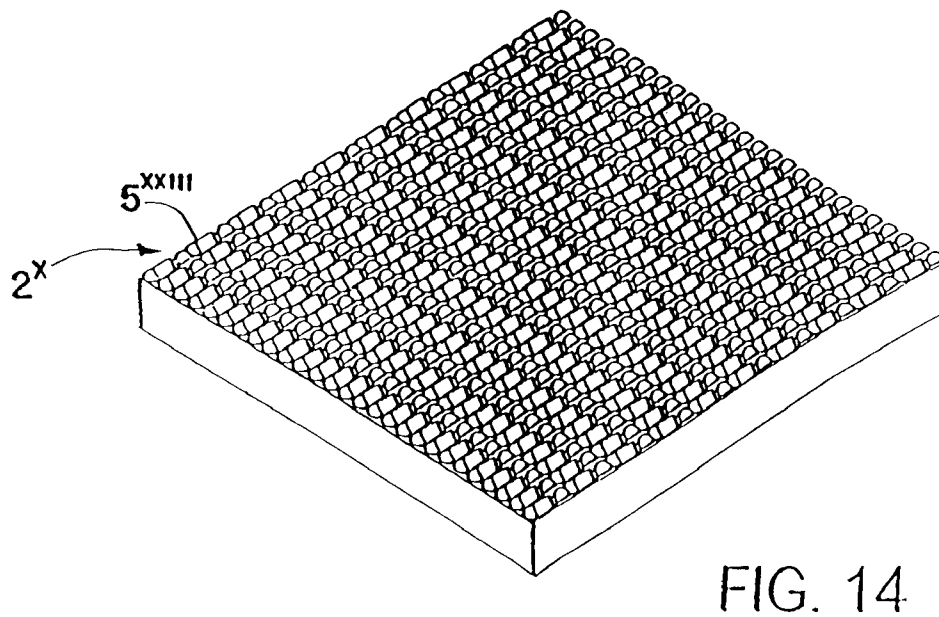
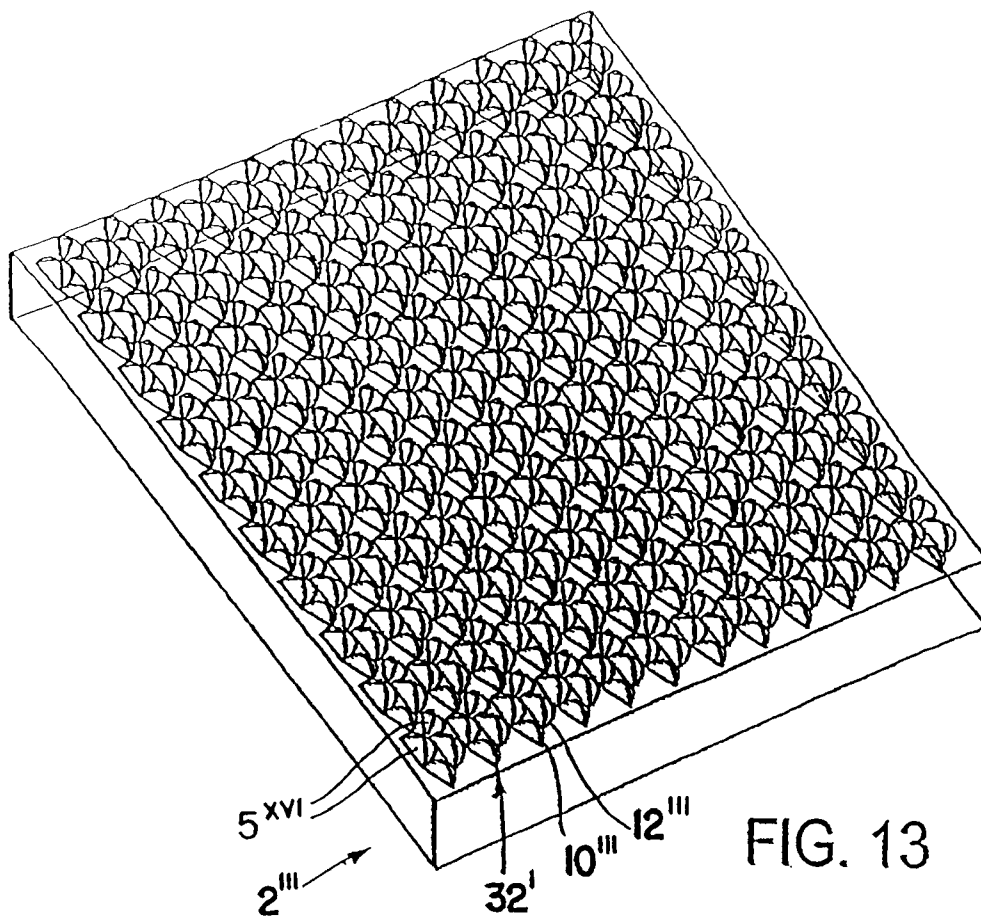


FIG. 12



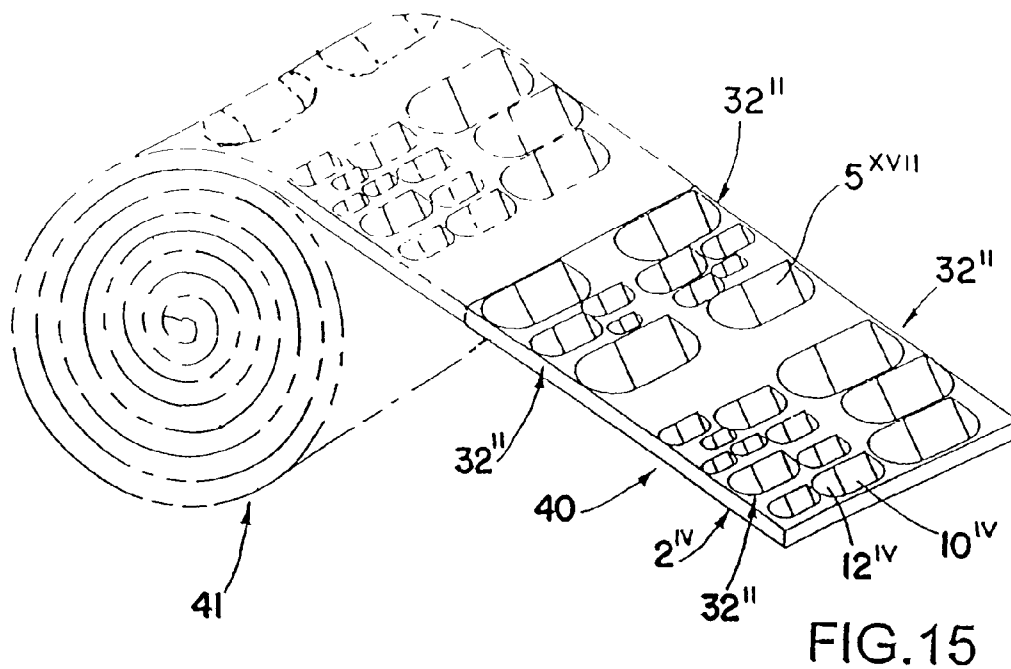


FIG. 15

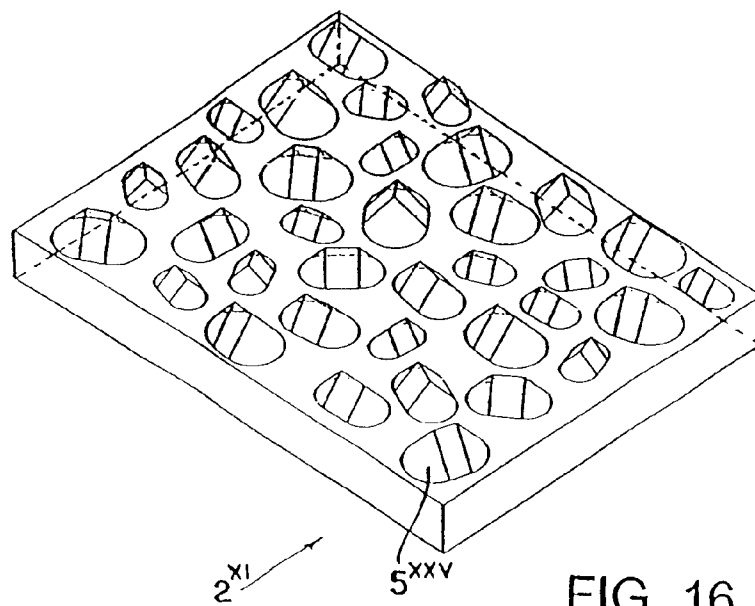


FIG. 16

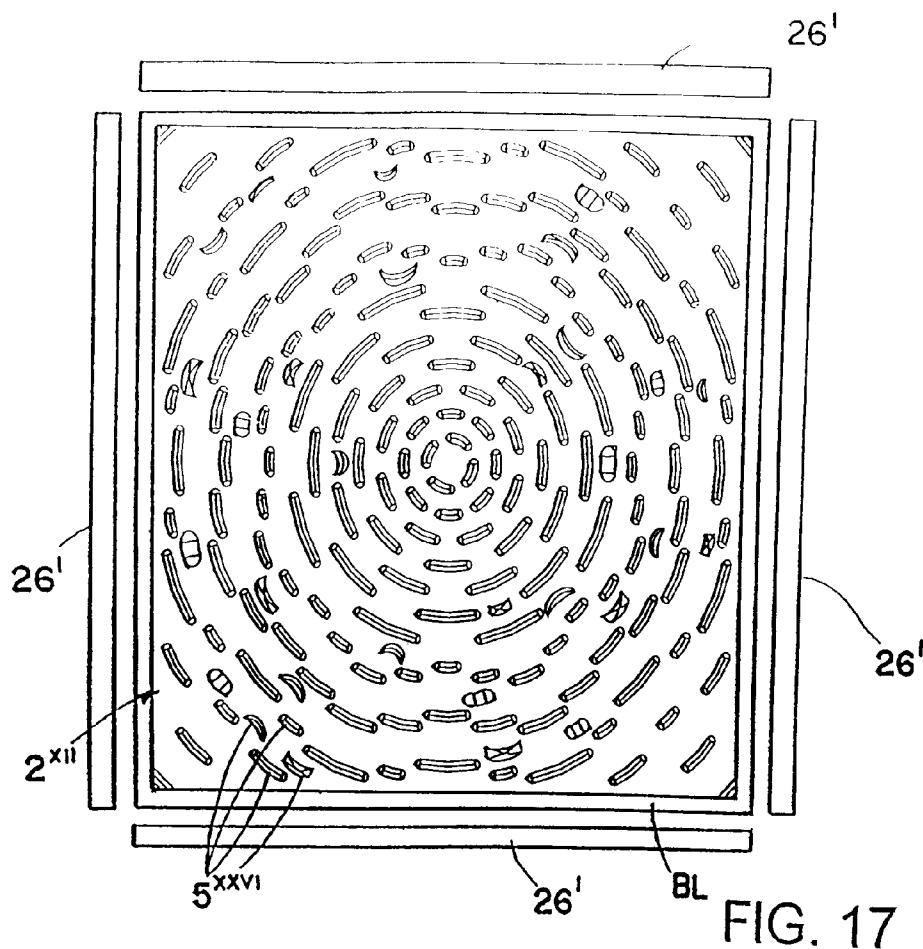


FIG. 17

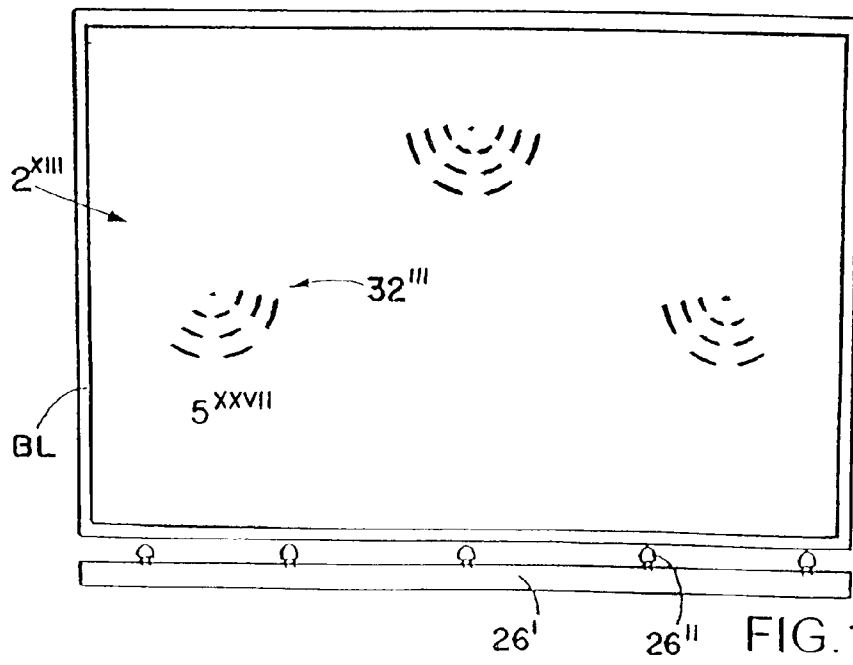


FIG. 18

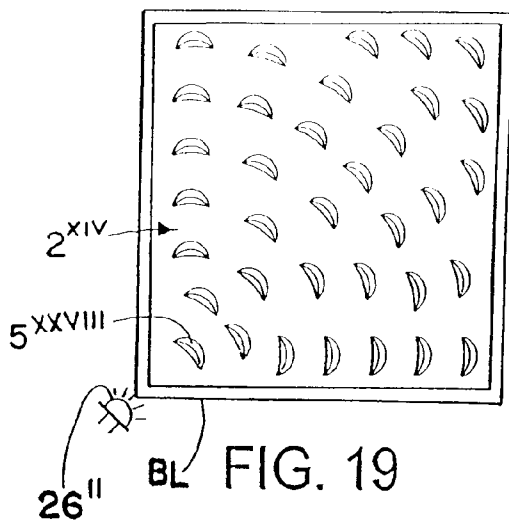


FIG. 19

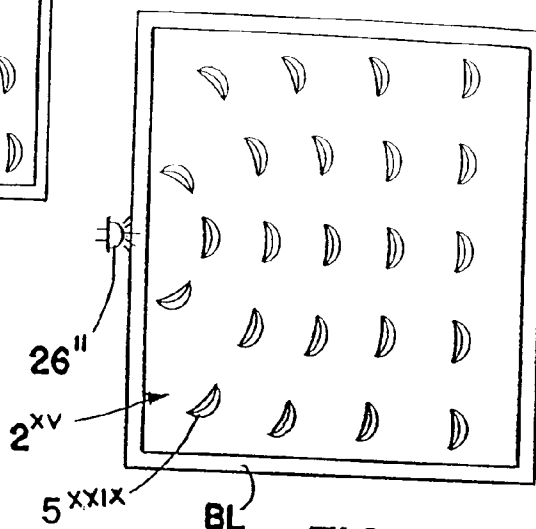


FIG. 20

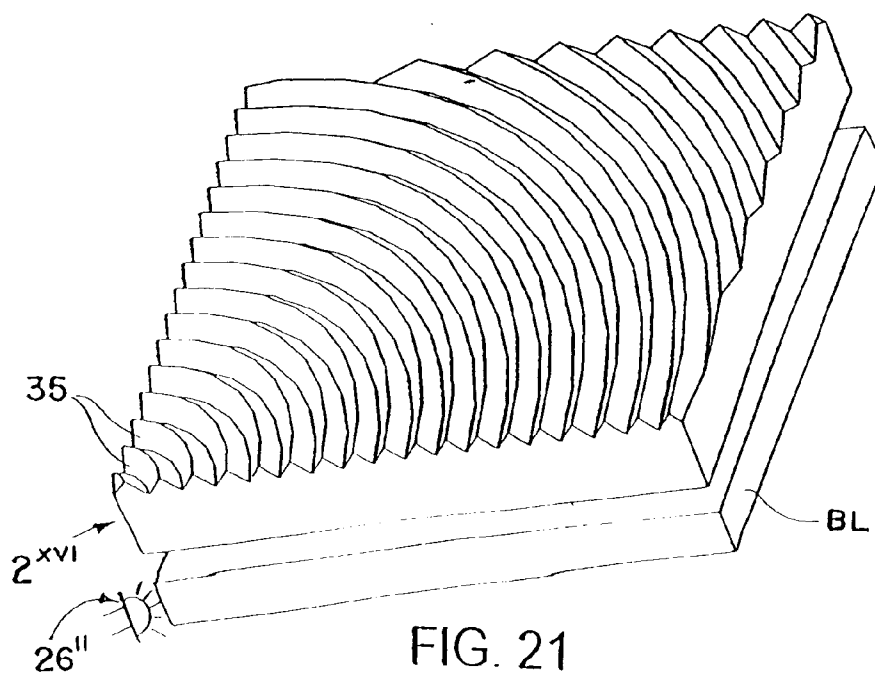
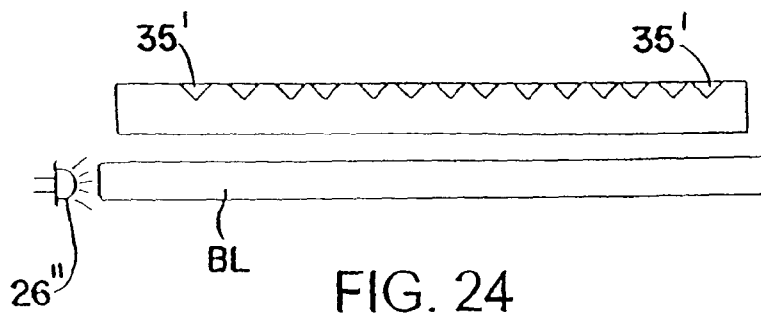
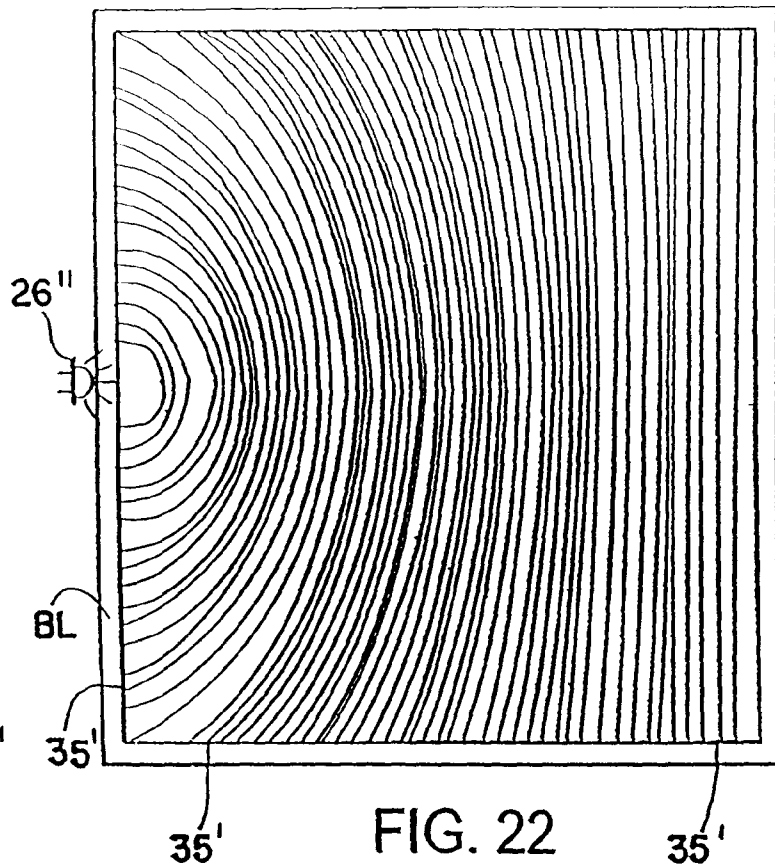
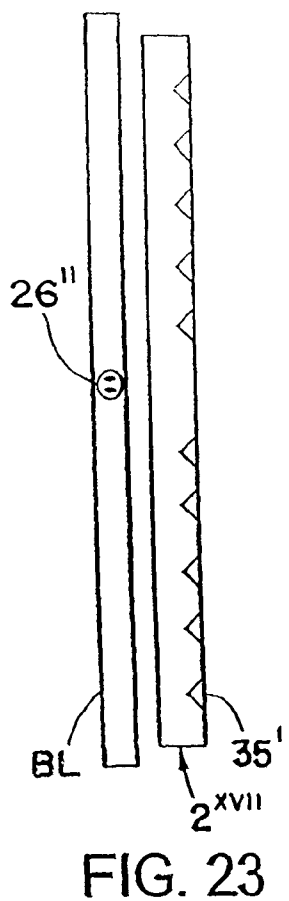


FIG. 21



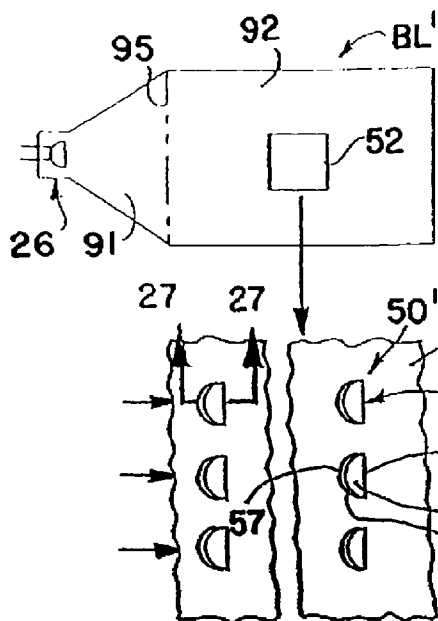


FIG. 25

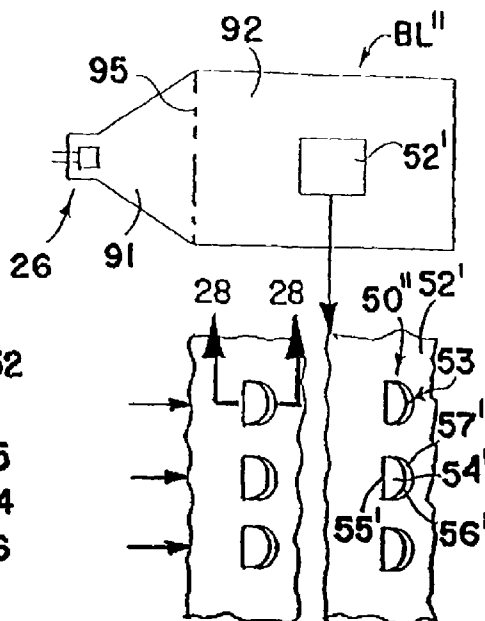


FIG. 26

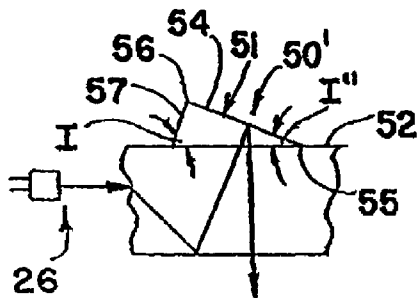


FIG. 27

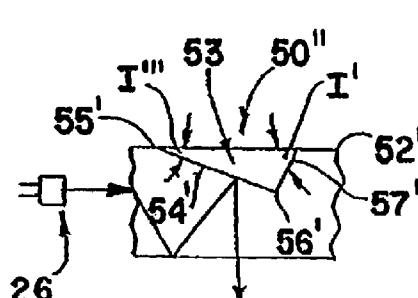


FIG. 28

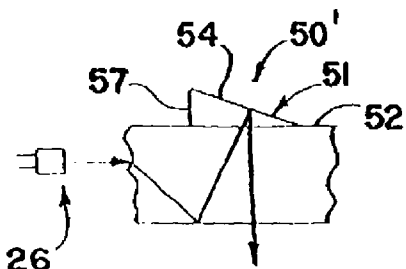


FIG. 29

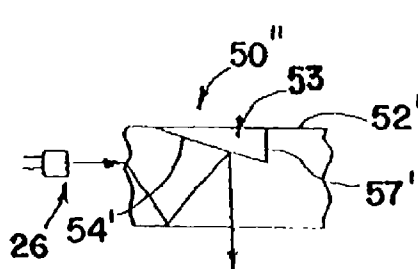


FIG. 30

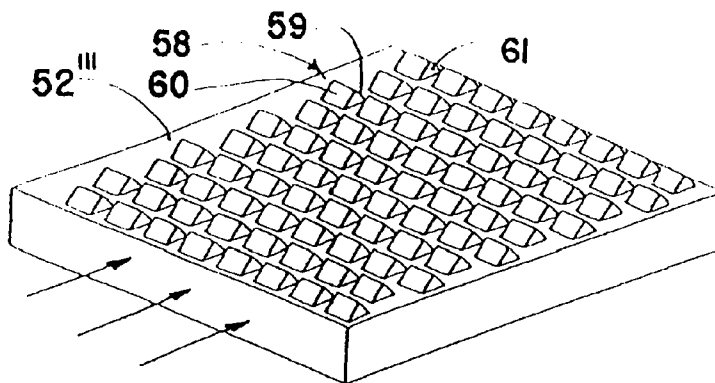


FIG. 31

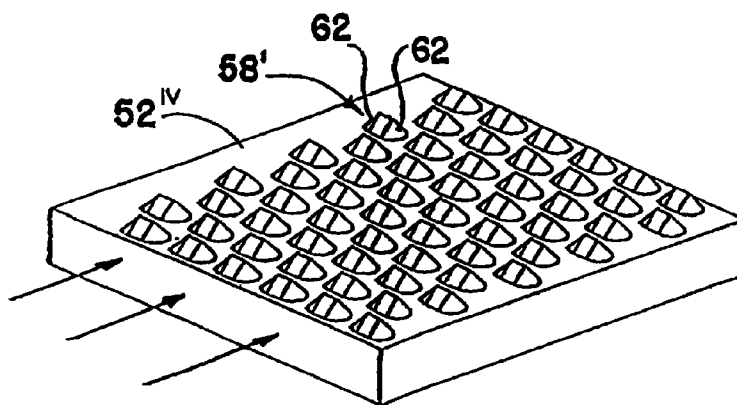


FIG. 32

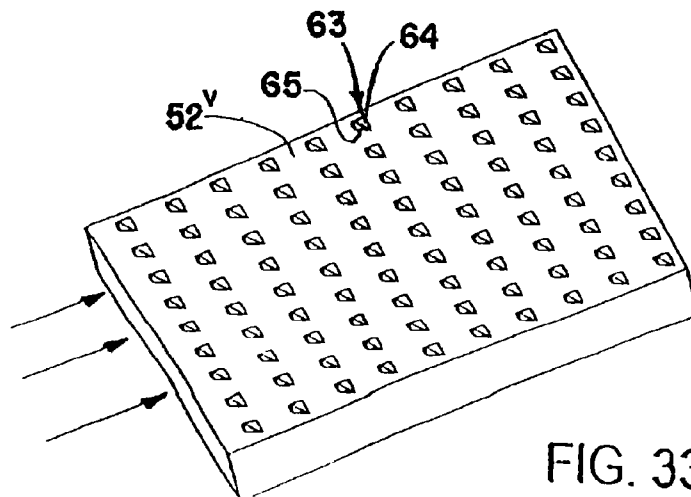
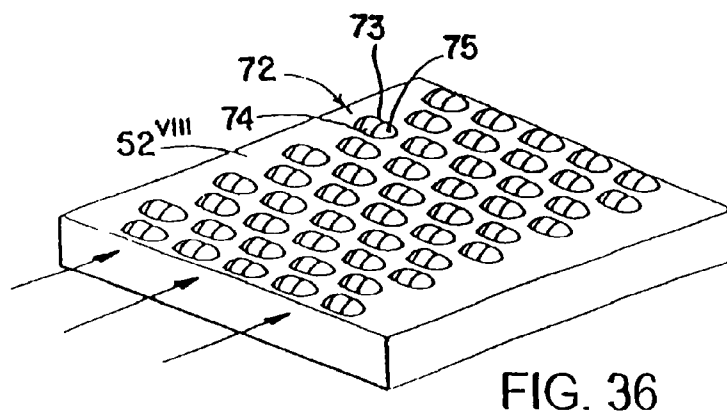
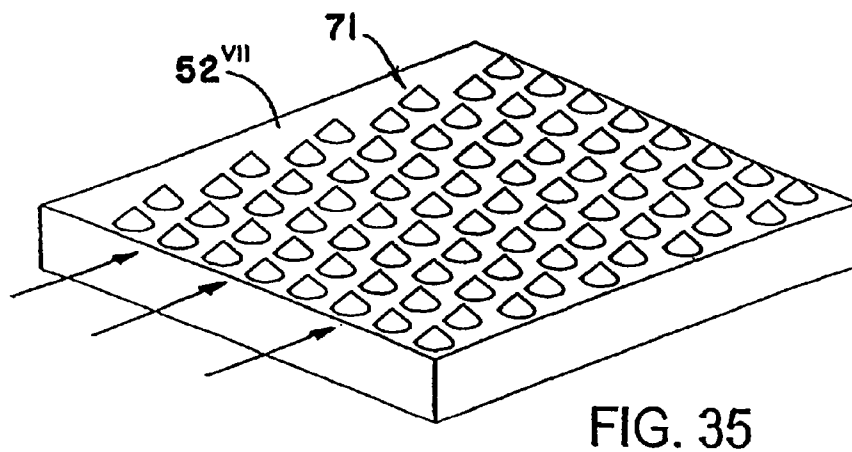
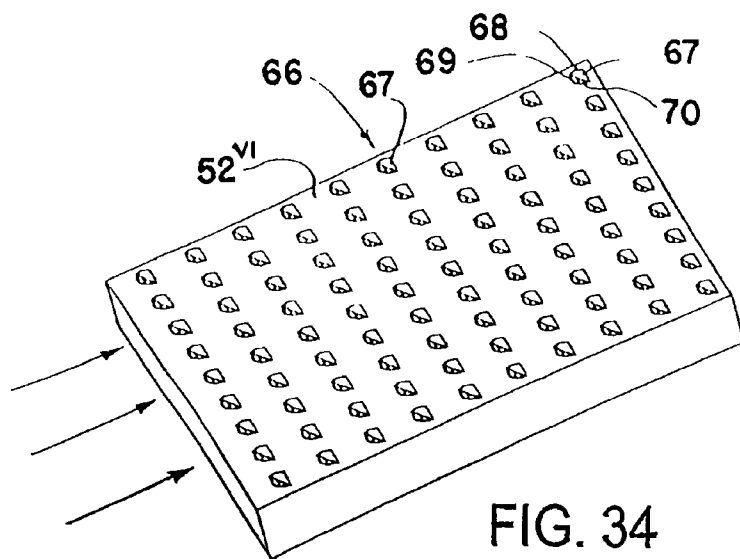


FIG. 33



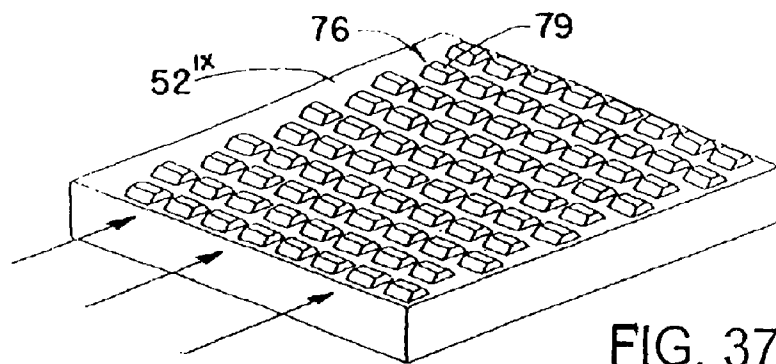


FIG. 37

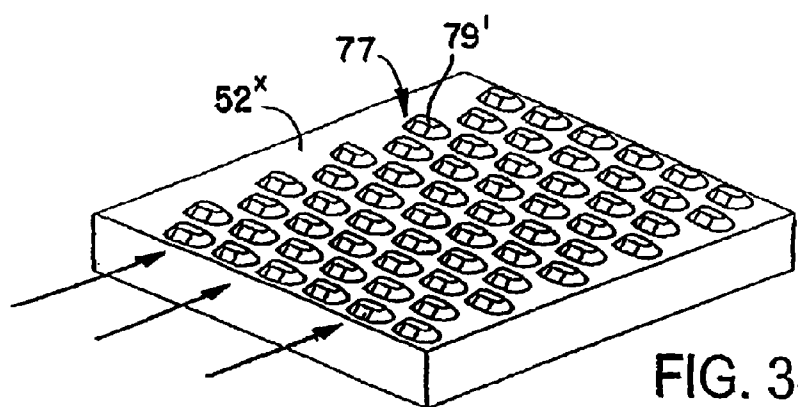


FIG. 38

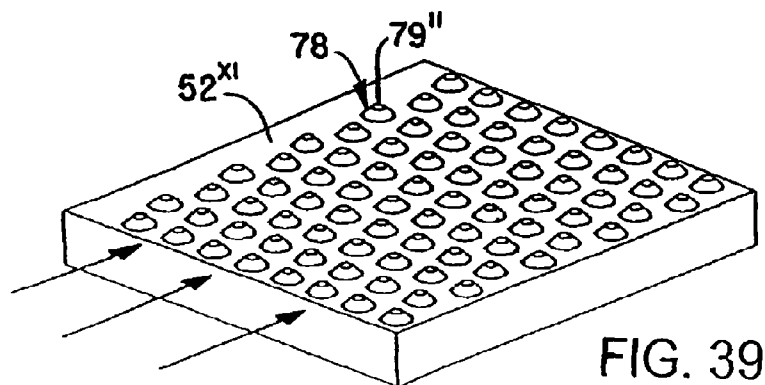


FIG. 39

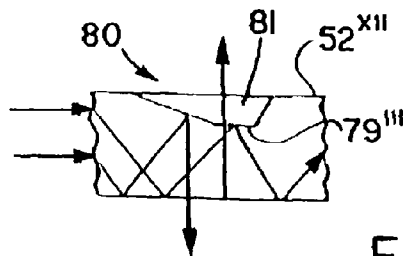
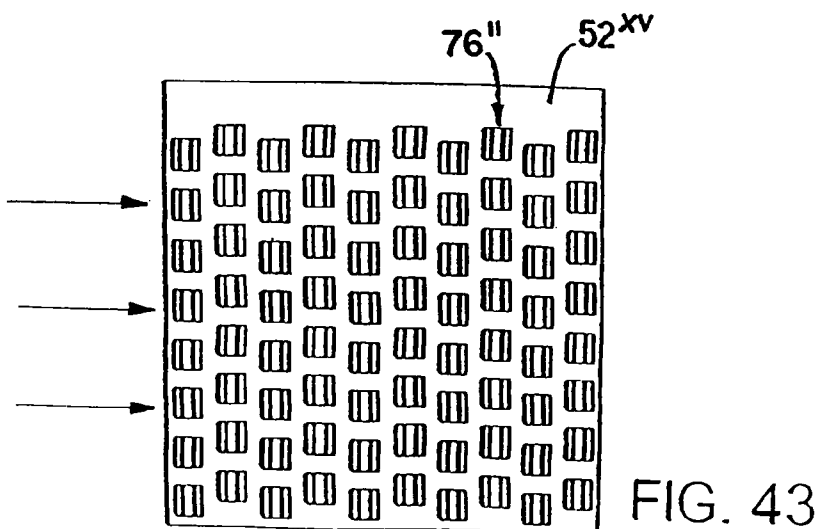
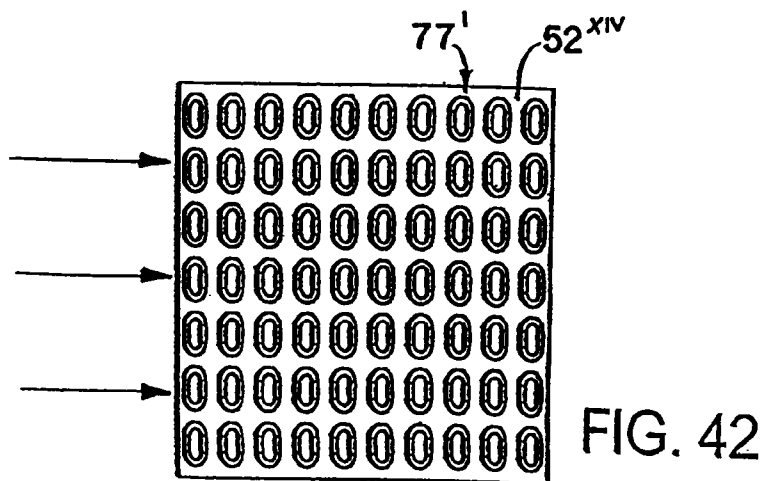
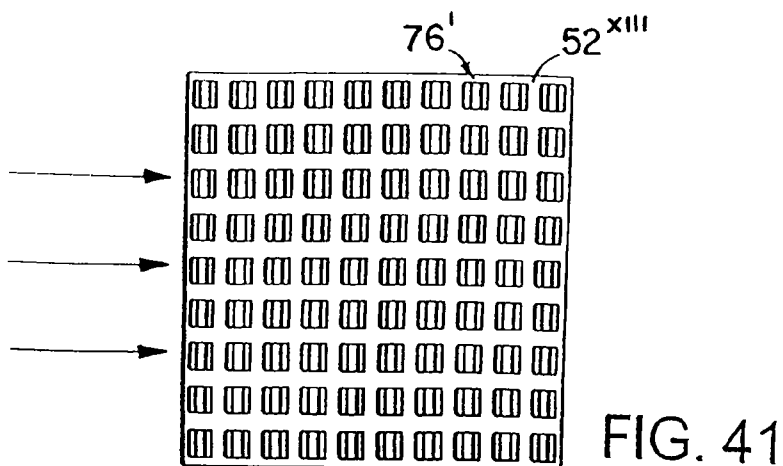
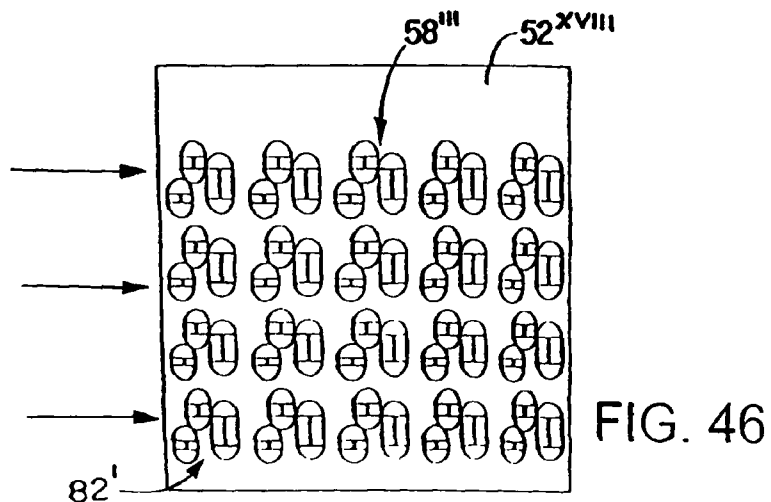
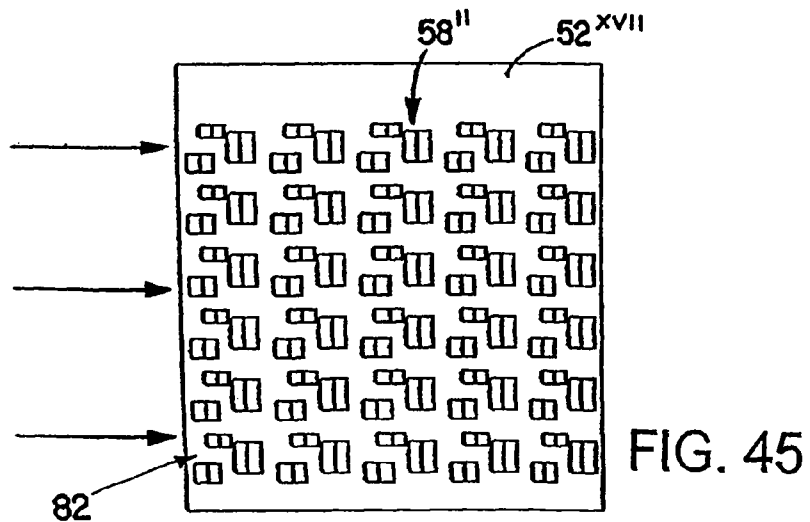
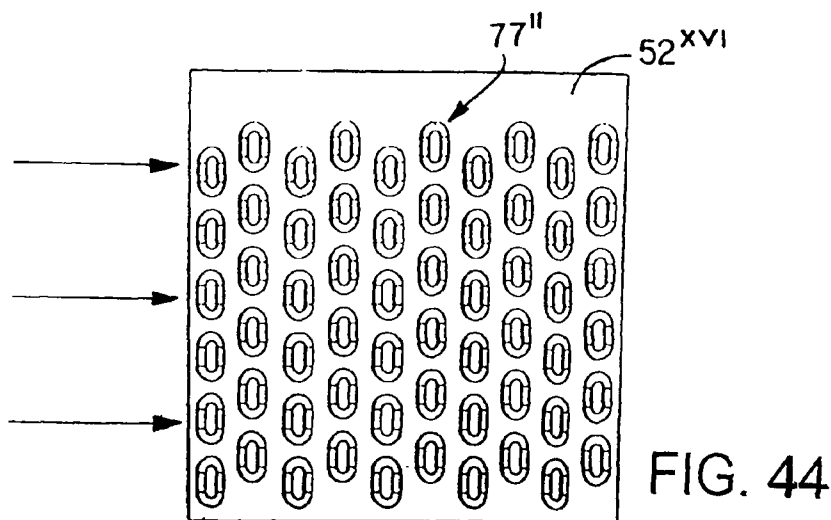
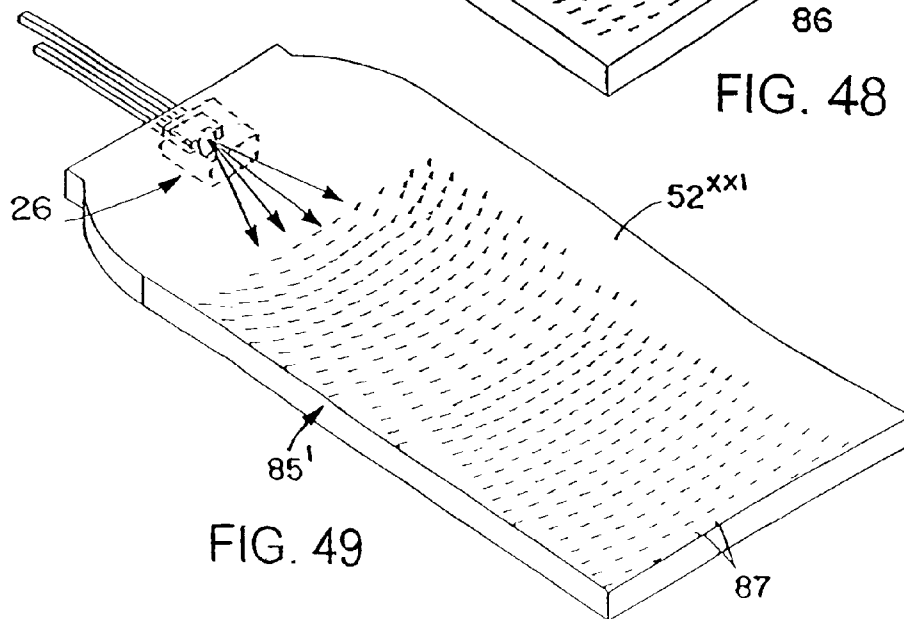
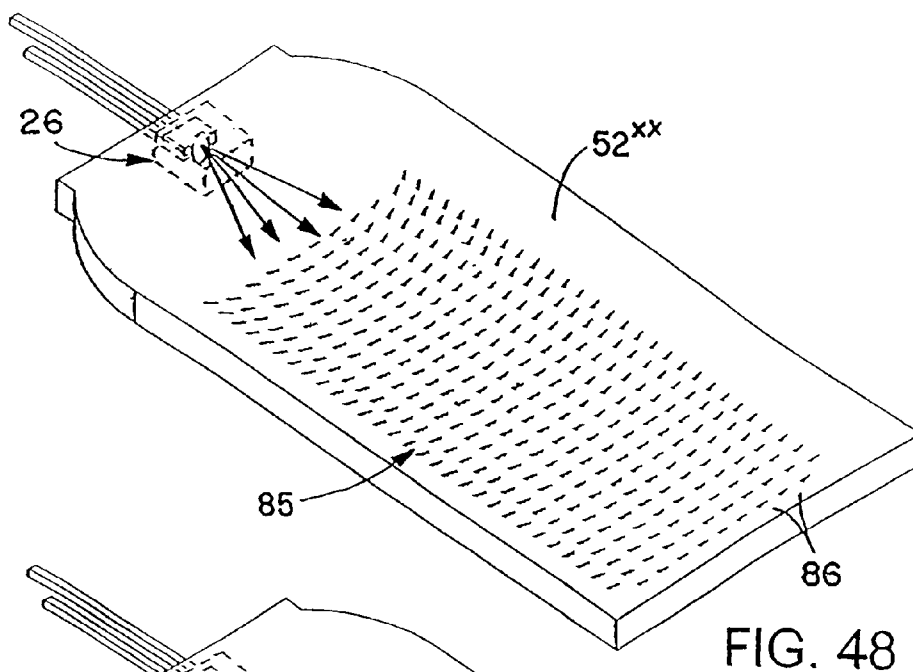
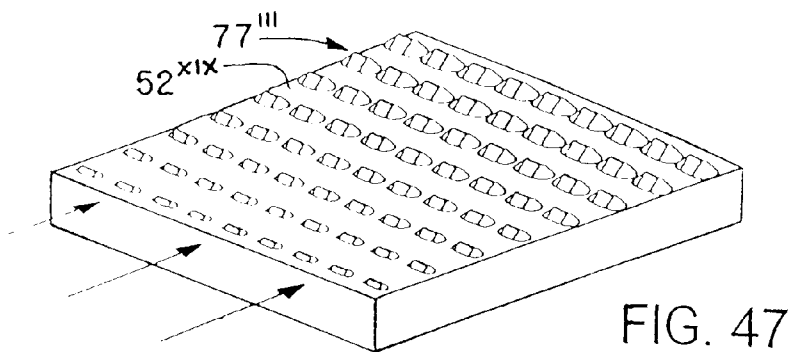


FIG. 40







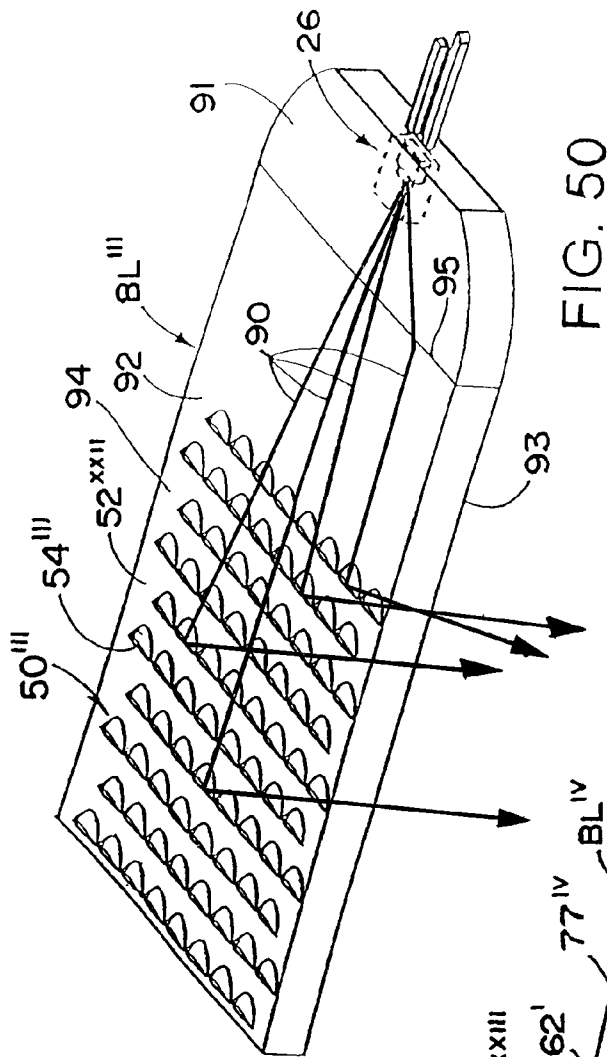


FIG. 50

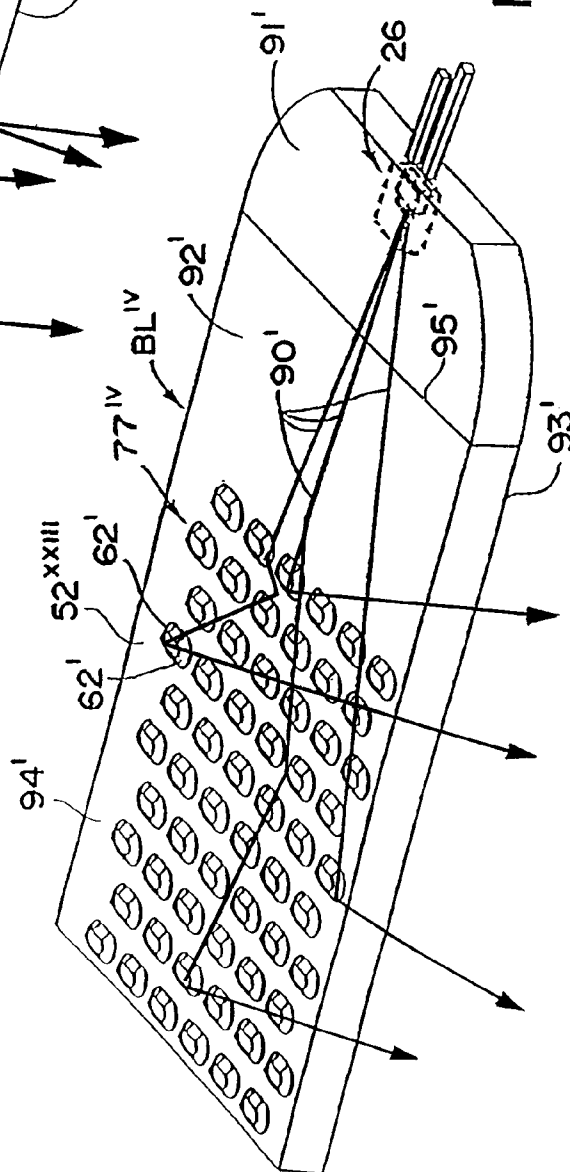


FIG. 51

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**LIGHT REDIRECTING FILM SYSTEMS
HAVING PATTERN OF VARIABLE OPTICAL
ELEMENTS**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a division of U.S. patent application Ser. No. 11/484,063, filed Jul. 11, 2006, which is a division of U.S. patent application Ser. No. 10/729,113, filed Dec. 5, 2003, now U.S. Pat. No. 7,090,389, which is a division of U.S. patent application Ser. No. 09/909,318, filed Jul. 19, 2001, now U.S. Pat. No. 6,752,505, which is a continuation-in-part of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481, the entire disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to light redirecting films and film systems for redirecting light from a light source toward a direction normal to the plane of the films.

BACKGROUND OF THE INVENTION

Light redirecting films are thin transparent or translucent optical films or substrates that redistribute the light passing through the films such that the distribution of the light exiting the films is directed more normal to the surface of the films. Heretofore, light redirecting films were provided with prismatic grooves, lenticular grooves, or pyramids on the light exit surface of the films which changed the angle of the film/air interface for light rays exiting the films and caused the components of the incident light distribution traveling in a plane perpendicular to the refracting surfaces of the grooves to be redistributed in a direction more normal to the surface of the films. Such light redirecting films are used, for example, with liquid crystal displays, used in laptop computers, word processors, avionic displays, cell phones, PDAs and the like to make the displays brighter.

The light entrance surface of the films usually has a transparent or matte finish depending on the visual appearance desired. A matte finish produces a softer image but is not as bright due to the additional scattering and resultant light loss caused by the matte or diffuse surface.

Heretofore, most applications used two grooved film layers rotated relative to each other such that the grooves in the respective film layers are at 90 degrees relative to each other. The reason for this is that a grooved light redirecting film will only redistribute, towards the direction normal to the film surface, the components of the incident light distribution traveling in a plane perpendicular to the refracting surfaces of the grooves. Therefore, to redirect light toward the normal of the film surface in two dimensions, two grooved film layers rotated 90 degrees with respect to each other are needed, one film layer to redirect light traveling in a plane perpendicular to the direction of its grooves and the other film layer to redirect light traveling in a plane perpendicular to the direction of its grooves.

Attempts have been made in the past to create a single layer light redirecting film that will redirect components of the incident light distribution traveling along two different axes 90 degrees to each other. One known way of accomplishing this is to provide a single layer film with two sets of grooves extending perpendicular to each other resulting in a pyramid structure which redirects light traveling in both such directions. However, such a film produces a much lower brightness

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than two film layers each with a single groove configuration rotated 90 degrees with respect to each other because the area that is removed from the first set of grooves by the second set of grooves in a single layer film reduces the surface area available to redirect light substantially by 50% in each direction of travel.

In addition, heretofore, the grooves of light redirecting films have been constructed so that all of the grooves meet the surface of the films at the same angle, mostly 45 degrees. This design assumes a constant, diffuse angular distribution of light from the light source, such as a lambertian source, a backlighting panel using a printing or etching technology to extract light, or a backlighting panel behind heavy diffusers. A light redirecting film where all of the light redirecting surfaces meet the film at the same angle is not optimized for a light source that has a nonuniform directional component to its light emission at different areas above the source. For example, the average angle about which a modern high efficiency edge lit backlight, using grooves or micro-optical surfaces to extract light, changes at different distances from the light source, requiring a different angle between the light redirecting surfaces and the plane of the film to optimally redirect light toward the normal of the film.

There is thus a need for a light redirecting film that can produce a softer image while eliminating the decrease in brightness associated with a matte or diffuse finish on the light input side of the film. Also, there is a need for a single layer of film which can redirect a portion of the light traveling in a plane parallel to the refracting surfaces in a grooved film, that would be brighter than a single layer of film using prismatic or lenticular grooves. In addition, there is a need for a light redirecting film that can compensate for the different angular distributions of light that may exist for a particular light source at different positions above the source, such as backlights used to illuminate liquid crystal displays. Also, there is a need for a light redirecting film system in which the film is matched or tuned to the light output distribution of a backlight or other light source to reorient or redirect more of the incident light from the backlight within a desired viewing angle.

SUMMARY OF THE INVENTION

The present invention relates to light redirecting films and light redirecting film systems that redistribute more of the light emitted by a backlight or other light source toward a direction more normal to the plane of the films, and to light redirecting films that produce a softer image without the brightness decrease associated with films that have a matte or diffuse finish on the light entrance surface of the films, for increased effectiveness.

The light exit surface of the films has a pattern of discrete individual optical elements of well defined shape for refracting the incident light distribution such that the distribution of light exiting the films is in a direction more normal to the surface of the films. These individual optical elements may be formed by depressions in or projections on the exit surface of the films, and include one or more sloping surfaces for refracting the incident light toward a direction normal to the exit surface. These sloping surfaces may for example include a combination of planar and curved surfaces that redirect the light within a desired viewing angle. Also, the curvature of the surfaces, or the ratio of the curved area to the planar area of the individual optical elements as well as the perimeter shapes of the curved and planar surfaces may be varied to tailor the light output distribution of the films, to customize the viewing angle of the display device used in conjunction with the films.

In addition, the curvature of the surfaces, or the ratio of the curved area to the planar area of the individual optical elements may be varied to redirect more or less light that is traveling in a plane that would be parallel to the grooves of a prismatic or lenticular grooved film. Also the size and population of the individual optical elements, as well as the curvature of the surfaces of the individual optical elements may be chosen to produce a more or less diffuse output or to randomize the input light distribution from the light source to produce a softer more diffuse light output distribution while maintaining the output distribution within a specified angular region about the direction normal to the films.

The light entrance surface of the films may have an optical coating such as an antireflective coating, a reflective polarizer, a retardation coating or a polarizer. Also a matte or diffuse texture may be provided on the light entrance surface depending on the visual appearance desired. A matte finish produces a softer image but is not as bright.

The individual optical elements on the exit surface of the films may be randomized in such a way as to eliminate any interference with the pixel spacing of a liquid crystal display. This randomization can include the size, shape, position, depth, orientation, angle or density of the optical elements. This eliminates the need for diffuser layers to defeat moiré and similar effects. Also, at least some of the individual optical elements may be arranged in groupings across the exit surface of the films, with at least some of the optical elements in each of the groupings having a different size or shape characteristic that collectively produce an average size or shape characteristic for each of the groupings that varies across the films to obtain average characteristic values beyond machining tolerances for any single optical element and to defeat moiré and interference effects with the pixel spacing of a liquid crystal display. In addition, at least some of the individual optical elements may be oriented at different angles relative to each other for customizing the ability of the films to reorient/redirect light along two different axes.

The angles that the light redirecting surfaces of the individual optical elements make with the light exit surface of the films may also be varied across the display area of a liquid crystal display to tailor the light redirecting function of the films to a light input distribution that is non-uniform across the surface of the light source.

The individual optical elements of the light redirecting films also desirably overlap each other, in a staggered, interlocked and/or intersecting configuration, creating an optical structure with excellent surface area coverage. Moreover, the individual optical elements may be arranged in groupings with some of the individual optical elements oriented along one axis and other individual optical elements oriented along another axis. Also, the orientation of the individual optical elements in each grouping may vary. Further, the size, shape, position and/or orientation of the individual optical elements of the light redirecting films may vary to account for variations in the distribution of light emitted by a light source.

The properties and pattern of the optical elements of light redirecting films may also be customized to optimize the light redirecting films for different types of light sources which emit different light distributions, for example, one pattern for single bulb laptops, another pattern for double bulb flat panel displays, and so on.

Further, light redirecting film systems are provided in which the orientation, size, position and/or shape of the individual optical elements of the light redirecting films are tailored to the light output distribution of a backlight or other light source to reorient or redirect more of the incident light from the backlight within a desired viewing angle. Also, the

backlight may include individual optical deformities that collimate light along one axis and the light redirecting films may include individual optical elements that collimate light along another axis perpendicular to the one axis.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter more fully described and particularly pointed out in the claims, the following description and annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but several of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1 is a schematic side elevation view of one form of light redirecting film system in accordance with the present invention;

FIG. 2 is an enlarged fragmentary side elevation view of a portion of the backlight and light redirecting film system of FIG. 1;

FIGS. 3 and 4 are schematic side elevation views of other forms of light redirecting film systems of the present invention;

FIGS. 5-20 are schematic perspective or plan views showing different patterns of individual optical elements on light redirecting films of the present invention;

FIGS. 5a-5n are schematic perspective views of different geometric shapes that the individual optical elements on the light redirecting films may take;

FIG. 21 is a schematic perspective view of a light redirecting film having optical grooves extending across the film in a curved pattern facing a corner of the film;

FIG. 22 is a top plan view of a light redirecting film having a pattern of optical grooves extending across the film facing a midpoint on one edge of the film that decreases in curvature as the distance from the one edge increases;

FIG. 23 is an end elevation view of the light redirecting film of FIG. 22 as seen from the left end thereof;

FIG. 24 is a side elevation view of the light redirecting film of FIG. 22;

FIGS. 25 and 26 are enlarged schematic fragmentary plan views of a surface area of a backlight/light emitting panel assembly showing various forms of optical deformities formed on or in a surface of the backlight;

FIGS. 27 and 28 are enlarged longitudinal sections through one of the optical deformities of FIGS. 25 and 26, respectively;

FIGS. 29 and 30 are enlarged schematic longitudinal sections through other forms of optical deformities formed on or in a surface of a backlight;

FIGS. 31-39 are enlarged schematic perspective views of backlight surface areas containing various patterns of individual optical deformities of other well defined shapes;

FIG. 40 is an enlarged schematic longitudinal section through another form of optical deformity formed on or in a surface of a backlight;

FIGS. 41 and 42 are enlarged schematic top plan views of backlight surface areas containing optical deformities similar in shape to those shown in FIGS. 37 and 38 arranged in a plurality of straight rows along the length and width of the surface areas;

FIGS. 43 and 44 are enlarged schematic top plan views of backlight surface areas containing optical deformities also similar in shape to those shown in FIGS. 37 and 38 arranged in staggered rows along the length of the surface areas;

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FIGS. 45 and 46 are enlarged schematic top plan views of backlight surface areas containing a random or variable pattern of different sized optical deformities on the surface areas;

FIG. 47 is an enlarged schematic perspective view of a backlight surface area showing optical deformities increasing in size as the distance of the deformities from the light input surface increases or intensity of the light increases along the length of the surface area;

FIGS. 48 and 49 are schematic perspective views showing different angular orientations of the optical deformities along the length and width of a backlight surface area; and

FIGS. 50 and 51 are enlarged perspective views schematically showing how exemplary light rays emitted from a focused light source are reflected or refracted by different individual optical deformities of well defined shapes of a backlight surface area.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 and 2 schematically show one form of light redirecting film system 1 in accordance with this invention including a light redirecting film 2 that redistributes more of the light emitted by a backlight BL or other light source toward a direction more normal to the surface of the film. Film 2 may be used to redistribute light within a desired viewing angle from almost any light source for lighting, for example, a display such as a liquid crystal display, used in laptop computers, word processors, avionic displays, cell phones, PDAs and the like, to make the displays brighter. The liquid crystal display can be any type including a transmissive liquid crystal display D as schematically shown in FIGS. 1 and 2, a reflective liquid crystal display D' as schematically shown in FIG. 3 and a transmissive liquid crystal display D'' as schematically shown in FIG. 4.

The reflective liquid crystal display D' shown in FIG. 3 includes a back reflector 42 adjacent the back side for reflecting ambient light entering the display back out the display to increase the brightness of the display. The light redirecting film 2 of the present invention is placed adjacent the top of the reflective liquid crystal display to redirect ambient light (or light from a front light) into the display toward a direction more normal to the plane of the film for reflection back out by the back reflector within a desired viewing angle to increase the brightness of the display. Light redirecting film 2 may be attached to, laminated to or otherwise held in place against the top of the liquid crystal display.

The transmissive liquid crystal display D'' shown in FIG. 4 includes a transreflector T placed between the display and a backlight BL for reflecting ambient light entering the front of the display back out the display to increase the brightness of the display in a lighted environment, and for transmitting light from the backlight through the transreflector and out the display to illuminate the display in a dark environment. In this embodiment the light redirecting film 2 may either be placed adjacent the top of the display or adjacent the bottom of the display or both as schematically shown in FIG. 4 for redirecting or redistributing ambient light and/or light from the backlight more normal to the plane of the film to make the light ray output distribution more acceptable to travel through the display to increase the brightness of the display.

Light redirecting film 2 comprises a thin transparent film or substrate 8 having a pattern of discrete individual optical elements 5 of well defined shape on the light exit surface 6 of the film for refracting the incident light distribution such that the distribution of the light exiting the film is in a direction more normal to the surface of the film.

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Each of the individual optical elements 5 has a width and length many times smaller than the width and length of the film, and may be formed by depressions in or projections on the exit surface of the film. These individual optical elements 5 include at least one sloping surface for refracting the incident light toward the direction normal to the light exit surface. FIG. 5 shows one pattern of individual optical elements 5 on a film 2. These optical elements may take many different shapes. For example, FIG. 5a shows one of the optical elements 5 of FIG. 5 which is a non-prismatic optical element having a total of two surfaces 10, 12, both of which are sloping. One of the surfaces 10 shown in FIG. 5a is planar or flat whereas the other surface 12 is curved. Moreover, both surfaces 10, 12 intersect each other and also intersect the surface of the film. Alternatively, both surfaces 10', 12' of the individual optical elements 5' may be curved as schematically shown in FIG. 5b.

Alternatively, the optical elements may each have only one surface that is curved and sloping and intersects the film. FIG. 5c shows one such optical element 5'' in the shape of a cone 13, whereas FIG. 5d shows another such optical element 5''' having a semispherical or dome shape 14. Also, such optical elements may have more than one sloping surface intersecting the film.

FIG. 5e shows an optical element 5'''' having a total of three surfaces, all of which intersect the film and intersect each other. Two of the surfaces 15 and 16 are curved, whereas the third surface 17 is planar.

FIG. 5f shows an optical element 5'''' in the shape of a pyramid 18 with four triangular shaped sides 19 that intersect each other and intersect the film. The sides 19 of the pyramid 18 may all be of the same size and shape as shown in FIG. 5f, or the sides 19' of the pyramid 18' may be stretched so the sides of the optical element 5'''' have different perimeter shapes as shown in FIG. 5g. Also, the optical elements may have any number of planar sloping sides. FIG. 5h shows an optical element 5'''' with four planar sloping sides 20, whereas FIG. 5i shows an optical element 5'''' with eight planar sloping sides 20'.

The individual optical elements may also have more than one curved and more than one planar sloping surface, all intersecting the film. FIG. 5j shows an optical element 5'''' having a pair of intersecting oppositely sloping planar sides 22 and oppositely rounded or curved ends or sides 23. Further, the sloping planar sides 22' and 22'' and curved ends or sides 23' and 23'' of optical elements 5x and 5y may have different angled slopes as shown in FIGS. 5k and 5l. Moreover, the optical elements may have at least one curved surface that does not intersect the film. One such optical element 5'''' is shown in FIG. 5m which includes a pair of oppositely sloping planar sides 22''' and oppositely rounded or curved ends or sides 23''' and a rounded or curved top 24 intersecting the oppositely sloping sides and oppositely rounded ends. Further, the optical elements 5'''' may be curved along their length as shown in FIG. 5n.

Providing the individual optical elements with a combination of planar and curved surfaces redirects or redistributes a larger viewing area than is possible with a grooved film. Also, the curvature of the surfaces, or the ratio of the curved area to the planar area of the individual optical elements may be varied to tailor the light output distribution of the film to customize the viewing area of a display device used in conjunction with the film.

The light entrance surface 7 of the film 2 may have an optical coating 25 (see FIG. 2) such as an antireflective coating, a reflective polarizer, a retardation coating or a polarizer. Also, a matte or diffuse texture may be provided on the light

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entrance surface 7 depending on the visual appearance desired. A matte finish produces a softer image but is not as bright. The combination of planar and curved surfaces of the individual optical elements of the present invention may be configured to redirect some of the light rays impinging thereon in different directions to produce a softer image without the need for an additional diffuser or matte finish on the entrance surface of the film.

The individual optical elements of the light redirecting film also desirably overlap each other in a staggered, interlocked and/or intersecting configuration, creating an optical structure with excellent surface area coverage. FIGS. 6, 7, 13 and 15, for example, show optical elements 5^{XIV} , 5^{XV} , 5^{XVI} , and 5^{XVII} of light redirecting films 2^I , 2^{II} , 2^{III} and 2^{IV} staggered with respect to each other; FIGS. 8-10 show the optical elements 5^{XVIII} , 5^{XIX} and 5^{XX} of light redirecting films 2^V , 2^{VI} and 2^{VII} intersecting each other; and FIGS. 11 and 12 show the optical elements intersecting 5^{XXI} and 5^{XXII} of light redirecting films 2^{VIII} and 2^{IX} interlocking each other.

Moreover, the slope angle, density, position, orientation, height or depth, shape, and/or size of the optical elements of the light redirecting film may be matched or tuned to the particular light output distribution of a backlight BL or other light source to account for variations in the distribution of light emitted by the backlight in order to redistribute more of the light emitted by the backlight within a desired viewing angle. For example, the angle that the sloping surfaces (e.g., surfaces 10, 12) of the optical elements 5 make with the surface of the light redirecting film 2 may be varied as the distance from the backlight BL from a light source 26 increases to account for the way the backlight emits light rays R at different angles as the distance from the light source increases as schematically shown in FIG. 2. Also, the backlight BL itself may be designed to emit more of the light rays at lower angles to increase the amount of light emitted by the backlight and rely on the light redirecting film to redistribute more of the emitted light within a desired viewing angle. In this way the individual optical elements of the light redirecting film may be selected to work in conjunction with the optical deformations of the backlight to produce an optimized output light ray angle distribution from the system.

FIGS. 2, 5 and 9 show different patterns of individual optical elements all of the same height or depth, whereas FIGS. 7, 8, 10, 13 and 14 show different patterns of individual optical elements of different shapes, sizes and height or depth. The individual optical elements 5^{XXIII} of the light redirecting film 2^X of FIG. 14 are also shown arranged in alternating rows along the width or length of the film.

The individual optical elements 5^{XXIV} and 5^{XXV} may also be randomized on the film 2^{XI} and 2^{XII} as schematically shown in FIGS. 16 and 17 in such a way as to eliminate any interference with the pixel spacing of a liquid crystal display. This eliminates the need for optical diffuser layers 30 shown in FIGS. 1 and 2 to defeat moiré and similar effects. Moreover, at least some of the individual optical elements may be arranged in groupings 32 , 32^I and 32^{II} across the film, with at least some of the optical elements in each grouping having a different size or shape characteristic that collectively produce an average size or shape characteristic for each of the groupings that varies across the film as schematically shown in FIGS. 7, 13 and 15 to obtain characteristic values beyond machining tolerances to defeat moiré and interference effects with the liquid crystal display pixel spacing. For example, at least some of the optical elements in each grouping may have a different depth or height that collectively produce an average depth or height characteristic for each grouping that varies across the film. Also, at least some of the optical elements in

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each grouping may have a different slope angle that collectively produce an average slope angle for each grouping that varies across the film. Further, at least one sloping surface of the individual optical elements in each grouping may have a different width or length that collectively produce an average width or length characteristic in each grouping that varies across the film.

Where the individual optical elements include a combination of planar and curved surfaces, for example planar and curved surfaces 10^{II} , 12^{II} , 10^{III} , 12^{III} and 10^{IV} , 12^{IV} as shown in FIGS. 7, 13 and 15, respectively, the curvature of the curved surfaces, or the ratio of the curved area to the planar area of the individual optical elements as well as the perimeter shapes of the curved and planar surfaces may be varied to tailor the light output distribution of the film. In addition, the curvature of the curved surfaces, or the ratio of the curved area to the planar area of the individual optical elements may be varied to redirect more or less light that is traveling in a plane that would be parallel to the grooves of a prismatic or lenticular grooved film, partially or completely replacing the need for a second layer of light redirecting film. Also, at least some of the individual optical elements may be oriented at different angles relative to each other as schematically shown in FIGS. 13 and 16 to redistribute more of the light emitted by a light source along two different axes in a direction more normal to the surface of the film, partially or completely replacing the need for a second layer of light redirecting film. However, it will be appreciated that two layers of such light redirecting film each having the same or different patterns of individual optical elements thereon may be placed between a light source and viewing area with the layers rotated 90 degrees (or other angles greater than 0 degrees and less than 90 degrees) with respect to each other so that the individual optical elements on the respective film layers redistribute more of the light emitted by a light source traveling in different planar directions in a direction more normal to the surface of the respective films.

Also, the light redirecting film 2^{IV} may have a pattern of optical elements 5^{XXIII} that varies at different locations on the film as schematically shown in FIG. 15 to redistribute the light ray output distribution from different locations of a backlight or other light source to redistribute the light ray output distribution from the different locations toward a direction normal to the film.

Further, the properties and pattern of the optical elements of the light redirecting film may be customized to optimize the light redirecting film for different types of light sources which emit different light distributions, for example, one pattern for single bulb laptops, another pattern for double bulb flat panel displays, and so on.

FIG. 17 shows the optical elements 5^{XXVI} arranged in a radial pattern from the outside edges of the film 2^{XII} toward the center to redistribute the light ray output distribution of a backlight BL that receives light from cold cathode fluorescent lamp 26^I along all four side edges of the backlight.

FIG. 18 shows the optical elements 5^{XXVII} arranged in a pattern of angled groupings 32^{III} across the film 2 that are tailored to redistribute the light ray output distribution of a backlight BL that receives light from one cold cathode fluorescent lamp 26^I or a plurality of light emitting diodes 26^{II} along one input edge of the backlight.

FIG. 19 shows the optical elements 5^{XXVIII} arranged in a radial type pattern facing a corner of the film 2^{XIV} to redistribute the light ray output distribution of a backlight BL that is corner lit by a light emitting diode 26^{II} . FIG. 20 shows the optical elements 5^{XXIX} arranged in a radial type pattern facing a midpoint on one input edge of the film 2^{XV} to redistribute the

light ray output distribution of a backlight BL that is lighted at a midpoint of one input edge of the backlight by a single light emitting diode 26^{II}.

FIG. 21 shows a light redirecting film 2^{XVII} having optical grooves 35 extending across the film in a curved pattern facing a corner of the film to redistribute the light ray output distribution of a backlight BL that is corner lit by a light emitting diode 26^{II}, whereas FIGS. 22-24 show a light redirecting film 2^{XVII} having a pattern of optical grooves 35^I extending across the film facing a midpoint along one edge of the film that decreases in curvature as the distance from the one edge increases to redistribute the light ray output distribution of a backlight BL that is edge lit by a light emitting diode 26^{II} at a midpoint of one input edge of the backlight.

Where the light redirecting film has a pattern 40 of optical elements 5 thereon that varies along the length of the film, a roll 41 of the film may be provided having a repeating pattern of optical elements thereon as schematically shown in FIG. 15 to permit a selected area of the pattern that best suits a particular application to be die cut from the roll of film.

The backlight BL may be substantially flat, or curved, or may be a single layer or multi-layers, and may have different thicknesses and shapes as desired. Moreover, the backlight may be flexible or rigid, and be made of a variety of compounds. Further, the backlight may be hollow, filled with liquid, air, or be solid, and may have holes or ridges.

Also, the light source 26 may be of any suitable type including, for example, an arc lamp, an incandescent bulb which may also be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a cold cathode fluorescent lamp, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light source 26 may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (e.g., red, blue, green) or a single LED with multiple color chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of optical deformities may be provided on one or both sides of the backlight BL or on one or more selected areas on one or both sides of the backlight as desired. As used herein, the term optical deformities means any change in the shape or geometry of a surface and/or coating or surface treatment that causes a portion of the light to be emitted from the backlight. These deformities can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, machined pattern, a printed pattern, a hot stamp pattern, or a molded pattern or the like on selected areas of the backlight. An ink or print pattern may be applied for example by pad printing, silk printing, inkjet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the backlight. This sheet or film may become a permanent part of the backlight for example by attaching or otherwise positioning the sheet or film against one or both sides of the backlight in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction or type of deformities on or in an area or areas of the backlight, the light output of the backlight can be controlled. The deformities may be used to control the percent of light output from a light emitting area of the backlight. For example, less and/or smaller size deformities may be placed on surface areas where less light output is wanted. Conversely, a greater percentage of and/or larger

deformities may be placed on surface areas of the backlight where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the backlight is necessary in order to provide a substantially uniform light output distribution. For example, the amount of light traveling through the backlight will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of deformities may be used to adjust for the light variances within the backlight, for example, by providing a denser concentration of deformities with increased distance from the light source thereby resulting in a more uniform light output distribution from the backlight.

The deformities may also be used to control the output ray angle distribution from the backlight to suit a particular application. For example, if the backlight is used to backlight a liquid crystal display, the light output will be more efficient if the deformities (or a light redirecting film is used in combination with the backlight) direct the light rays emitted by the backlight at predetermined ray angles such that they will pass through the liquid crystal display with low loss. Additionally, the pattern of optical deformities may be used to adjust for light output variances attributed to light extractions of the backlight. The pattern of optical deformities may be printed on the backlight surface areas utilizing a wide spectrum of paints, inks, coatings, epoxies or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity coverage. Moreover, the pattern of optical deformities may be multiple layers or vary in index of refraction.

Print patterns of optical deformities may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like. Also, print patterns of sixty lines per inch or finer are desirably employed. This makes the deformities or shapes in the print patterns nearly invisible to the human eye in a particular application, thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the backlight. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the backlight. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the backlight. The color of the deformities may also vary throughout the backlight, for example, to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of optical deformities, other optical deformities including prismatic or lenticular grooves or cross grooves, or depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more surface areas of the backlight. The prismatic or lenticular surfaces, depressions or raised surfaces will cause a portion of the light rays contacted thereby to be emitted from the backlight. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

A back reflector 42 may be attached or positioned against one side of the backlight BL as schematically shown in FIGS.

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1 and 2 in order to improve light output efficiency of the backlight by reflecting the light emitted from that side back through the backlight for emission through the opposite side. Additionally, a pattern of optical deformities 50 may be provided on one or both sides of the backlight as schematically shown in FIGS. 1 and 2 in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the backlight.

FIGS. 25-28 show optical deformities 50^I, 50^{II} which may either be individual projections 51 on the respective backlight surface areas 52 or individual depressions 53 in such surface areas 52^I of a backlight BL^I, BL^{II}. In either case, each of these optical deformities has a well defined shape including a reflective or refractive surface 54, 54^I (hereafter sometimes collectively referred to as a reflective/refractive surface) that intersects the respective backlight surface area 52, 52^I at one edge 55, 55^I and has a uniform slope throughout its length for more precisely controlling the emission of light by each of the deformities. Along a peripheral edge portion 56, 56^I of each reflective/refractive surface 54, 54^I is an end wall 57, 57^I of each deformity that intersects the respective panel surface area 52, 52^I at a greater included angle I, I^I than the included angle I^{II}, I^{III} between the reflective/refractive surfaces 54, 54^I and the panel surface area 52, 52^I (see FIGS. 27 and 28) to minimize the projected surface area of the end walls on the panel surface area. This allows more deformities to be placed on or in the panel surface areas than would otherwise be possible if the projected surface areas of the end walls 57, 57^I were substantially the same as or greater than the projected surface areas of the reflective/refractive surfaces 54, 54^I.

In FIGS. 25 and 26 the peripheral edge portions 56, 56^I of the reflective/refractive surfaces 54, 54^I and associated end walls 57, 57^I are curved in the transverse direction. Also in FIGS. 27 and 28 the end walls 57, 57^I of the deformities are shown extending substantially perpendicular to the reflective/refractive surfaces 54, 54^I of the deformities. Alternatively, such end walls may extend substantially perpendicular to the panel surface areas 52, 52^I as schematically shown in FIGS. 29 and 30. This virtually eliminates any projected surface area of the end walls on the panel surface areas whereby the density of the deformities on the panel surface areas may be even further increased.

The optical deformities may also be of other well defined shapes to obtain a desired light output distribution from a panel surface area. FIG. 31 shows individual light extracting deformities 58 on a panel surface area 52^{III} each including a generally planar, rectangular reflective/refractive surface 59 and associated end wall 60 of a uniform slope throughout their length and width and generally planar side walls 61. Alternatively, the deformities 58^I may have rounded or curved side walls 62 on a panel surface area 52^{IV} as schematically shown in FIG. 32.

FIG. 33 shows individual light extracting deformities 63 on a panel surface area 52^V each including a planar, sloping triangular shaped reflective/refractive surface 64 and associated planar, generally triangularly shaped side walls or end walls 65. FIG. 34 shows individual light extracting deformities 66 on a panel surface area 52^{VI} each including a planar sloping reflective/refractive surface 67 having angled peripheral edge portions 68 and associated angled end and side walls 69 and 70.

FIG. 35 shows individual light extracting deformities 71 on a panel surface area 52^{VII} which are generally conically shaped, whereas FIG. 36 shows individual light extracting deformities 72 on a panel surface area 52^{VIII} each including a rounded reflective/refractive surface 73 and rounded end walls 74 and rounded or curved side walls 75 all blended

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together. These additional surfaces will reflect or refract other light rays impinging thereon in different directions to spread light across the backlight/panel member BL to provide a more uniform distribution of light emitted from the panel member.

Regardless of the particular shape of the reflective/refractive surfaces and end and side walls of the individual deformities, such deformities may also include planar surfaces intersecting the reflective/refractive surfaces and end and/or side walls in parallel spaced relation to the panel surface areas 52. FIGS. 37-39 show deformities 76, 77 and 78 in the form of individual projections on a panel surface area 52^{IX}, 52^X, 52^{XI} having representative shapes similar to those shown in FIGS. 31, 32 and 35, respectively, except that each deformity is intersected by a planar surface 79, 79^I, 79^{II} in parallel spaced relation to the panel surface area. In like manner, FIG. 40 shows one of a multitude of deformities 80 in the form of individual depressions 81 in a panel surface area 52^{XII} each intersected by a planar surface 79^{III} in parallel spaced relation to the general planar surface of the panel surface area. Any light rays that impinge on such planar surfaces at internal angles less than the critical angle for emission of light from the panel surface area will be internally reflected by the planar surfaces, whereas any light rays impinging on such planar surfaces at internal angles greater than the critical angle will be emitted by the planar surfaces with minimal optical discontinuities, as schematically shown in FIG. 40.

Where the deformities are projections on the panel surface area, the reflective/refractive surfaces extend at an angle away from the panel in a direction generally opposite to that in which the light rays from the light source 26 travel through the panel as schematically shown in FIGS. 27 and 29. Where the deformities are depressions in the panel surface area, the reflective/refractive surfaces extend at an angle into the panel in the same general direction in which the light rays from the light source 26 travel through the panel member as schematically shown in FIGS. 28 and 30.

Regardless of whether the deformities are projections or depressions on or in the panel surface areas, the slopes of the light reflective/refractive surfaces of the deformities may be varied to cause the light rays impinging thereon to be either refracted out of the light emitting panel or reflected back through the panel and emitted out the opposite side of the panel which may be etched to diffuse the light emitted therefrom or covered by a light redirecting film to produce a desired effect. Also, the pattern of optical deformities on the panel surface area may be uniform or variable as desired to obtain a desired light output distribution from the panel surface areas. FIGS. 41 and 42 show deformities 76^I and 77^I similar in shape to those shown in FIGS. 37 and 38 arranged in a plurality of generally straight uniformly spaced apart rows along the length and width of a panel surface area 52^{XIII}, 52^{XIV}, whereas FIGS. 43 and 44 show such deformities 76^{II} and 77^{II} arranged in staggered rows that overlap each other along the length of a panel surface area 52^{XV}, 52^{XVI}.

Also, the size, including the width, length and depth or height as well as the angular orientation and position of the optical deformities may vary along the length and/or width of any given panel surface area to obtain a desired light output distribution from the panel surface area. FIGS. 45 and 46 show a random or variable pattern of different size deformities 58^{II}, 58^{III} similar in shape to those shown in FIGS. 31 and 32, respectively, arranged in staggered rows on a panel surface area 52^{XVII}, 52^{XVIII}, whereas FIG. 47 shows deformities 77^{III} similar in shape to those shown in FIG. 38 increasing in size as the distance of the deformities from the light source increases or intensity of the light decreases along the length and/or width of the panel surface area 52^{XIX}. The deformities

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are shown in FIGS. 45 and 46 arranged in clusters 82, 82' across the panel surface, with at least some of the deformities in each cluster having a different size or shape characteristic that collectively produce an average size or shape characteristic for each of the clusters that varies across the panel surface. For example, at least some of the deformities in each of the clusters may have a different depth or height or different slope or orientation that collectively produce an average depth or height characteristic or average slope or orientation of the sloping surface that varies across the panel surface. Likewise at least some of the deformities in each of the clusters may have a different width or length that collectively produce an average width or length characteristic that varies across the panel surface. This allows one to obtain a desired size or shape characteristic beyond machinery tolerances, and also defeats moiré and interference effects.

FIGS. 48 and 49 schematically show different angular orientations of optical deformities 85, 85' of any desired shape along the length and width of a panel surface area 52^{XX}, 52^{XXI} of a light emitting panel assembly backlight. In FIG. 48 the deformities are arranged in straight rows 86 along the length of the panel surface area but the deformities in each of the rows are oriented to face the light source 26 so that all of the deformities are substantially in line with the light rays being emitted from the light source. In FIG. 49 the deformities 85' are also oriented to face the light source 26 similar to FIG. 48. In addition, the rows 87 of deformities in FIG. 49 are in substantial radial alignment with the light source 26.

FIGS. 50 and 51 schematically show how exemplary light rays 90, 90' emitted from a focused light source 26 insert molded or cast within a light transition area 91, 91' of a light emitting panel assembly backlight BL^{III}, BL^{IV} in accordance with this invention are reflected during their travel through the light emitting panel member 92, 92' until they impinge upon individual light extracting deformities 50^{III}, 77^{IV} of well defined shapes on or in a panel surface area 52^{XXXII}, 52^{XXXIII} causing more of the light rays to be reflected or refracted out of one side 93, 93' of the panel member than the other side 94, 94'. In FIG. 50 the exemplary light rays 90 are shown being reflected by the reflective/refractive surfaces 54^{III} of the deformities 50^{III} in the same general direction out through the same side 93 of the panel member, whereas in FIG. 51 the light rays 90' are shown being scattered in different directions within the panel member 92' by the rounded side walls 62' of the deformities 77^{IV} before the light rays are reflected/refracted out of the same side 93' of the panel member. Such a pattern of individual light extracting deformities of well defined shapes in accordance with the present invention can cause 60 to 70% or more of the light received through the input edge 95' of the panel member to be emitted from the same side of the panel member.

From the foregoing, it will be apparent that the light redirecting films of the present invention redistribute more of the light emitted by a backlight or other light source toward a direction more normal to the plane of the films. Also, the light redirecting films and backlights of the present invention may be tailored or tuned to each other to provide a system in which the individual optical elements of the light redirecting films work in conjunction with the optical deformities of the backlights to produce an optimized output light ray angle distribution from the system.

Although the invention has been shown and described with respect to certain embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. In particular, with regard to the various functions performed by the above described components, the terms (in-

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cluding any reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed component which performs the function in the herein illustrated exemplary embodiments of the invention. In addition, while a particular feature of the invention may have been disclosed with respect to only one embodiment, such feature may be combined with one or more other features of other embodiments as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A light redirecting film system comprising a backlight including at least one input edge for receiving light from a light source, and at least one light output surface for emitting light, the backlight having deformities that cause most of the light entering the input edge to be emitted from the light output surface at relatively low angles, and a light redirecting film in close proximity to the light output surface for receiving light emitted from the light output surface, the light redirecting film having a pattern of individual optical elements of well-defined shape that vary at different locations on the film to redistribute the light emitted from the light output surface toward a direction normal to the film.

2. The system of claim 1 wherein the deformities of the backlight cause most of the light to be emitted from the light output surface at angles substantially greater than ninety degrees away from the input edge.

3. The system of claim 1 wherein the size or shape of the optical elements are tailored to redistribute more of the light emitted from the light output surface of the backlight within a desired viewing angle.

4. The system of claim 1 wherein at least some of the optical elements are oriented at different angles.

5. The system of claim 1 wherein at least some of the optical elements have different slope angles.

6. The system of claim 1 wherein at least some of the optical elements are oriented at different angles across the film to redistribute the light along two different axes.

7. The system of claim 1 wherein the size of at least some of the optical elements varies across the film.

8. The system of claim 1 wherein the density of the optical elements varies across the film.

9. The system of claim 1 wherein the optical elements comprise depressions in or projections on the film.

10. The system of claim 1 further comprising a liquid crystal display in close proximity to the film, wherein the variations in the pattern of optical elements on the film cause a change in angle of a light ray output distribution from the light output surface to make the light ray output distribution more acceptable to travel through the liquid crystal display.

11. The system of claim 1 wherein the optical elements on the film are randomized in size, shape, position, depth, orientation, angle or density.

12. The system of claim 1 wherein at least some of the optical elements include a combination of planar and curved surfaces.

13. The system of claim 12 wherein the ratio of the areas of the planar and curved surfaces is selected to produce a desired viewing angle.

14. The system of claim 1 wherein at least some of the optical elements overlap each other.

15. The system of claim 14 wherein at least some of the optical elements intersect each other.

16. The system of claim 14 wherein at least some of the optical elements interlock each other.

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17. The system of claim 14 wherein at least some of the optical elements are staggered with respect to each other.

18. The system of claim 1 wherein the deformities of the backlight partially collimate light along one axis, and the optical elements of the film partially collimate the light emitted by the backlight along another axis perpendicular to the one axis.

19. The system of claim 18 wherein at least some of the optical elements are quite small in relation to the width and length of the film and differ in size or shape to redistribute more of the light emitted by the backlight.

20. The system of claim 18 wherein at least some of the optical elements are oriented at different angles relative to each other to redistribute more of the light emitted by the backlight within a desired viewing angle.

21. The system of claim 18 wherein at least some of the optical elements are randomly distributed across the film.

22. A light redirecting film system comprising a backlight including at least one input edge for receiving light from a light source, and at least one light output surface for emitting

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light, the backlight having individual optical deformities of well-defined shape for causing 60 to 70% or more of the light received through the input edge to be reflected or refracted out of the light output surface, and a light redirecting film in close proximity to the light output surface for receiving light emitted from the light output surface, the light redirecting film having a pattern of individual optical elements of well-defined shape to redistribute the light emitted by the backlight toward a direction normal to the film.

23. The system of claim 22 wherein at least some of the deformities have rounded side walls for scattering the light in different directions within the backlight before the light is reflected or refracted out of the one output surface of the backlight.

24. The system of claim 22 wherein a plurality of focused light sources are positioned in laterally spaced relation along the input edge.

25. The system of claim 24 wherein the focused light sources are LEDs.

* * * * *

EXHIBIT G



US008215816B2

(12) **United States Patent**
Parker

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(45) **Date of Patent:** ***Jul. 10, 2012**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
F21V 7/04 (2006.01)

(52) **U.S. Cl.** **362/609; 362/606; 362/608; 362/619**

(58) **Field of Classification Search** **362/603, 362/606, 608, 612, 618, 619, 621, 623, 632-634, 362/609, 613**

See application file for complete search history.

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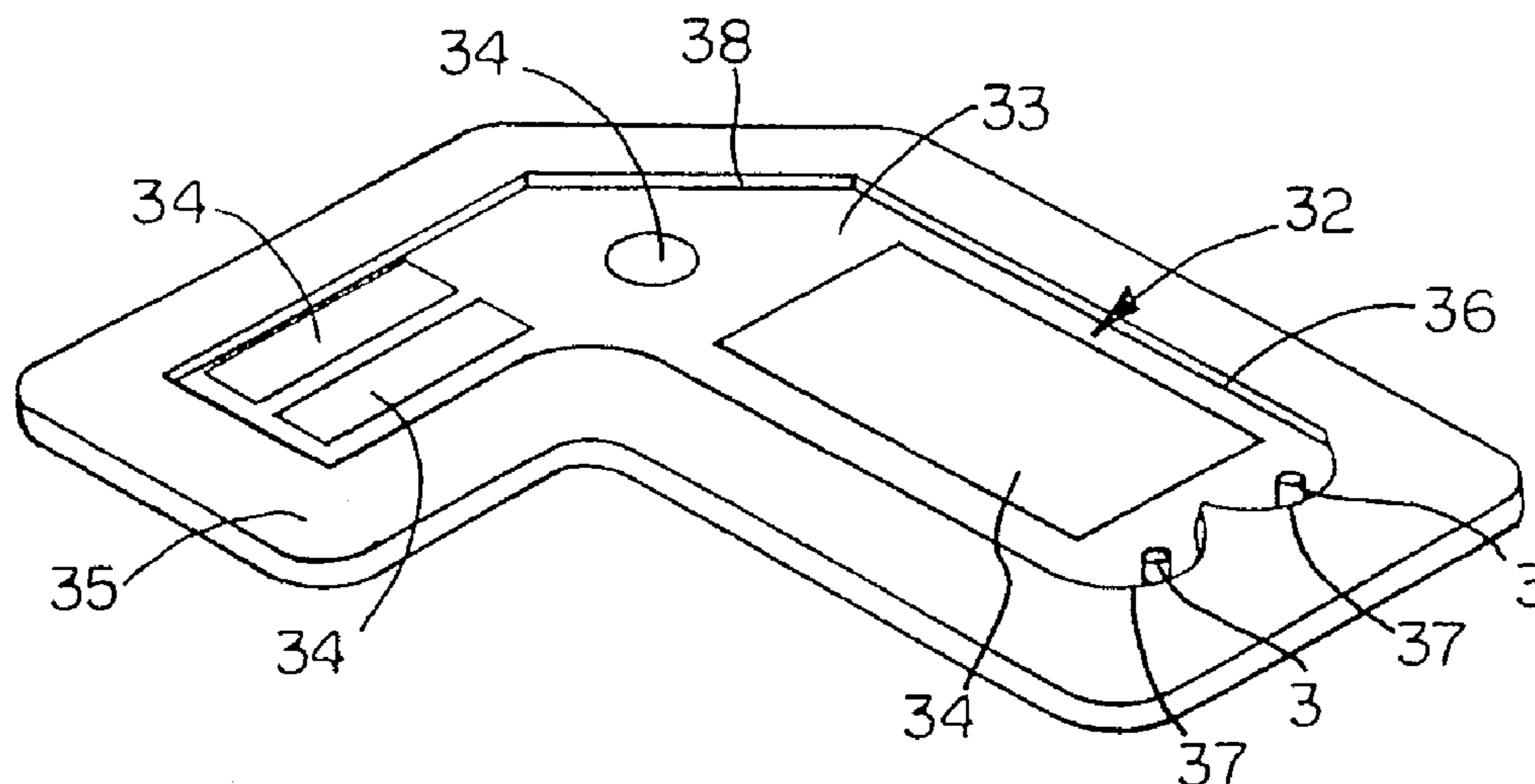
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(57) **ABSTRACT**

A light emitting assembly comprises a light source, a light emitting panel member having an input edge that receives light from the light source, and end edge and side edge reflectors. The panel member is received in a cavity or recess of a tray or housing. An additional component overlies the panel member. Light extracting deformities on or in a surface of the panel member cause light to be emitted from the panel member.

4 Claims, 4 Drawing Sheets



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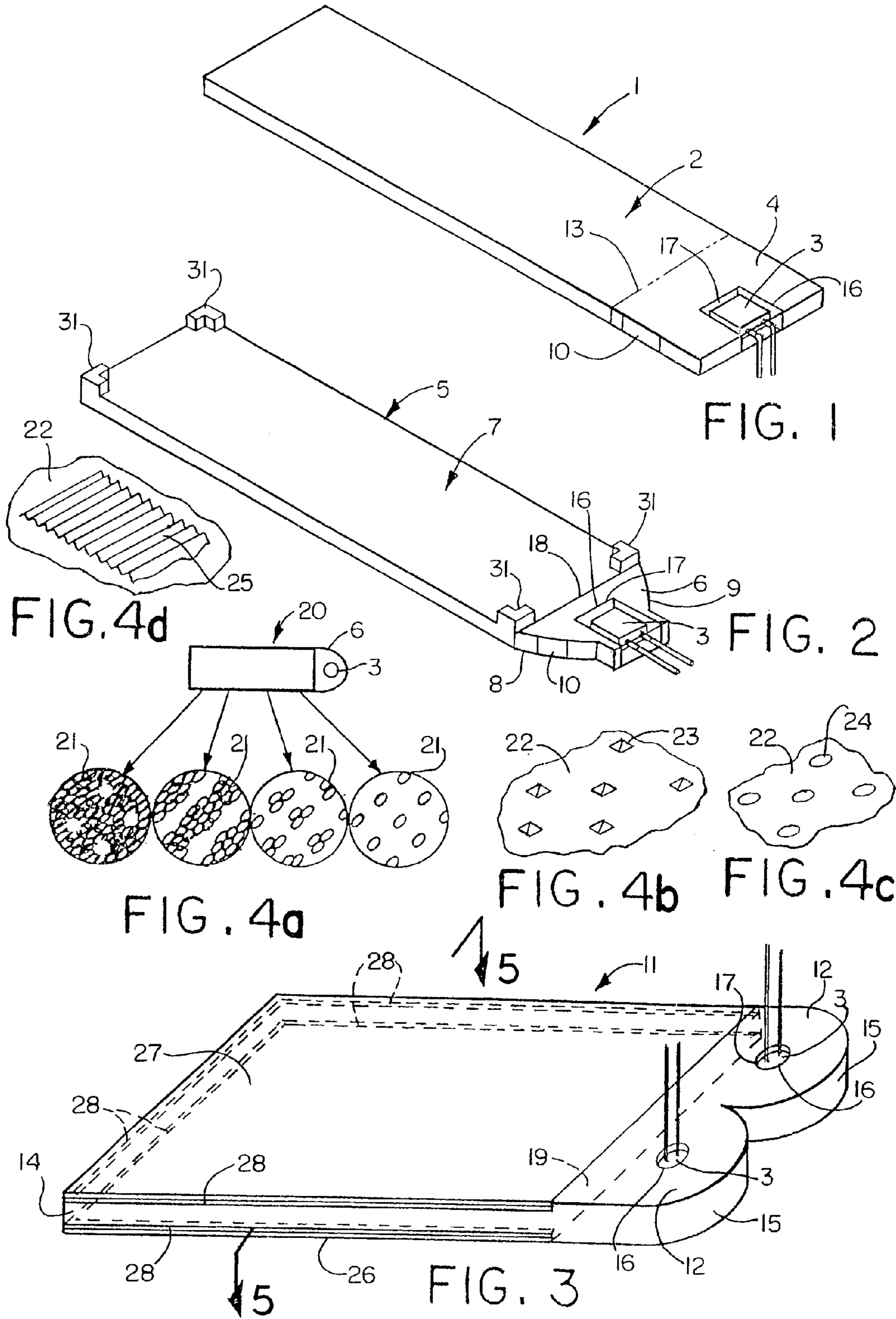
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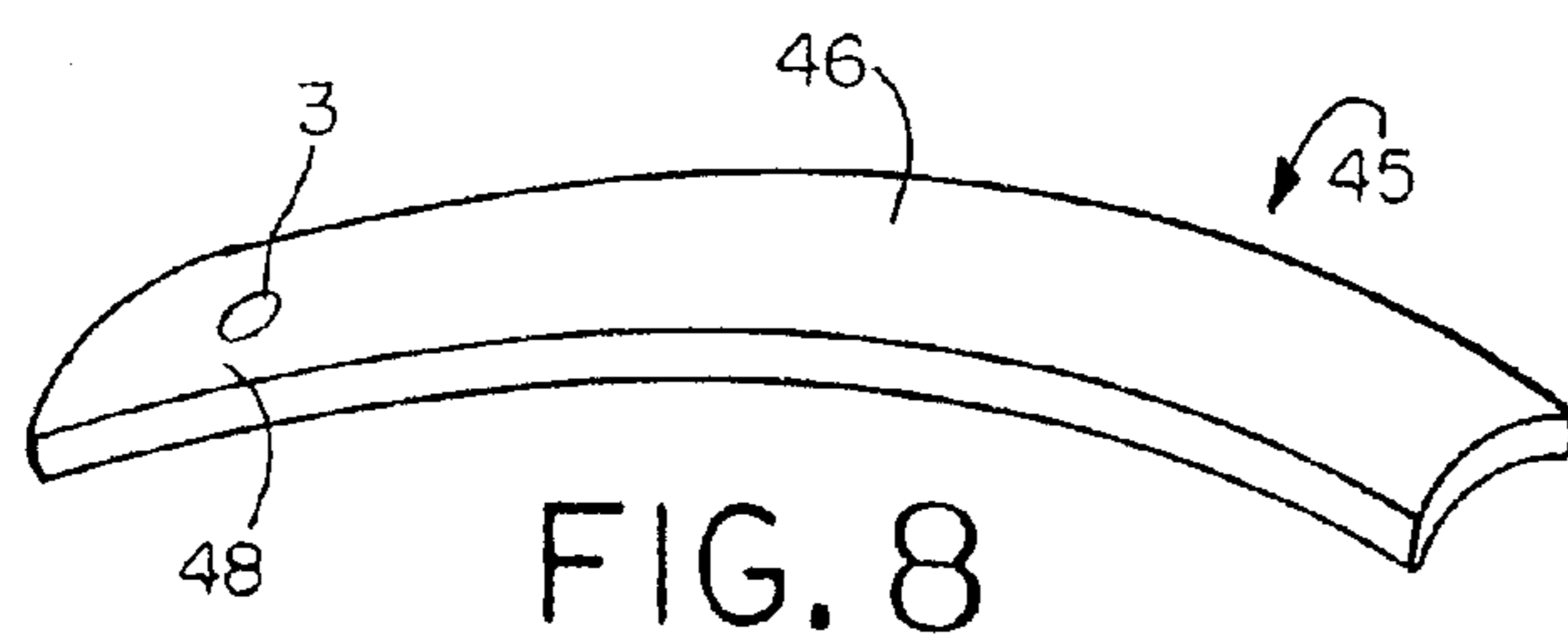
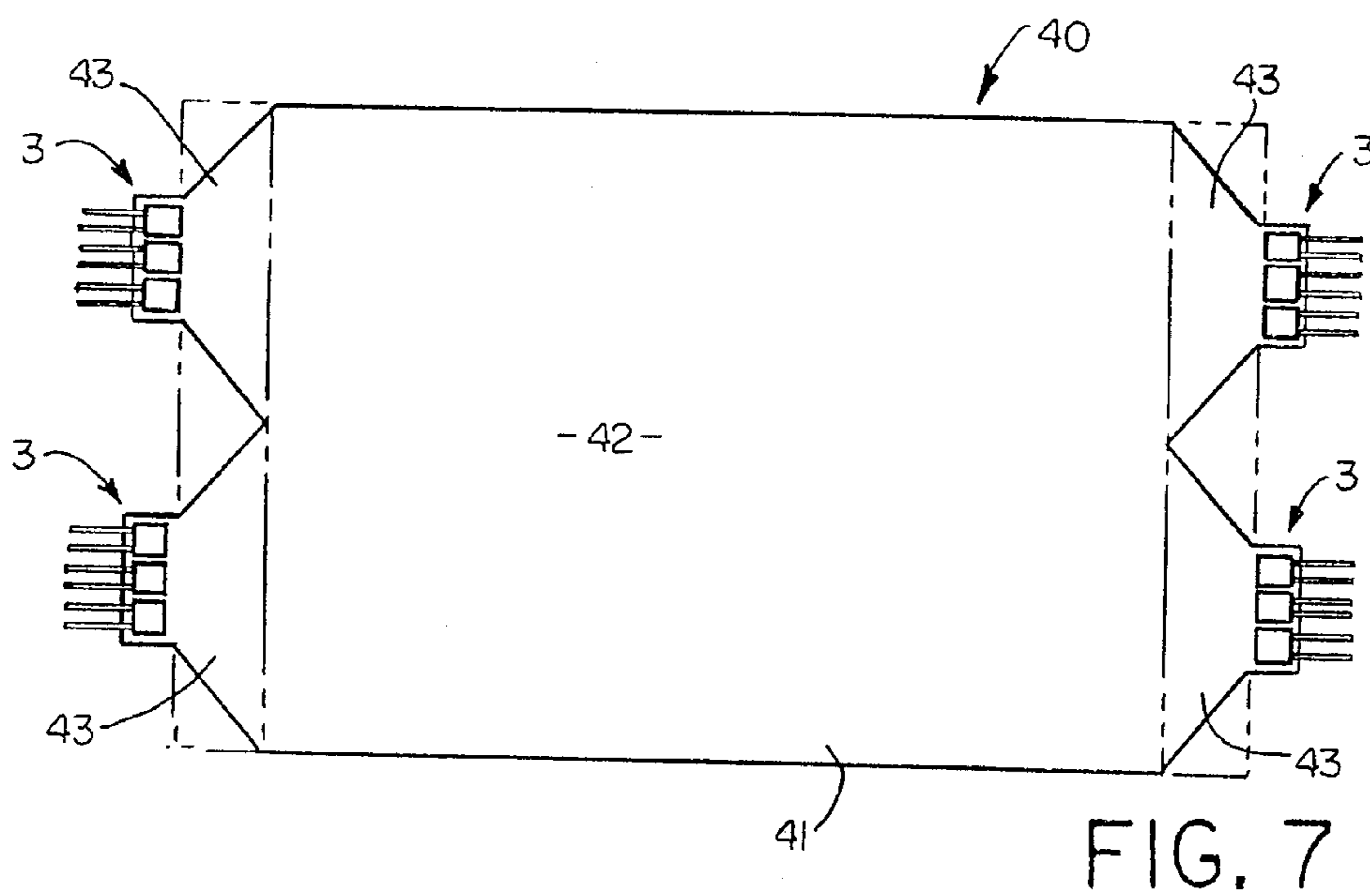
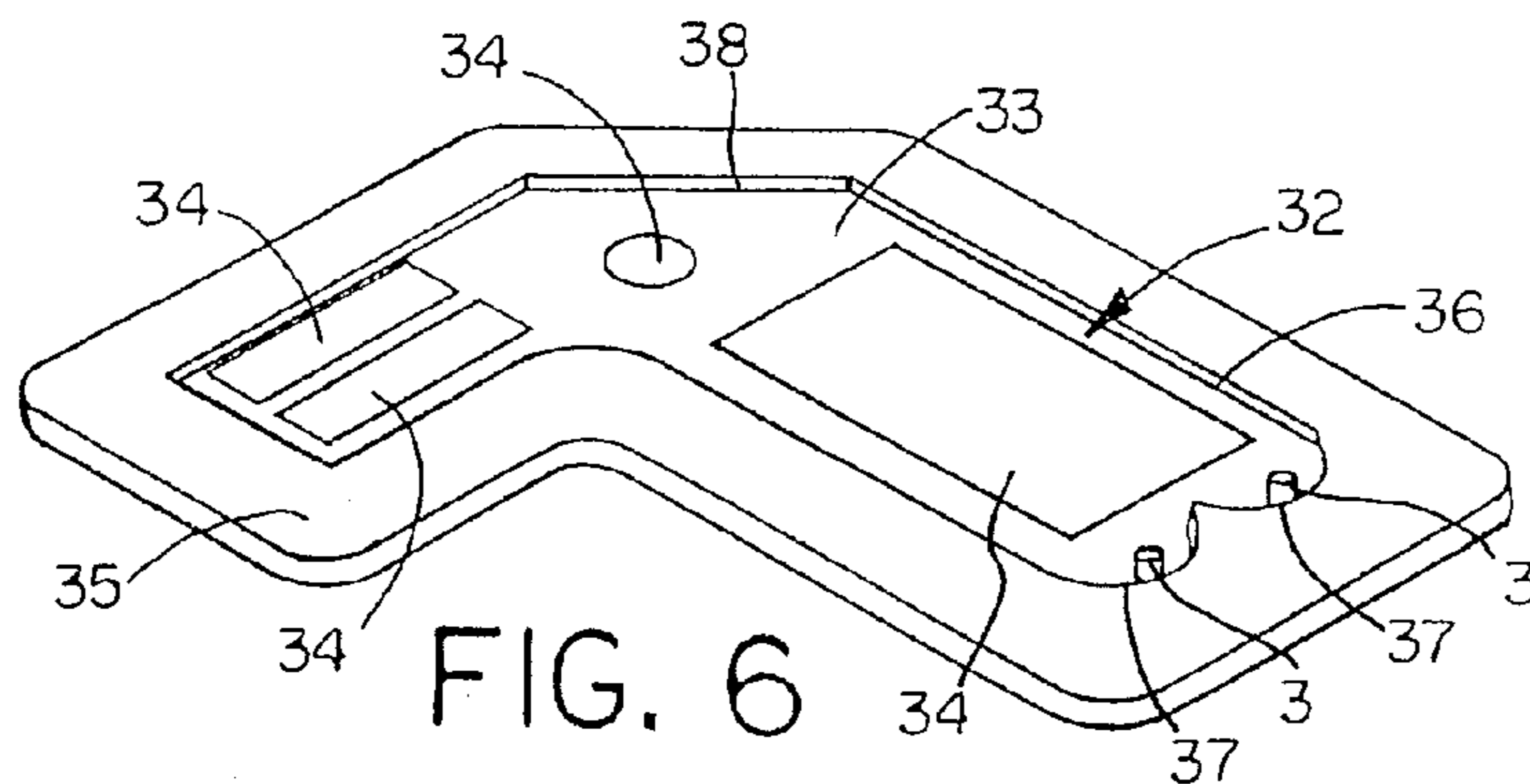
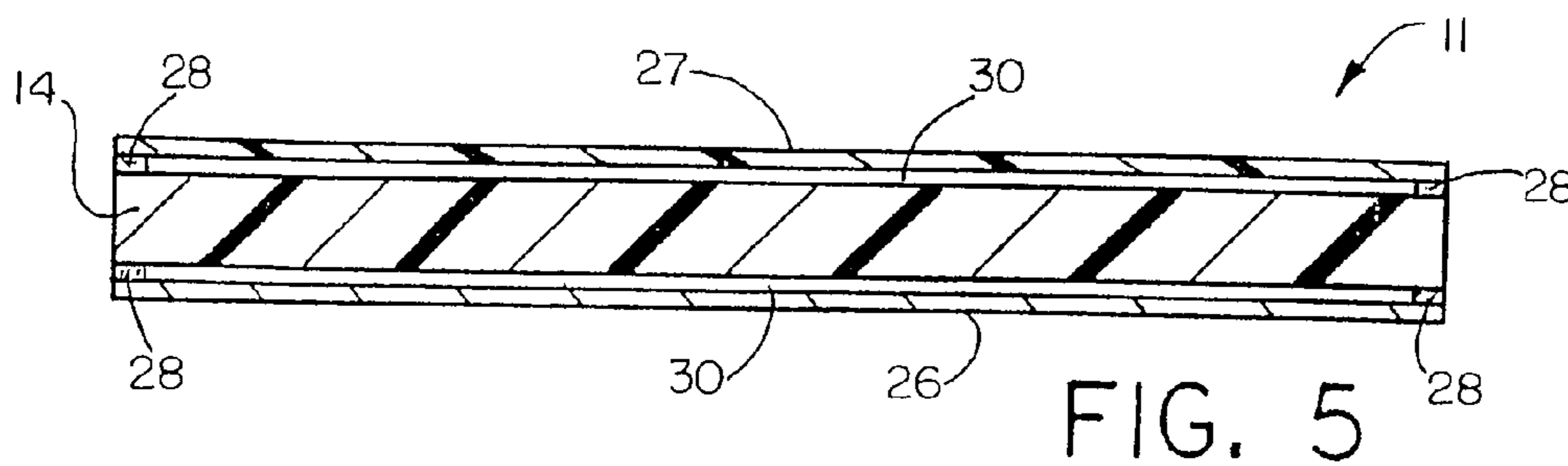
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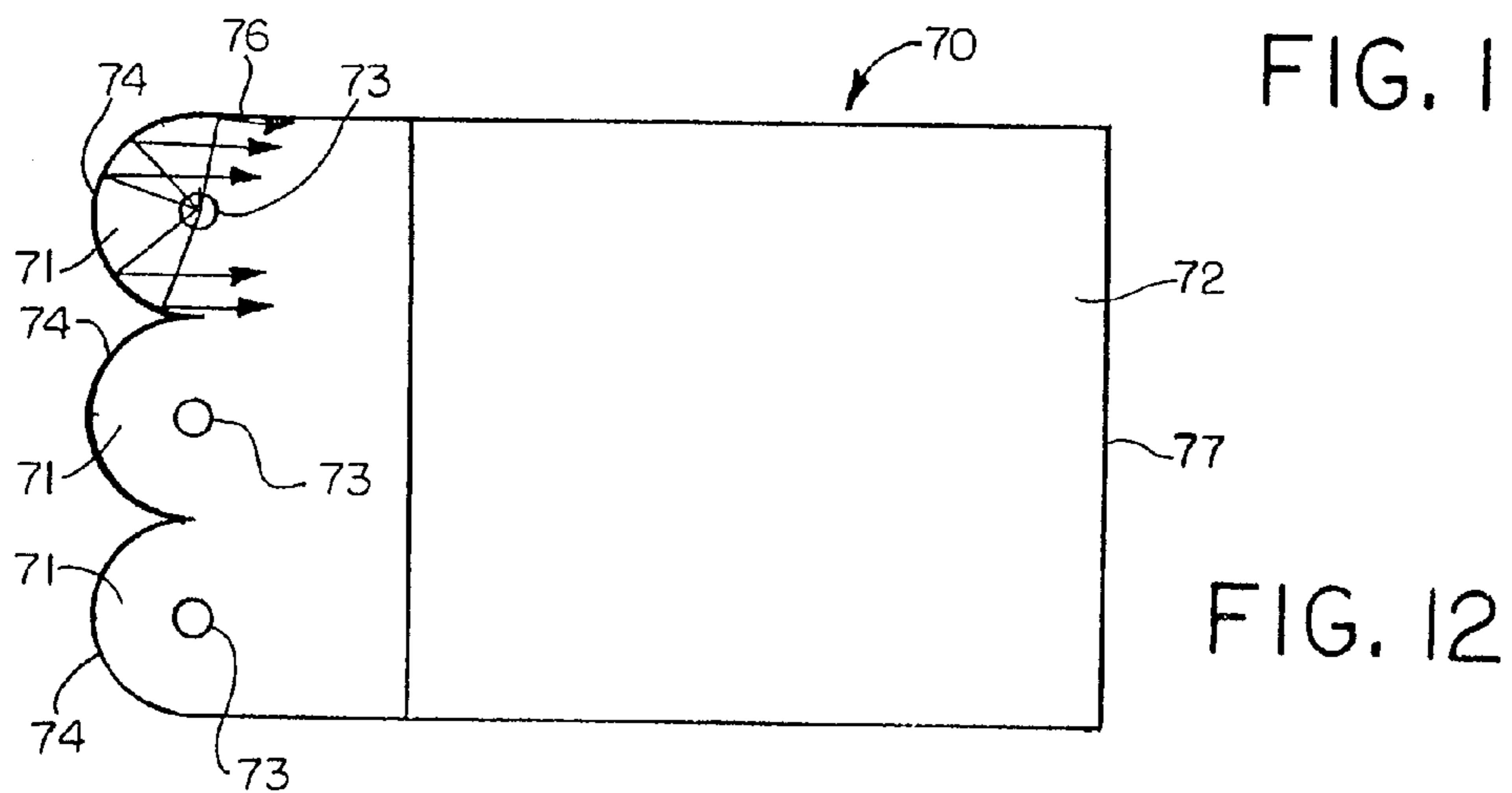
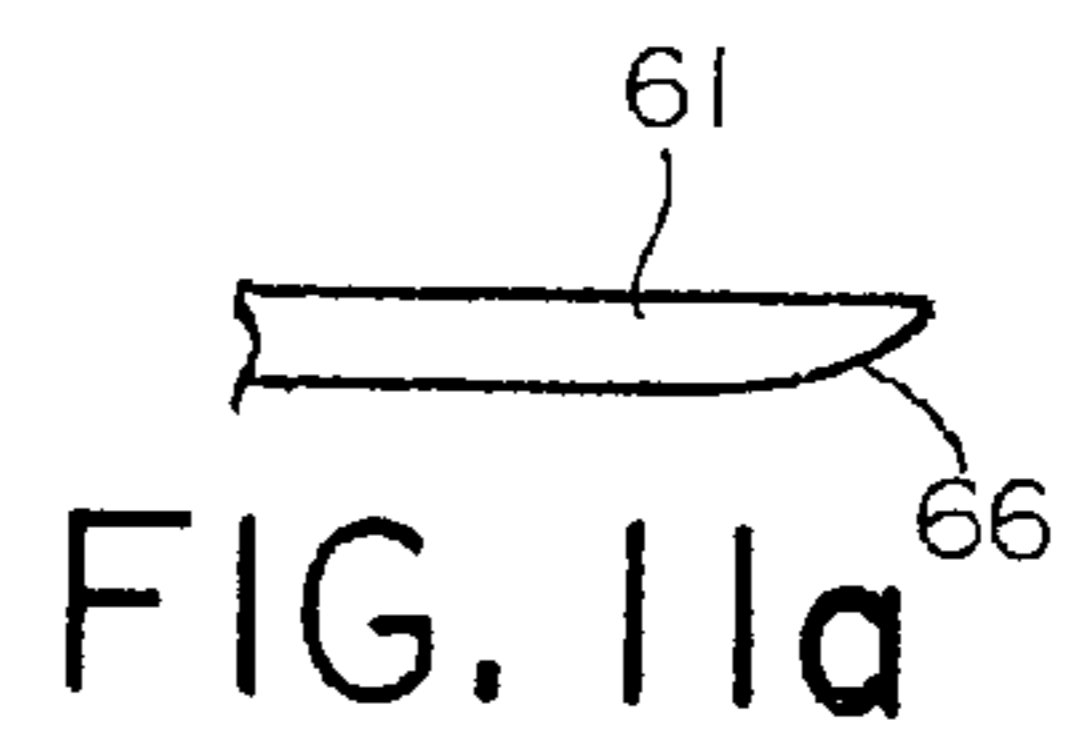
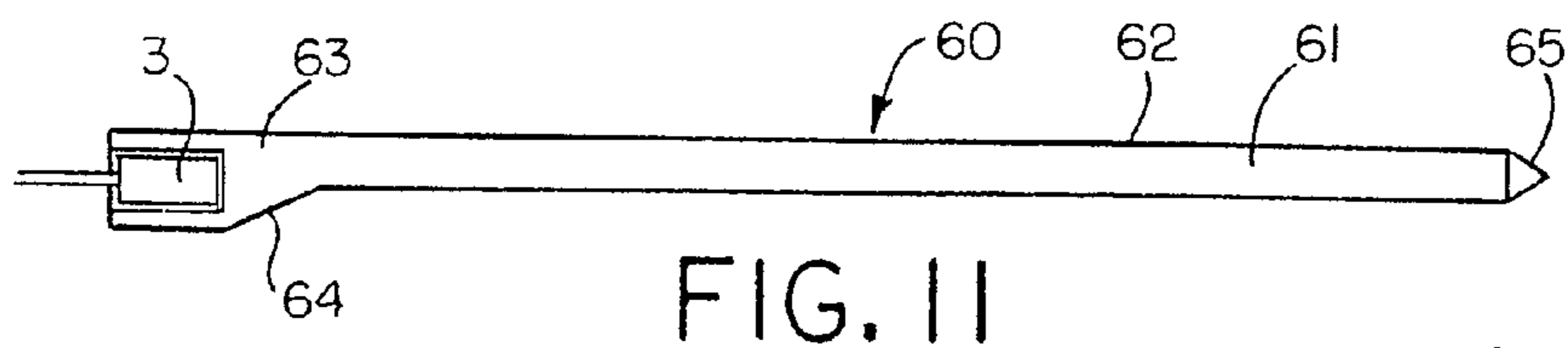
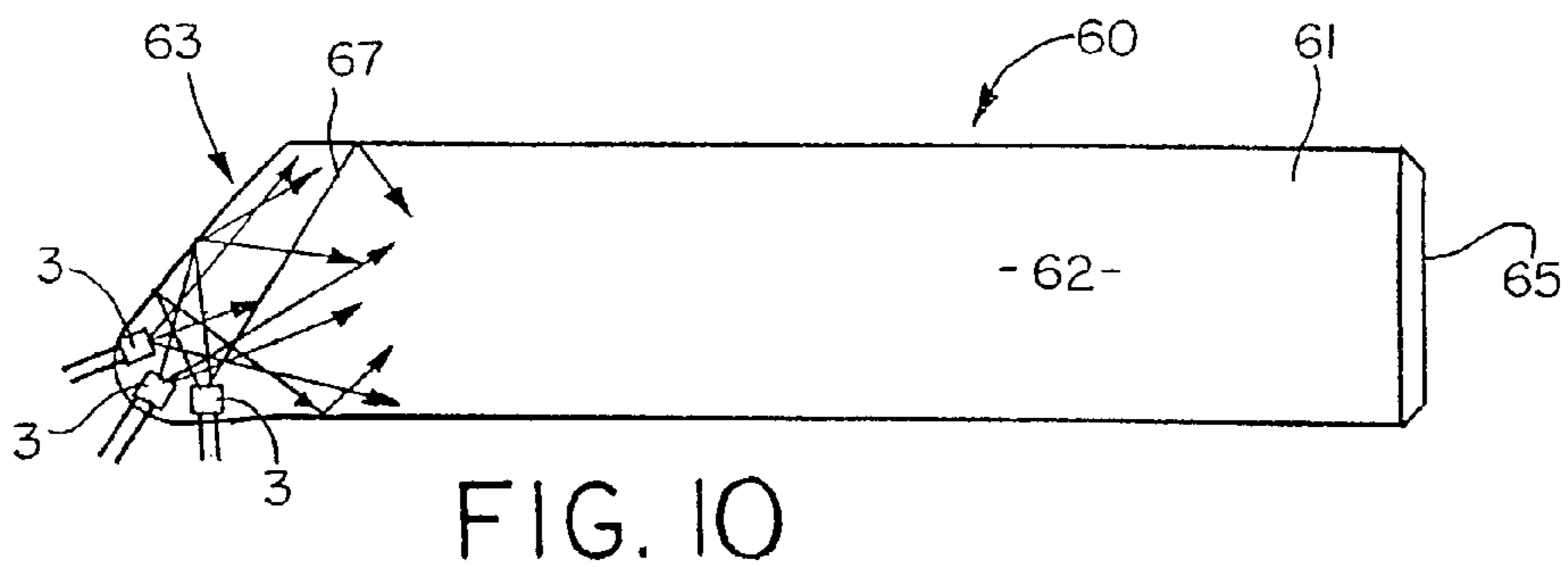
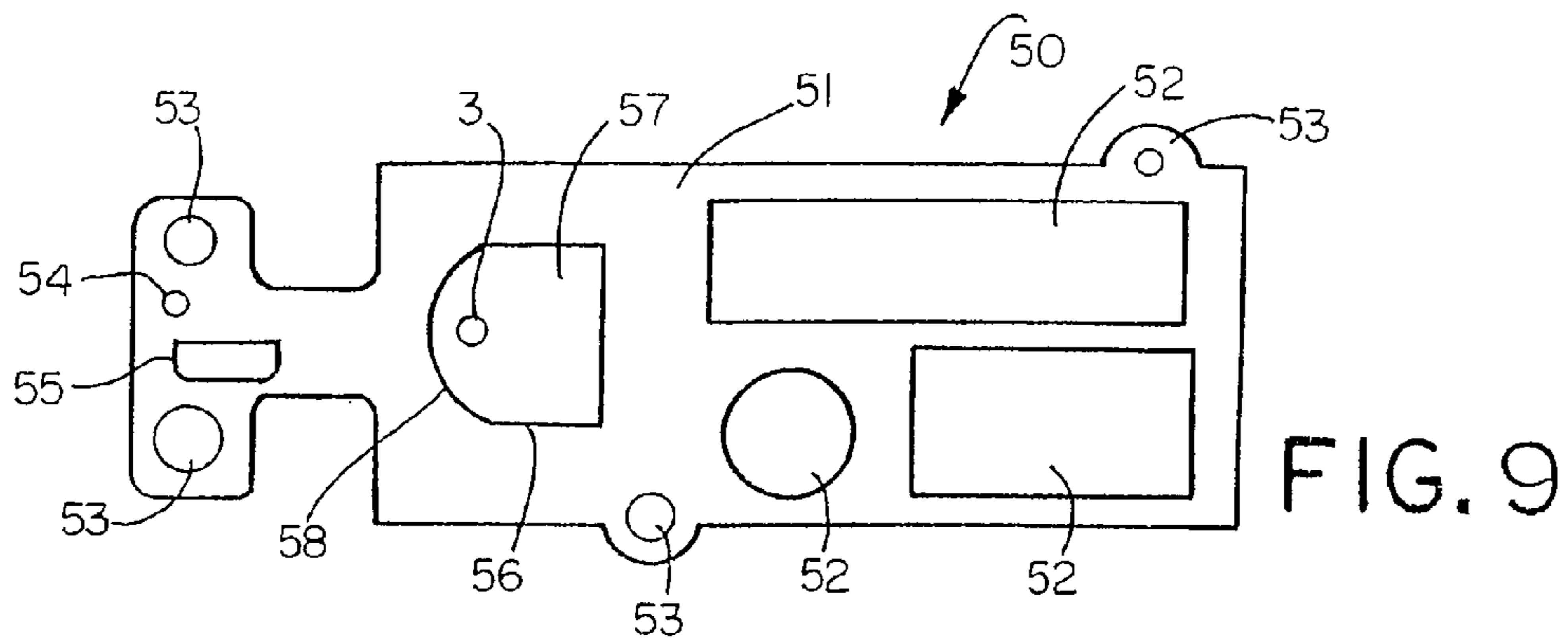
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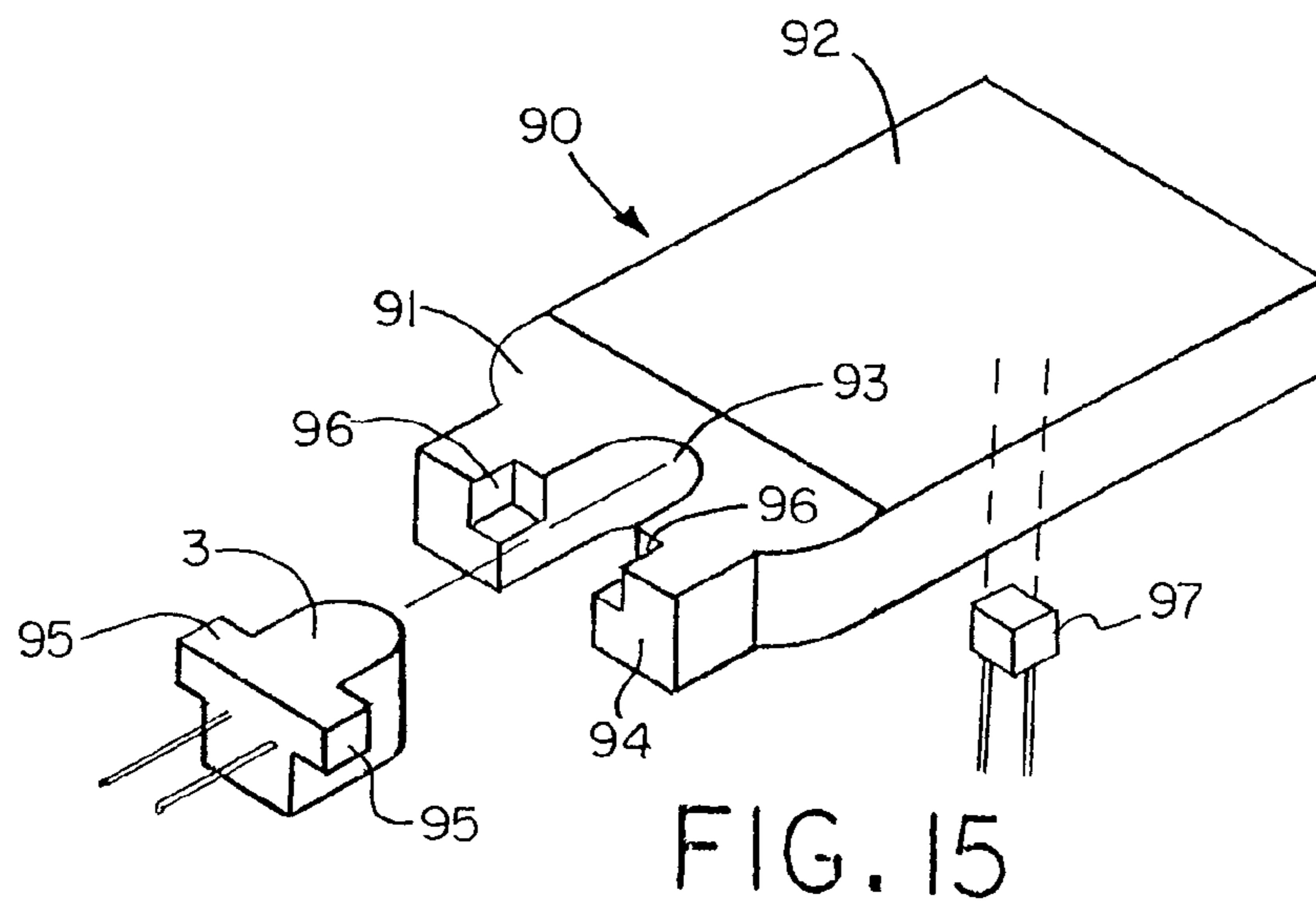
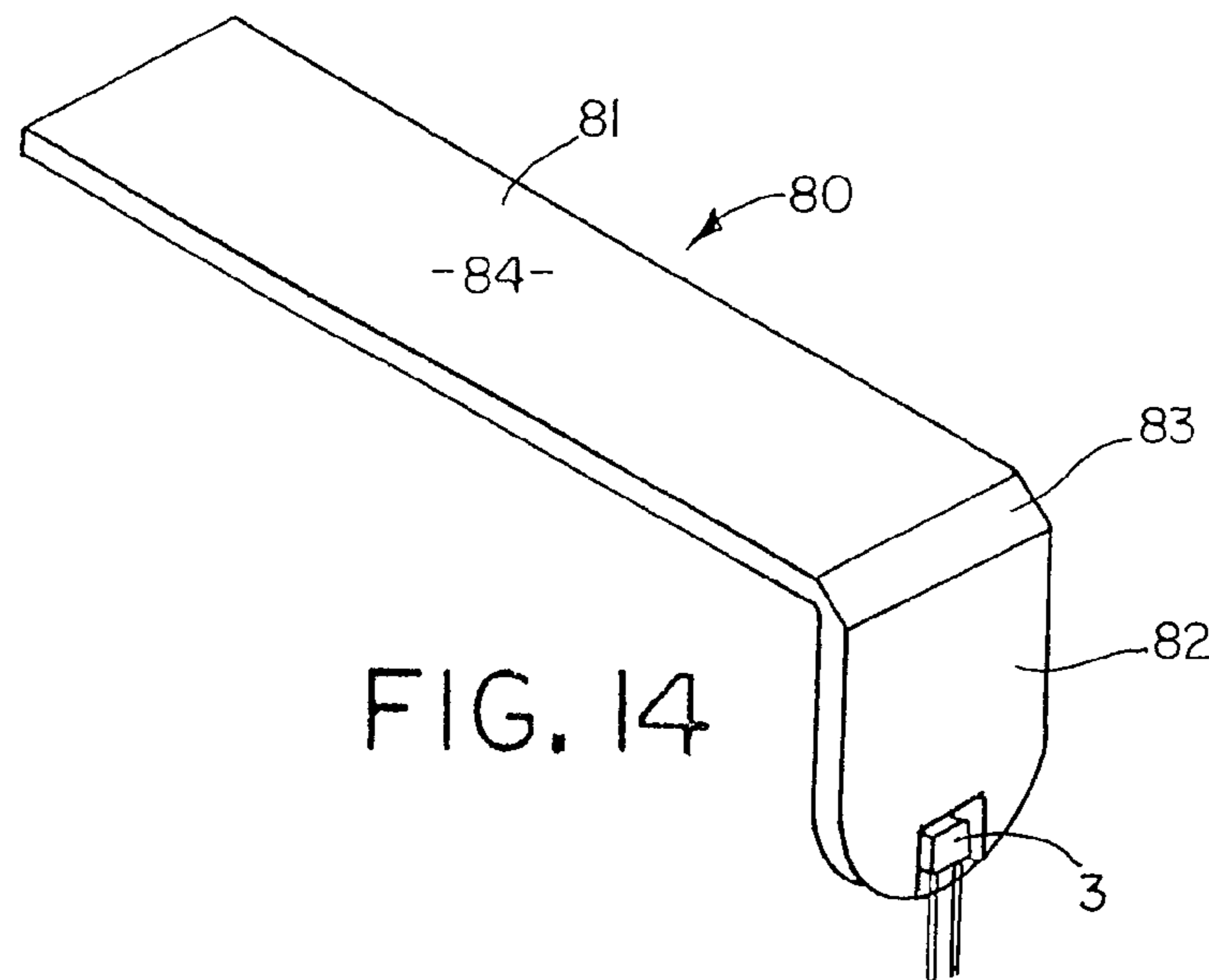
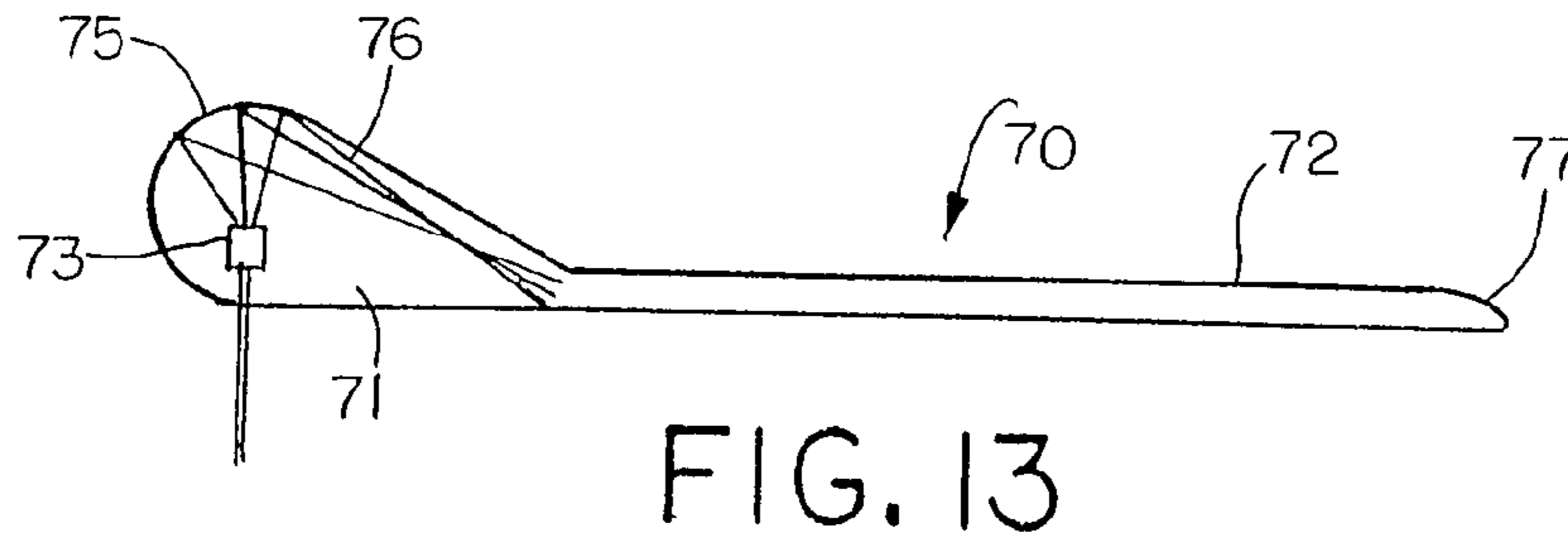
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LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED
APPLICATIONS

This application is a continuation of U.S. patent applica-
tion Ser. No. 12/940,424, filed Nov. 5, 2010, which is a
continuation of U.S. patent application Ser. No. 12/488,617,
filed Jun. 22, 2009, now abandoned, which is a continuation
of U.S. patent application Ser. No. 12/246,613, filed Oct. 7,
2008, now abandoned, which is a division of U.S. patent
application Ser. No. 11/504,203, filed Aug. 15, 2006, now
U.S. Pat. No. 7,467,887, dated Dec. 23, 2008, which is a
continuation of U.S. patent application Ser. No. 10/784,527,
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2007, which is a division of U.S. patent application Ser. No.
09/256,275, filed Feb. 23, 1999, now U.S. Pat. No. 6,712,481,
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patent application Ser. No. 08/778,089, filed Jan. 2, 1997,
now U.S. Pat. No. 6,079,838, dated Jun. 27, 2000, which is a
division of U.S. patent application Ser. No. 08/495,176, filed
Jun. 27, 1995, now U.S. Pat. No. 5,613,751, dated Mar. 25,
1997.

BACKGROUND OF THE INVENTION

This invention relates generally, as indicated, to light emit-
ting panel assemblies each including a transparent panel
member for efficiently conducting light, and controlling the
light conducted by the panel member to be emitted from one
or more light output areas along the length thereof.

Light emitting panel assemblies are generally known.
However, the present invention relates to several different
light emitting panel assembly configurations which provide
for better control of the light output from the panel assemblies
and for more efficient utilization of light, which results in
greater light output from the panel assemblies.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, the light
emitting panel assemblies include a light emitting panel
member having a light transition area in which at least one
light source is suitably mounted for transmission of light to
the light input surface of the panel member.

In accordance with another aspect of the invention, the
light source is desirably embedded, potted or bonded to the
light transition area to eliminate any air gaps, decrease surface
reflections and/or eliminate any lens effect between the light
source and light transition area, thereby reducing light loss
and increasing the light output from the panel assembly.

In accordance with another aspect of the invention, the
panel assemblies may include reflective or refractive surfaces
for changing the path of a portion of the light, emitted from
the light source, that would not normally enter the panel
members at an acceptable angle that allows the light to remain
in the panel members for a longer period of time and/or
increase the efficiency of the panel members.

In accordance with another aspect of the invention, the
light emitting panel members include a pattern of light
extracting deformities or disruptions which provide a desired
light output distribution from the panel members by changing
the angle of refraction of a portion of the light from one or
more light output areas of the panel members.

In accordance with still another aspect of the invention, the
light source may include multiple colored light sources for

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supplying light to one or more light output areas, and for
providing a colored or white light output distribution.

In accordance with yet another aspect of the invention, the
panel assemblies include a transition area for mixing the
multiple colored lights, prior to the light entering the panel
members, in order to effect a desired colored or white light
output distribution.

The various light emitting panel assemblies of the present
invention are very efficient panel assemblies that may be used
to produce increased uniformity and higher light output from
the panel members with lower power requirements, and allow
the panel members to be made thinner and/or longer, and/or of
various shapes and sizes.

To the accomplishment of the foregoing and related ends,
the invention then comprises the features hereinafter fully
described and particularly pointed out in the claims, the fol-
lowing description and the annexed drawings setting forth in
detail certain illustrative embodiments of the invention, these
being indicative, however, of but several of the various ways
in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIGS. 1 through 3 are schematic perspective views of three
different forms of light emitting panel assemblies in accor-
dance with this invention;

FIG. 4a is an enlarged plan view of a portion of a light
output area of a panel assembly showing one form of pattern
of light extracting deformities on the light output area;

FIGS. 4b, c and d are enlarged schematic perspective views
of a portion of a light output area of a panel assembly showing
other forms of light extracting deformities formed in or on the
light output area;

FIG. 5 is an enlarged transverse section through the light
emitting panel assembly of FIG. 3 taken generally on the
plane of the line 5-5 thereof;

FIG. 6 is a schematic perspective view of another form of
light emitting panel assembly in accordance with this inven-
tion;

FIG. 7 is a schematic top plan view of another form of light
emitting panel assembly in accordance with this invention;

FIG. 8 is a schematic perspective view of another form of
light emitting panel assembly in accordance with this inven-
tion;

FIG. 9 is a schematic top plan view of another form of light
emitting panel assembly in accordance with this invention;

FIG. 10 is a schematic top plan view of still another form of
light emitting panel assembly in accordance with this inven-
tion;

FIG. 11 is a side elevation view of the light emitting panel
assembly of FIG. 10;

FIG. 11a is a fragmentary side elevation view showing a
tapered or rounded end on the panel member in place of the
prismatic surface shown in FIGS. 10 and 11;

FIG. 12 is a schematic top plan view of another form of
light emitting panel assembly in accordance with this inven-
tion;

FIG. 13 is a schematic side elevation view of the light
emitting panel assembly of FIG. 12; and

FIGS. 14 and 15 are schematic perspective views of still
other forms of light emitting panel assemblies in accordance
with this invention.

DETAILED DESCRIPTION OF THE PREFERRED
EMBODIMENTS

Referring now in detail to the drawings, and initially to
FIG. 1, there is schematically shown one form of light emit-

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ting panel assembly **1** in accordance with this invention including a transparent light emitting panel **2** and one or more light sources **3** which emit light in a predetermined pattern in a light transition member or area **4** used to make the transition from the light source **3** to the light emitting panel **2**, as well known in the art. The light that is transmitted by the light transition area **4** to the transparent light emitting panel **2** may be emitted along the entire length of the panel or from one or more light output areas along the length of the panel as desired to produce a desired light output distribution to fit a particular application.

In FIG. **1** the light transition area **4** is shown as an integral extension of one end of the light emitting panel **2** and as being generally rectangular in shape. However, the light transition area may be of other shapes suitable for embedding, potting, bonding or otherwise mounting the light source. Also, reflective or refractive surfaces may be provided to increase efficiency. Moreover, the light transition area **4** may be a separate piece suitably attached to the light input surface **13** of the panel member if desired. Also, the sides of the light transition area may be curved to more efficiently reflect or refract a portion of the light emitted from the light source through the light emitting panel at an acceptable angle.

FIG. **2** shows another form of light emitting panel assembly **5** in accordance with this invention including a panel light transition area **6** at one end of the light emitting panel **7** with sides **8, 9** around and behind the light source **3** shaped to more efficiently reflect and/or refract and focus the light emitted from the light source **3** that impinges on these surfaces back through the light transition area **6** at an acceptable angle for entering the light input surface **18** at one end of the light emitting panel **7**. Also, a suitable reflective material or coating **10** may be provided on the portions of the sides of the light transition areas of the panel assemblies of FIGS. **1** and **2** on which a portion of the light impinges for maximizing the amount of light or otherwise changing the light that is reflected back through the light transition areas and into the light emitting panels.

The panel assemblies shown in FIGS. **1** and **2** include a single light source **3**, whereas FIG. **3** shows another light emitting panel assembly **11** in accordance with this invention including two light sources **3**. Of course, it will be appreciated that the panel assemblies of the present invention may be provided with any number of light sources as desired, depending on the particular application.

The panel assembly **11** of FIG. **3** includes a light transition area **12** at one end of the light emitting panel **14** having reflective and/or refractive surfaces **15** around and behind each light source **3**. These surfaces **15** may be appropriately shaped including for example curved, straight and/or faceted surfaces, and if desired, suitable reflective materials or coatings may be provided on portions of these surfaces to more efficiently reflect and/or refract and focus a portion of the light emitted for example from an incandescent light source which emits light in a 360° pattern through the light transition areas **12** into the light input surface **19** of the light emitting panel **14**.

The light sources **3** may be mechanically held in any suitable manner in slots, cavities or openings **16** machined, molded or otherwise formed in the light transition areas of the panel assemblies. However, preferably the light sources **3** are embedded, potted or bonded in the light transition areas in order to eliminate any air gaps or air interface surfaces between the light sources and surrounding light transition areas, thereby reducing light loss and increasing the light output emitted by the light emitting panels. Such mounting of the light sources may be accomplished, for example, by bond-

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ing the light sources **3** in the slots, cavities or openings **16** in the light transition areas using a sufficient quantity of a suitable embedding, potting or bonding material **17**. The slots, cavities or openings **16** may be on the top, bottom, sides or back of the light transition areas. Bonding can also be accomplished by a variety of methods that do not incorporate extra material, for example, thermal bonding, heat staking, ultrasonic or plastic welding or the like. Other methods of bonding include insert molding and casting around the light source(s).

A transparent light emitting material of any suitable type, for example acrylic or polycarbonate, may be used for the light emitting panels. Also, the panels may be substantially flat, or curved, may be a single layer or multi-layers, and may have different thicknesses and shapes. Moreover, the panels may be flexible, or rigid, and may be made out of a variety of compounds. Further, the panels may be hollow, filled with liquid, air, or be solid, and may have holes or ridges in the panels.

Each light source **3** may also be of any suitable type including, for example, any of the types disclosed in U.S. Pat. Nos. 4,897,771 and 5,005,108, assigned to the same assignee as the present application, the entire disclosures of which are incorporated herein by reference. In particular, the light sources **3** may be an arc lamp, an incandescent bulb which also may be colored, filtered or painted, a lens end bulb, a line light, a halogen lamp, a light emitting diode (LED), a chip from an LED, a neon bulb, a fluorescent tube, a fiber optic light pipe transmitting from a remote source, a laser or laser diode, or any other suitable light source. Additionally, the light sources **3** may be a multiple colored LED, or a combination of multiple colored radiation sources in order to provide a desired colored or white light output distribution. For example, a plurality of colored lights such as LEDs of different colors (red, blue, green) or a single LED with multiple colored chips may be employed to create white light or any other colored light output distribution by varying the intensities of each individual colored light.

A pattern of light extracting deformities or disruptions may be provided on one or both sides of the panel members or on one or more selected areas on one or both sides of the panel members, as desired. FIG. **4a** schematically shows one such light surface area **20** on which a pattern of light extracting deformities or disruptions **21** is provided. As used herein, the term deformities or disruptions are used interchangeably to mean any change in the shape or geometry of the panel surface and/or coating or surface treatment that causes a portion of the light to be emitted. The pattern of light extracting deformities **21** shown in FIG. **4a** includes a variable pattern which breaks up the light rays such that the internal angle of reflection of a portion of the light rays will be great enough to cause the light rays either to be emitted out of the panel through the side or sides on which the light extracting deformities **21** are provided or reflected back through the panel and emitted out the other side.

These deformities or disruptions **21** can be produced in a variety of manners, for example, by providing a painted pattern, an etched pattern, a machined pattern, a printed pattern, a hot stamped pattern, or a molded pattern or the like on selected light output areas of the panel members. An ink or printed pattern may be applied for example by pad printing, silk screening, ink jet, heat transfer film process or the like. The deformities may also be printed on a sheet or film which is used to apply the deformities to the panel member. This sheet or film may become a permanent part of the light panel assembly for example by attaching or otherwise positioning

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the sheet or film against one or both sides of the panel member similar to the sheet or film 27 shown in FIGS. 3 and 5 in order to produce a desired effect.

By varying the density, opaqueness or translucence, shape, depth, color, area, index of refraction, or type of deformities 21 on an area or areas of the panels, the light output of the panels can be controlled. The deformities or disruptions may be used to control the percent of light emitted from any area of the panels. For example, less and/or smaller size deformities 21 may be placed on panel areas where less light output is wanted. Conversely, a greater percentage of and/or larger deformities may be placed on areas of the panels where greater light output is desired.

Varying the percentages and/or size of deformities in different areas of the panel is necessary in order to provide a uniform light output distribution. For example, the amount of light traveling through the panels will ordinarily be greater in areas closer to the light source than in other areas further removed from the light source. A pattern of light extracting deformities 21 may be used to adjust for the light variances within the panel members, for example, by providing a denser concentration of light extracting deformities with increased distance from the light source 3 thereby resulting in a more uniform light output distribution from the light emitting panels.

The deformities 21 may also be used to control the output ray angle distribution of the emitted light to suit a particular application. For example, if the panel assemblies are used to provide a liquid crystal display backlight, the light output will be more efficient if the deformities 21 cause the light rays to emit from the panels at predetermined ray angles such that they will pass through the liquid crystal display with low loss.

Additionally, the pattern of light extracting deformities may be used to adjust for light output variances attributed to light extractions of the panel members. The pattern of light extracting deformities 21 may be printed on the light output areas utilizing a wide spectrum of paints, inks, coatings, epoxies, or the like, ranging from glossy to opaque or both, and may employ half-tone separation techniques to vary the deformity 21 coverage. Moreover, the pattern of light extracting deformities 21 may be multiple layers or vary in index of refraction.

Print patterns of light extracting deformities 21 may vary in shapes such as dots, squares, diamonds, ellipses, stars, random shapes, and the like, and are desirably 0.006 square inch per deformity/element or less. Also, print patterns that are 60 lines per inch or finer are desirably employed, thus making the deformities or shapes 21 in the print patterns nearly invisible to the human eye in a particular application thereby eliminating the detection of gradient or banding lines that are common to light extracting patterns utilizing larger elements. Additionally, the deformities may vary in shape and/or size along the length and/or width of the panel members. Also, a random placement pattern of the deformities may be utilized throughout the length and/or width of the panel members. The deformities may have shapes or a pattern with no specific angles to reduce moiré or other interference effects. Examples of methods to create these random patterns are printing a pattern of shapes using stochastic print pattern techniques, frequency modulated half tone patterns, or random dot half tones. Moreover, the deformities may be colored in order to effect color correction in the panel members. The color of the deformities may also vary throughout the panel members, for example to provide different colors for the same or different light output areas.

In addition to or in lieu of the patterns of light extracting deformities 21 shown in FIG. 4a, other light extracting de-

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formities including prismatic surfaces, depressions or raised surfaces of various shapes using more complex shapes in a mold pattern may be molded, etched, stamped, thermoformed, hot stamped or the like into or on one or more areas of the panel member. FIGS. 4b and 4c show panel areas 22 on which prismatic surfaces 23 or depressions 24 are formed in the panel areas, whereas FIG. 4d shows prismatic or other reflective or refractive surfaces 25 formed on the exterior of the panel area. The prismatic surfaces, depressions or raised surfaces will cause a portion of the light rays contacted thereby to be emitted from the panel member. Also, the angles of the prisms, depressions or other surfaces may be varied to direct the light in different directions to produce a desired light output distribution or effect. Moreover, the reflective or refractive surfaces may have shapes or a pattern with no specific angles to reduce moiré or other interference effects.

As best seen in the cross sectional view of FIG. 5, a back reflector (including trans reflectors) 26 may be attached or positioned against one side of the panel member 14 of FIG. 3 using a suitable adhesive 28 or other method in order to improve light output efficiency of the panel assembly 11 by reflecting the light emitted from that side back through the panel for emission through the opposite side. Additionally, a pattern of light extracting deformities 21, 23, 24 and/or 25 may be provided on one or both sides of the panel member in order to change the path of the light so that the internal critical angle is exceeded and a portion of the light is emitted from one or both sides of the panel. Moreover, a transparent film, sheet or plate 27 may be attached or positioned against the side or sides of the panel member from which light is emitted using a suitable adhesive 28 or other method in order to produce a desired effect.

The member 27 may be used to further improve the uniformity of the light output distribution. For example, the member 27 may be a colored film, a diffuser, or a label or display, a portion of which may be a transparent overlay that may be colored and/or have text or an image thereon.

If adhesive 28 is used to adhere the back reflector 26 and/or film 27 to the panel, the adhesive is preferably applied only along the side edges of the panel, and if desired the end edge opposite the light transition areas 12, but not over the entire surface area or areas of the panel because of the difficulty in consistently applying a uniform coating of adhesive to the panel. Also, the adhesive changes the internal critical angle of the light in a less controllable manner than the air gaps 30 (see FIG. 5) which are formed between the respective panel surfaces and the back reflector 26 and/or film 27 when only adhered along the peripheral edges. Additionally, longer panel members are achievable when air gaps 30 are used. If adhesive were to be used over the entire surface, the pattern of deformities could be adjusted to account for the additional attenuation in the light caused by the adhesive.

Referring further to FIG. 2, the panel assembly 5 shown therein also includes molded posts 31 at one or more corners of the panel 7 (four such posts being shown) which may be used to facilitate mounting of the panel assembly and providing structural support for other parts or components, for example, a display panel such as a liquid crystal display panel as desired.

FIG. 6 shows another form of light emitting panel assembly 32 in accordance with this invention including a panel member 33, one or more light sources 3, and one or more light output areas 34. In addition, the panel assembly 32 includes a tray 35 having a cavity or recess 36 in which the panel assembly 32 is received. The tray 35 may act as a back reflector as well as end edge and/or side edge reflectors for the panel 33 and side and/or back reflectors 37 for the light sources 3.

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Additionally, one or more secondary reflective or refractive surfaces **38** may be provided on the panel member **33** and/or tray **35** to reflect a portion of the light around one or more corners or curves in a non-rectangular shaped panel member **33**. These secondary reflective/refractive surfaces **38** may be flat, angled, faceted or curved, and may be used to extract a portion of the light away from the panel member in a predetermined pattern. FIG. **6** also shows multiple light output areas **34** on the panel member that emit light from one or more light sources **3**.

FIG. **7** is a schematic illustration of still another form of light emitting panel assembly **40** in accordance with this invention including a panel member **41** having one or more light output areas **42** and one or more light transition areas (mixing areas) **43** containing a plurality of light sources **3** at one or both ends of the panel. Each transition area mixes the light from one or more light sources having different colors and/or intensities. In this particular embodiment, each of the light sources **3** desirably employs three colored LEDs (red, blue, green) in each transition mixing area **43** so that the light from the three LEDs can be mixed to produce a desired light output color that will be emitted from the light output area **42**. Alternatively, each light source may be a single LED having multiple colored chips bonded to the lead film. Also, two colored LEDs or a single LED having two colored chips may be used for a particular application. By varying the intensities of the individual respective LEDs, virtually any colored light output or white light distribution can be achieved.

FIG. **8** shows yet another form of light emitting panel assembly **45** in accordance with this invention including a light emitting panel member **46** and a light source **3** in a light transition area **48** integral with one end of the panel member. In this particular embodiment, the panel member **46** is three-dimensionally curved, for example, such that light rays may be emitted in a manner that facilitates aesthetic design of a lighted display.

FIG. **9** schematically shows another form of light emitting panel assembly **50** in accordance with this invention, including a panel member **51** having multiple light output areas **52**, and mounting posts and/or mounting tabs **53**. This particular panel assembly **50** may serve as a structural member to support other parts or components as by providing holes or cavities **54**, **55** in the panel member **51** which allow for the insertion of modular components or other parts into the panel member. Moreover, a separate cavity or recess **56** may be provided in the panel member **51** for receipt of a correspondingly shaped light transition area **57** having one or more light sources **3** embedded, bonded, cast, insert molded, epoxied, or otherwise mounted or positioned therein and a curved reflective or refractive surface **58** on the transition area **57** and/or wall of the cavity or recess **56** to redirect a portion of the light in a predetermined manner. In this way the light transition area **57** and/or panel member may be in the form of a separate insert which facilitates the easy placement of the light source in a modular manner. A reflector **58** may be placed on the reflective or refractive surface of the cavity or recess **56** or insert **57**. Where the reflector **58** is placed on the reflective or refractive surface of the cavity or recess **56**, the cavity or recess may act as a mold permitting transparent material from which the transition area **57** is made to be cast around one or more light sources **3**.

FIGS. **10** and **11** schematically show another form of light emitting panel assembly **60** in accordance with this invention including a panel member **61** having one or more light output areas **62**. In this particular embodiment, an off-axis light transition area **63** is provided that is thicker in cross section than the panel member to permit use of one or more light

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sources **3** embedded or otherwise mounted in the light transition area that are dimensionally thicker than the panel member. Also, a three-dimensional reflective surface **64** (FIG. **11**) may be provided on the transition area **63**. Moreover, a prism **65** (FIG. **11**) or tapered, rounded, or otherwise shaped end **66** (FIG. **11a**) may be provided at the end of the panel opposite the light sources **3** to perform the function of an end reflector. The light sources **3** may be oriented at different angles relative to each other and offset to facilitate better mixing of the light rays **67** in the transition area **63** as schematically shown in FIG. **10** and/or to permit a shorter length transition area **63** to be used.

FIGS. **12** and **13** schematically show still another form of light emitting panel assembly **70** in accordance with this invention which includes one or more light transition areas **71** at one or both ends of the panel member **72** each containing a single light source **73**. The transition area or areas **71** shown in FIGS. **12** and **13** collect light with multiple or three-dimensional surfaces and/or collect light in more than one plane. For example each transition area **71** shown in FIGS. **12** and **13** has elliptical and parabolic shape surfaces **74** and **75** in different planes for directing the light rays **76** into the panel member at a desired angle.

Providing one or more transition areas at one or both ends of the panel member of any desired dimension to accommodate one or more light sources, with reflective and/or refractive surfaces on the transition areas for redirecting the light rays into the panel member at relatively low angles allows the light emitting panel member to be made much longer and thinner than would otherwise be possible. For example the panel members of the present invention may be made very thin, i.e., 0.125 inch thick or less.

FIG. **14** schematically illustrates still another form of light emitting panel assembly **80** in accordance with this invention including a light emitting panel **81** and one or more light sources **3** positioned, embedded, potted, bonded or otherwise mounted in a light transition area **82** that is at an angle relative to the panel member **81** to permit more efficient use of space. An angled or curved reflective or refractive surface **83** is provided at the junction of the panel member **81** with the transition area **82** in order to reflect/refract light from the light source **3** into the body of the panel member **81** for emission of light from one or more light emitting areas **84** along the length of the panel member.

FIG. **15** schematically illustrates still another form of light emitting panel assembly **90** in accordance with this invention including a light transition area **91** at one or both ends of a light emitting panel member **92** containing a slot **93** for sliding receipt of an LED or other suitable light source **3**. Preferably the slot **93** extends into the transition area **91** from the back edge **94**, whereby the light source **3** may be slid and/or snapped in place in the slot from the back, thus allowing the transition area to be made shorter and/or thinner. The light source **3** may be provided with wings, tabs or other surfaces **95** for engagement in correspondingly shaped recesses or grooves **96** or the like in the transition area **91** for locating and, if desired, securing the light source in place. Also, the light source **3** may be embedded, potted, bonded or otherwise secured within the slot **93** in the light transition area **91** of the panel member **92**. Light from a secondary light source **97** may be projected through the panel member **92** for indication or some other effect.

The various light emitting panel assemblies disclosed herein may be used for a great many different applications including for example LCD back lighting or lighting in general, decorative and display lighting, automotive lighting, dental lighting, phototherapy or other medical lighting, mem-

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brane switch lighting, and sporting goods and apparel lighting or the like. Also the panel assemblies may be made such that the panel members and deformities are transparent without a back reflector. This allows the panel assemblies to be used for example to front light an LCD or other display such that the display is viewed through the transparent panel members.

Although the invention has been shown and described with respect to certain preferred embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

What is claimed is:

1. A light emitting assembly comprising at least one light source, a light emitting panel member having at least one input edge for receiving light from the light source and a light emitting surface, a tray or housing having a cavity or recess in which the panel member is entirely received, wherein the

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panel member has a pattern of light extracting deformities on or in at least one surface to cause light to be emitted from the light emitting surface of the panel member, end edge reflectors and side edge reflectors, and an additional component overlying the panel member, wherein the panel member has a greater width than height, and the light input edge has a refractive surface that redirects the light output distribution of the light source more in the width direction as the light enters the panel member.

2. The assembly of claim 1, wherein the end edge reflectors and the side edge reflectors are on end edges and side edges of the panel member.

3. The assembly of claim 1, wherein the end edge reflectors and the side edge reflectors are on end walls and side walls of the tray or housing.

4. The assembly of claim 1, wherein the light source comprises one or more LEDs.

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