INNOVATIVE DISPLAY TECHNOLOGIES LLC's EXHIBIT 2004

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LG ELECTRONICS, INC.
Petitioner

v.

INNOVATIVE DISPLAY TECHNOLOGIES LLC
Patent Owner

Case IPR2015-00489
U.S. Patent No. 7,384,177

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

INNOVATIVE DISPLAY TECHNOLOGIES LLC,	§	
	§	
Plaintiff,	§	**C.A. No. ____**
	§	
v.	§	**JURY TRIAL DEMANDED**
	§	
HEWLETT-PACKARD COMPANY,	§	
	§	
Defendant.	§	

PLAINTIFF'S COMPLAINT

Plaintiff Innovative Display Technologies LLC, by and through its undersigned counsel, files this Complaint against Defendant Hewlett-Packard Company ("HP").

THE PARTIES

1. Innovative Display Technologies LLC is a Texas limited liability company with its principal place of business located at 2400 Dallas Parkway, Suite 200, Plano, TX 75093.

2. Upon information and belief, HP is a Delaware corporation that claims as its principal place of business, 3000 Hanover Street, Palo Alto, CA 94304. Upon information and belief, HP may be served with process by serving its registered agent in Texas, C T Corporation System, 350 N. St. Paul St., Suite 2900, Dallas, TX 75201. Upon information and belief, HP 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 Texas. HP has an office in this District at 5400 Legacy Drive, Plano, TX 75024. HP also has an office at 20555 SH 249, Houston, TX 77070.

JURISDICTION AND VENUE

3. 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).

4. As further detailed herein, this Court has personal jurisdiction over HP. HP is amenable to service of summons for this action. Furthermore, personal jurisdiction over HP in this action comports with due process. HP maintains an office in this District at 5400 Legacy Drive, Plano, TX 75024. HP has conducted and regularly conducts business within the United States and this District. HP has purposefully availed itself of the privileges of conducting business in the United States, and more specifically in Texas and this District. HP has sought protection and benefit from the laws of the State of Texas by maintaining an office in this District and by placing infringing products into the stream of commerce through an established distribution channel with the awareness and/or intent that they will be purchased by consumers in this District.

5. HP – 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. HP has purposefully and voluntarily placed one or more of its infringing products, as described below, into the stream of commerce with the awareness and/or intent that they will be purchased by consumers in this District. Defendant knowingly and purposefully ships infringing products into 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, through those activities, HP has committed the tort of patent infringement in this District and/or has induced others to commit patent infringement in this District. Plaintiff's cause of action for patent infringement arises directly from HP's activities in this District.

6. Venue is proper in this Court according to the venue provisions set forth by 28 U.S.C. §§ 1391(b)-(d) and 1400(b). HP is subject to personal jurisdiction in this District, and therefore is deemed to reside in this District for purposes of venue. Upon information and belief, Defendant 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, available to persons in this District, that advertises, markets, and/or offers for sale infringing products.

BACKGROUND

A. The Patents-In-Suit.

7. U.S. Patent No. 6,755,547 titled "Light Emitting Panel Assemblies" ("the '547 patent") was duly and legally issued by the U.S. Patent and Trademark Office on June 29, 2004, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the '547 patent. The '547 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the '547 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the '547 patent is attached as **Exhibit A** and made a part hereof.

8. U.S. Patent No. 7,300,194 titled "Light Emitting Panel Assemblies" ("the '194 patent") was duly and legally issued by the U.S. Patent and Trademark Office on November 27, 2007, after full and fair examination. Jeffery R. Parker is the sole inventor listed on the '194 patent. The '194 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the '194 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the '194 patent is attached as **Exhibit B** and made a part hereof.

9. 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. The '177 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the '177 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the '177 patent is attached as **Exhibit C** and made a part hereof.

10. 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. The '660 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the '660 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the '660 patent is attached as **Exhibit D** and made a part hereof.

11. 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. The '974 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the '974 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the '974 patent is attached as **Exhibit E** and made a part hereof.

12. 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. The ’370 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the ’370 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the ’370 patent is attached as **Exhibit F** and made a part hereof.

13. 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. The ’816 patent has been assigned to Plaintiff, and Plaintiff holds all rights, title, and interest in the ’816 patent, including the right to collect and receive damages for past, present and future infringements. A true and correct copy of the ’816 patent is attached as **Exhibit G** and made a part hereof.

14. Jeffery R. Parker is an inventor of the ’547 patent, the ’194 patent, the ’177 patent, the ’660 patent, the ’974 patent, the ’370 patent, and the ’816 patent (collectively, the “patents-in-suit”). In total, he is a named inventor on over eighty-five (85) U.S. patents.

B. HP’s Infringing Conduct.

15. Upon information and belief, HP makes, uses, offers to sell, and/or sells within, and/or imports into the United States display products that incorporate the fundamental technologies covered by the patents-in-suit. Upon information and belief, the infringing display products include, but are not limited to, desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor).

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

17. Upon information and belief, third-party distributors purchase and have purchased HP'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 HP's infringing display products in the United States, including this District.

18. Upon information and belief, HP 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. 6,755,547

19. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-18 as though fully set forth herein.

20. The '547 patent is valid and enforceable.

21. HP has never been licensed, either expressly or impliedly, under the '547 patent.

22. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff surmises that any express licensees of the '547 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the '547 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.

23. Upon information and belief, HP 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 '547 patent by making, using, offering to sell, and/or selling to third-party manufacturers, 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 ’547 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the ’547 patent.

24. Upon information and belief, distributors and consumers that purchase HP’s products that include all of the limitations of one or more claims of the ’547 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the ’547 patent by using, offering to sell, and/or selling infringing display products in this District and elsewhere in the United States.

25. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP that include all of the limitations of one or more claims of the ’547 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the ’547 patent by making, offering to sell, and/or selling infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

26. Upon information and belief, HP had knowledge of the ’547 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

27. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b),

third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the ’547 patent. Since at least the notice provided on the above-mentioned date, HP does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the ’547 patent. Upon information and belief, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

28. Upon information and belief, HP’s acts of infringement of the ’547 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the ’547 patent by refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

29. As a direct and proximate result of these acts of patent infringement, HP has encroached on the exclusive rights of Plaintiff and its licensees to practice the ’547 patent, for which Plaintiff is entitled to at least a reasonable royalty.

COUNT II

Patent Infringement of U.S. Patent No. 7,300,194

30. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-29 as though fully set forth herein.

31. The ’194 patent is valid and enforceable.

32. HP has never been licensed, either expressly or impliedly, under the ’194 patent.

33. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff surmises that any express licensees of the ’194 patent have complied with the marking requirements of 35 U.S.C. § 287 by placing a notice of the ’194 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.

34. Upon information and belief, HP 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 ’194 patent by making, using, offering to sell, and/or selling to third-party manufacturers, 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 ’194 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the ’194 patent.

35. Upon information and belief, distributors and consumers that purchase HP's products that include all of the limitations of one or more claims of the '194 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '194 patent by using, offering to sell, and/or selling infringing display products in this District and elsewhere in the United States.

36. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP that include all of the limitations of one or more claims of the '194 patent, also directly infringe, either literally or under the doctrine of equivalents, under 35 U.S.C. § 271(a), the '194 patent by making, offering to sell, and/or selling infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

37. Upon information and belief, HP had knowledge of the '194 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

38. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the '194 patent. Since at least the notice provided on the above-mentioned date, HP does so with knowledge, or with willful blindness of the fact, that the induced acts constitute infringement of the '194 patent. Upon information and belief, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

39. Upon information and belief, HP's acts of infringement of the '194 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the '194 patent by refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

40. As a direct and proximate result of these acts of patent infringement, HP has encroached on the exclusive rights of Plaintiff and its licensees to practice the '194 patent, for which Plaintiff is entitled to at least a reasonable royalty.

COUNT III

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

41. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-40 as though fully set forth herein.

42. The '177 patent is valid and enforceable.

43. HP has never been licensed, either expressly or impliedly, under the '177 patent.

44. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff

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.

45. Upon information and belief, HP 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 manufacturers, 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 desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the '177 patent.

46. Upon information and belief, distributors and consumers that purchase HP's products that include all of the limitations of one or more claims of the '177 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), 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 infringing display products in this District and elsewhere in the United States.

47. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP 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 infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

48. Upon information and belief, HP had knowledge of the ’177 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

49. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the ’177 patent. Since at least the notice provided on the above-mentioned date, HP 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, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

50. Upon information and belief, HP’s acts of infringement of the ’177 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the ’177 patent by refusing to take a license and continuing to make and sell its display products, including but not

limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

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

COUNT IV

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

52. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-51 as though fully set forth herein.

53. The '660 patent is valid and enforceable.

54. HP has never been licensed, either expressly or impliedly, under the '660 patent.

55. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff 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.

56. Upon information and belief, HP 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 manufacturers, 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 desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the ’660 patent.

57. Upon information and belief, distributors and consumers that purchase HP’s products that include all of the limitations of one or more claims of the ’660 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), 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 infringing display products in this District and elsewhere in the United States.

58. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP 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 infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

59. Upon information and belief, HP had knowledge of the ’660 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

60. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b),

third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the ’660 patent. Since at least the notice provided on the above-mentioned date, HP 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, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

61. Upon information and belief, HP’s acts of infringement of the ’660 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the ’660 patent by refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

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

COUNT V

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

63. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-62 as though fully set forth herein.

64. The ’974 patent is valid and enforceable.

65. HP has never been licensed, either expressly or impliedly, under the ’974 patent.

66. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff 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.

67. Upon information and belief, HP 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 manufacturers, 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 desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the ’974 patent.

68. Upon information and belief, distributors and consumers that purchase HP's products that include all of the limitations of one or more claims of the '974 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), 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 infringing display products in this District and elsewhere in the United States.

69. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP 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 infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

70. Upon information and belief, HP had knowledge of the '974 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

71. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the '974 patent. Since at least the notice provided on the above-mentioned date, HP 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, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

72. Upon information and belief, HP's acts of infringement of the '974 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the '974 patent by refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

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

COUNT VI

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

74. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-73 as though fully set forth herein.

75. The '370 patent is valid and enforceable.

76. HP has never been licensed, either expressly or impliedly, under the '370 patent.

77. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual

or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff 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.

78. Upon information and belief, HP 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 manufacturers, 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 desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the '370 patent.

79. Upon information and belief, distributors and consumers that purchase HP's products that include all of the limitations of one or more claims of the '370 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), 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 infringing display products in this District and elsewhere in the United States.

80. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP 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 infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

81. Upon information and belief, HP had knowledge of the ’370 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

82. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the ’370 patent. Since at least the notice provided on the above-mentioned date, HP 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, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

83. Upon information and belief, HP’s acts of infringement of the ’370 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the ’370 patent by

refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

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

COUNT VII

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

85. Plaintiff repeats and re-alleges each and every allegation of paragraphs 1-84 as though fully set forth herein.

86. The ’816 patent is valid and enforceable.

87. HP has never been licensed, either expressly or impliedly, under the ’816 patent.

88. Upon information and belief, to the extent any marking or notice was required by 35 U.S.C. § 287, Plaintiff has complied with the requirements of that statute by providing actual or constructive notice to HP of its alleged infringement. Upon information and belief, Plaintiff 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.

89. Upon information and belief, HP 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 manufacturers, 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 desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), their display components, and/or other products made, used, sold, offered for sale, or imported by HP that include all of the limitations of one or more claims of the ’816 patent.

90. Upon information and belief, distributors and consumers that purchase HP’s products that include all of the limitations of one or more claims of the ’816 patent, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), 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 infringing display products in this District and elsewhere in the United States.

91. Upon information and belief, the third-party manufacturers, distributors, and importers that sell display products to HP 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 infringing products in this District and elsewhere within the United States and/or importing infringing products into the United States.

92. Upon information and belief, HP had knowledge of the ’816 patent and its infringing conduct at least since August 28, 2012, when HP was formally placed on notice of its infringement.

93. Upon information and belief, since at least the above-mentioned date when Plaintiff formally placed HP on notice of its infringement, HP has actively induced, under U.S.C. § 271(b), third-party manufacturers, distributors, importers and/or consumers to directly infringe one or more claims of the ’816 patent. Since at least the notice provided on the above-mentioned date, HP 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, HP intends to cause infringement by these third-party manufacturers, distributors, importers, and/or consumers. HP has taken affirmative steps to induce their infringement 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.

94. Upon information and belief, HP’s acts of infringement of the ’816 patent have been willful and intentional. Since at least the above-mentioned date of notice, HP has acted with an objectively high likelihood that its actions constituted infringement of the ’816 patent by refusing to take a license and continuing to make and sell its display products, including but not limited to desktops, laptops, monitors, tablets, calculators, and printers (*e.g.*, the HP g6-2321dx laptop and the HP W2071d monitor), and the objectively-defined risk was either known or so obvious that it should have been known.

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

CONCLUSION

96. Plaintiff is entitled to recover from HP the damages sustained by Plaintiff as a result of HP'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.

97. 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 Plaintiff is entitled to recover its reasonable and necessary attorneys' fees, costs, and expenses.

JURY DEMAND

98. Plaintiff hereby requests a trial by jury pursuant to Rule 38 of the Federal Rules of Civil Procedure.

PRAYER FOR RELIEF

99. Plaintiff respectfully request that the Court find in its favor and against HP, and that the Court grant Plaintiff the following relief:

A. A judgment that HP 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 Plaintiff as a result of the acts of infringement by HP;

C. A judgment and order requiring HP to pay Plaintiff damages under 35 U.S.C. § 284, including up to treble damages for willful infringement as provided by 35 U.S.C. § 284, and any royalties determined to be appropriate;

D. A permanent injunction enjoining HP 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 HP to pay Plaintiff pre-judgment and post-judgment interest on the damages awarded;

F. A judgment and order finding this to be an exceptional case and requiring HP 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: June 28, 2013

Respectfully submitted,

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EXHIBIT A

US006755547B2

(12) **United States Patent**
Parker

(10) **Patent No.: US 6,755,547 B2**
(45) **Date of Patent: *Jun. 29, 2004**

(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.: **10/232,047**

(22) Filed: **Aug. 30, 2002**

(65) **Prior Publication Data**

US 2003/0007344 A1 Jan. 9, 2003

Related U.S. Application Data

(62) Division of application No. 09/256,275, filed on Feb. 23, 1999, 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.**[7] **F21V 7/04**

(52) **U.S. Cl.** **362/31**; 362/27; 362/235; 362/297; 362/308

(58) **Field of Search** 362/26, 31, 330, 362/332, 335, 336, 337, 339, 27

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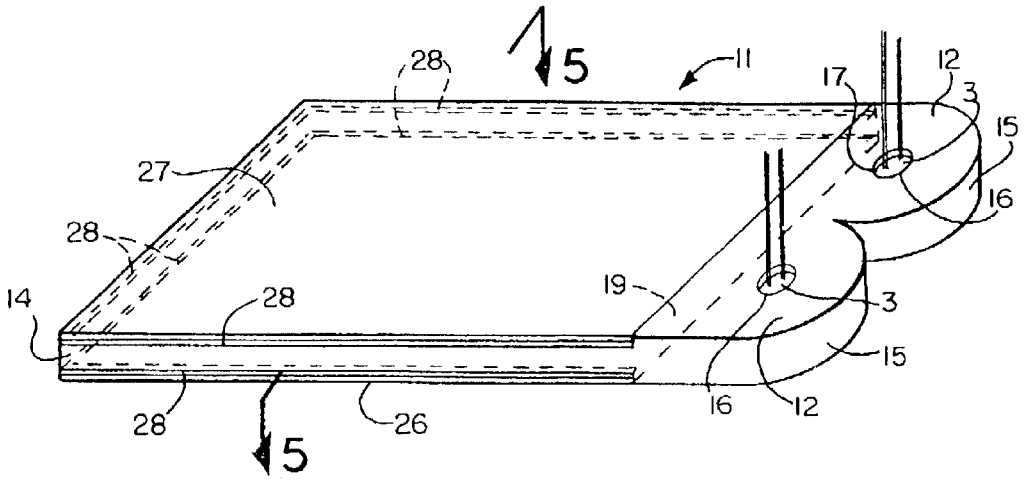
Primary Examiner—John Anthony Ward
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boiselle & Sklar, LLP

(57) **ABSTRACT**

Light emitting panel assemblies include a sheet, film or plate overlying a light emitting member. The sheet, film or plate has a pattern of deformities on one or both sides that may vary or be random in size, shape or geometry, placement, index of refraction, density, angle, depth, height and type for controlling the light output distribution to suit a particular application. Also the sheet, film or plate may have a coating or surface treatment for causing the light to pass through a liquid crystal display with low loss.

31 Claims, 4 Drawing Sheets



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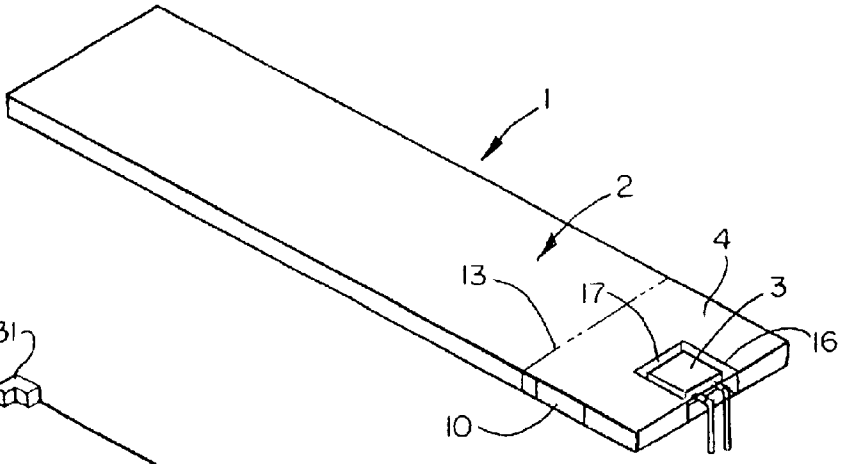


FIG. 1

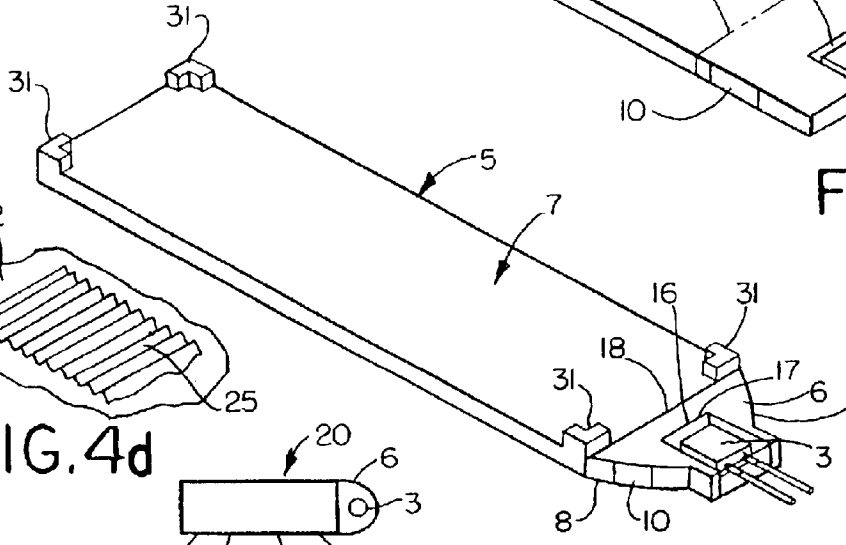


FIG. 2

FIG.4d

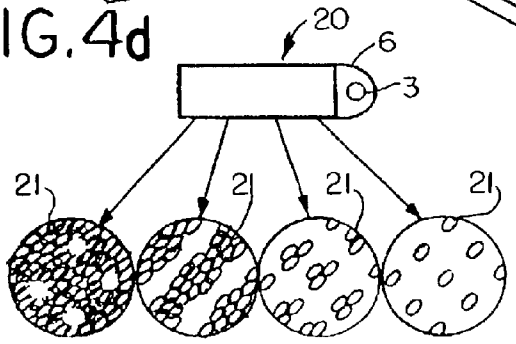


FIG. 4a

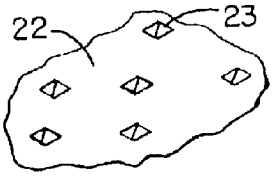


FIG. 4b

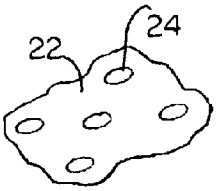


FIG. 4c

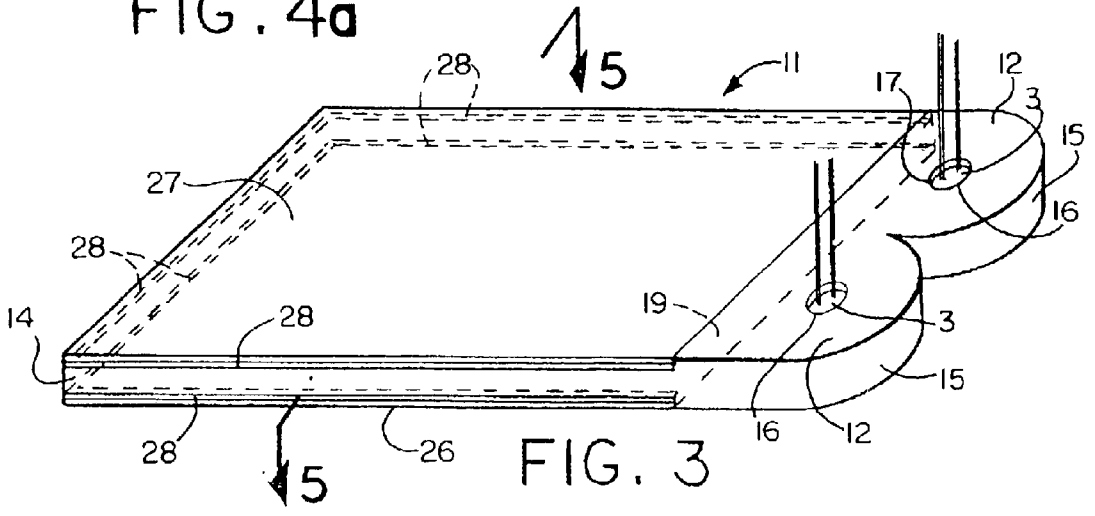


FIG. 3

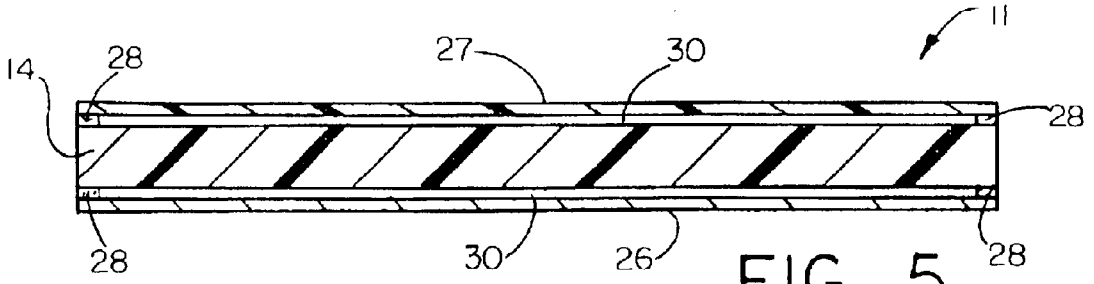


FIG. 5

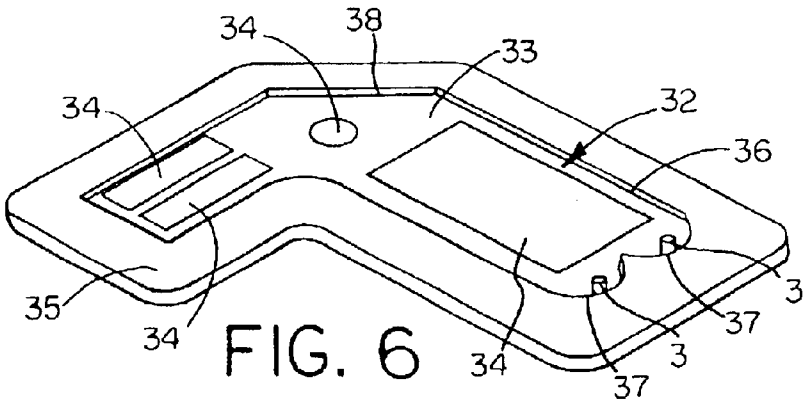


FIG. 6

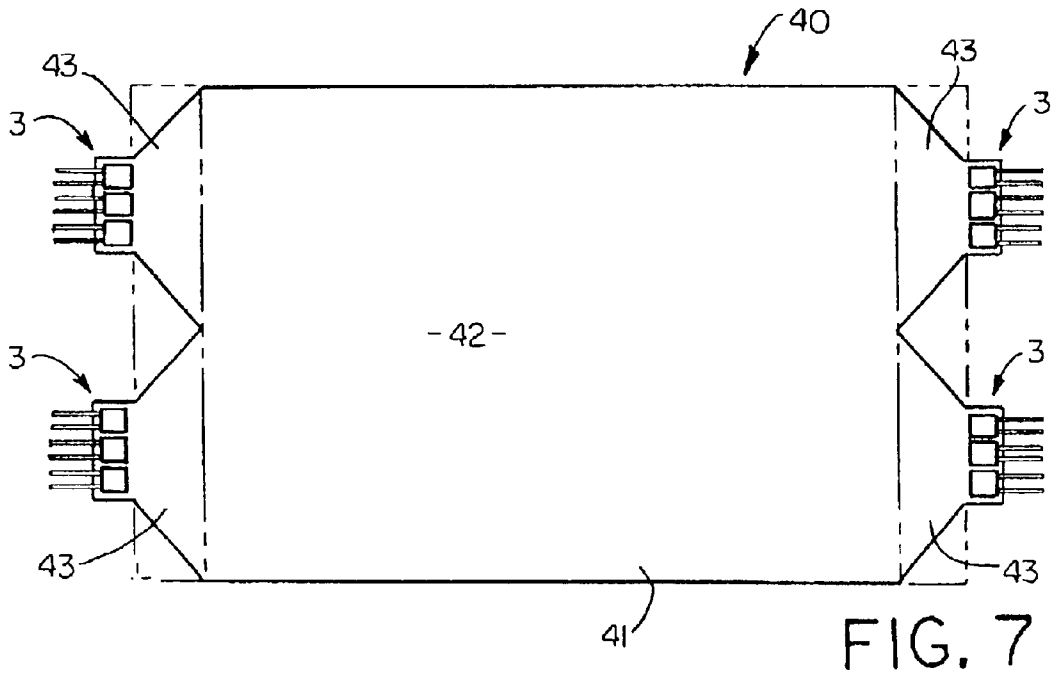


FIG. 7

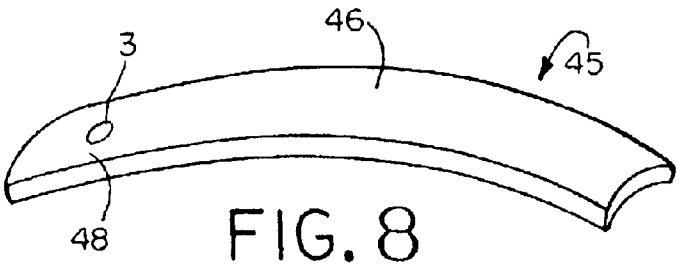


FIG. 8

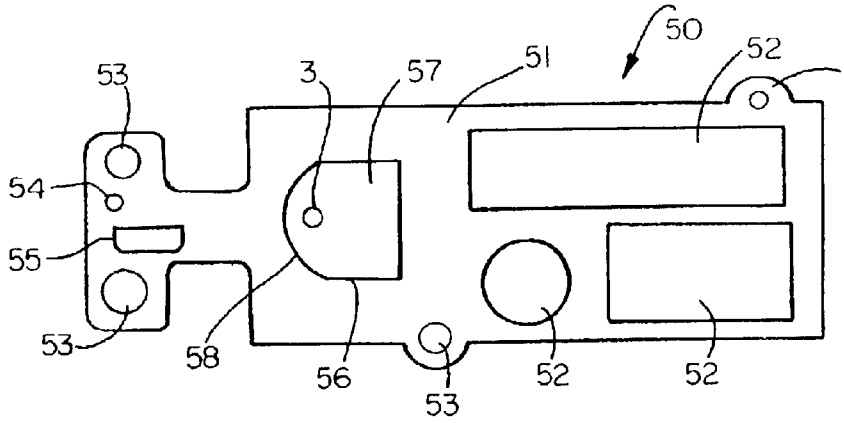


FIG. 9

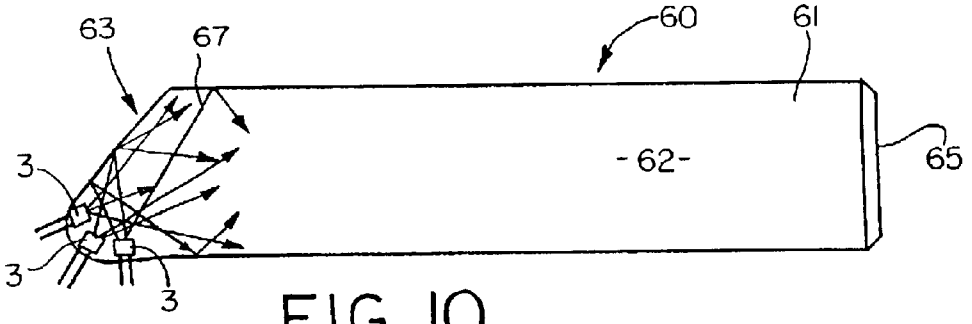


FIG. 10

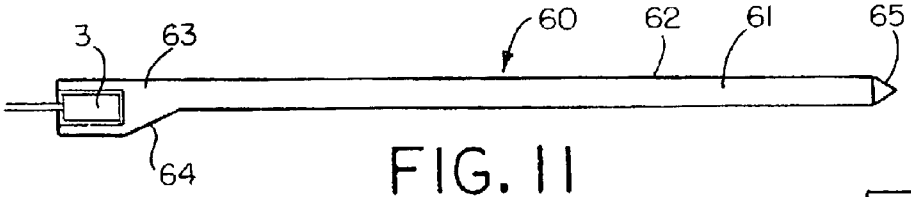


FIG. 11

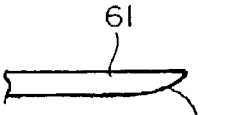


FIG. 11a

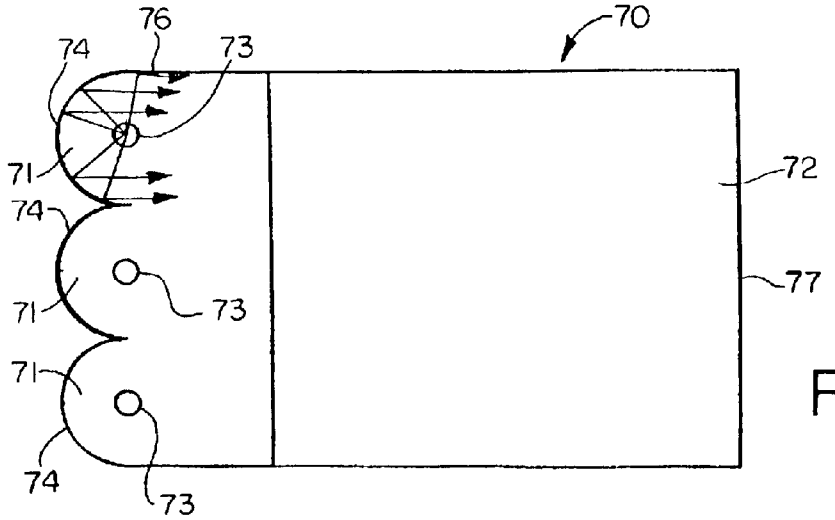


FIG. 12

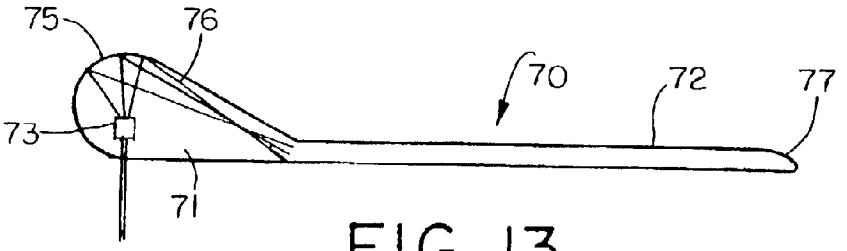


FIG. 13

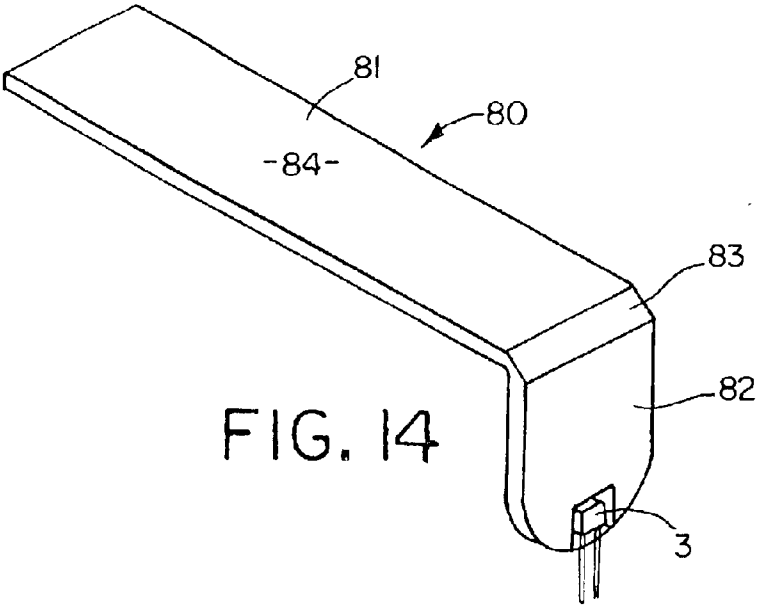


FIG. 14

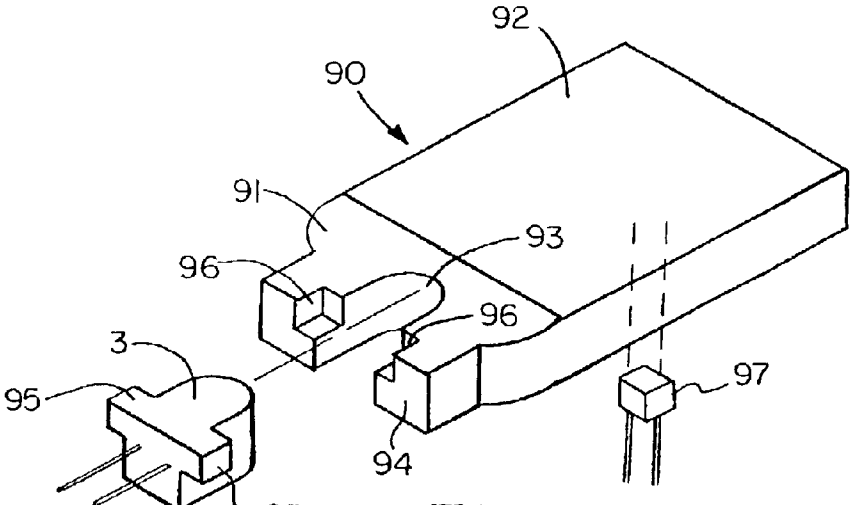


FIG. 15

LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a division of U.S. patent application Ser. No. 09/256,275, filed Feb. 23, 1999, 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, 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.

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 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. **4***a* 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. **4***b, 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. **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**; 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 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, 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. **4***a* 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. **4***a* 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 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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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 sheet or film **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** (see FIG. **5**) or other method in order to produce a desired effect.

The sheet or film **27** may be used to further improve the uniformity of the light output distribution. For example, the sheet or film **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 sheet 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 sheet 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 nonrectangular 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 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. **11***a*) 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 backlight assembly comprising a light emitting member having at least one light emitting area that emits light that is internally reflected within the light emitting member, a separate transparent sheet or film overlying the light emitting area with an air gap therebetween, a pattern of deformities on one side of the sheet or film having a width and length that is quite small in relation to the width and length of the sheet or film, the deformities varying at different locations on the sheet or film to direct the light that is emitted by the, light emitting member in different directions to produce a desired light output distribution such that the light will pass through a liquid crystal display with low loss.

2. The assembly of claim **1** wherein the deformities vary in size at different locations on the sheet or film to direct the light in different directions.

3. The assembly of claim **1** wherein the deformities vary in shape at different locations on the sheet or film to direct the light in different directions.

4. The assembly of claim **1** wherein the deformities vary in placement at different locations on the sheet or film to direct the light in different directions.

5. The assembly of claim **1** wherein the deformities vary in index of refraction at different locations on the sheet or film to direct the light in different directions.

6. The assembly of claim **1** wherein the deformities vary in density at different locations on the sheet or film to direct the light in different directions.

7. The assembly of claim **1** wherein the deformities vary in angle at different locations on the sheet or film to direct the light in different directions.

8. The assembly of claim **1** wherein the deformities vary in depth or height at different locations on the sheet or film to direct the light in different directions.

9. The assembly of claim **1** wherein the deformities vary in type at different locations on the sheet or film to direct the light in different directions.

10. The assembly of claim **1** wherein the deformities comprise depressions on the sheet or film.

11. The assembly of claim **1** wherein the deformities comprise projections on the sheet or film.

12. The assembly of claim **1** wherein the sheet or film has at least one of a coating and surface treatment for causing the light to pass through a liquid crystal display with low loss.

13. The assembly of claim **1** wherein the sheet or film comprises at least one of multiple layers and materials.

14. The assembly of claim **13** wherein the at least one of the multiple layers and materials has a different index of refraction.

15. The assembly of claim **1** wherein the deformities are varied to reduce moiré or other interference effects when the light passes through a liquid crystal display.

16. The assembly of claim **1** wherein the deformities are at least one of prisms, prismatic and lenticular.

17. The assembly of claim **1** wherein the deformities randomly vary in size on the sheet film to direct the light in different directions.

18. The assembly of claim **1** wherein the deformities randomly vary in shape on the sheet film to direct the light in different directions.

19. The assembly of claim **1** wherein the deformities randomly vary in placement on the sheet film to direct the light in different directions.

20. The assembly of claim **1** wherein the deformities randomly vary in density on the sheet film to direct the light in different directions.

21. The assembly of claim **1** wherein the deformities randomly vary in angle on the sheet film to direct the light in different directions.

22. The assembly of claim **1** wherein the deformities randomly vary in depth or height on the sheet film to direct the light in different directions.

23. The assembly of claim **1** wherein the deformities randomly vary in type on the sheet film to direct the light in different directions.

24. The assembly of claim **1** wherein the deformities have a pattern with no specific angle.

25. The assembly of claim **1** wherein at least some of the deformities include prismatic surfaces haying angles that vary at different locations on the sheet or film to direct the light in different directions.

26. The assembly of claim **1** wherein at least some of the deformities have random or varying changes in shape or geometry on the sheet or film to direct the light in different directions.

27. The assembly of claim **1** wherein the sheet or film has random or varying changes in at least one of a coating or surface treatment to direct the light in different directions.

28. The assembly of claim **27** wherein the at least one of the coating and surface treatment varies in at least one of the following characteristics: density, color, index of refraction, reflection, opaqueness, translucence, area, depth, shape size, and type.

29. The assembly of claim **27** wherein at least one of the coating and surface treatment is at least one of paint, ink, and epoxy.

30. The assembly of claim **1** wherein the sheet or film has a coating that is selected to improve at least to one of the following characteristics of the backlight assembly: color correction opaqueness, diffusion, reflection translucence and transmission.

31. The assembly of claim **1** wherein at least some of the deformities touch, intersect or overlap other deformities.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,755,547 B2
APPLICATION NO. : 10/232047
DATED : June 29, 2004
INVENTOR(S) : Jeffery R. Parker

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

Claim 1, line 10, after "the" delete ",".

Claim 17, line 2, after "sheet" insert --or--.
Claim 18, line 2, after "sheet" insert --or--.
Claim 19, line 2, after "sheet" insert --or--.
Claim 20, line 2, after "sheet" insert --or--.
Claim 21, line 2, after "sheet" insert --or--.
Claim 22, line 2, after "sheet" insert --or--.
Claim 23, line 2, after "sheet" insert --or--.

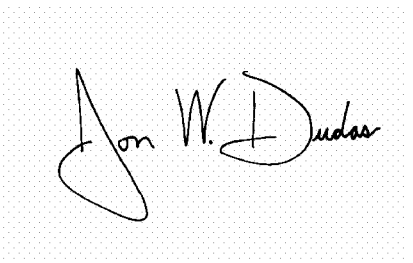
Claim 25, line 2, replace "haying" with --having--.

Claim 28, line 4, after "shape" insert --,--.

Claim 30, line 2, after "least" delete "to"; line 4, after "correction" insert --,--; after "reflection" insert --,--.

Signed and Sealed this

Twelfth Day of December, 2006



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

EXHIBIT B

US007300194B2

(12) **United States Patent**
Parker

(10) **Patent No.: US 7,300,194 B2**
(45) **Date of Patent: *Nov. 27, 2007**

(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 125 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/245,408**

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

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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, and 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.** **362/619**; 362/612

(58) **Field of Classification Search** 362/600–625
See application file for complete search history.

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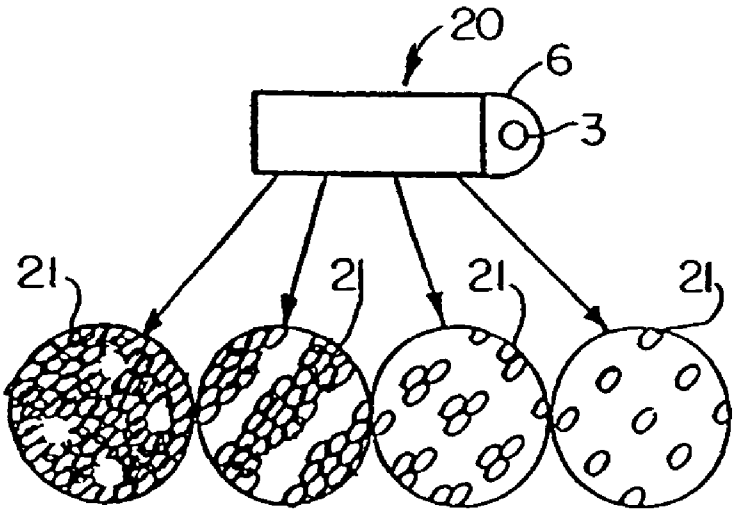
(57) **ABSTRACT**

Light emitting assemblies include at least one light source and at least one film, sheet, plate or substrate having optical elements or deformities of well defined shape on at least one surface that have reflective or refractive surfaces for controlling the light output ray angle distribution of the emitted light. The film, sheet, plate or substrate may be positioned near the light emitting surface of a light emitting panel member with an air gap therebetween or over a cavity or recess in a tray through which light from a light source in the cavity or recess is emitted.

31 Claims, 4 Drawing Sheets



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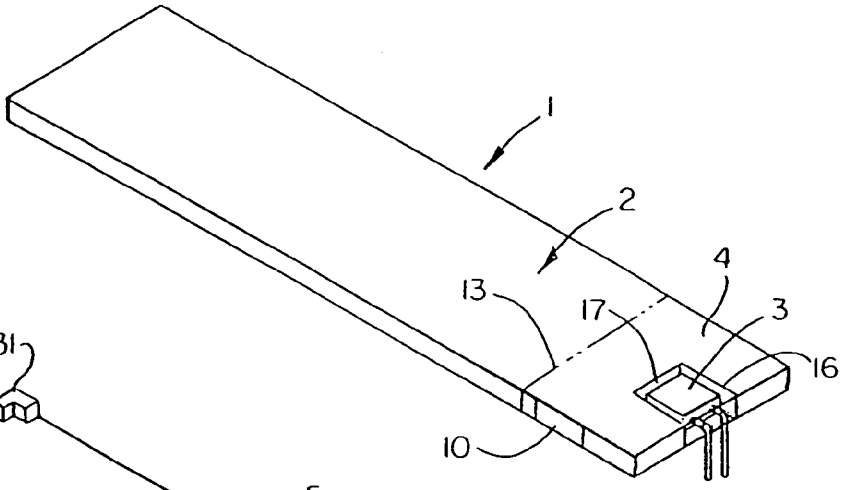

FIG. 1

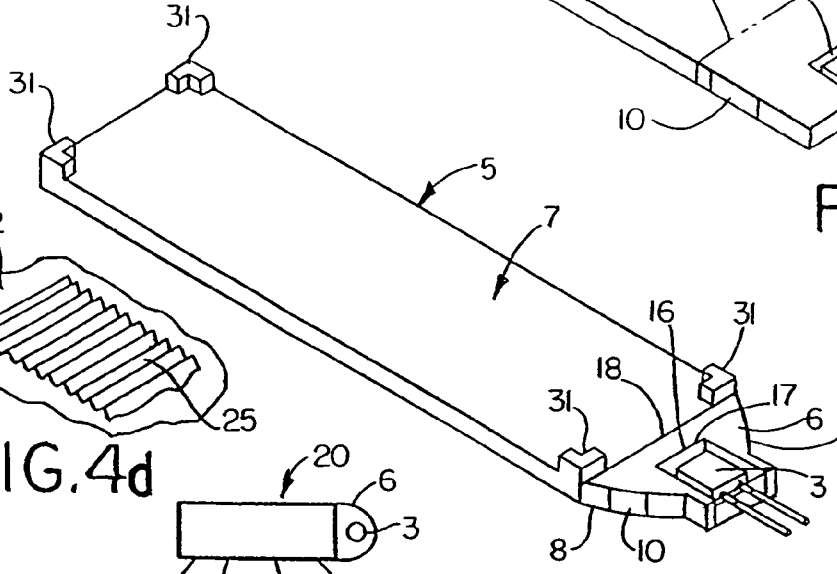

FIG. 2

FIG.4d

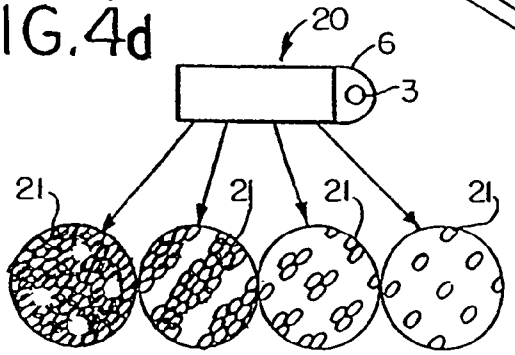

FIG. 4a

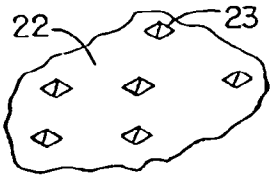

FIG. 4b

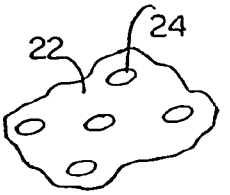

FIG. 4c

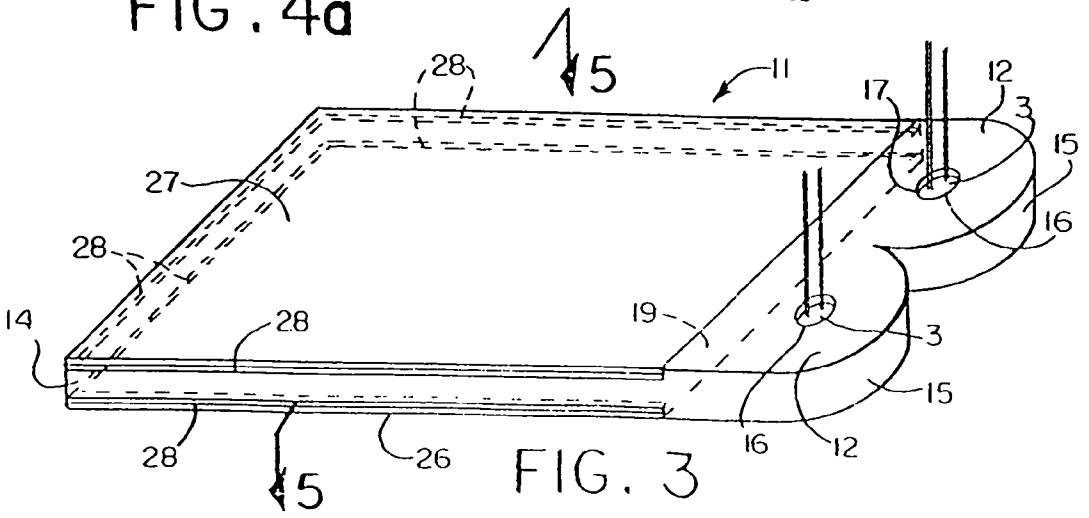

FIG. 3

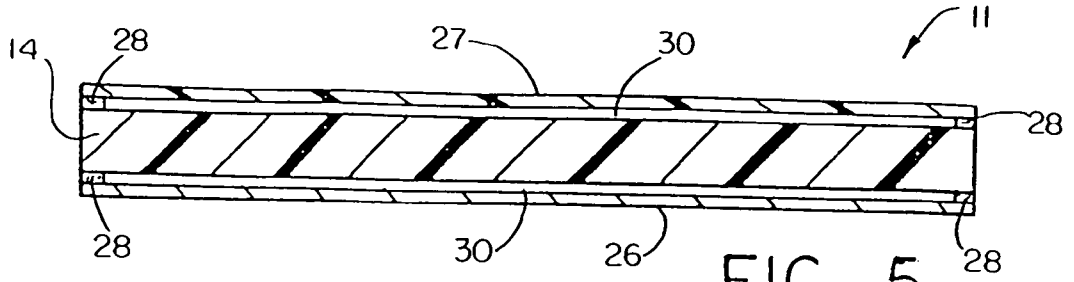

FIG. 5

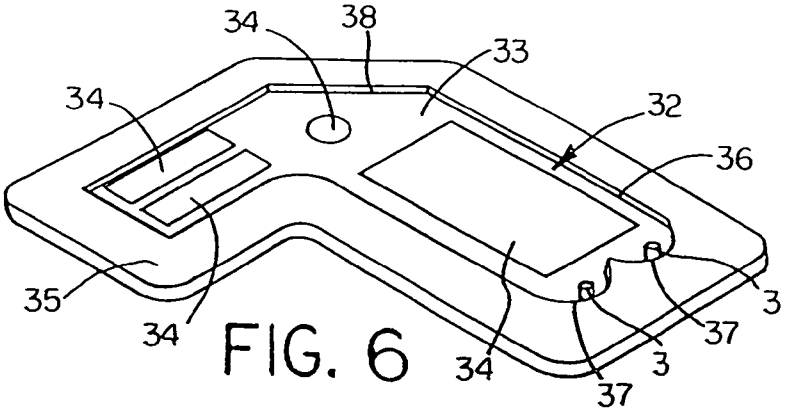

FIG. 6

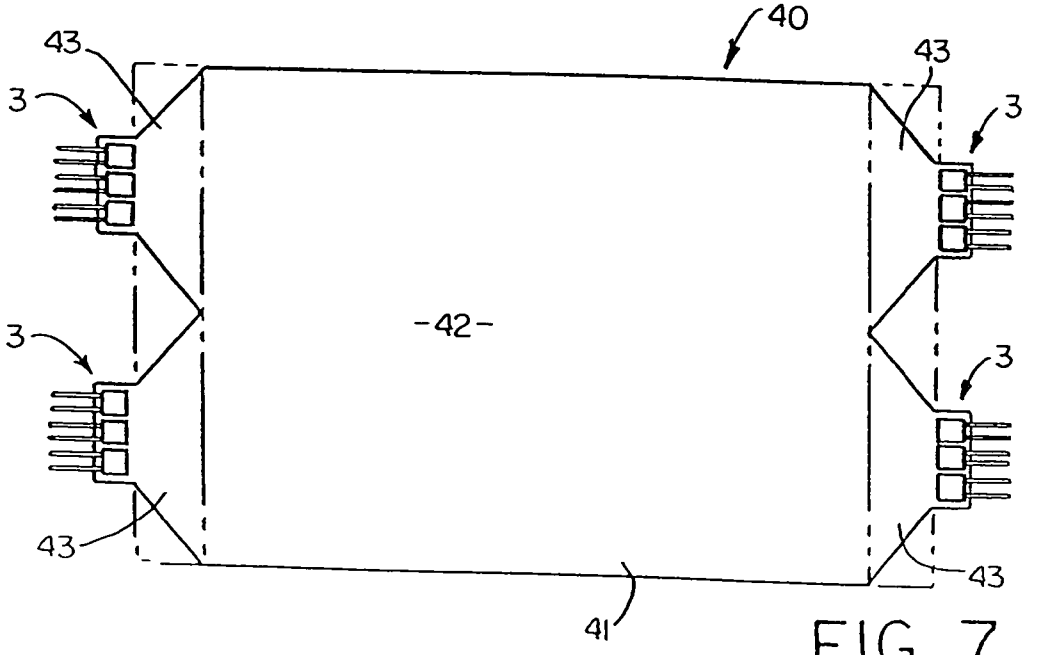

FIG. 7

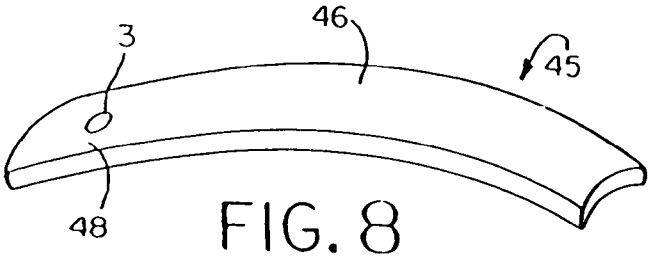

FIG. 8

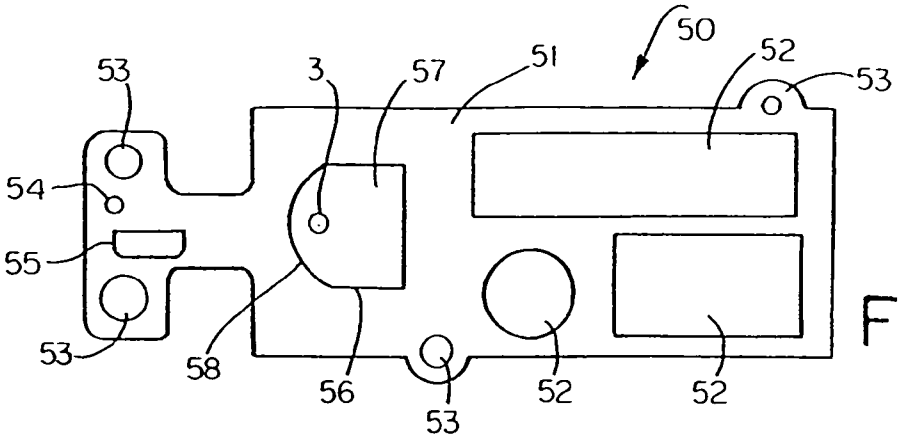

FIG. 9

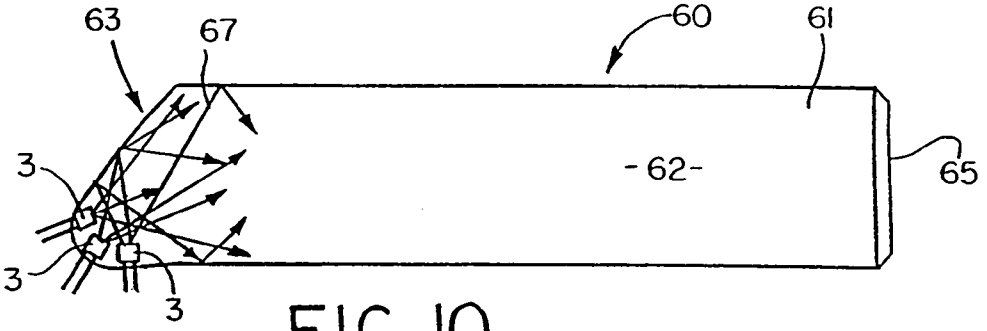

FIG. 10

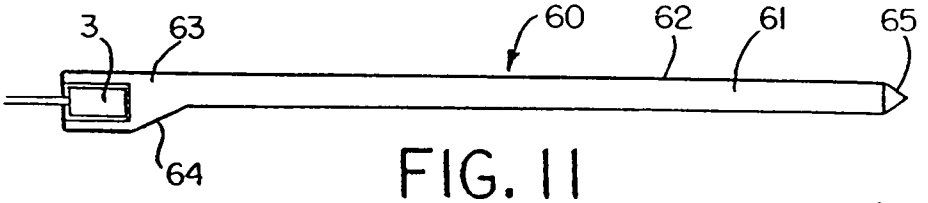

FIG. 11

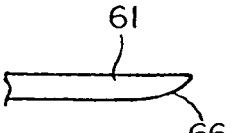

FIG. 11a

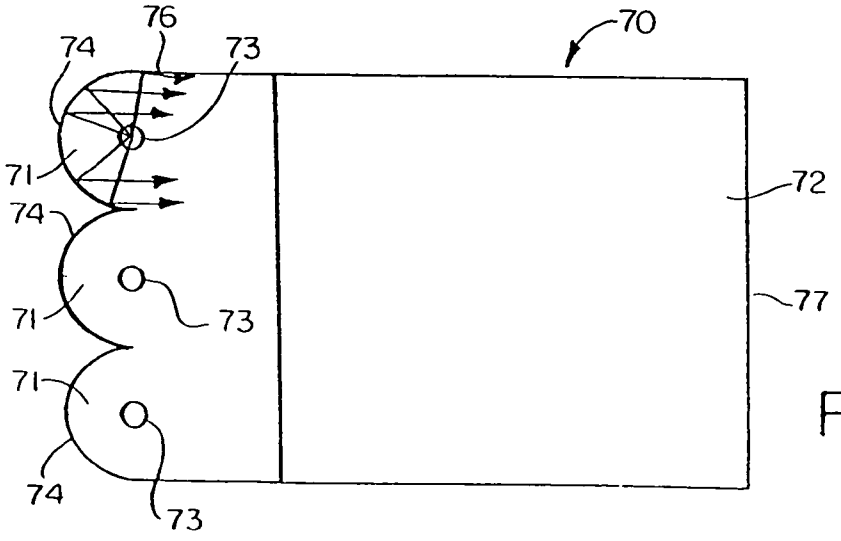

FIG. 12

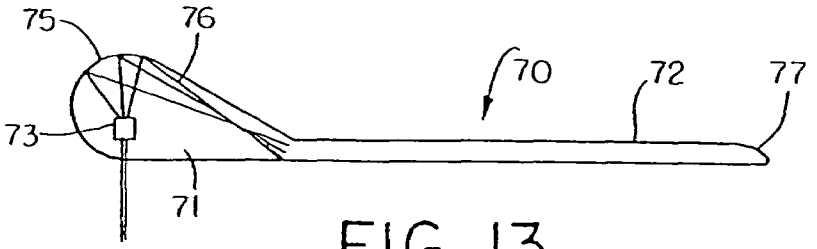

FIG. 13

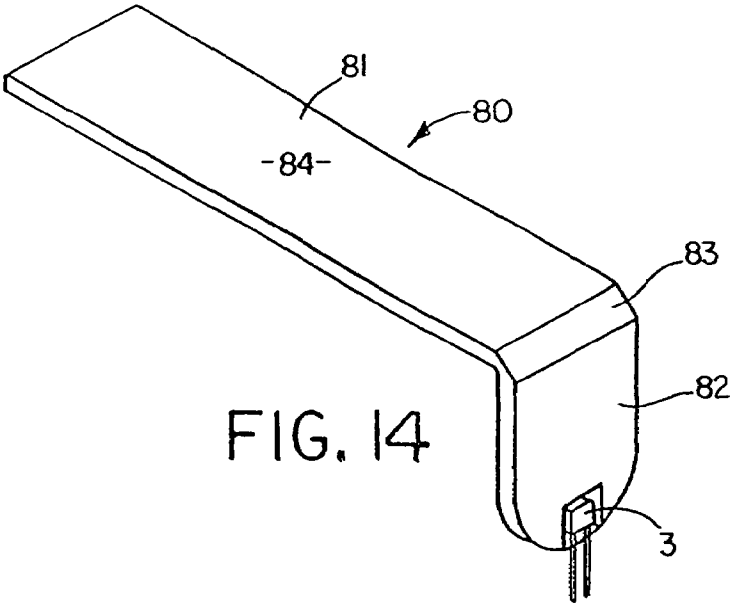

FIG. 14

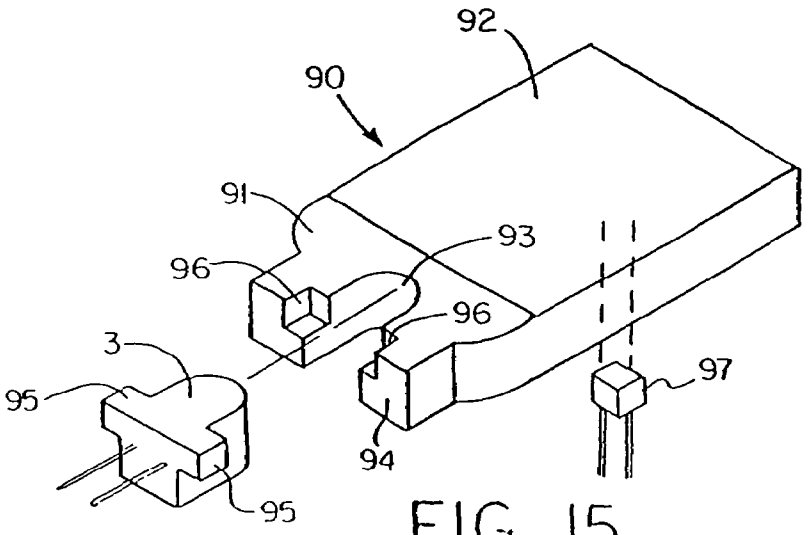

FIG. 15

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 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. **4***a* 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. **4***b, 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. **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**; 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 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, 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. **4***a* 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. **4***a* 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 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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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**. 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 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. **11***a*) 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 at least a light emitting panel member having a light emitting surface, at least one light source, at least one film, sheet, plate or substrate positioned near the light emitting surface through which light from the panel member is emitted, and an air gap between the film, sheet, plate or substrate and the panel member, wherein at least one surface of the film, sheet, plate or substrate has one or more reflective or refractive surfaces, and at least one of the reflective or refractive surfaces has well defined optical elements or deformities for controlling the emitted light such that at least some of the light is redirected to pass through a liquid crystal display with low loss.

2. The assembly of claim **1** wherein at least some of the reflective surfaces or deformities have a reflective material or coating.

3. The assembly of claim **1** wherein at least some of the reflective or refractive surfaces are shaped or patterned to reduce moirié or other interference effects.

4. The assembly of claim **1** wherein light from at least two light sources partially mixes in at least a portion of the light emitting assembly.

5. The assembly of claim **4** wherein the portion of the light emitting assembly in which the light partially mixes is the panel member.

6. The assembly of claim **4** wherein the portion of the light emitting assembly in which the light partially mixes is the air gap.

7. The assembly of claim **4** wherein two or more of the light sources are different colored light sources.

8. The assembly of claim **4** wherein two or more of the light sources are different colored LEDs.

9. The assembly of claim **1** wherein at least one light source is a single LED with multicolored chips.

10. The assembly of claim **1** further comprising a tray that holds or positions the film, sheet, plate or substrate relative to one or more light sources.

11. The assembly of claim **1** wherein an additional film, sheet, plate or substrate is positioned near the one film, sheet, plate or substrate to redirect at least a portion of the emitted light to produce a desired light output distribution or effect.

12. The assembly of claim **11** wherein there is an additional air gap between the one film, sheet, plate or substrate and the additional film, sheet, plate or substrate.

13. The assembly of claim **11** wherein the additional film, sheet, plate or substrate has prismatic or lenticular surfaces.

14. The assembly of claim **11** wherein the additional film sheet, plate or substrate has optical elements that are quite small relative to the length and width of the additional film, sheet, plate or substrate.

15. The assembly of claim **11** wherein the additional film, sheet, plate or substrate is a diffuser or brightness enhancement film.

16. A light emitting assembly comprising at least a tray that forms a cavity or recess, at least one light source positioned within the cavity or recess, at least one film, sheet, plate or substrate positioned over the cavity or recess through which light from the light source is emitted, wherein at least one surface of the film, sheet, plate or substrate has one or more reflective or refractive surfaces, and at least one of the reflective or refractive surfaces has well defined optical elements or deformities for controlling the emitted light such that at least some of the light is redirected to pass through a liquid crystal display with low loss.

17. The assembly of claim **16** wherein the tray acts as a back reflector, an end edge reflector and/or a side edge reflector.

18. The assembly of claim **16** wherein light from at least two light sources partially mixes in at least a portion of the light emitting assembly.

19. The assembly of claim **18** wherein two or more of the light sources are different colored light sources.

20. The assembly of claim **18** wherein two or more of the light sources are different colored LEDs.

21. The assembly of claim **16** wherein at least one light source is a single LED with multicolored chips.

22. The assembly of claim **16** wherein the tray holds or positions the one film, sheet, plate or substrate relative to the one or more light sources.

23. The assembly of claim **16** wherein an additional transparent film, sheet, plate or substrate is positioned near the one film, sheet, plate or substrate to redirect at least a portion of the emitted light to produce a desired light output distribution or effect.

24. The assembly of claim **23** wherein there is an air gap between the one film, sheet, plate or substrate and the additional film, sheet, plate or substrate.

25. The assembly of claim **23** wherein the additional film, sheet, plate or substrate has prismatic or lenticular surfaces.

26. The assembly of claim **23** wherein the additional film, sheet, plate or substrate has optical elements that are quite small relative to the length and width of the additional film, sheet, plate or substrate.

27. The assembly of claim **23** wherein the additional film, sheet, plate or substrate is a diffuser or brightness enhancement film.

28. A light emitting assembly comprising at least one light source and at least one transparent film, sheet, plate or substrate having top and bottom surfaces, a plurality of optical elements or deformities of well defined shape on or in the top and bottom surfaces, at least some of the optical elements or deformities on or in at least one of the top and bottom surfaces having one or more reflective or refractive surfaces for controlling the emitted light such that at least some of the light is redirected to pass through a liquid crystal display with low loss.

29. The assembly of claim **28** wherein the optical elements or deformities on or in the top surface of the film, sheet, plate or substrate are different than the optical elements or deformities on or in the bottom surface.

30. The assembly of claim **28** wherein at least some of the optical elements or deformities are multiple layers or vary in index of refraction.

31. A light emitting assembly comprising at least a tray that forms a cavity or recess, at least one light source positioned within the cavity or recess, at least one film, sheet, plate or substrate positioned over the cavity or recess through which light from the light source is emitted, wherein at least one surface of the film, sheet, plate or substrate has one or more reflective or refractive surfaces that are well defined optical elements or deformities for controlling the light output ray angle distribution of the light emitted to suit a particular application.

* * * * *

EXHIBIT C

US007384177B2

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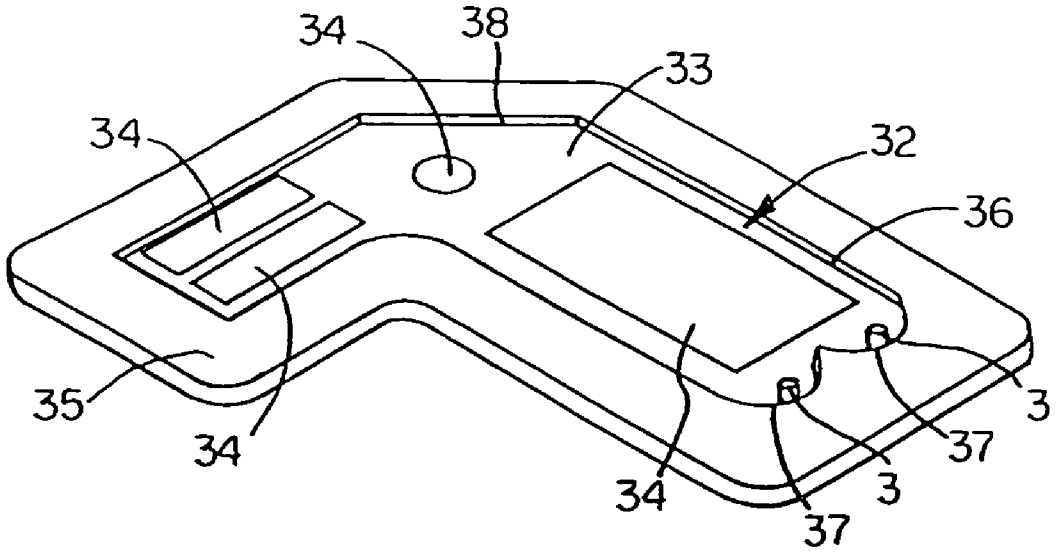
Primary Examiner—Thomas M. Sember
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(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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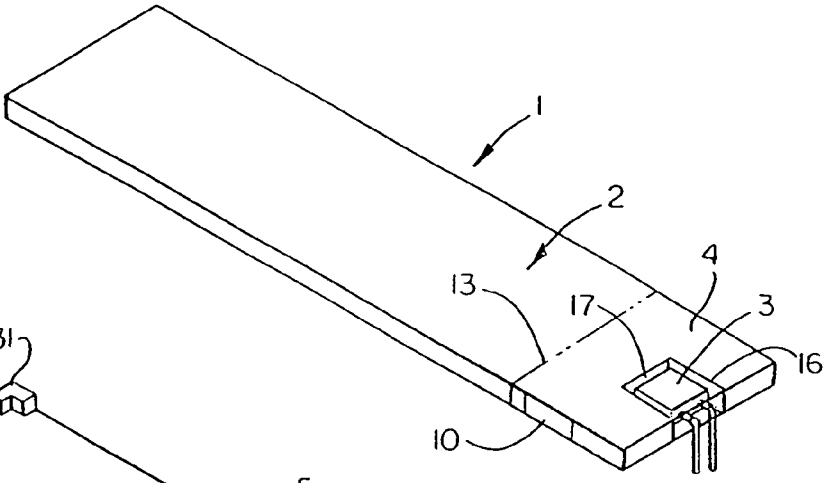

FIG. 1

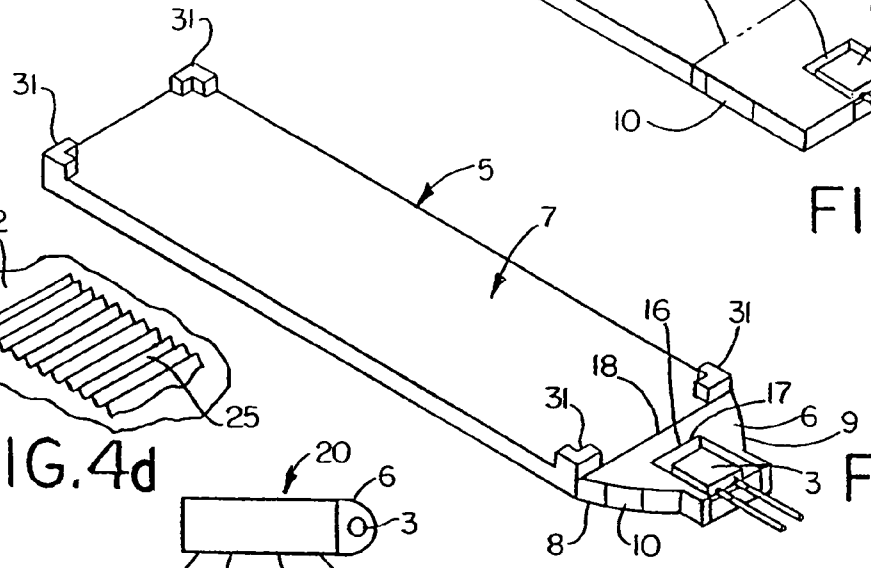

FIG. 2

FIG.4d

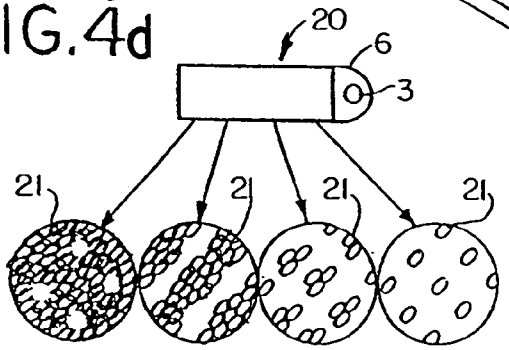

FIG. 4a

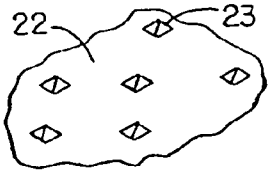

FIG. 4b

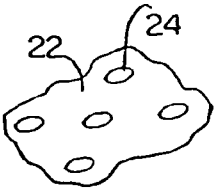

FIG. 4c

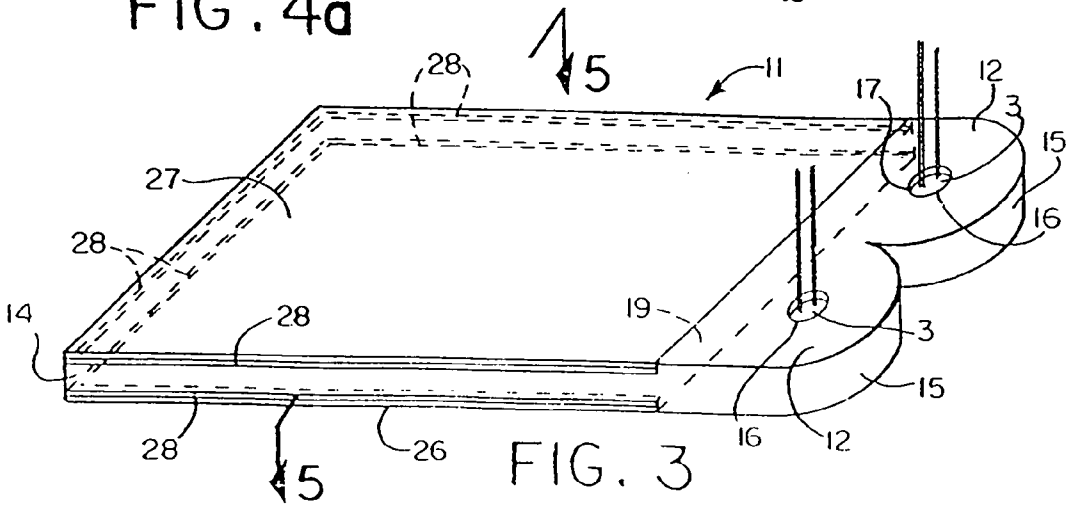

FIG. 3

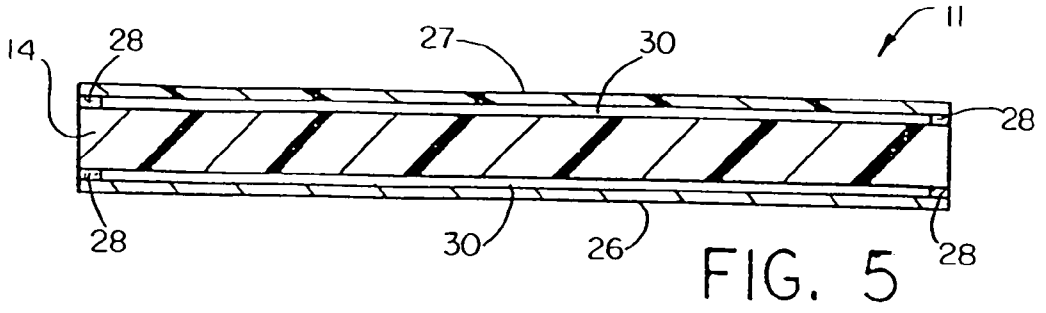

FIG. 5

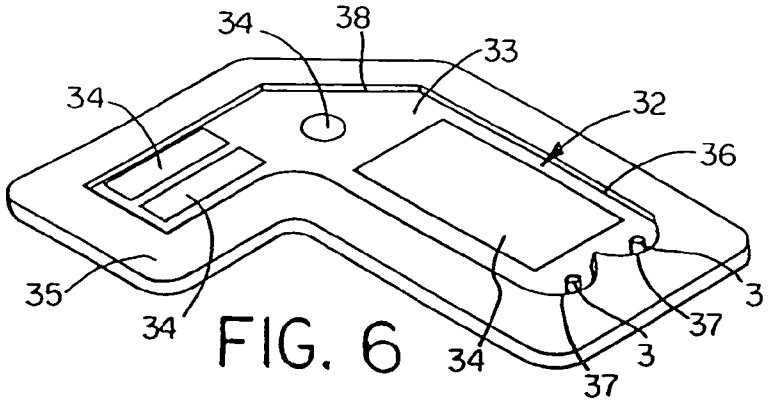

FIG. 6

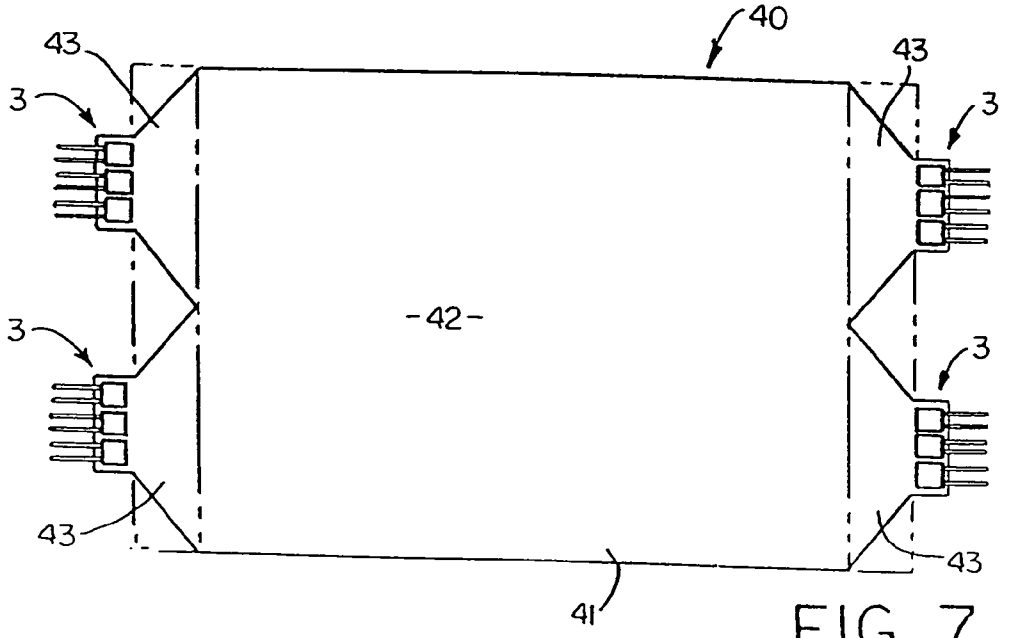

FIG. 7

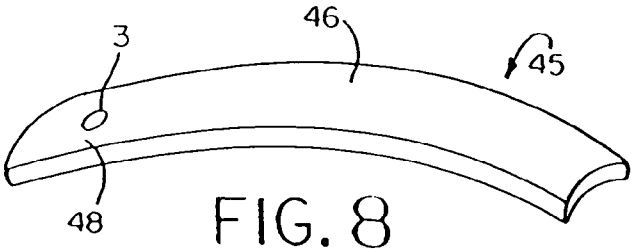

FIG. 8

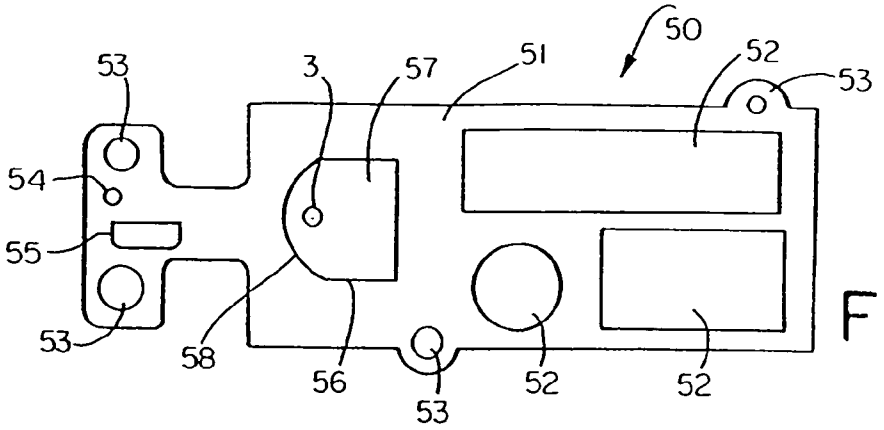

FIG. 9

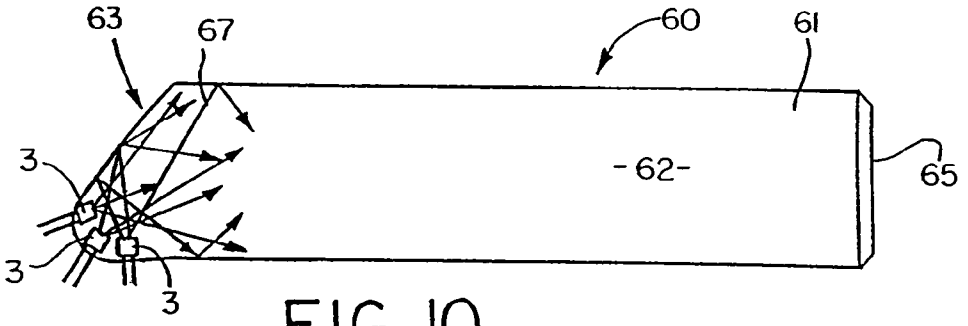

FIG. 10

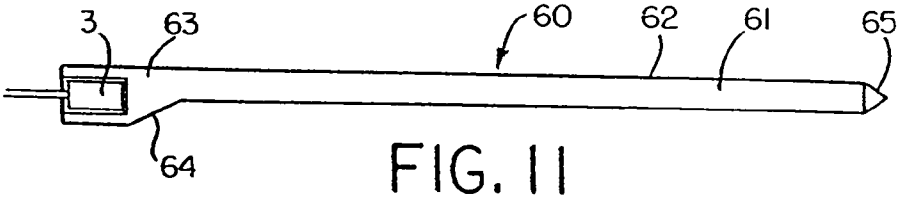

FIG. 11

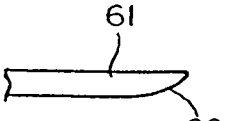

FIG. 11a

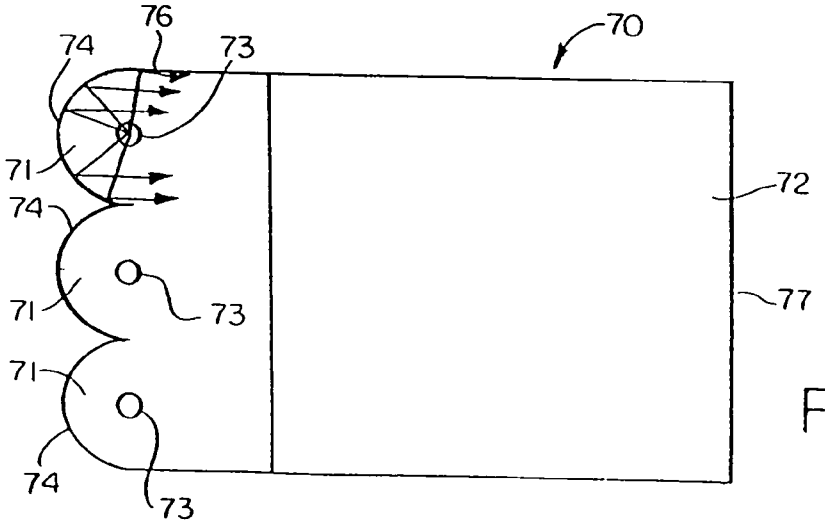

FIG. 12

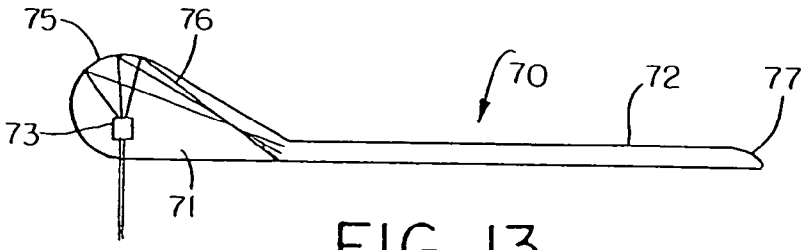

FIG. 13

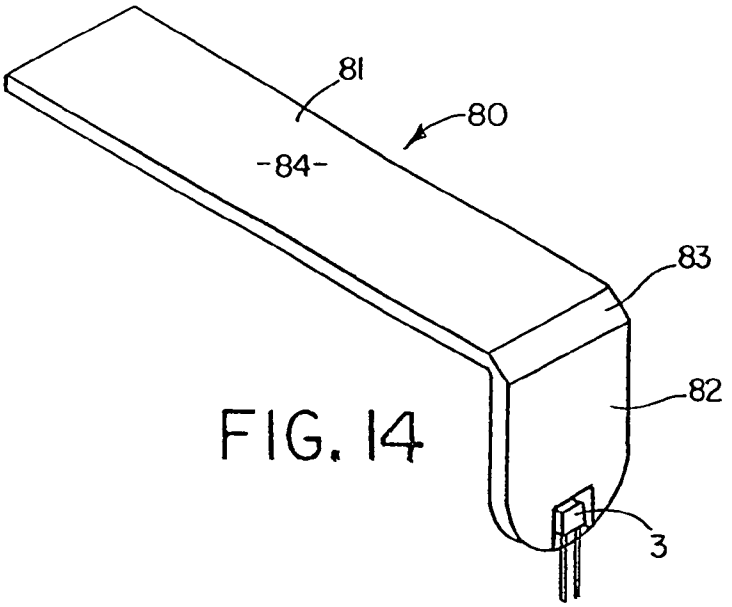

FIG. 14

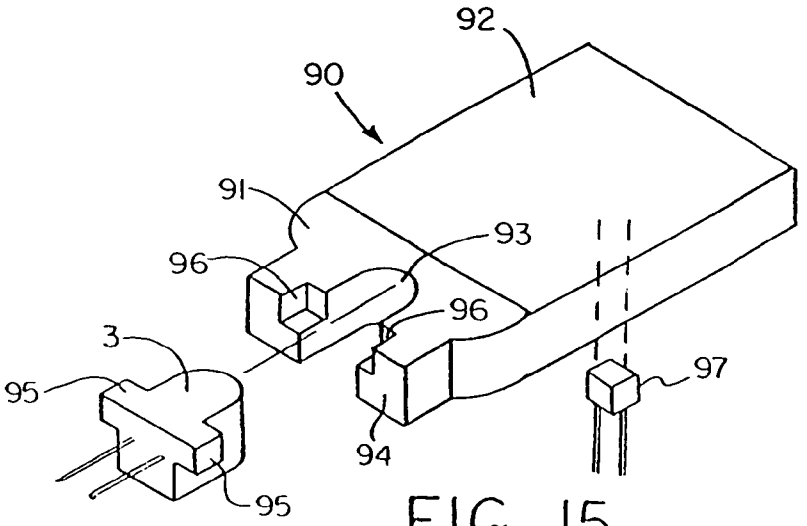

FIG. 15

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 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. **4***a* 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. **4***b, 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. **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**; 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 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, 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. **4***a* 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. **4***a* 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 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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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**. 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 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. **11***a*) 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 D

US007404660B2

(12) **United States Patent**
Parker

(10) **Patent No.: US 7,404,660 B2**
(45) **Date of Patent: Jul. 29, 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 0 days.

(21) Appl. No.: **11/454,822**

(22) Filed: **Jun. 16, 2006**

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(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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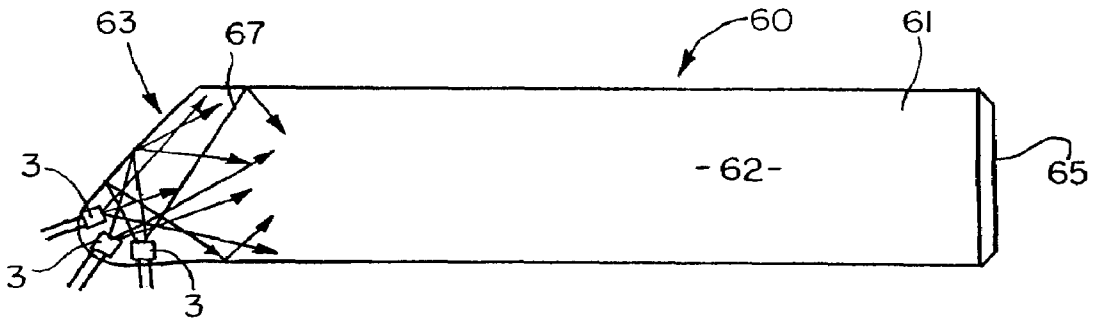
(57) **ABSTRACT**

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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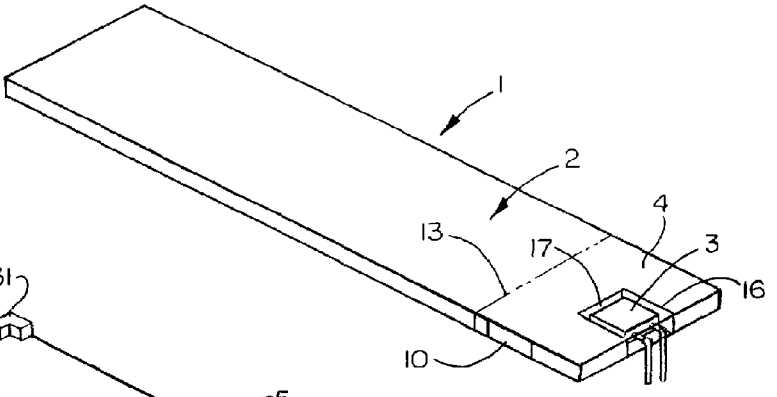

FIG. 1

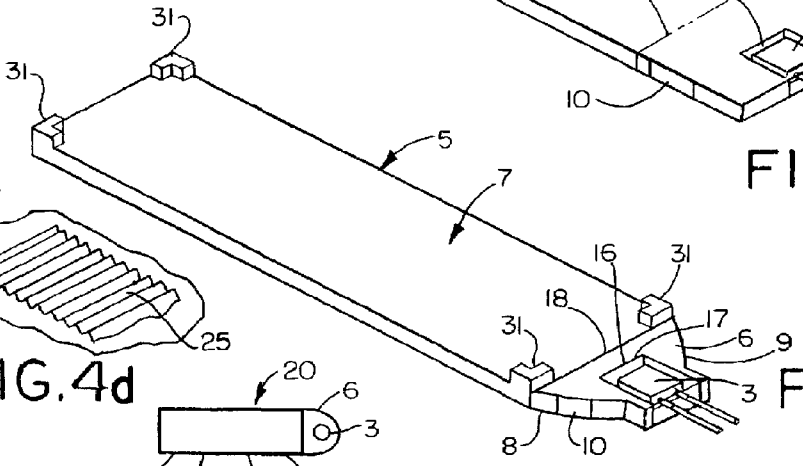

FIG. 2

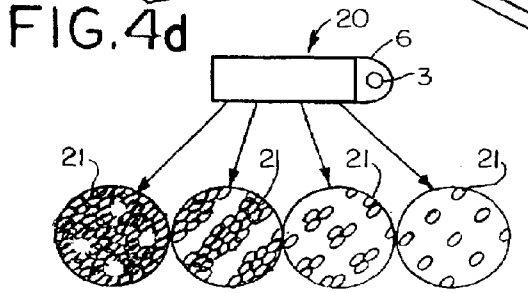

FIG. 4a

FIG. 4b

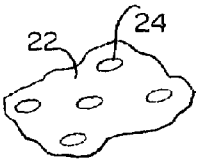

FIG. 4c

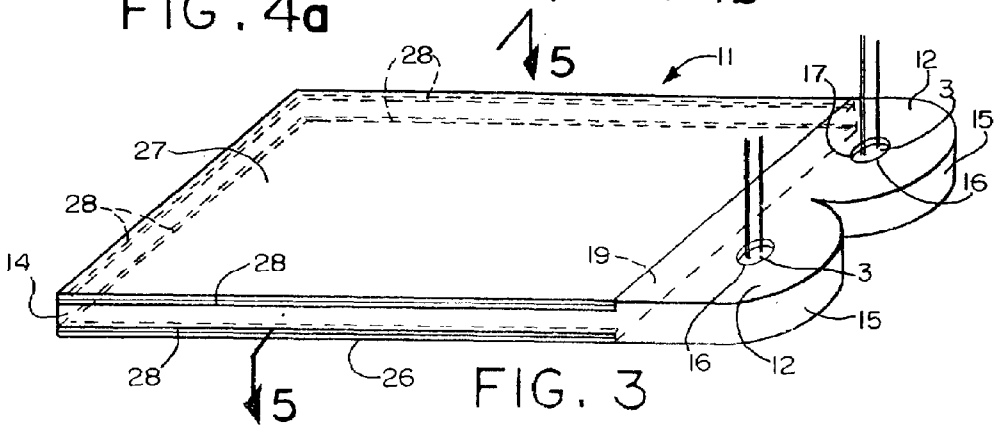

FIG. 3

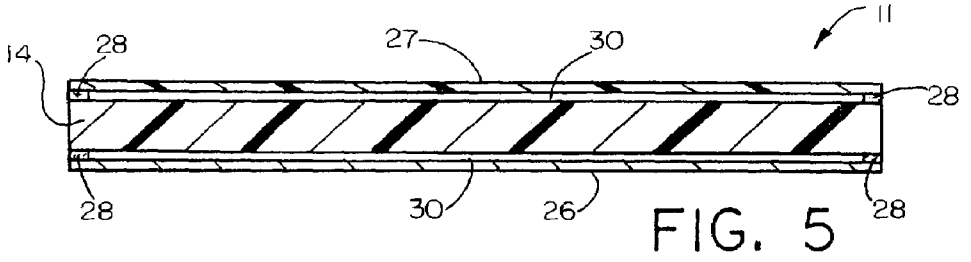

FIG. 5

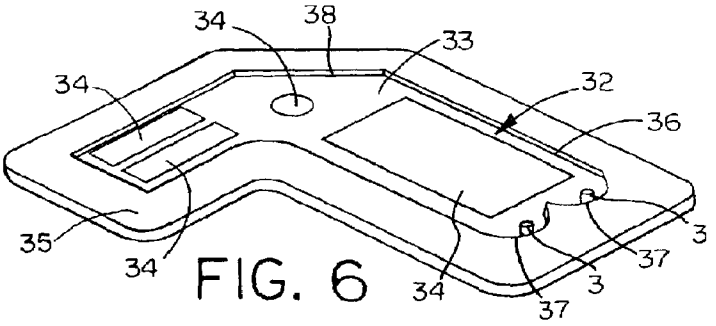

FIG. 6

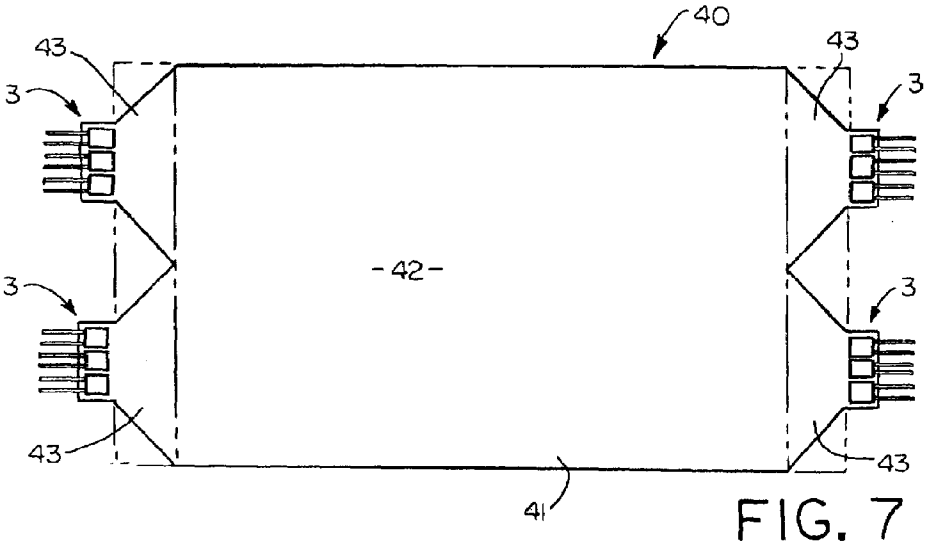

FIG. 7

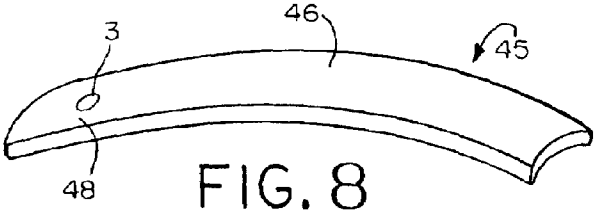

FIG. 8

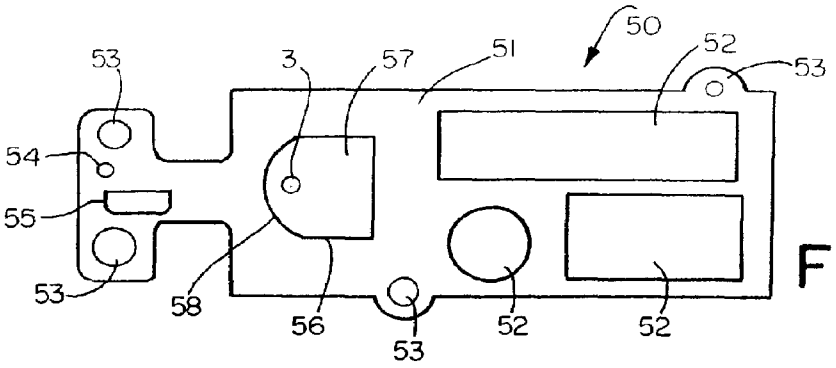

FIG. 9

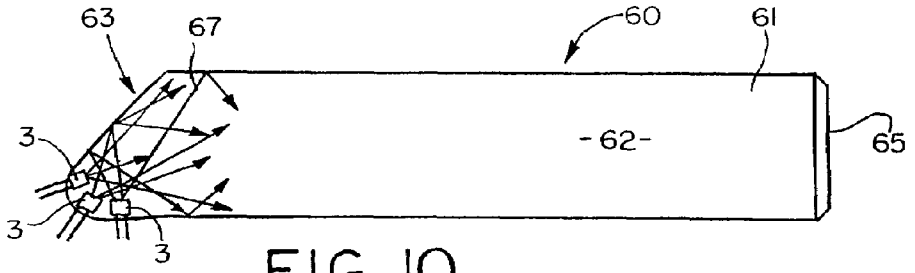

FIG. 10

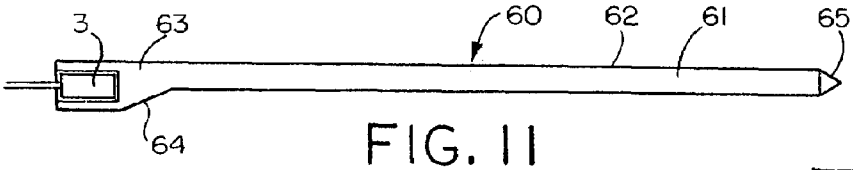

FIG. 11

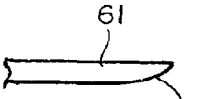

FIG. 11a

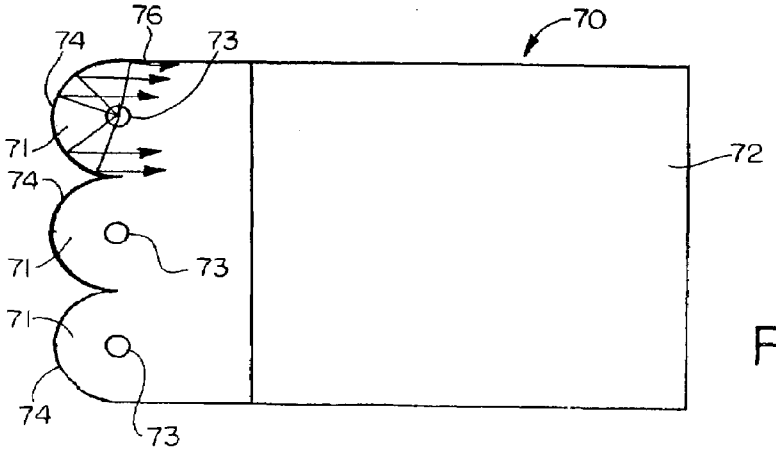

FIG. 12

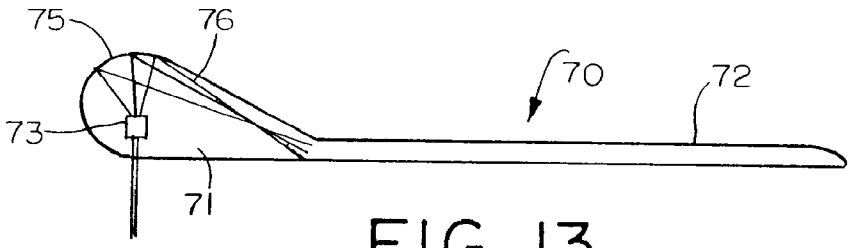

FIG. 13

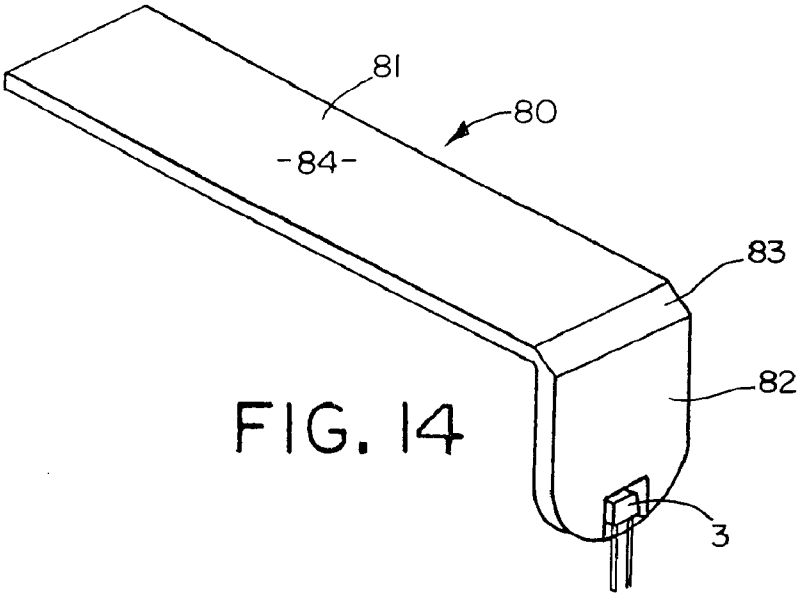

FIG. 14

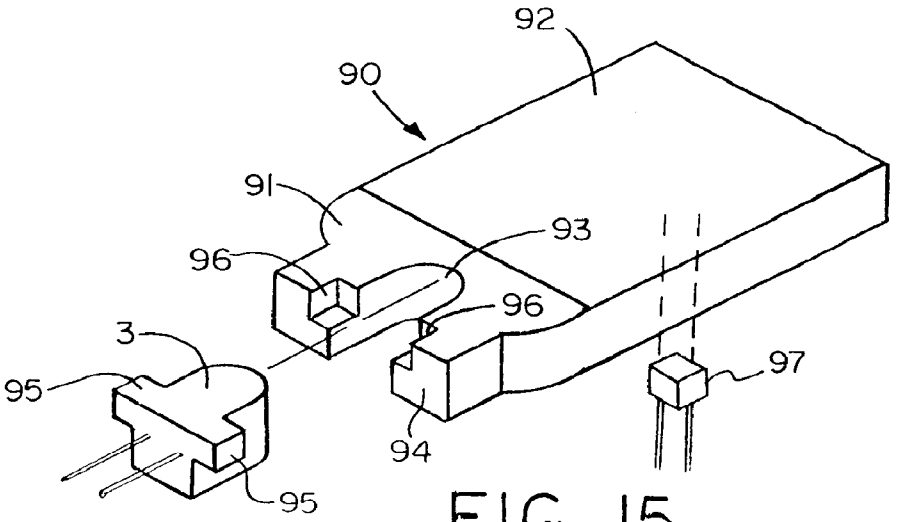

FIG. 15

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 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. **4***a* 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. **4***b, 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. **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**; 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 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, 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. **4***a* 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. **4***a* 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-

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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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**. 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-

termined 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. **11***a*) 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 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.

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

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 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 E

US007434974B2

(12) **United States Patent**
Parker

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(45) **Date of Patent: Oct. 14, 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 103 days.

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(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.

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

(52) **U.S. Cl.** **362/612**; 362/619; 362/632; 362/634

(58) **Field of Classification Search** 362/231, 362/800, 27, 619, 613, 612, 620, 608, 609, 362/621, 600, 632, 634, 26
See application file for complete search history.

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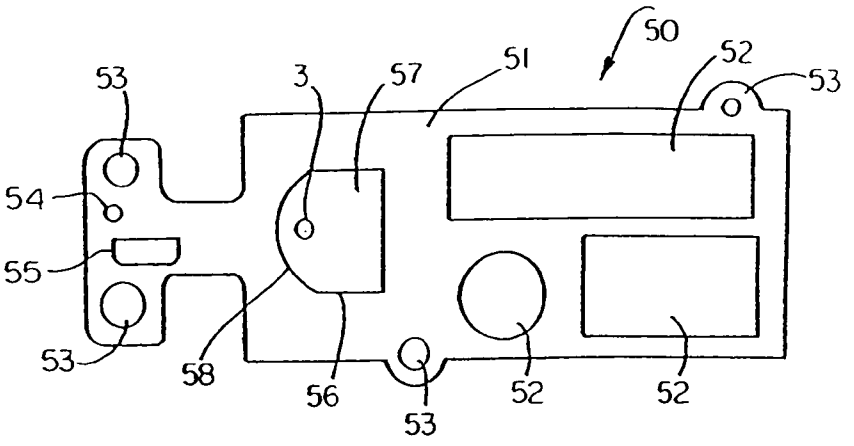
(57) **ABSTRACT**

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.

24 Claims, 4 Drawing Sheets



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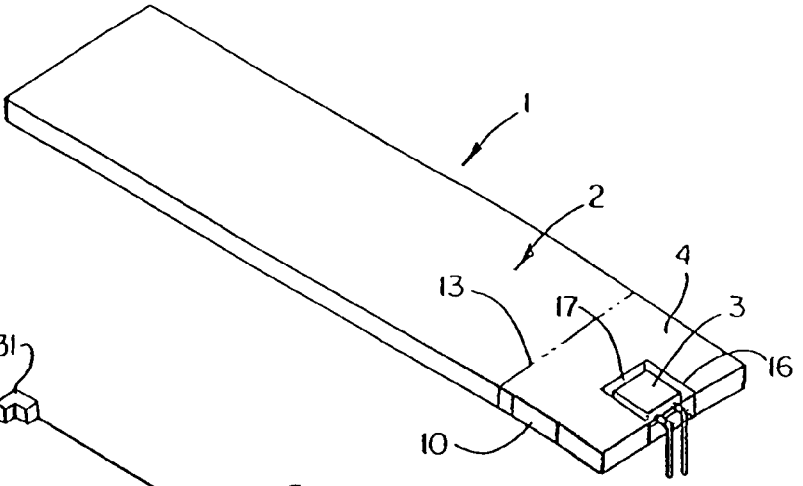


FIG. 1

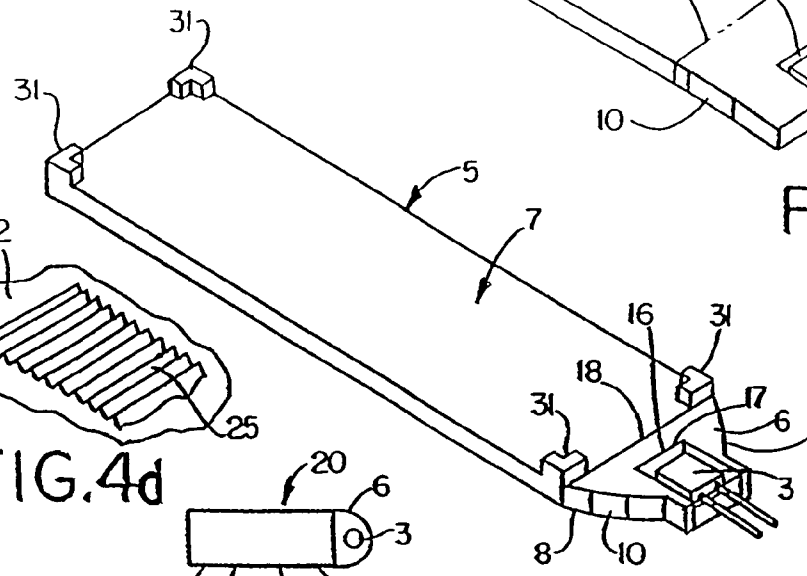


FIG. 2

FIG.4d

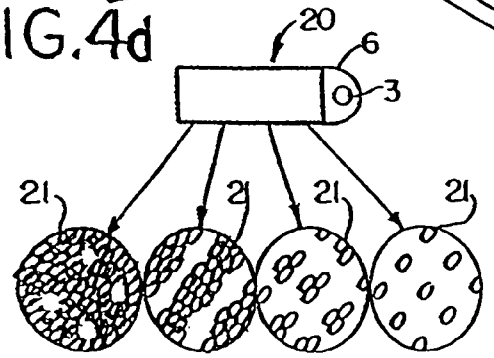


FIG.4a

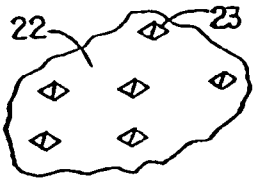


FIG.4b

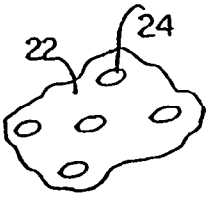


FIG.4c

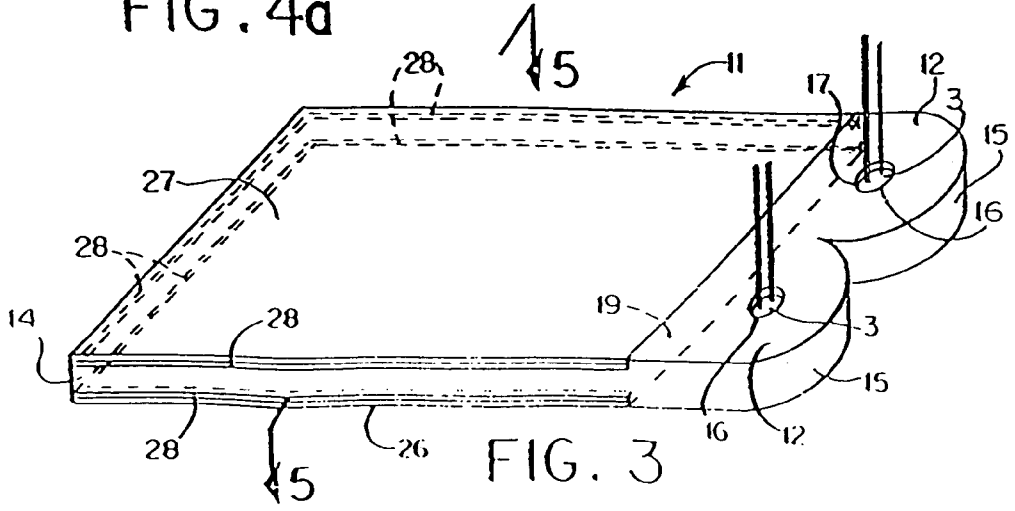


FIG. 3

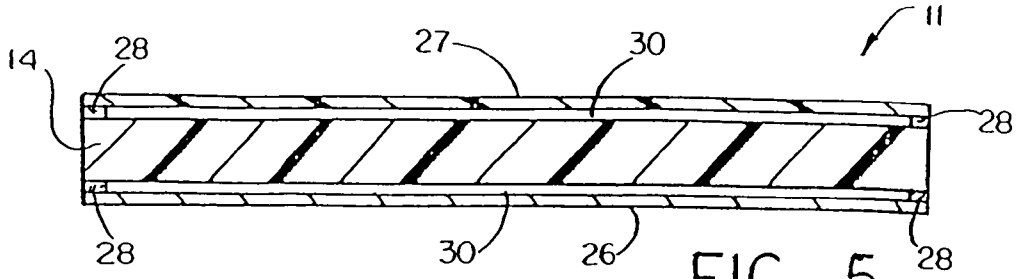


FIG. 5

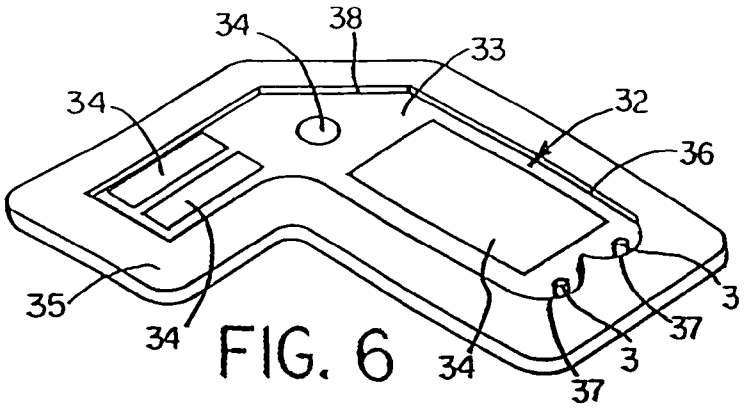


FIG. 6

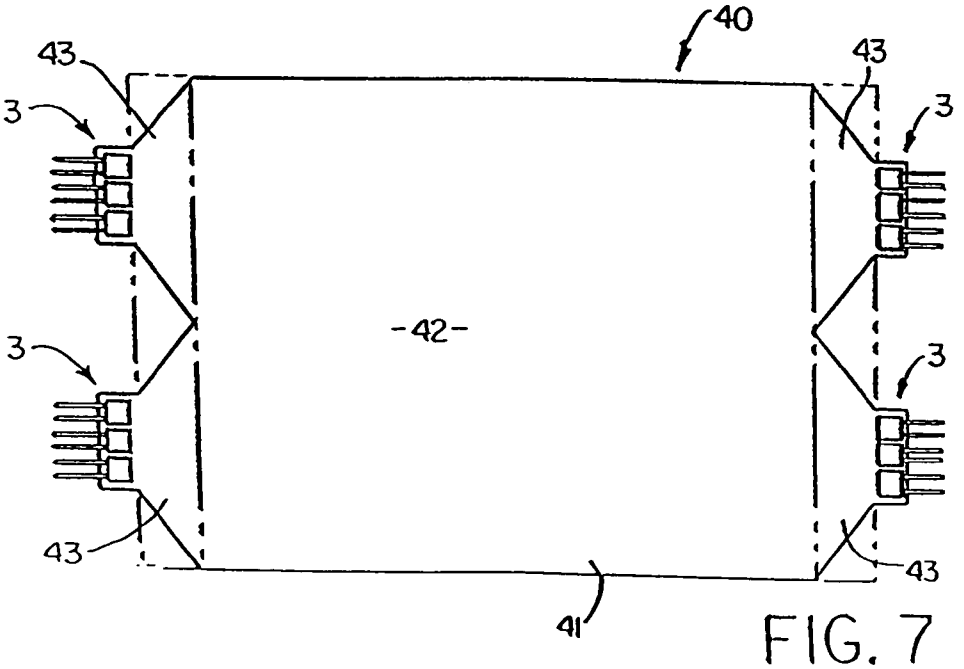


FIG. 7

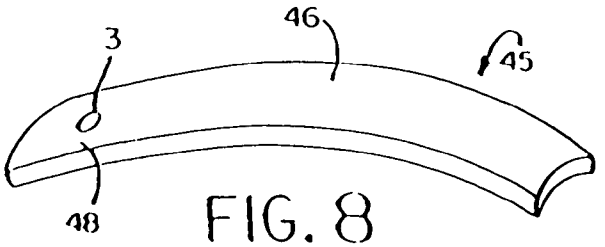


FIG. 8

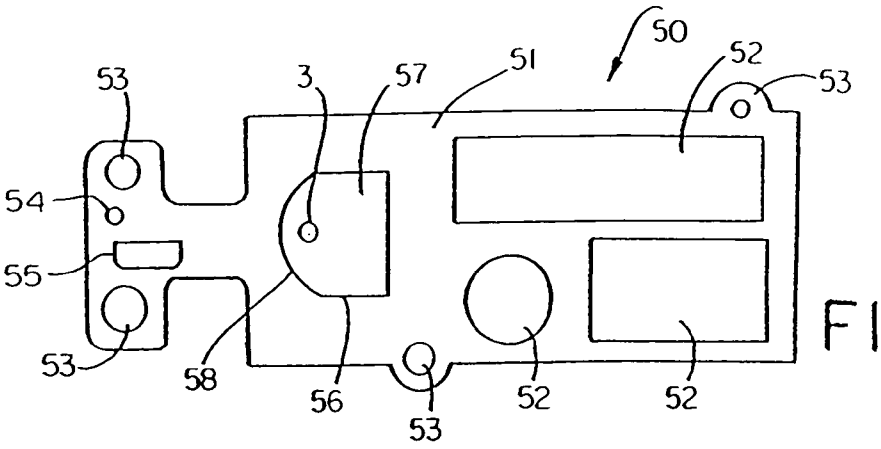


FIG. 9

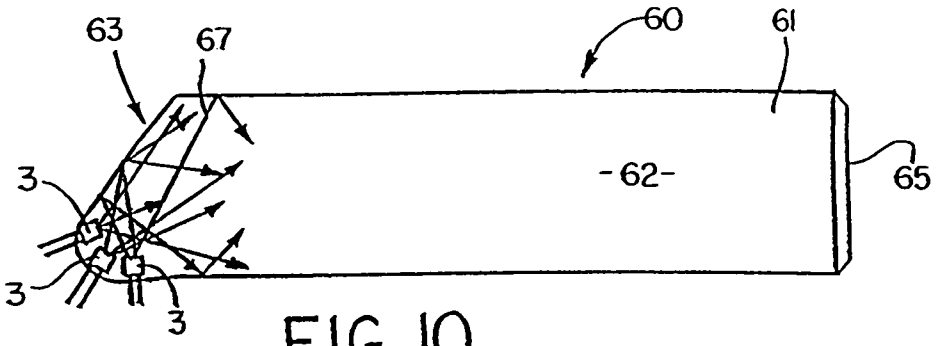


FIG. 10

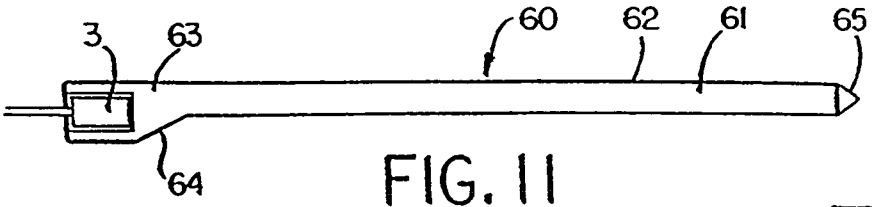


FIG. 11

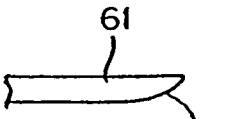


FIG. 11a

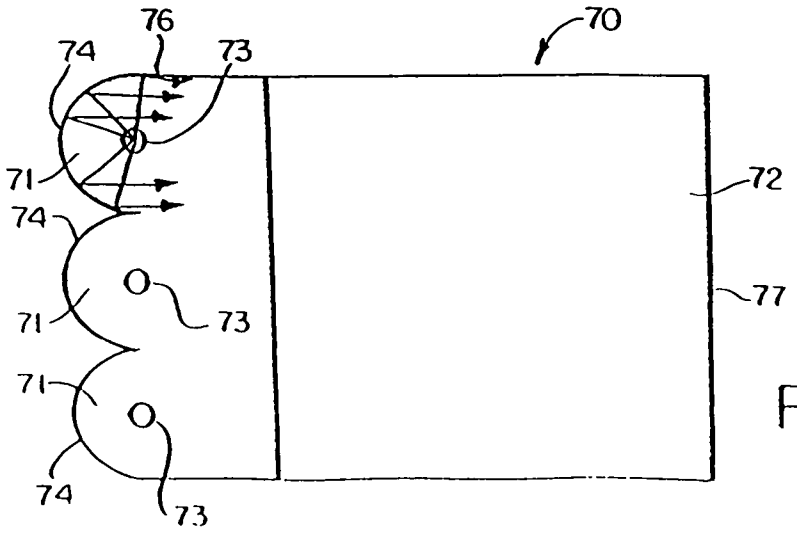


FIG. 12

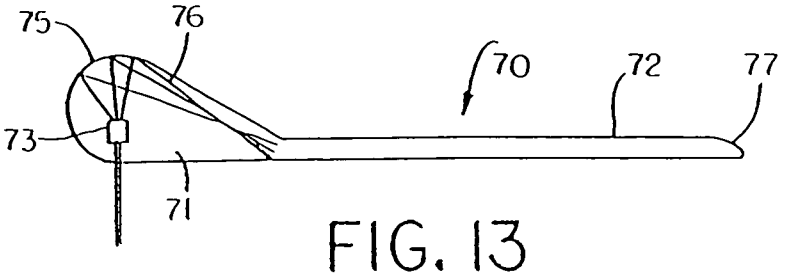


FIG. 13

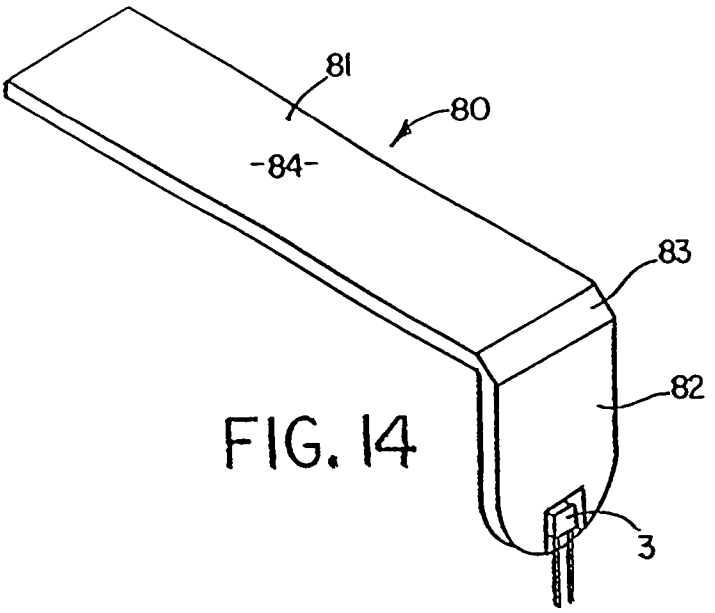


FIG. 14

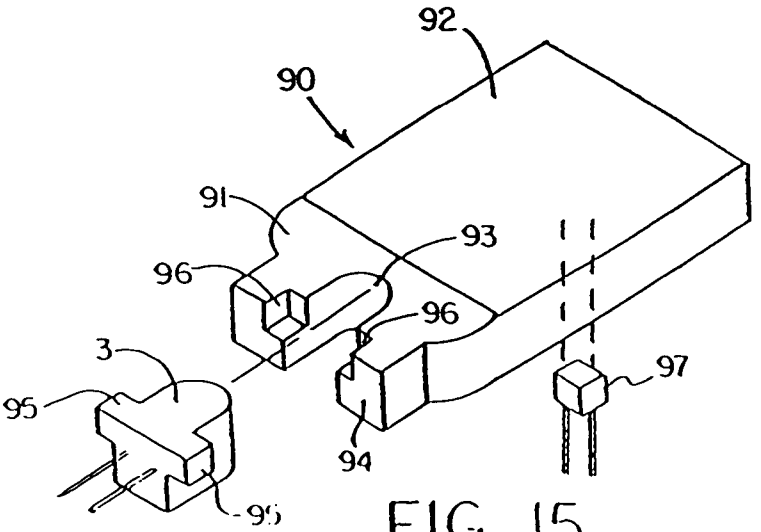


FIG. 15

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 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. **4***a* 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. **4***b, 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. **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**; 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

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, 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. **4***a* 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. **4***a* 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-

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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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 moiréor 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-

termined 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. **11***a*) 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 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.

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.

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.

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

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

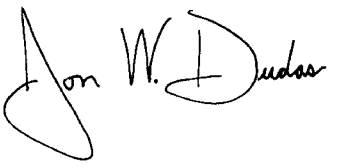
PATENT NO. : 7,434,974 B2
APPLICATION NO. : 11/378080
DATED : October 14, 2008
INVENTOR(S) : Jeffery R. Parker

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



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

EXHIBIT F

US007537370B2

(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**

(22) Filed: **Oct. 11, 2006**

(65) **Prior Publication Data**

US 2007/0153549 A1 Jul. 5, 2007

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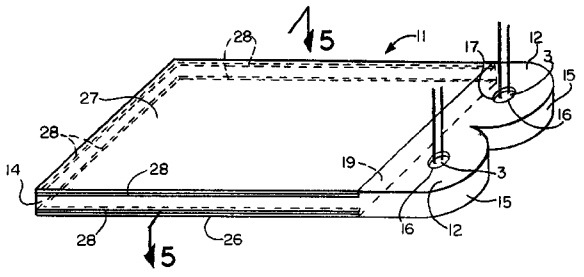
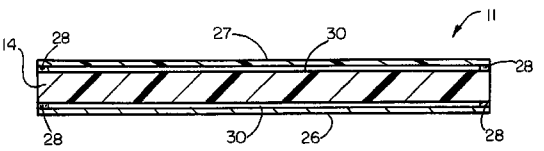
Primary Examiner—Thomas M Sember
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(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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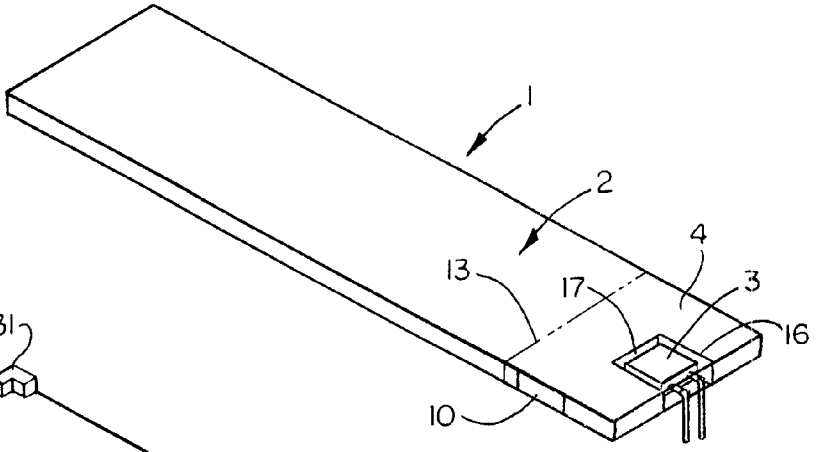

FIG. 1

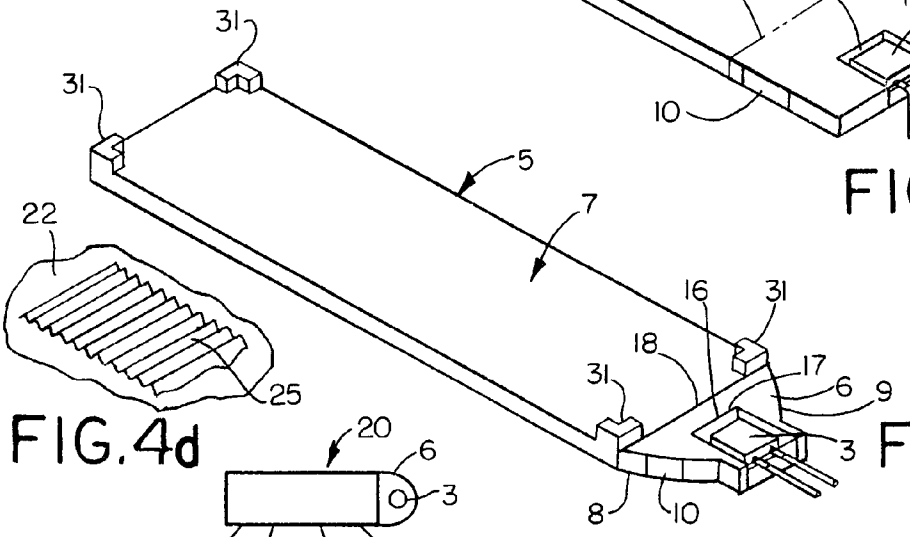

FIG. 2

FIG. 4d

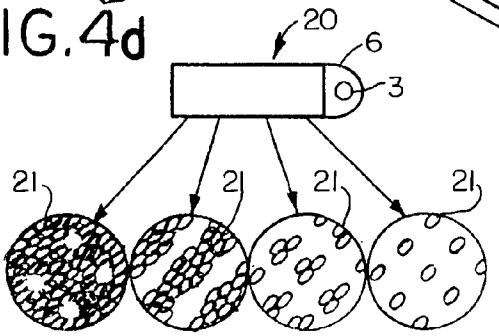

FIG. 4a

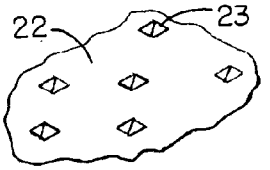

FIG. 4b

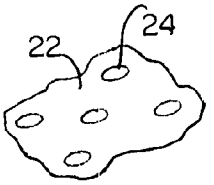

FIG. 4c

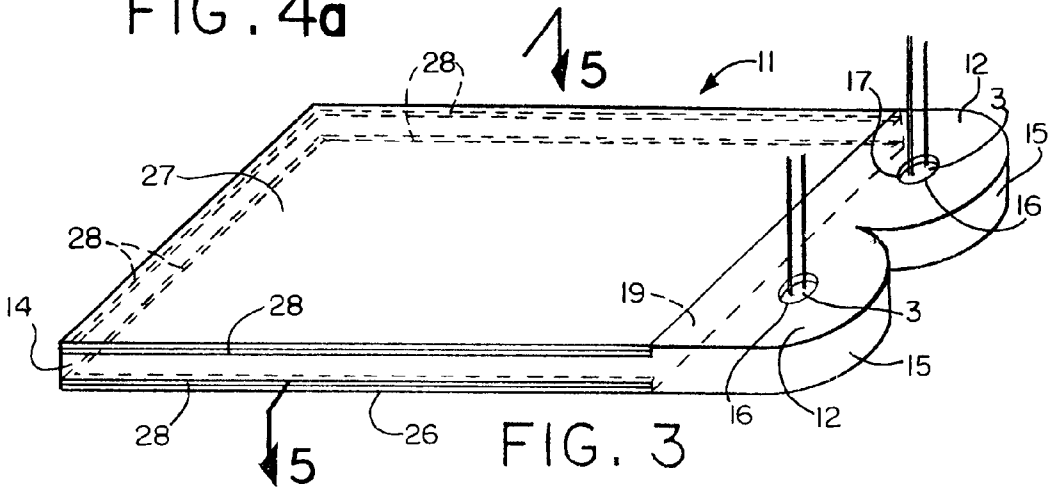

FIG. 3

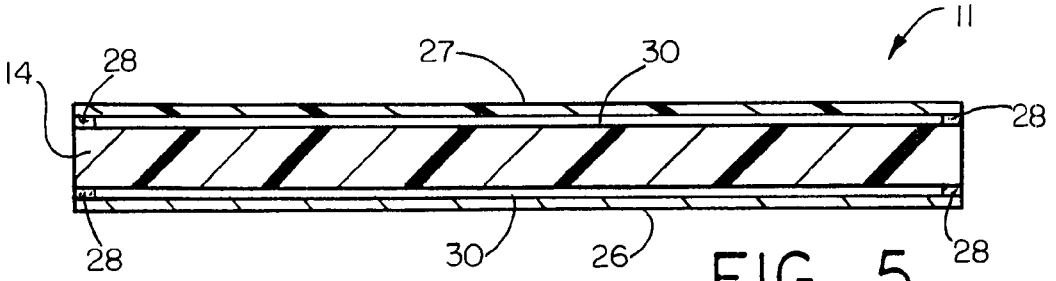

FIG. 5

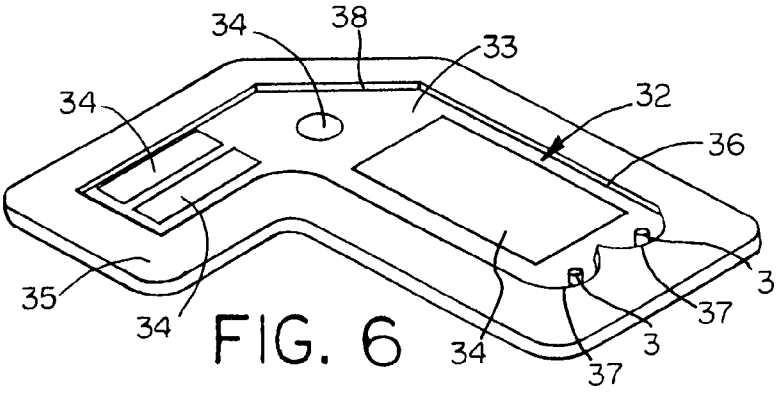

FIG. 6

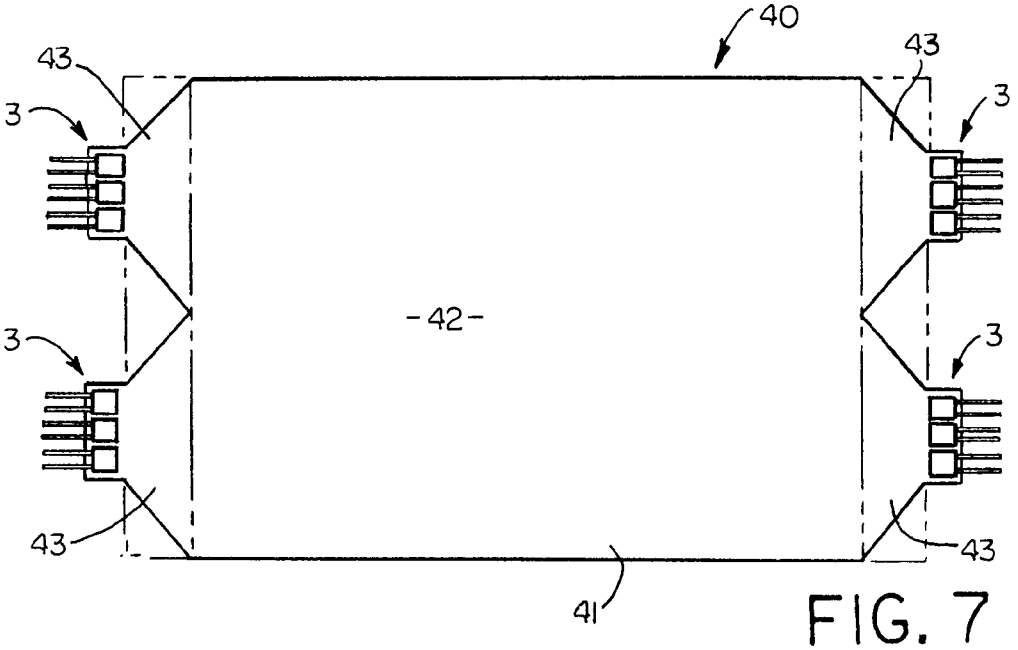

FIG. 7

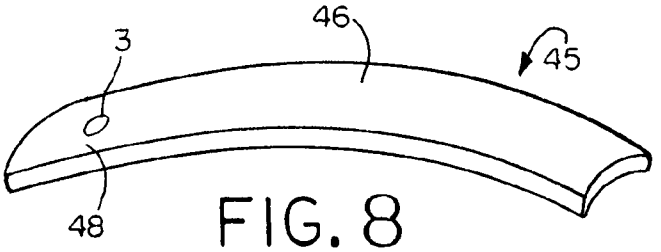

FIG. 8

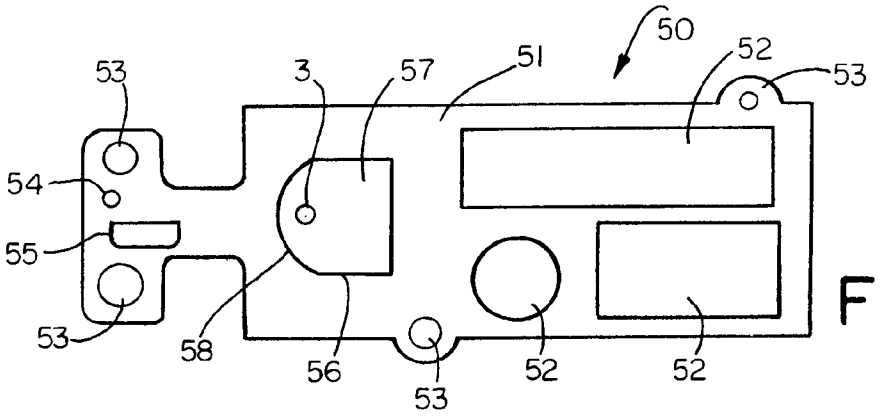

FIG. 9

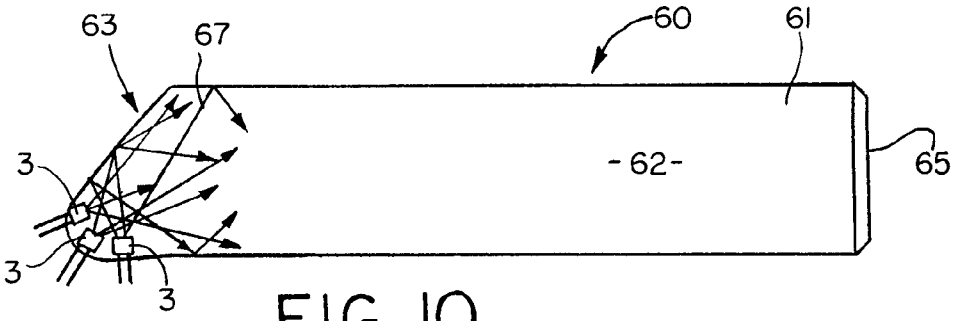

FIG. 10

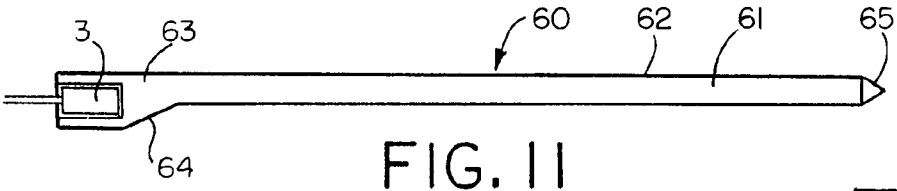

FIG. 11

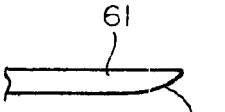

FIG. 11a

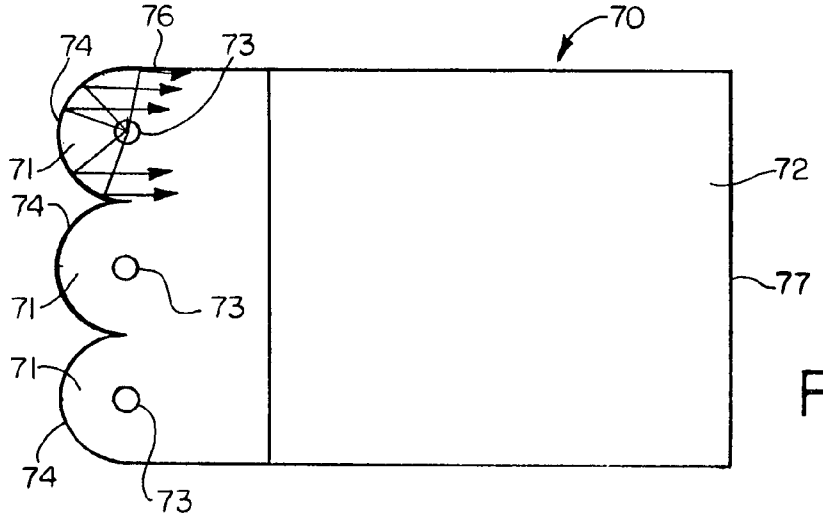

FIG. 12

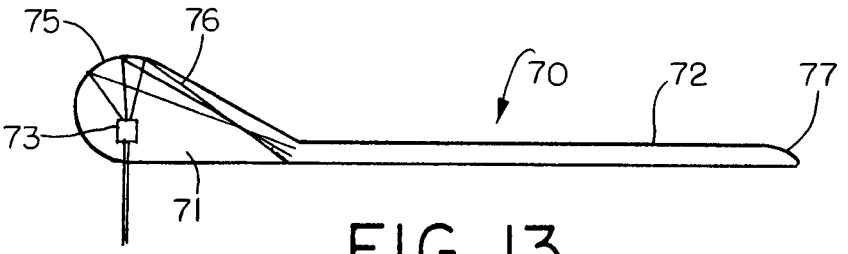

FIG. 13

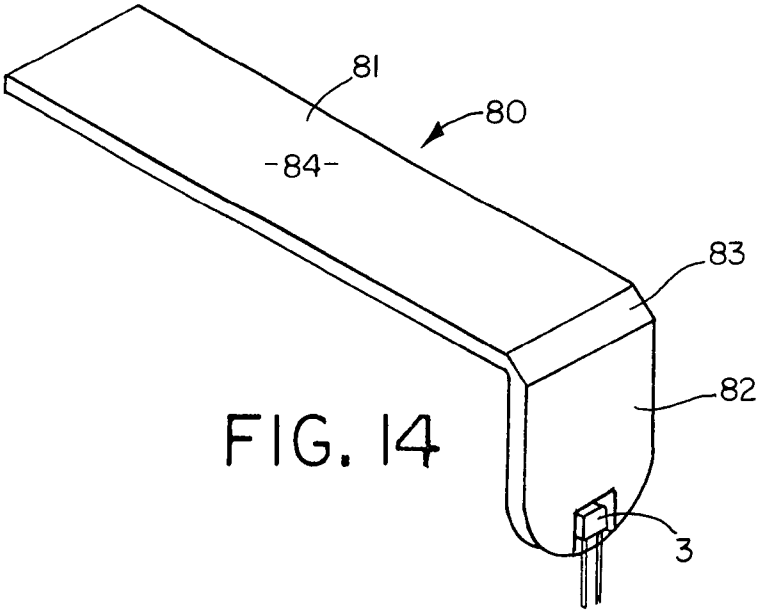

FIG. 14

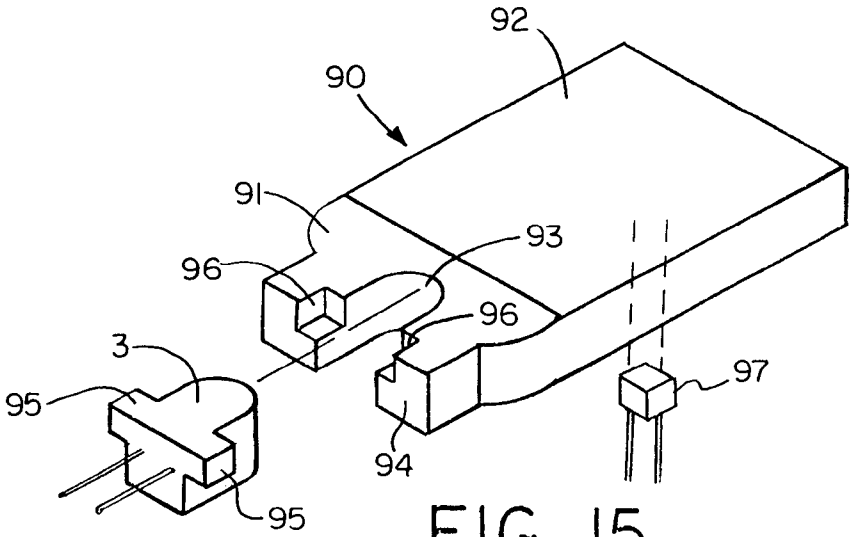

FIG. 15

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 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. **4***a* 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. **4***b, 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. **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**; 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

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, 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. **4***a* 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. **4***a* 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-

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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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 moire 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-

termined 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. **11***a*) 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 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 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

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.

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 G

US008215816B2

(12) **United States Patent**
Parker

(10) **Patent No.: US 8,215,816 B2**
(45) **Date of Patent: *Jul. 10, 2012**

(54) **LIGHT EMITTING PANEL ASSEMBLIES**

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

(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 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/315,412**

(22) Filed: **Dec. 9, 2011**

(65) **Prior Publication Data**

US 2012/0081921 A1 Apr. 5, 2012

Related U.S. Application Data

(60) Continuation of application No. 12/940,424, filed on Nov. 5, 2010, now Pat. No. 8,142,063, which is a continuation of application No. 12/488,617, filed on Jun. 22, 2009, now abandoned, which is a continuation of application No. 12/246,613, filed on Oct. 7, 2008, now abandoned, which is a division of application No. 11/504,203, filed on Aug. 15, 2006, now Pat. No. 7,467,887, which is a 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.

(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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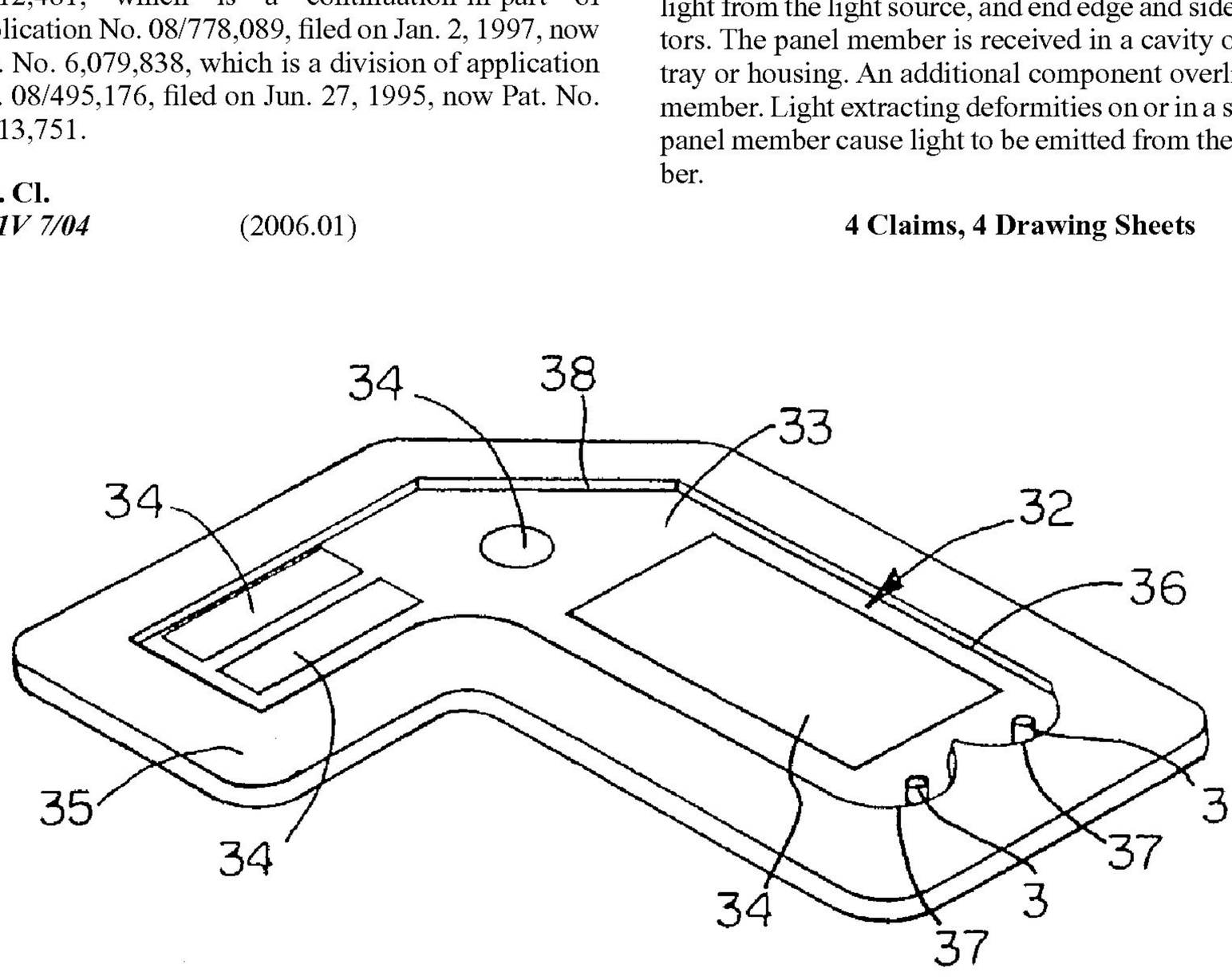
(57) **ABSTRACT**

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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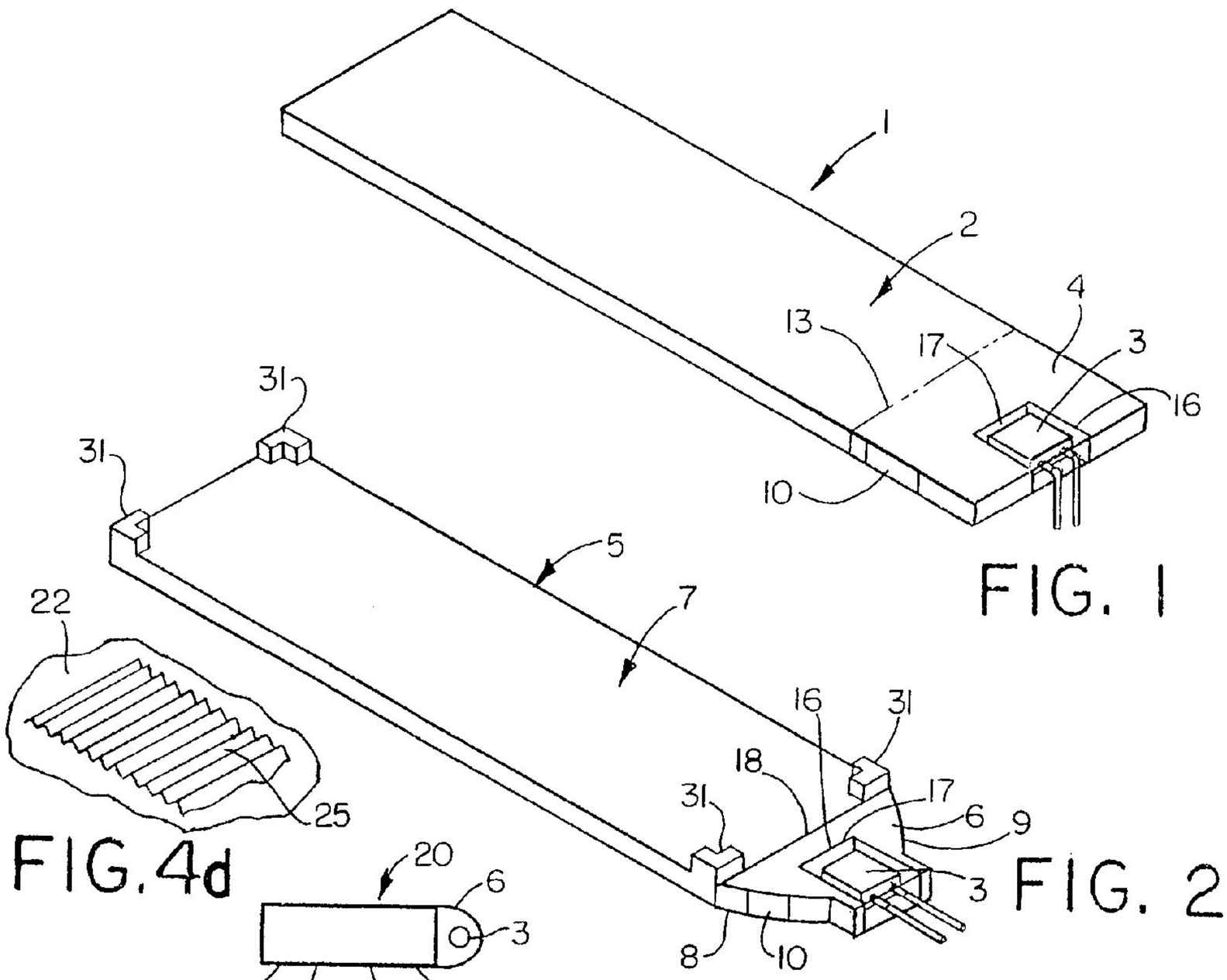


FIG. 1

FIG. 2

FIG. 4d

FIG. 4a

FIG. 4b

FIG. 4c

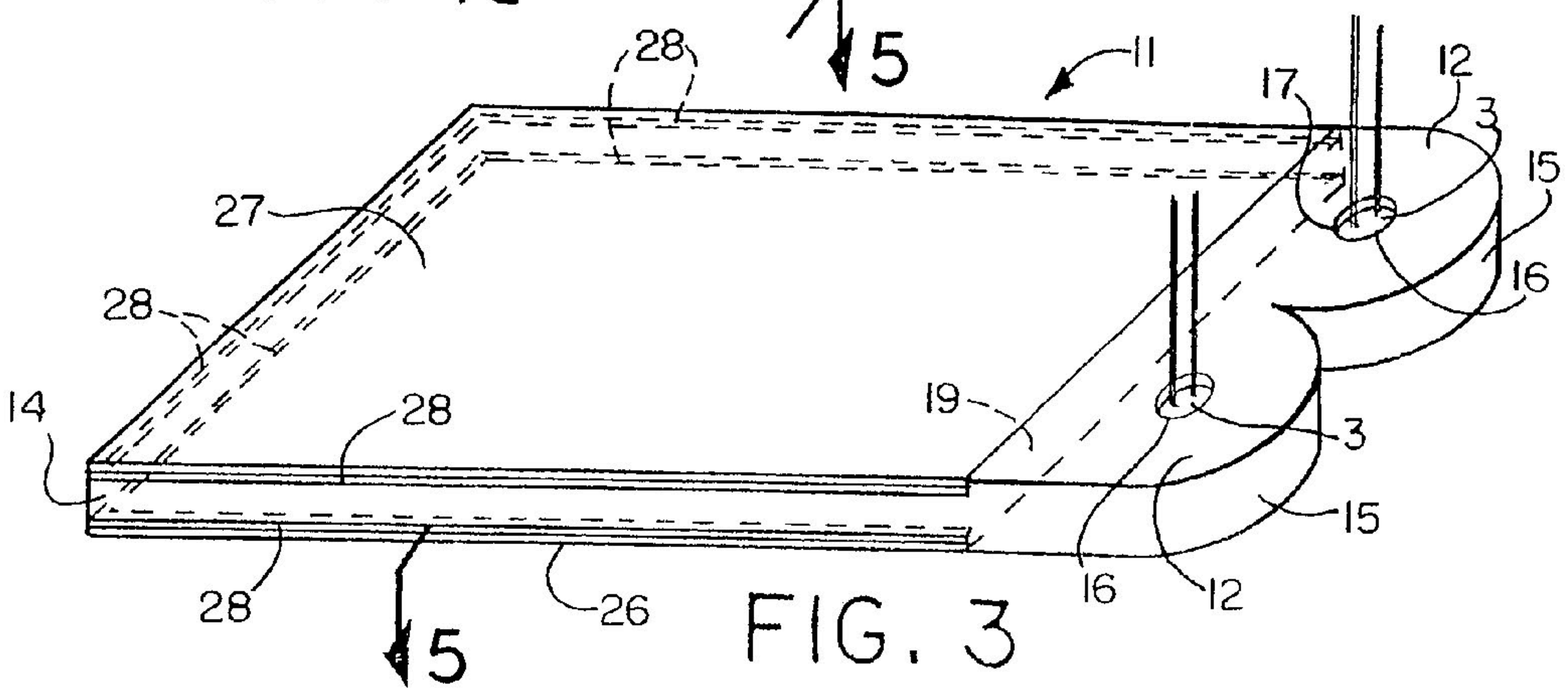


FIG. 3

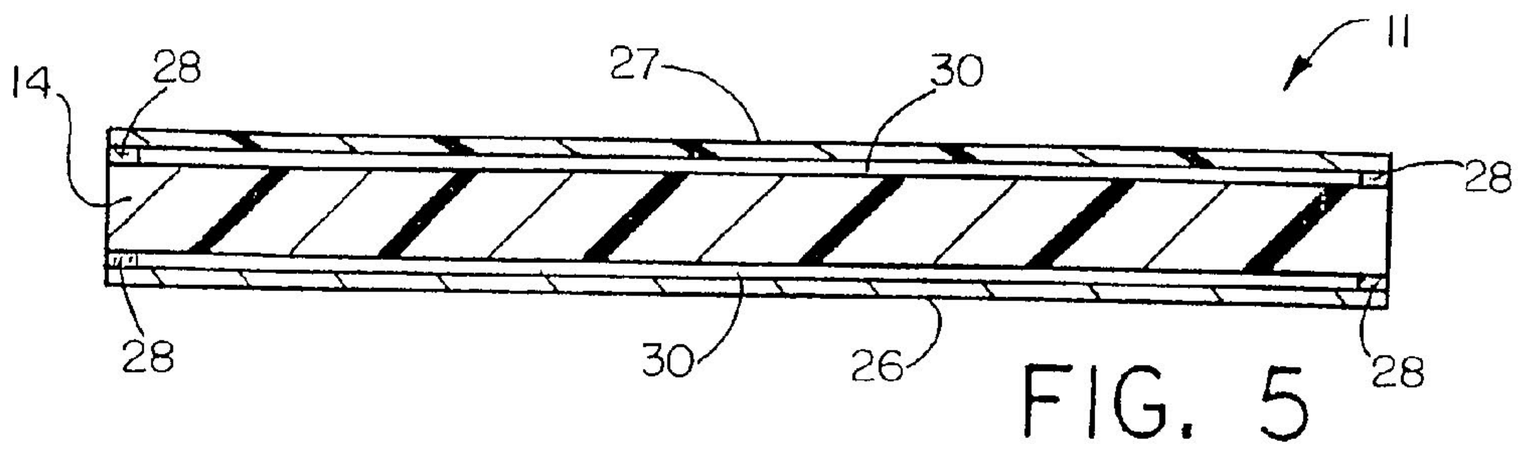


FIG. 5

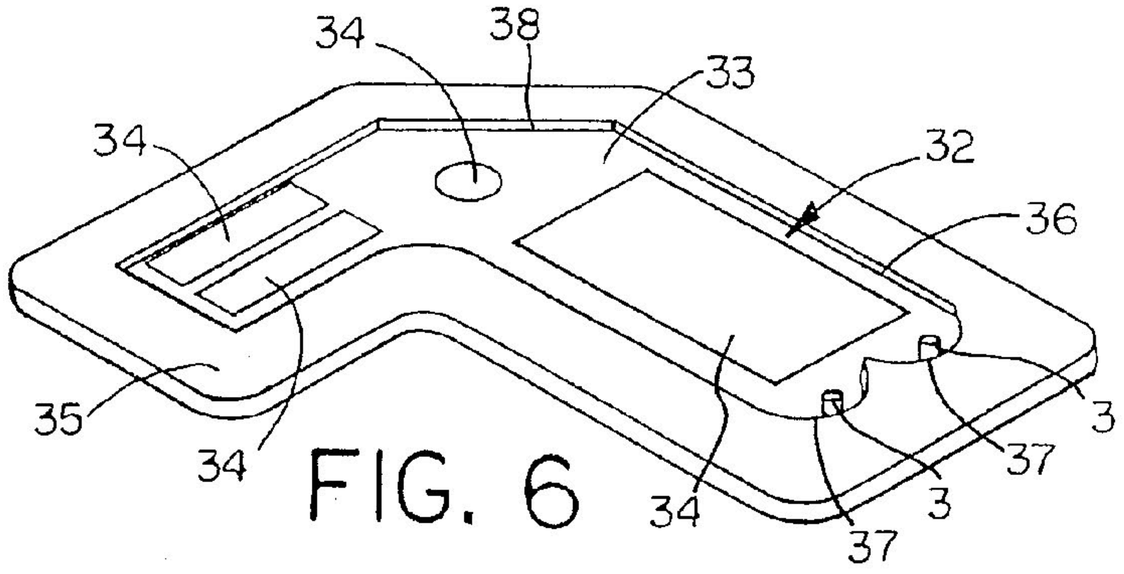


FIG. 6

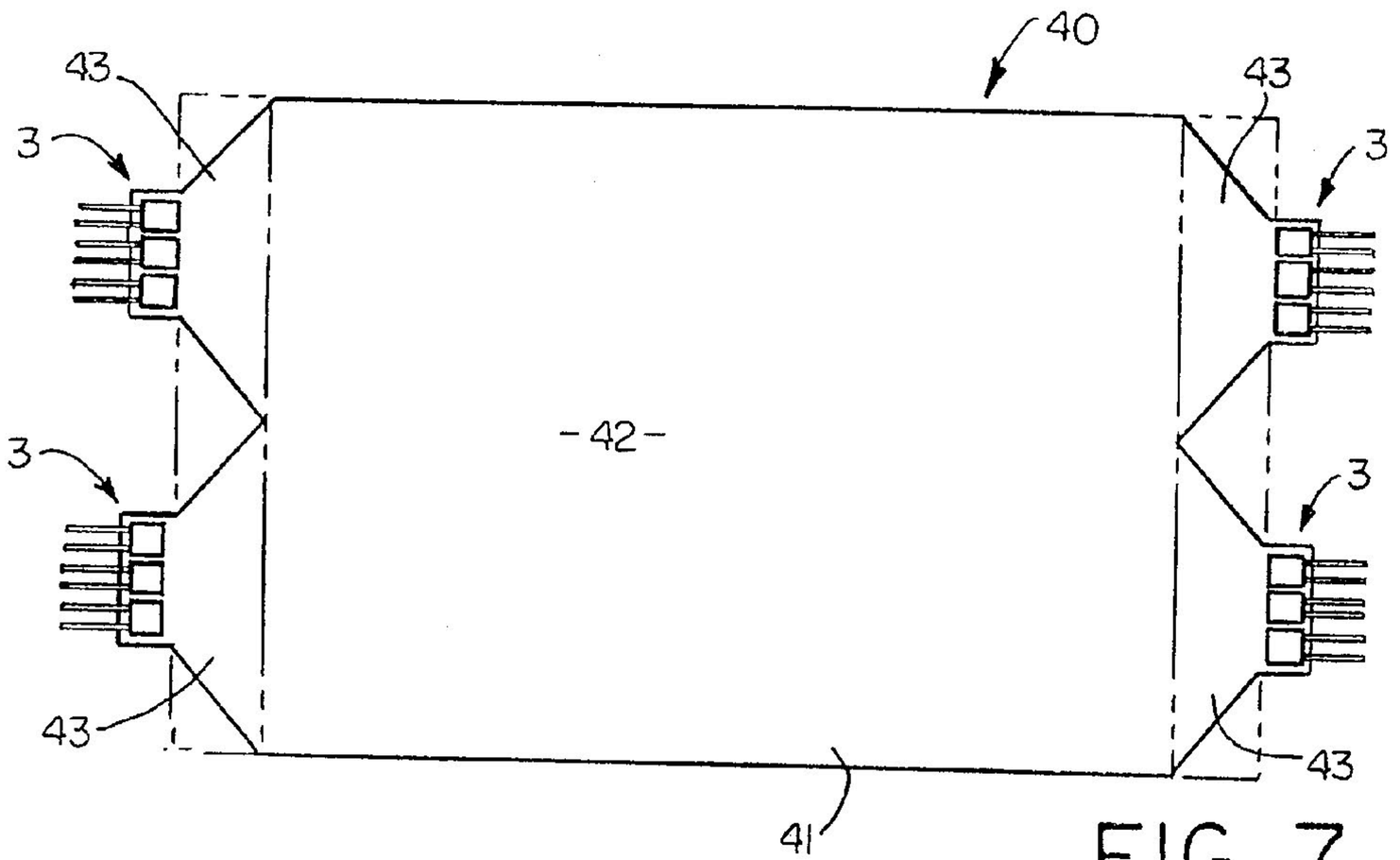


FIG. 7

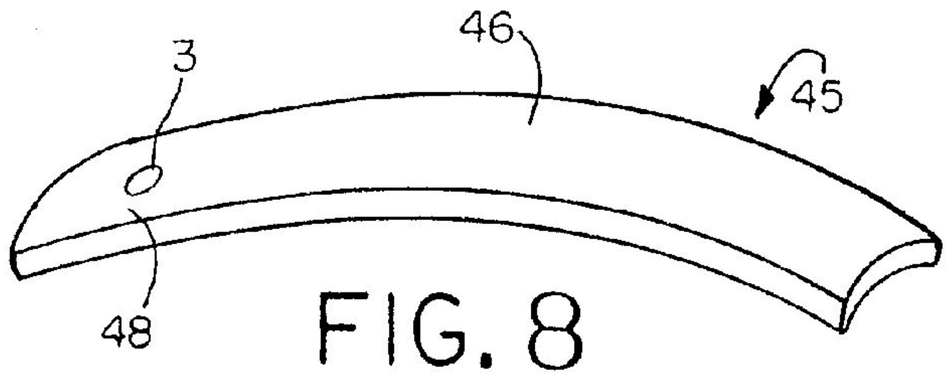


FIG. 8

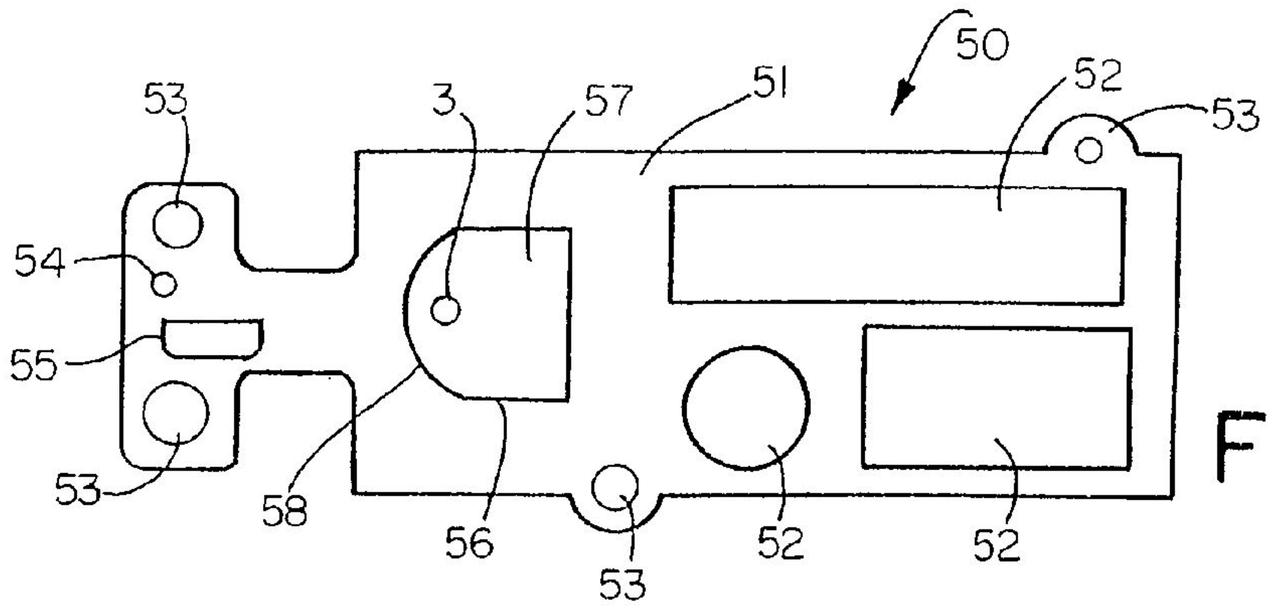
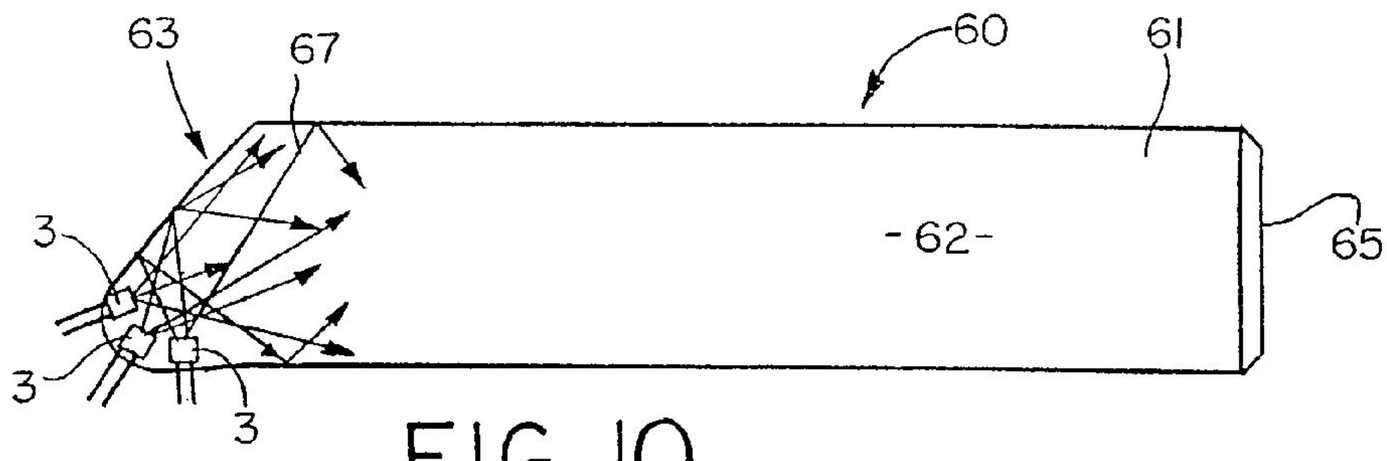


FIG. 9



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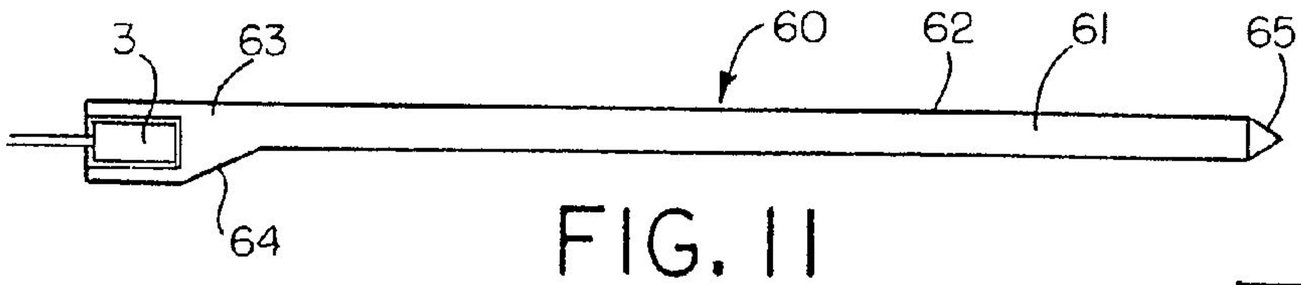


FIG. 11

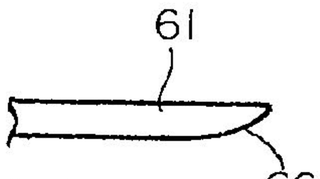
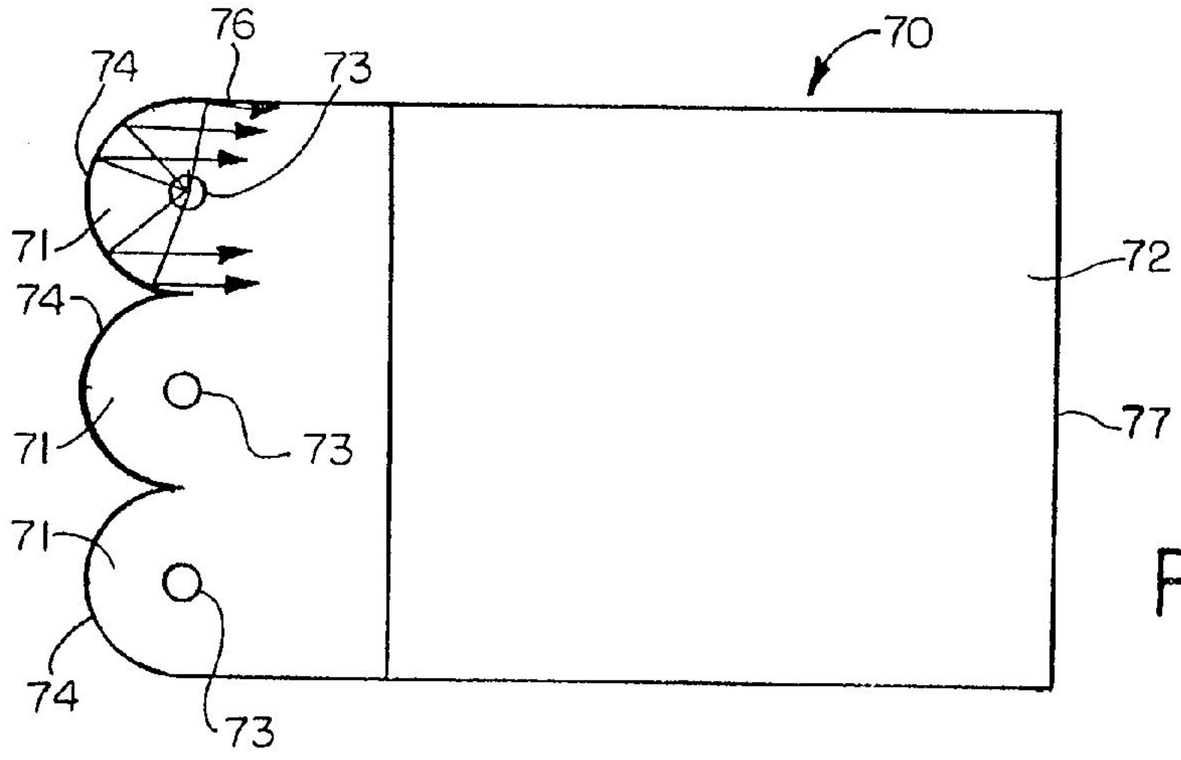


FIG. 11a



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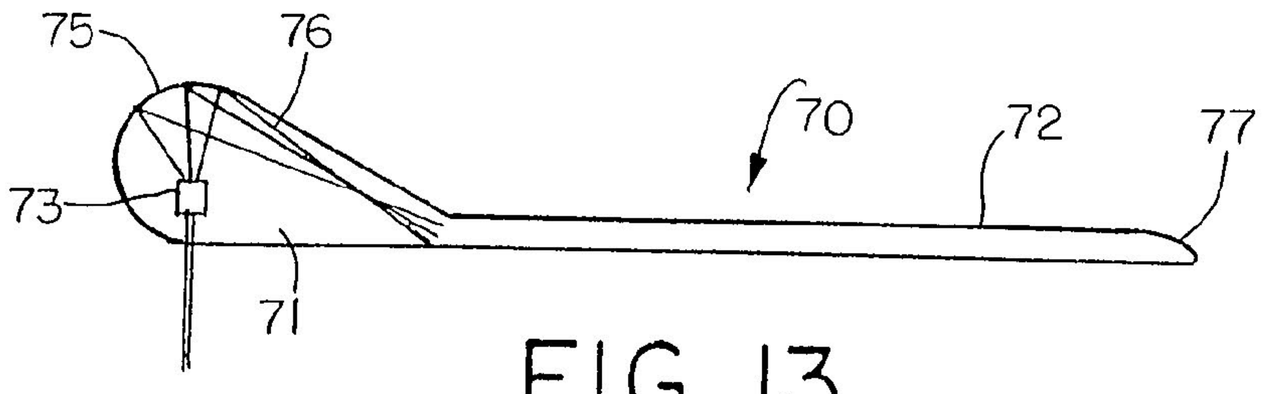

FIG. 13

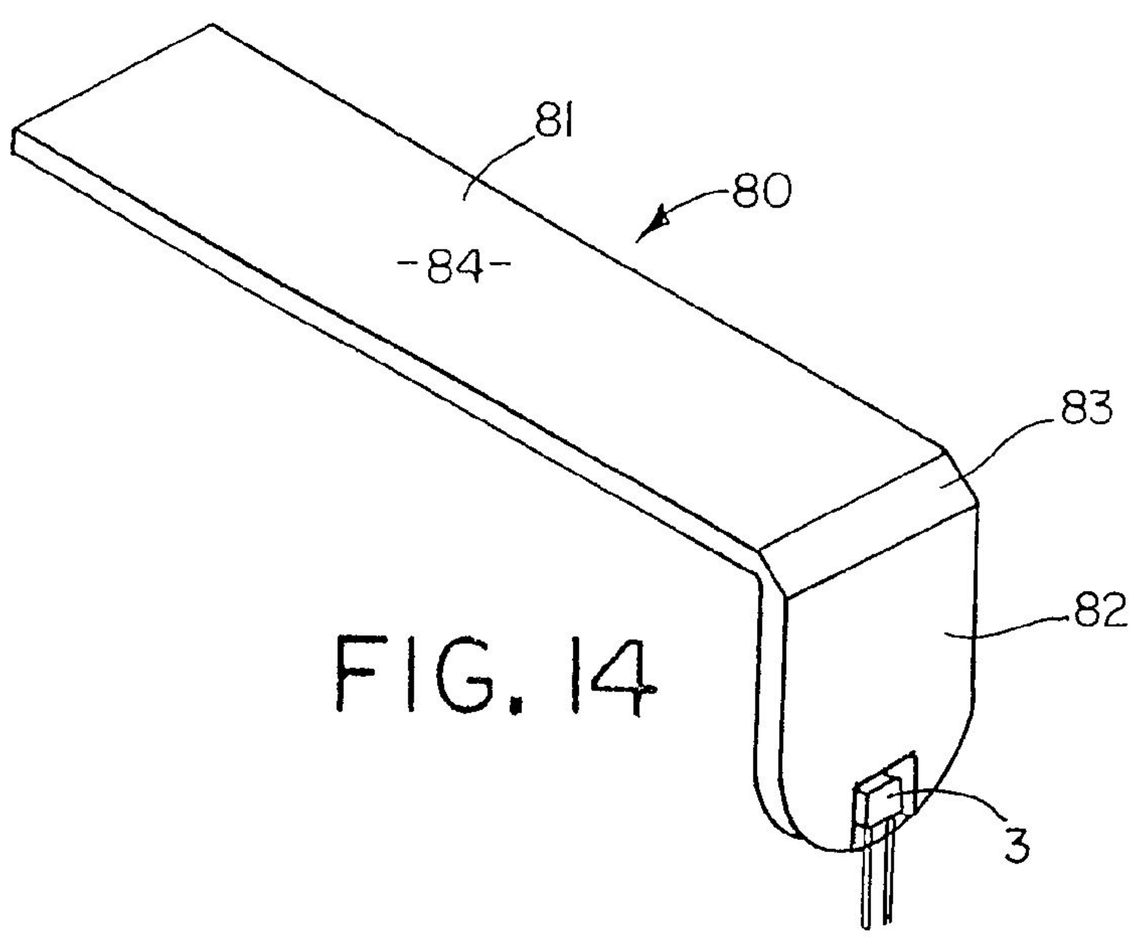

FIG. 14

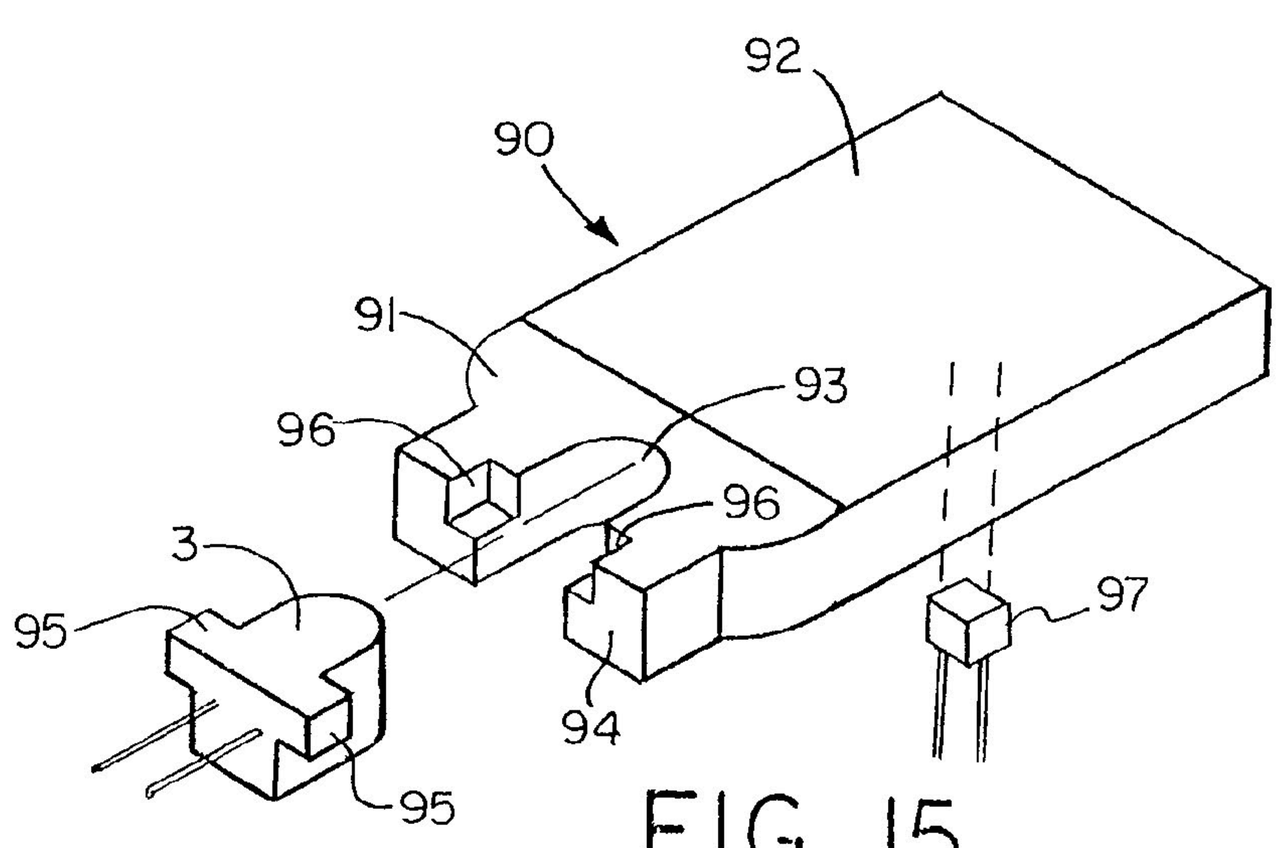

FIG. 15

LIGHT EMITTING PANEL ASSEMBLIES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application 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, filed Feb. 23, 2004, now U.S. Pat. No. 7,160,015, dated Jan. 9, 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, 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 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. **4***a* 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. **4***b, 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. **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**; 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-

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 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.

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. **4***a* 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. **4***a* 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 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. **4***a*, 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. **4***b* and **4***c* show panel areas **22** on which prismatic surfaces **23** or depressions **24** are formed in the panel areas, whereas FIG. **4***d* 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**.

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 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. **11***a*) 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-

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 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.

* * * * *