IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

LIGHTING SCIENCE GROUP CORP., Plaintiff,	)	**REDACTED PUBLIC VERSION**
v.	)	C.A. No. 19-806-LPS
GENERAL ELECTRIC COMPANY, CONSUMER LIGHTING (U.S.), LLC (D/B/A GE LIGHTING, LLC), & CURRENT LIGHTING SOLUTIONS, LLC	)	JURY TRIAL DEMANDED
Defendants.	)	

PLAINTIFF'S FIRST AMENDED COMPLAINT

Plaintiff Lighting Science Group Corp. files this Amended Complaint against Defendants General Electric Company, Consumer Lighting (U.S.), LLC (d/b/a GE Lighting, LLC), and Current Lighting Solutions, LLC for patent infringement under 35 U.S.C. § 271 and false and misleading advertising under Section 43(a) of the Lanham Act, 15 U.S.C. § 1125(a), and federal common law of unfair competition. Plaintiff alleges, based on its own personal knowledge with respect to its own actions and based upon information and belief with respect to all others' actions, as follows:

INTRODUCTION

1. For nearly two decades, Lighting Science Group Corporation ("LSG") has been at the forefront of innovation in the light-emitting diode ("LED" or "LEDs") lighting space. LSG was the first U.S.-based manufacturer to make an LED light commercially available. In the ensuing years, LSG proved instrumental to the proliferation of LED lighting across American residences. In May 2010, through a relationship with The Home Depot, LSG released a 40-watt equivalent, 429 lumen LED bulb under The Home Depot's EcoSmart brand for $20. In an article titled, "The

Home Depot takes LED lighting mainstream with $20 bulbs," Endgaget celebrated the product for making high-quality LED lighting more economically accessible, noting that LSG's product was "cheaper and nearly as powerful as the 450 lumen, $40-$50 design industry heavyweight GE unveiled" the month before, and concluding, "[h]onestly, we're starting to wonder what the catch is."[1]

2. By 2011, LSG's winning combination of innovation, quality, and accessible pricing had led the company to become the largest North American producer of LED lights, selling 4.5 million LED lights in 2011 alone, and increasing sales by 450-percent over the prior year.[2] That success, in turn, led LSG to become a significant American employer. For three consecutive years, from 2012 to 2014, LSG was named on Deloitte's Technology Fast 500™ as one of the top 500 fastest growing companies in North America.[3]

3. Meanwhile, as LSG continued to advance the field of LED lighting both commercially and technologically, it simultaneously protected and disclosed its innovative intellectual property through hundreds of issued U.S. patents. Those patents, in turn, further advanced the LED lighting space, garnering thousands of citations from later patents filed by LSG's competitors.

4. But in recent years, an explosion of products which infringe LSG's innovative patents has eroded LSG's market position. LSG has been further unfairly injured by false and

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[1] Sean Hollister, "The Home Depot Takes LED Lighting Mainstream with $20 Bulbs," Engadget (May 11, 2010), https://www.engadget.com/2010/05/11/the-home-depot-takes-led-lighting-mainstream-with-20-bulbs/.

[2] Jasmine Zhuang, "Lighting Science Group Becomes North American Largest LED Lights Producer," LEDinside (Jan. 31, 2012), https://www.ledinside.com/news/2012/1/lighting_science_group_north_american_largest_producer_20120131.

[3] "Lighting Science Group Corporation Ranked in Top 500 Fastest Growing Companies for Third Consecutive Year in North America on Deloitte's 2014 Technology Fast 500™," Pegasus Capital Advisors (Nov. 17, 2014), http://www.pcalp.com/lighting-science-group-corporation-ranked-top-500-fastest-growing-companies-third-consecutive-year-north-america-deloittes-2014-technology-fast-500/

misleading advertisements from certain of its competitors, who have touted its products to the American public as meeting rigorous ENERGY STAR® certification standards when, in fact, they do not. Thus, in order to protect its valuable intellectual property rights and substantial investments in innovating the LED lighting space, LSG files this complaint for patent infringement and false and misleading advertising in violation of Section 43(a) of the Lanham Act, 15 U.S.C. § 1125(a), and federal common law of unfair competition.

5. This matter is a companion case to a pending ITC proceeding, captioned *In the Matter of Certain Light-Emitting Diode Products, Systems, and Components Thereof*, filed by the same Plaintiff, naming the same Defendants as respondents. Plaintiff hereby incorporates by reference the relevant portions of the Complaint filed in that ITC proceeding as if restated herein.

THE PARTIES

6. Lighting Science Group Corp. is a Delaware corporations with its principal place of business located at 801 N. Atlantic Avenue, Cocoa Beach, FL 32931.

7. Both directly and through its subsidiaries, LSG is in the business of manufacturing, researching, developing, and selling devices and systems that use LEDs as the light source.

8. Defendant General Electric Company is a publicly traded company organized under the laws of New York. It has its principal place of business at 41 Farnsworth Street, Boston, Massachusetts 02210. General Electric Company has designated Corporation Trust Company, Corporation Trust Center, 1209 Orange St., Wilmington, DE 19801 as its agent for service of process.

9. On information and belief, General Electric Company, directly or through its affiliates, imports into the United States, sells for importation into the United States, and/or sells

after importation into the United States certain GE and Current Accused Products and/or knowingly induces such activity.

10. Defendant Consumer Lighting (U.S.), LLC, (d/b/a GE Lighting, LLC) ("GE Lighting") is a privately-owned company organized under the laws of the State of Delaware. GE Lighting's principal place of business is at 1975 Noble Road, Cleveland, Ohio 44112. GE Lighting has designated Corporation Trust Company, Corporation Trust Center, 1209 Orange St., Wilmington, DE 19801 as its agent for service of process.

11. On information and belief, GE Lighting is a subsidiary of General Electric Company and, directly or through its affiliates, imports into the United States, sells for importation into the United States, and/or sells after importation into the United States certain GE and Current Accused Products and/or knowingly induces such activity.

12. General Electric Company, by and through its subsidiary GE Lighting, manufactures and sells "consumer lighting applications" including LEDs throughout the United States. Upon information and belief, GE Lighting manufactures certain Accused Products abroad in China. On information and belief, GE Lighting then imports and sells those GE Accused Products in the United States, including through its headquarters in East Cleveland, Ohio.

13. General Electric Company and GE Lighting, LLC are collectively referred to as "GE."

14. Current Lighting Solutions, LLC ("Current") is a company organized under the laws of Delaware. It has its principal place of business at 1975 Noble Road, Nela Park, Cleveland, Ohio 44112. Current Lighting Solutions, LLC has designated Corporation Trust Company, Corporation Trust Center, 1209 Orange St., Wilmington, DE 19801 as its agent for service of process.

15. Current is a former subsidiary of General Electric Company. As of April 1, 2019, it is a separate business, but is still branded as "Current, powered by GE." "Under a long-term licensing agreement, Current will continue using the GE brand on its products and services moving forward."[4]

16. Current is a provider of energy efficiency and digital productivity solutions for commercial facilities and offices, retail stores, and industrial sites. Its commercial technology portfolio includes LED lighting solutions, and a wide variety of connected sensors, controls, and software. Current manufactures certain Accused Products abroad in China. On information and belief, Current then imports and sells those Accused Products in the United States, including through one or more of the GE defendants.

17. As of April 11, 2019, General Electric Company, GE Lighting, and Current had represented in a complaint filed with the International Trade Commission, in a case captioned *Certain LED Packages Containing PFS Phosphor and Products Containing Same* (337-TA-1156), that GE Lighting "focuses on residential and consumer applications, such as residential light bulbs, while Current focuses on applications for the commercial and industrial markets." Plaintiff relied on this information and did not include Current as a Defendant in the May 1, 2019 Complaint, because Plaintiff had not accused the commercial or industrial LED products found on Current's website. Days after filing the Complaint, Complainants became aware that certain of the GE Accused Products included in the May 1, 2019 Complaint were removed from the GE Lighting website and transferred to Current's website.

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[4] https://www.businesswire.com/news/home/20190402005341/en/American-Industrial-Partners-Completes-Acquisition

JURISDICTION AND VENUE

18. This action arises under the patent laws of the United States, Title 35 of the United States Code. This Court has original subject matter jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1338(a).

19. This Court has personal jurisdiction over Defendants in this action because they have committed acts within this district giving rise to this action, and have established minimum contacts with this forum such that the exercise of jurisdiction over them would not offend traditional notions of fair play and substantial justice. GE maintains one manufacturing site in Delaware, one education partnership in Delaware, and has 35 suppliers in Delaware. These contacts are systematic and continuous. Further, Defendants, directly and through subsidiaries or intermediaries, have committed and continue to commit acts of infringement in this district by, among other things, importing, offering to sell, and selling products that infringe the asserted patents. General Electric Company's wholly owned subsidiary, GE Lighting, and former subsidiary and affiliated business, Current, both reside in this district. General Electric Company controls the products sold by GE Lighting, and controls or acts jointly with GE Lighting and Current in the marketing and sale of the accused products.

20. Venue is proper as to Defendants in this district under 28 U.S.C. §§ 1391(b), 1391(c), and 1400(b).

21. Defendant GE Lighting is organized under the laws of Delaware, and thus resides in this district.

22. Defendant Current is organized under the laws of Delaware, and thus resides in this district.

23. Defendant General Electric Company has committed acts of infringement in this district, including through its subsidiary GE Lighting, and has a regular and established business in this district through its manufacturing site, educational partnership, and 35 suppliers.

24. GE and Current are jointly and severally liable for the infringement of LSG's patents. Infringement by Current arises from the same transactions and occurrences as the GE Defendant's infringement. GE initially infringed LSG's patents and subsequently licensed, sold, imported, or otherwise induced Current's infringement by causing Current to license, sell, import, or otherwise infringe the products formerly sold by GE (*i.e.* GE Accused Products that are now Current Accused Products). GE continues to induce infringement of Current's products by lending its brand name to the Current Accused Products and the "Current, powered by GE" brand. GE and Current's infringement of LSG's patents will give rise to common questions of law and fact, such that they should be joined under Rule 20. General Electric Company, Consumer Lighting (U.S.) LLC, and Current Lighting, LLC are liable jointly, severally, or in the alternative with respect to the same series of transactions or occurrences, and questions of fact common to both of them will arise in this action, consistent with 35 U.S.C. § 299.

COUNT ONE: INFRINGEMENT OF THE '421 PATENT BY GE

25. U.S. Patent No. 7,528,421 ("the '421 Patent"), titled "Surface Mountable Light Emitting Diode Assemblies Packaged for High Temperature Operation," issued on May 5, 2009, naming Joseph Mazzochette as the inventor. Ex. 1 ('421 Patent).

26. LSG owns by assignment all rights, title, and interest in the '421 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

27. On information and belief, GE imports, sells for importation, and/or sells after importation into the United States certain Accused Products ("GE Accused Products") that infringe the '421 Patent, including products sold as the GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607).

28. The GE Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 1-2, 6-7, and 10 of the '421 Patent, in violation of 35 U.S.C. § 271(a). GE directly infringes at least these claims by importing, selling for importation, and/or selling after importation into the United States the GE Accused Products. The GE Accused Products satisfy all claim limitations of at least claims 1-2, 6-7, and 10 of the '421 Patent at the time of importation into the United States.

29. Moreover, on information and belief, one or more of the GE Defendants knowingly and intentionally induces infringement of the '421 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import GE Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, one or more of the GE Defendants is encouraging and facilitating infringement by others. For example, on information and belief, one or more of the GE Defendants sells the GE Accused Products or otherwise provides the GE Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the GE Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, the GE Defendants have had knowledge of, or have been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the GE Accused Products.

30. A claim chart comparing claims 1-2, 6-7, and 10 of the ’421 Patent to a representative GE Accused Product, the GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607),[5] is attached as Exhibit 2.

31. Additionally, on information and belief, including based on teardown analyses and imaging, at least the following additional products constitute GE Accused Products that infringe the ’421 Patent for the reasons set forth above:

- GE C-Sleep™ 11W Dimmable A19 Smart LED Light Bulb (LED11DA19/CSLP 2000-7000K)
- GE 9W (60W Replacement) Non-Dimmable A19 LED Light Bulb (Soft White) (92879)
- GE Refresh 10.5W (60W Replacement) Dimmable A19 HD LED Light Bulb (Daylight) (28003)
- GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
- GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
- GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
- GE 10W (60W Replacement) Dimmable A19 LED Light Bulb (Soft White) (32943)
- GE 4W (40W Replacement) Dimmable A15 LED Light Bulb (Daylight) (36776)
- GE 10W (65W Replacement) Dimmable BR30 LED Light Bulb (Soft White) (41308)
- GE 13W (85W Replacement) Dimmable BR40 Flood LED Light Bulb (Soft White) (92171)
- GE Classic 15W (100W Replacement) Dimmable A21 LED Light Bulb (Daylight) (33076)
- GE Basic 8.5W (60W Replacement) Non-Dimmable A19 LED Light Bulb (Daylight) (46244)
- GE Basic 8.5W (60W Replacement) Non-Dimmable A19 LED Light Bulb (Soft White) (46241)
- GE Relax 8.5W (60W Replacement) Dimmable A19 LED Light Bulb (Soft White) (44930)
- GE Basic 20W (150W Replacement) Non-Dimmable A21 LED Light Bulb (Soft White) (46245)
- GE Classic 10W (60W Replacement) Dimmable A21 LED Light Bulb (Daylight) (44781)
- GE Refresh 17W (100W Replacement) Dimmable A21 HD LED Light Bulb (Daylight) (46326)
- GE Classic 15W (100W Replacement) Dimmable A21 HD LED Light Bulb (Soft White) (33071)
- GE Classic 8W (60W Replacement) Dimmable A19 LED Light Bulb (Daylight) (44923)

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[5] Upon information and belief, this product was manufactured by or for GE.

- GE Refresh 8.5W (60W Replacement) Dimmable A19 LED Light Bulb (Daylight) (44937)
- GE 10W (65W Replacement) Dimmable BR30 Flood LED Light Bulb (Soft White) (40925)
- GE Relax 17W (100W Replacement) Dimmable A21 HD LED Light Bulb (Soft White) (44148)
- GE Reveal® 10.5W (60W Replacement) Dimmable LED Light Bulb (39101)
- C by GE, C-Life 11W A19 Smart LED Light Bulb (44298)
- GE 7W (50W Replacement) Dimmable MR16 Floodlight LED Light Bulb (Bright White) (45639)
- GE 10W (60W Replacement) LED A19 (Warm White) (92492)

COUNT TWO: INFRINGEMENT OF THE '118 PATENT BY GE

32. U.S. Patent No. 8,506,118 ("the '118 Patent"), titled "Light Fixture and Associated LED Board and Monolithic Optic," issued on August 13, 2013, naming Fredric S. Maxik, Zach Gibler, Eric Bretschneider, David Henderson, and Addy Widjaja as the inventors. Ex. 3 ('118 Patent).

33. LSG owns by assignment all rights, title, and interest in the '118 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

34. On information and belief, GE imports, sells for importation, and/or sells after importation into the United States certain Accused Products ("GE Accused Products") that infringe the '118 Patent, including products sold as the GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073).

35. The GE Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 1 and 5 of the '118 Patent, in violation of 35 U.S.C. § 271(a). GE directly infringes at least this claim by importing, selling for importation, and/or selling after importation into the United States the GE Accused Products. The GE Accused Products satisfy

all claim limitations of at least claims 1 and 5 of the ’118 Patent at the time of importation into the United States.

36. Moreover, on information and belief, one or more of the GE Defendants knowingly and intentionally induces infringement of the ’118 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import GE Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, one or more of the GE Defendants is encouraging and facilitating infringement by others. For example, on information and belief, one or more of the GE Defendants sells the GE Accused Products or otherwise provides the GE Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the GE Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, the GE Defendants have had knowledge of, or have been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the GE Accused Products.

37. A claim chart comparing claims 1 and 5 of the ’118 Patent to a representative GE Accused Product, the GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073),[6] is attached as Exhibit 4.

COUNT THREE: INFRINGEMENT OF THE ’608 PATENT BY GE

38. U.S. Patent No. 8,674,608 (“the ’608 Patent”), titled “Configurable Environmental Condition Sensing Luminaire, System and Associated Methods,” issued on March 18, 2014, naming Eric Holland, Mark P. Boomgaarden, and Eric Thosteson as the inventors. Ex. 5 (’608 Patent).

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[6] Upon information and belief, this product was manufactured by or for GE.

39. LSG owns by assignment all rights, title, and interest in the ’608 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

40. On information and belief, GE imports, sells for importation, and/or sells after importation into the United States certain Accused Products (“GE Accused Products”) that infringe the ’608 Patent, including products sold as the C by GE System (the C by GE C-Start™ Smart Switch Dimmer and/or the C-Reach Smart Bridge in conjunction with one or more C by GE luminaires and sensors and the C by GE App).

41. The GE Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 1, 2, 6, 12-13, 16, 19, 20-22, 24, 28, and 37 of the ’608 Patent, in violation of 35 U.S.C. § 271(a). GE directly infringes at least these claims by importing, selling for importation, and/or selling after importation into the United States the GE Accused Products. The GE Accused Products satisfy all claim limitations of at least claim 1, 2, 6, 12-13, 16, 19, 20-22, 24, 28, and 37 of the ’608 Patent at the time of importation into the United States.

42. Moreover, on information and belief, one or more of the GE Defendants knowingly and intentionally induces infringement of the ’608 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import GE Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, one or more of the GE Defendants is encouraging and facilitating infringement by others. For example, on information and belief, one or more of the GE Defendants sells the GE Accused Products or otherwise provides the GE Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the GE Accused Products in the United States. On information and belief, as of

the filing of this Complaint or earlier, the GE Defendants have had knowledge of, or have been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the GE Accused Products.

43. A claim chart comparing claims 1, 2, 6, 12-13, 16, 19, 20-22, 24, 28, and 37 of the ’608 Patent to a representative GE Accused Product, the C by GE System,[7] (the C by GE C-Start™ Smart Switch Dimmer and/or the C-Reach Smart Bridge in conjunction with one or more C by GE luminaires and sensors and the C by GE App), as defined in the corresponding claim chart as well as certain products designed and sold to be used in conjunction with the C by GE System, including the C by GE C-Life Starter Kit, containing two C-Life 11W A19 Smart LED Light Bulbs (44298) and one C-Reach Smart Bridge (22518), and the C by GE C-Start™ Smart Switch Dimmer (CSWDMBLBWF1), is attached as Exhibit 6.

COUNT FOUR: FALSE AND MISLEADING ADVERTISING BY GE

44. GE advertises its products, including at least the GE 11W (60W Replacement) Dimmable A19 LED Light Bulb (Soft White) (25037) (“GE 25037 LED A19 Bulb”) and the GE 10W (60W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67591) (“GE 67591 LED A19 Bulb”), as being Energy Star certified by including the Energy Star® logo on its packaging.

45. LSG tested the GE 25037 LED A19 Bulb for compliance with Sections 9.2 and 9.6 of the ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Version 2.1 at its facility in Cocoa Beach, Florida.

46. Even though the bulb’s packaging displays the Energy Star® logo, it failed to meet the requirements of either Section 9.2 or 9.6 of the ENERGY STAR® Program Requirements.

[7] Upon information and belief, this product was manufactured by or for GE.

47. Ten of the fourteen tested bulbs emitted less than the 800 lumens of light required by Section 9.2 for a 60-watt equivalent bulb, and the average light level was below the 800-lumen average required by the Specification. Each of these failures independently prevents the GE 25037 LED A19 Bulb from meeting the requirements of Section 9.2.

48. In addition, the GE 25037 LED A19 Bulbs failed to meet Section 9.6's requirement that at least nine out of ten bulbs emit light within the ANSI range corresponding to the advertised color temperature of 2700K. At least three of the fourteen tested bulbs fell outside the ANSI range corresponding to the advertised color temperature. Accordingly, the bulbs also fail to meet the correlated color temperature requirements of Section 9.6.

49. LSG also tested the GE 67591 LED A19 Bulb for compliance with Section 9.2 of the ENERGY STAR® Program Requirements Product Specification for Lamps (Light Bulbs) Version 2.1 at its facility in Cocoa Beach, Florida. Even though the bulb's packaging displays the Energy Star® logo, it failed to meet the requirements of Section 9.2 of the ENERGY STAR® Program Requirements.

50. All ten of the tested bulbs emitted less than the 800 lumens of light required by Section 9.2 for a 60-watt equivalent bulb, and the average light level was below the 800-lumen average required by the Specification. Each of these failures independently prevents the GE 67591 LED A19 Bulb from meeting the requirements of Section 9.2.

51. As these failures show, at least GE's GE 25037 LED A19 Bulbs and GE 67591 LED A19 Bulbs mislead consumers because the bulbs will be dimmer than advertised and will emit a different color of light than advertised. GE's GE 25037 LED A19 and GE 67591 LED A19 Bulbs will thus fail to meet the expectations of consumers who have grown to rely on the Energy Star® logo as a signal of reliability and quality.

52. GE misrepresents the characteristics and qualities of its LED bulbs at least by falsely and misleadingly advertising them as Energy Star compliant in violation of Section 43(a) of the Lanham Act, 15 U.S.C. § 1125(a), and the federal common law of unfair competition. GE is a direct competitor of Plaintiff. GE's false advertising misleads consumers into purchasing products that do not perform as advertised and misleads utility companies into providing subsidies to GE's non-compliant products. As a result, Plaintiff has and will continue to suffer substantial injury to Plaintiff's domestic industry, including, without limitation, due to actual or potential (1) diminishment or tarnishing of the Energy Star brand and certification, and thus, by implication, the quality and reliability of Plaintiff's Energy Star certified products, (2) lost sales, (3) lost profitability, (4) reduced domestic employment, and (5) lost market share.

COUNT FIVE: INFRINGEMENT OF THE '483 PATENT BY CURRENT

53. U.S. Patent No. 7,098,483 ("the '483 Patent"), titled "Light Emitting Diodes Packaged for High Temperature Operation," was issued on August 29, 2006, naming Joseph Mazzochette and Greg Blonder as the inventors. Ex. 7 ('483 Patent).

54. LSG owns by assignment all rights, title, and interest in the '483 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

55. On information and belief, Current imports, sells for importation, and/or sells after importation into the United States certain Accused Products ("Current Accused Products") that infringe the '483 Patent, including products sold as the GE Infusion™ LED Module (M1000/830/W/N).

56. The Current Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 11 and 16 of the '483 Patent, in violation of 35 U.S.C. § 271(a).

Current directly infringes at least this claim by importing, selling for importation, and/or selling after importation into the United States the Current Accused Products. The Current Accused Products satisfy all claim limitations of at least claims 11 and 16 of the ’483 Patent at the time of importation into the United States.

57. Moreover, on information and belief, Current knowingly and intentionally induces infringement of the ’483 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import Current Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, Current is encouraging and facilitating infringement by others. For example, on information and belief, Current sells the Current Accused Products or otherwise provides the Current Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the Current Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, Current has had knowledge of, or has been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the Current Accused Products.

58. A claim chart comparing claims 11 and 16 of the ’483 Patent to a representative Current Accused Product, the GE Infusion™ LED Module (M1000/830/W/N),[8] is attached as Exhibit 8. Additionally, on information and belief, including based on teardown analyses and imaging, at least the following additional products constitute Current Accused Products that infringe the ’483 Patent for the reasons set forth above:

- GE Infusion™ LED Module (M1000/827/W/G4)

[8] Upon information and belief, this product was manufactured by or for Current.

- GE Infusion™ LED Module (M1000/830/W/G4)

COUNT SIX: INFRINGEMENT OF THE ’053 PATENT BY CURRENT

59. U.S. Patent No. 7,095,053 (“the ’053 Patent”), titled “Light Emitting Diodes Packaged for High Temperature Operation,” issued on August 22, 2006, naming Joseph Mazzochette and Greg Blonder as the inventors. Ex. 9 (’053 Patent).

60. LSG owns by assignment all rights, title, and interest in the ’053 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

61. On information and belief, Current imports, sells for importation, and/or sells after importation into the United States certain Accused Products (“Current Accused Products”) that infringe the ’053 Patent, including products sold as the GE Infusion™ LED Module (M1000/830/W/N).

62. The Current Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 7, 11, 13-14, 22, 26, and 28-29 of the ’053 Patent, in violation of 35 U.S.C. § 271(a). Current directly infringes at least this claim by importing, selling for importation, and/or selling after importation into the United States the Current Accused Products. The Current Accused Products satisfy all claim limitations of at least claims 7, 11, 13-14, 22, 26, and 28-29 of the ’053 Patent at the time of importation into the United States.

63. Moreover, on information and belief, Current knowingly and intentionally induces infringement of the ’053 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import Current Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, Current is encouraging and facilitating infringement by

others. For example, on information and belief, Current sells the Current Accused Products or otherwise provides the Current Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the Current Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, Current has had knowledge of, or has been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the Current Accused Products.

64. A claim chart comparing claims 7, 11, 13-14, 22, 26, and 28-29 of the '053 Patent to a representative Current Accused Product, the GE Infusion™ LED Module (M1000/830/W/N),[9] is attached as Exhibit 10.

65. Additionally, on information and belief, including based on teardown analyses and imaging, at least the following additional products constitute Current Accused Products that infringe the '053 Patent for the reasons set forth above:

- GE Infusion™ LED Module (M1000/827/W/G4)
- GE Infusion™ LED Module (M1000/830/W/G4)

COUNT SEVEN: INFRINGEMENT OF THE '421 PATENT BY CURRENT

66. U.S. Patent No. 7,528,421 ("the '421 Patent"), titled "Surface Mountable Light Emitting Diode Assemblies Packaged for High Temperature Operation," issued on May 5, 2009, naming Joseph Mazzochette as the inventor. Ex. 1 ('421 Patent).

67. LSG owns by assignment all rights, title, and interest in the '421 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

[9] Upon information and belief, this product was manufactured by or for Current.

68. On information and belief, Current imports, sells for importation, and/or sells after importation into the United States certain Accused Products ("Current Accused Products") that infringe the '421 Patent, including products sold as the GE Refresh 10.5W (60W Replacement) Dimmable A19 HD LED Light Bulb (Daylight) (28003).

69. The Current Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 1-2, 6-7, and 10 of the '421 Patent, in violation of 35 U.S.C. § 271(a). Current directly infringes at least these claims by importing, selling for importation, and/or selling after importation into the United States the Current Accused Products. The Current Accused Products satisfy all claim limitations of at least claims 1-2, 6-7, and 10 of the '421 Patent at the time of importation into the United States.

70. Moreover, on information and belief, Current knowingly and intentionally induces infringement of the '421 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import Current Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, Current is encouraging and facilitating infringement by others. For example, on information and belief, Current sells the Current Accused Products or otherwise provides the Current Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the Current Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, Current has had knowledge of, or has been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the Current Accused Products.

71. A claim chart comparing claims 1-2, 6-7, and 10 of the ’421 Patent to a representative Current Accused Product, the GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857),[10] is attached as Exhibit 11.

72. Additionally, on information and belief, including based on teardown analyses and imaging, at least the following additional products constitute Current Accused Products that infringe the ’421 Patent for the reasons set forth above:

- GE Classic 15W (100W Replacement) Dimmable A21 LED Light Bulb (Daylight) (33076)
- GE 18W (90W Replacement) Dimmable PAR38 Floodlight LED Light Bulb (Bright White) (89992)

COUNT EIGHT: INFRINGEMENT OF THE ’118 PATENT BY CURRENT

73. U.S. Patent No. 8,506,118 (“the ’118 Patent”), titled “Light Fixture and Associated LED Board and Monolithic Optic,” issued on August 13, 2013, naming Fredric S. Maxik, Zach Gibler, Eric Bretschneider, David Henderson, and Addy Widjaja as the inventors. Ex. 3 (’118 Patent).

74. LSG owns by assignment all rights, title, and interest in the ’118 Patent., and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

75. On information and belief, Current imports, sells for importation, and/or sells after importation into the United States certain Accused Products (“Current Accused Products”) that infringe the ’118 Patent, including products sold as the GE Tetra® MAX LED Lighting System (GEMX2471-W1).

[10] Upon information and belief, this product was manufactured by or for Current.

76. The Current Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claim 15 of the ’118 Patent, in violation of 35 U.S.C. § 271(a). Current directly infringes at least this claim by importing, selling for importation, and/or selling after importation into the United States the Current Accused Products. The Current Accused Products satisfy all claim limitations of at least claim 15 of the ’118 Patent at the time of importation into the United States.

77. Moreover, on information and belief, Current knowingly and intentionally induces infringement of the ’118 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import Current Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge and intent, or with willful blindness, one or more of the Defendants is encouraging and facilitating infringement by others. For example, on information and belief, one or more of the Defendants sells the Current Accused Products or otherwise provides the Current Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the Current Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, the Defendants have had knowledge of, or have been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the Current Accused Products.

78. A claim chart comparing claim 15 of the ’118 Patent to a representative Current Accused Product, the GE Tetra® MAX LED Lighting System (GEMX2471-W1), is attached as Exhibit 12.

COUNT EIGHT: INFRINGEMENT OF THE ’608 PATENT BY CURRENT

79. U.S. Patent No. 8,674,608 (“the ’608 Patent”), titled “Configurable Environmental Condition Sensing Luminaire, System and Associated Methods,” issued on March 18, 2014, naming Eric Holland, Mark P. Boomgaarden, and Eric Thosteson as the inventors. Ex. 5 (’608 Patent).

80. LSG owns by assignment all rights, title, and interest in the ’608 Patent, and holds all substantial rights pertinent to this suit, including the right to sue and recover for all past, current, and future infringement.

81. On information and belief, Current imports, sells for importation, and/or sells after importation into the United States certain Accused Products (“Current Accused Products”) that infringe the ’608 Patent, including products sold as the Daintree EZ Connect System (one or more luminaires containing a Daintree Wireless embedded sensor in conjunction with the Daintree EZ Connect App).

82. The Current Accused Products directly infringe, literally and/or under the doctrine of equivalents, at least claims 20-21, 24, 28, and 37 of the ’608 Patent, in violation of 35 U.S.C. § 271(a). Current directly infringes at least this claim by importing, selling for importation, and/or selling after importation into the United States the Current Accused Products. The Current Accused Products satisfy all claim limitations of at least claim 20-21, 24, 28, and 37 of the ’608 Patent at the time of importation into the United States.

83. Moreover, on information and belief, Currrent knowingly and intentionally induces infringement of the ’608 Patent in violation of 35 U.S.C. § 271(b) by actively encouraging others to offer to sell, sell, use, and/or import Current Accused Products into the United States (that is, by actively encouraging others to directly infringe). On information and belief, with knowledge

and intent, or with willful blindness, Current is encouraging and facilitating infringement by others. For example, on information and belief, Current sells the Current Accused Products or otherwise provides the Current Accused Products to another Defendant or to distributors knowing that these distributors intend to import and/or sell the Current Accused Products in the United States. On information and belief, as of the filing of this Complaint or earlier, Current has had knowledge of, or has been willfully blind toward, the Asserted Patents and the infringement of the Asserted Patents by making, using, selling, offering to sell, and/or importing the Current Accused Products.

84. A claim chart comparing claims 20-21, 24, 28, and 37 of the ’608 Patent to a representative Current Accused Product, the Daintree EZ Connect System (one or more luminaires containing a Daintree Wireless embedded sensor in conjunction with the Daintree EZ Connect App), as defined in the corresponding claim chart as well certain products designed and sold to be used in conjunction with the Daintree EZ Connect System, which are charted in the claim chart, include the Lumination™ LVT Series LED luminaires, Lumination™ LET Series LED luminaires, and Lumination™ LBR Series LED luminaires, is attached as Exhibit 13.

JURY DEMAND

Plaintiff hereby demands a trial by jury on all issues so triable.

PRAYER FOR RELIEF

WHEREFORE Plaintiff Lighting Science Group Corp. prays this Court issue an order granting the following relief:

a. A judgment in favor of Plaintiff that GE has infringed, either literally and/or under the doctrine of equivalents, the ’421 patent, the ’118 patent, and the ’608 patent;

b. A permanent injunction prohibiting GE from further acts of infringement of the ’421 patent, the’118 patent, and the ’608 patent;

c. A judgment and order requiring GE to pay Plaintiff its damages, costs, expenses, and any enhanced damages to which LSG is entitled for GE’s infringement of the ’421 patent, the ’118 patent, and the ’608 patent;

d. A judgment in favor of Plaintiff that GE has violated the Lanham Act and federal common law in committing false and misleading advertising;

e. A judgment and order requiring GE to pay Plaintiff its damages, costs, expenses, and pre-judgment and post-judgment interest for GE’s violations of the Lanham Act;

f. A judgment in favor of Plaintiff that Current has infringed, either literally and/or under the doctrine of equivalents, ’483 patent, the ’053 patent, the ’421 patent, the ’118 patent, and the ’608 patent;

g. A permanent injunction prohibiting Current from further acts of infringement of the ’483 patent, the ’053 patent, the ’421 patent, the ’118 patent, and the ’608 patent;

h. A judgment and order requiring Current to pay Plaintiff its damages, costs, expenses, and any enhanced damages to which LSG is entitled for Current’s infringement of the ’483 patent, the ’053 patent, the ’421 patent, the ’118 patent, and the ’608 patent;

i. A judgment and order requiring GE and Current to provide an accounting and to pay supplemental damages to Plaintiff, including without limitation, pre-judgment and post-judgment interest;

j. A judgment and order finding that this is an exceptional case within the meaning of 35 U.S.C. § 285 and awarding to Plaintiff its reasonable attorneys' fees against GE and Current; and

k. Any and all other relief as the Court may deem appropriate and just under the circumstances.

ASHBY & GEDDES

/s/ Andrew C. Mayo

John G. Day (#2403)
Andrew C. Mayo (#5207)
500 Delaware Avenue, 8th Floor
P.O. Box 1150
Wilmington, DE 19899
(302) 654-1888
jday@ashbygeddes.com
amayo@ashbygeddes.com

Attorneys for Plaintiff
Lighting Science Group Corp.

Of Counsel:

Bradley W. Caldwell
John Austin Curry
Christopher S. Stewart
Justin T. Nemunaitis
Hamad M. Hamad
Daniel R. Pearson
Alexis F. Mosser
CALDWELL CASSADY CURRY PC
2101 Cedar Springs Road, Suite 1000
Dallas, Texas 75201
(214) 888-4848

Kayvan B. Noroozi
Joel P. Stonedale
James A. Milkey
Karly Valenzuela
NOROOZI PC
11601 Wilshire Blvd., Suite 2170
Los Angeles, CA 90025
(310) 975-7074

Dated: May 23, 2019

Exhibit 1

US007528421B2

(12) **United States Patent**
Mazzochette

(10) **Patent No.: US 7,528,421 B2**
(45) **Date of Patent: May 5, 2009**

(54) **SURFACE MOUNTABLE LIGHT EMITTING DIODE ASSEMBLIES PACKAGED FOR HIGH TEMPERATURE OPERATION**

(75) Inventor: **Joseph Mazzochette**, Cherry Hill, NJ (US)

(73) Assignee: **Lamina Lighting, Inc.**, Westampton, NJ (US)

(*) 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.: **11/179,863**

(22) Filed: **Jul. 12, 2005**

(65) **Prior Publication Data**

US 2006/0006405 A1 Jan. 12, 2006

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/638,579, filed on Aug. 11, 2003, now Pat. No. 7,095,053.

(60) Provisional application No. 60/467,857, filed on May 5, 2003.

(51) **Int. Cl.**
H01L 33/00 (2006.01)

(52) **U.S. Cl.** **257/99**; 257/98; 257/100; 257/E33.057; 257/E33.058; 257/E33.075

(58) **Field of Classification Search** 257/81, 257/88, 98, 99, 100, 676, 707, 708, E33.057, 257/E33.058, E33.059, E33.075, 82
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,711,789	A	1/1973	Dierschke	
4,729,076	A *	3/1988	Masami et al.	362/235
4,902,567	A	2/1990	Eilertsen et al.	
5,117,281	A	5/1992	Katsuraoka	357/81
5,122,781	A	6/1992	Saubolle	340/473
5,140,220	A	8/1992	Hasegawa	313/512
5,235,347	A	8/1993	Lee et al.	
5,441,774	A	8/1995	Dutta et al.	
5,482,898	A	1/1996	Marrs	437/216
5,485,037	A	1/1996	Marrs	257/712
5,581,876	A	12/1996	Prabhu et al.	29/851
5,674,554	A	10/1997	Liu et al.	
5,725,808	A	3/1998	Tormey et al.	252/514
5,745,624	A	4/1998	Chan et al.	385/91
5,841,244	A	11/1998	Hamilton et al.	
5,847,507	A	12/1998	Butterworth et al.	
5,847,935	A *	12/1998	Thaler et al.	361/761
5,857,767	A	1/1999	Hochstein	362/294
5,908,155	A	6/1999	Duffy et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

DE	19625622	1/1998

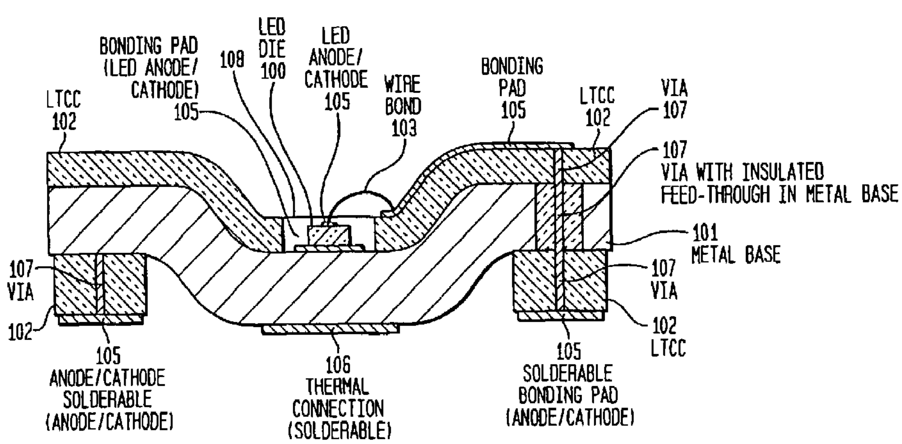
(Continued)

Primary Examiner—Ngan Ngo
Assistant Examiner—Benjamin Tzu-Hung Liu
(74) *Attorney, Agent, or Firm*—Cantor Colburn LLP

(57) **ABSTRACT**

Light emitting diode (LED) assemblies packaged for high temperature operation and surface mounting. In particular, the LED assemblies according to the present invention are constructed to include a thermally conducting base and an optically efficient cavity that provides protection for the LED assembly and maximizes light extraction. The LED assemblies are particularly adapted for easy and efficient surface mounting or bolt down assembly mounting in high temperature environments.

24 Claims, 6 Drawing Sheets



U.S. PATENT DOCUMENTS

5,953,203	A	9/1999	Tormey et al.	361/313
5,959,316	A	9/1999	Lowery	
5,977,567	A	11/1999	Verdiell	257/99
5,998,925	A	12/1999	Shimizu et al.	
6,016,038	A	1/2000	Mueller et al.	
6,045,240	A	4/2000	Hochstein	362/294
6,066,861	A	5/2000	Hohn et al.	
6,069,440	A	5/2000	Shimizu et al.	
6,137,224	A	10/2000	Centofante	
6,224,216	B1	5/2001	Parker et al.	
6,245,259	B1	6/2001	Hohn et al.	
6,259,846	B1 *	7/2001	Roach et al.	385/123
6,277,301	B1	8/2001	Hohn et al.	
6,325,524	B1	12/2001	Weber et al.	362/245
6,376,268	B1	4/2002	Verdiell	438/26
6,417,019	B1	7/2002	Mueller et al.	
6,428,189	B1	8/2002	Hochstein	362/373
6,455,930	B1	9/2002	Palanisamy et al.	257/706
6,478,402	B1	11/2002	Greive et al.	
6,480,389	B1	11/2002	Shie et al.	361/707
6,483,623	B1	11/2002	Maruyama	359/180
6,498,355	B1	12/2002	Harrah et al.	
6,518,502	B2	2/2003	Hammond et al.	174/52.4
6,565,239	B2 *	5/2003	Rizkin et al.	362/373
6,576,488	B2	6/2003	Collins, III et al.	
6,576,930	B2	6/2003	Reeh et al.	
6,577,073	B2	6/2003	Shimizu et al.	
6,592,780	B2	7/2003	Hohn et al.	
6,608,332	B2	8/2003	Shimizu et al.	
6,613,247	B1	9/2003	Hohn et al.	
6,614,179	B1	9/2003	Shimizu et al.	
6,622,948	B1	9/2003	Haas et al.	
6,627,115	B2	9/2003	Hampden-Smith et al.	
6,630,691	B1	10/2003	Mueller-Mach et al.	
6,634,750	B2	10/2003	Neal et al.	351/211
6,634,770	B2	10/2003	Cao	362/294
6,682,207	B2	1/2004	Weber et al.	
6,692,252	B2	2/2004	Scott	433/29
6,727,643	B2	4/2004	Suehiro et al.	
6,734,465	B1	5/2004	Taskar et al.	
6,747,293	B2	6/2004	Nitta et al.	
6,791,119	B2	9/2004	Slater, Jr. et al.	
6,793,374	B2	9/2004	Begemann et al.	
6,799,864	B2	10/2004	Bohler et al.	362/236
6,812,500	B2	11/2004	Reeh et al.	
6,827,469	B2	12/2004	Coushaine et al.	
6,828,170	B2	12/2004	Roberts et al.	438/27
6,831,302	B2	12/2004	Erchak et al.	
6,833,669	B2	12/2004	George et al.	
6,866,394	B1	3/2005	Hutchins et al.	
6,885,035	B2	4/2005	Bhat et al.	
6,943,380	B2	9/2005	Ota et al.	
6,964,877	B2	11/2005	Chen et al.	
6,982,829	B1	1/2006	Berman	
7,033,060	B2	4/2006	Dubuc et al.	
7,095,053	B2	8/2006	Mazzochette et al.	
7,098,483	B2	8/2006	Mazzochette et al.	
7,235,189	B2	6/2007	Hohn et al.	
7,276,736	B2	10/2007	Hohn et al.	
2001/0030326	A1	10/2001	Reeh et al.	
2001/0030866	A1 *	10/2001	Hochstein	362/294
2002/0163006	A1 *	11/2002	Yoganandan et al.	257/81
2002/0175621	A1	11/2002	Song et al.	313/315
2003/0010993	A1	1/2003	Nakamura et al.	
2003/0025485	A1	2/2003	McTigue	
2003/0057421	A1	3/2003	Chen	257/79
2003/0077385	A1	4/2003	Ainsworth et al.	
2003/0156608	A1	8/2003	Ido et al.	
2003/0189830	A1 *	10/2003	Sugimoto et al.	362/294
2003/0189930	A1 *	10/2003	Sugimoto et al.	362/294
2003/0193055	A1	10/2003	Martter et al.	
2004/0026706	A1	2/2004	Bogner et al.	257/99
2004/0223315	A1	11/2004	Suehiro et al.	
2005/0088625	A1	4/2005	Imade	
2005/0168147	A1	8/2005	Innocenti et al.	
2005/0189557	A1	9/2005	Mazzochette et al.	
2005/0225222	A1	10/2005	Mazzochette et al.	
2005/0270666	A1	12/2005	Loh et al.	
2006/0006405	A1	1/2006	Mazzochette	
2006/0105484	A1	5/2006	Basin et al.	

FOREIGN PATENT DOCUMENTS

DE	19638667	4/1998
EP	0862794	9/1998
EP	0936682	8/1999
EP	1017112	7/2000
EP	1221724	7/2002
JP	10-012926	1/1998
JP	2000-294701	10/2000
WO	WO-97/50132	12/1997
WO	WO-98/05078	2/1998
WO	WO-98/12757	3/1998

* cited by examiner

FIG. 1A

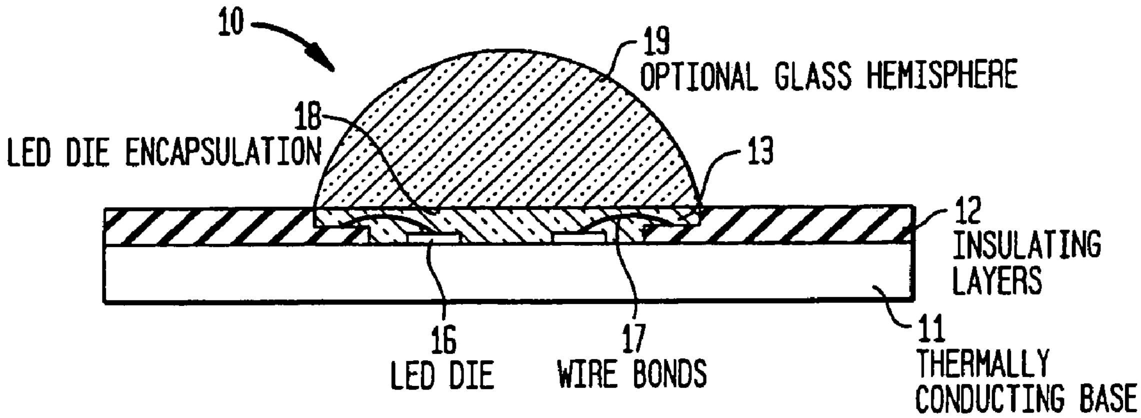

10
19
OPTIONAL GLASS HEMISPHERE
18
LED DIE ENCAPSULATION
13
12
INSULATING
LAYERS
16
LED DIE
17
WIRE BONDS
11
THERMALLY
CONDUCTING BASE

FIG. 1B

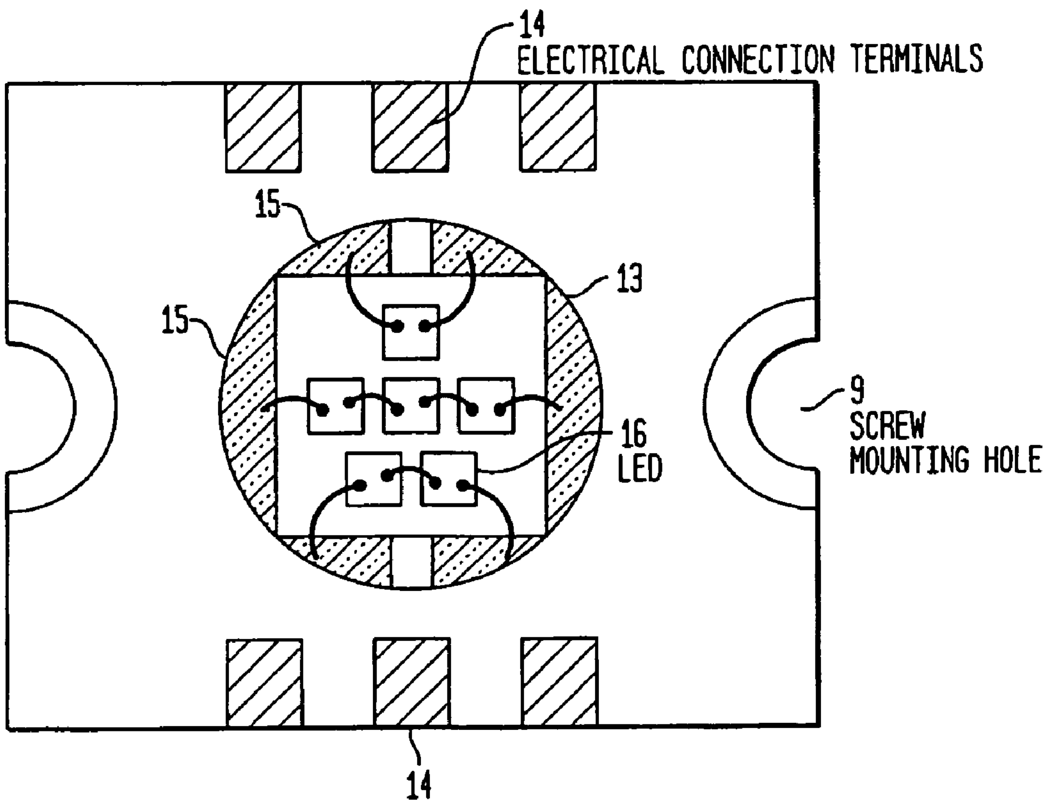

14
ELECTRICAL CONNECTION TERMINALS
15
15
13
9
SCREW
MOUNTING HOLE
16
LED
14

FIG. 2

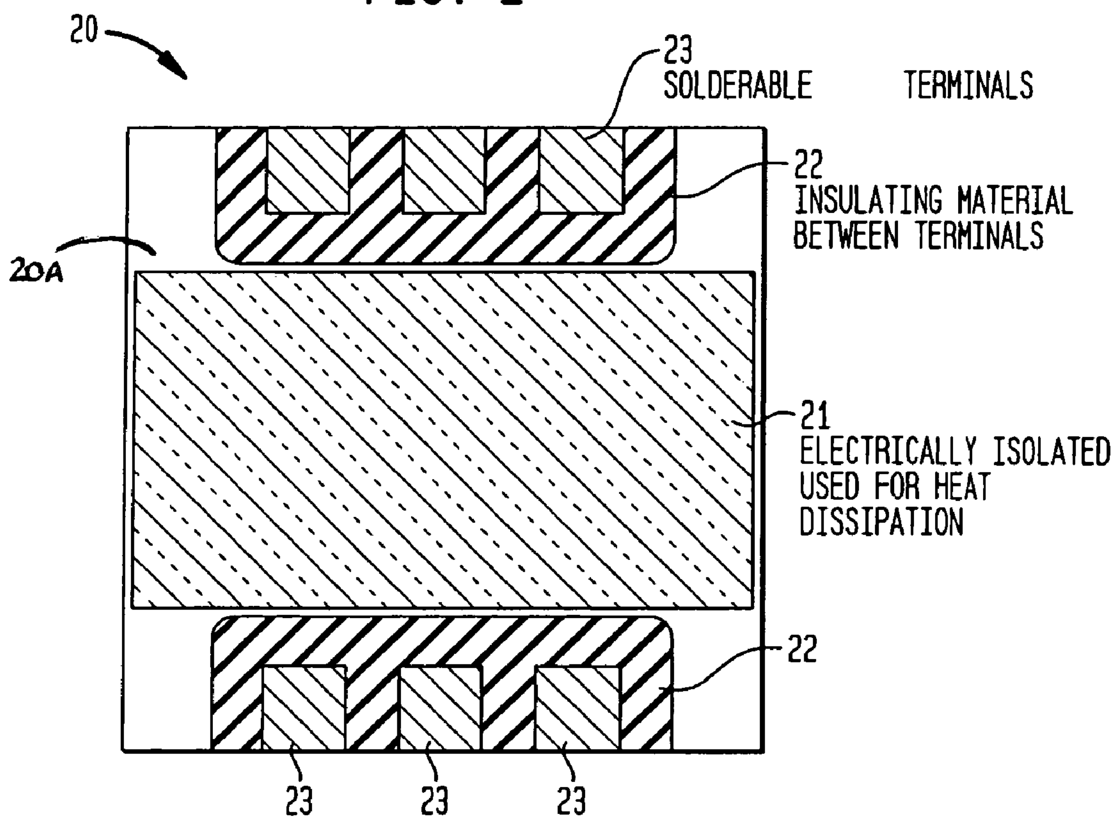

20
20A
23
SOLDERABLE TERMINALS
22
INSULATING MATERIAL
BETWEEN TERMINALS
21
ELECTRICALLY ISOLATED
USED FOR HEAT
DISSIPATION
22
23
23
23

FIG. 3

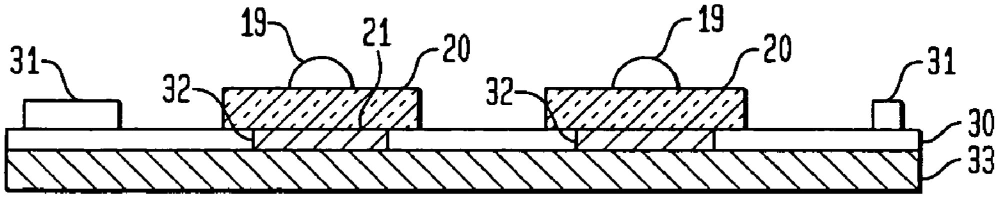

31
19
21
20
32
32
19
20
31
30
33

FIG. 4

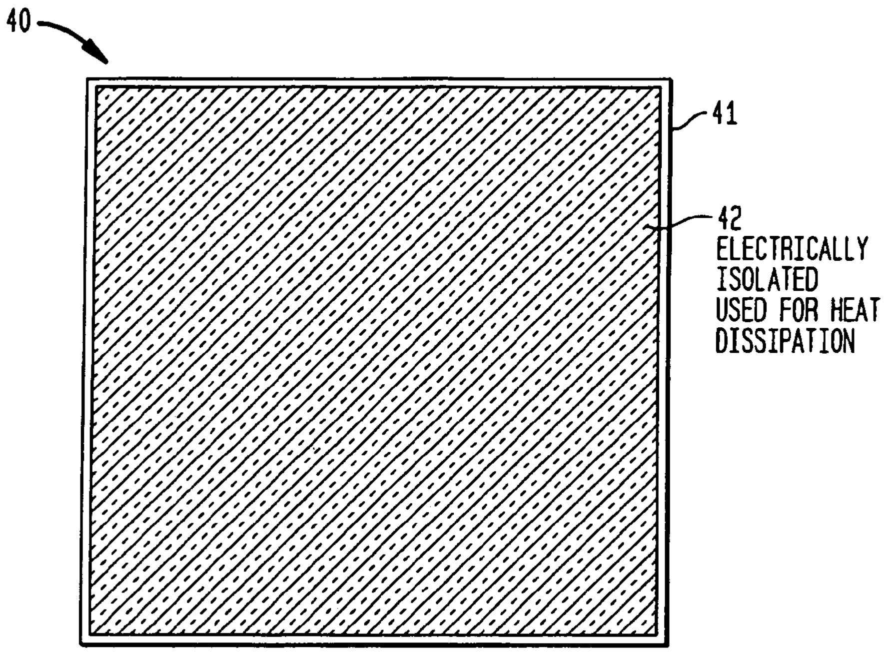

40
41
42
ELECTRICALLY
ISOLATED
USED FOR HEAT
DISSIPATION

FIG. 5

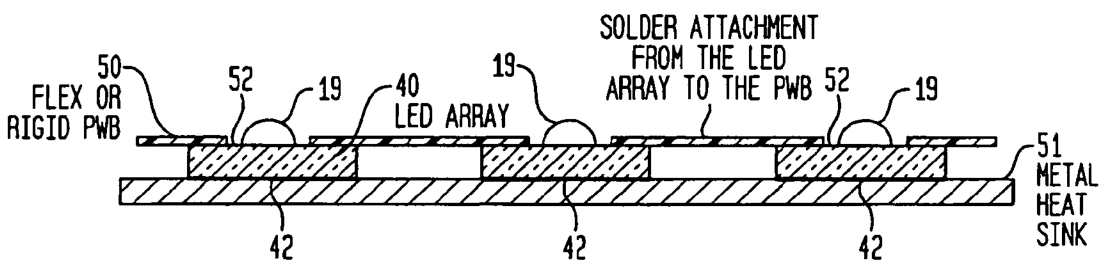

SOLDER ATTACHMENT
FROM THE LED
ARRAY TO THE PWB
50
FLEX OR
RIGID PWB
52
19
40
LED ARRAY
19
52
19
51
METAL
HEAT
SINK
42
42
42

FIG. 6A

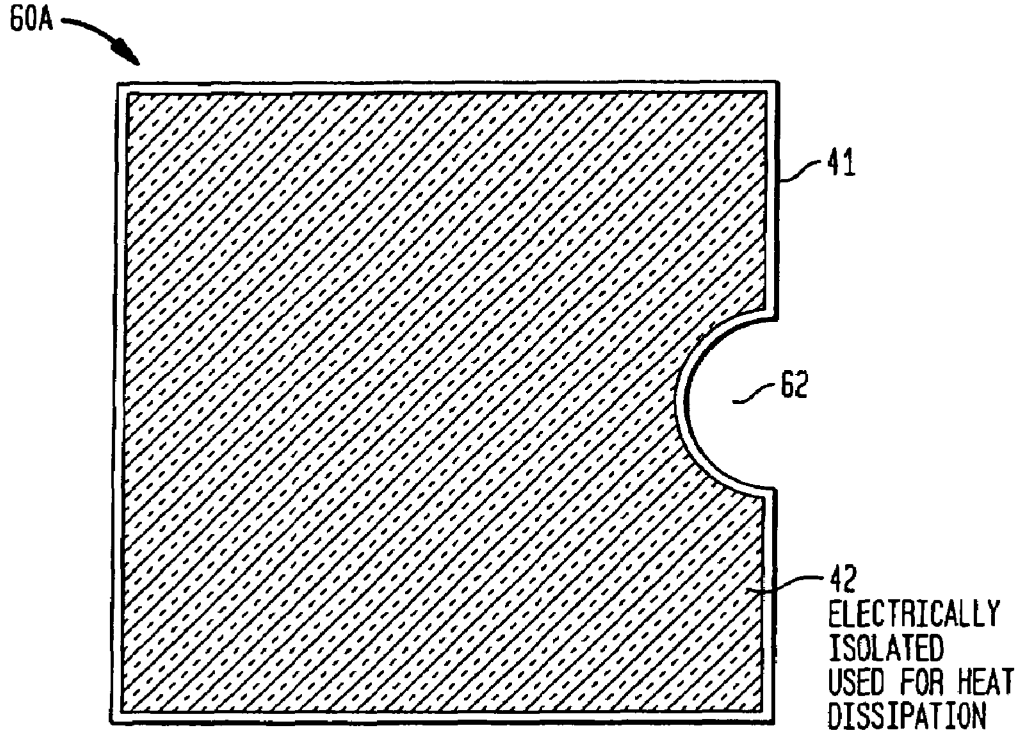

60A
41
62
42
ELECTRICALLY
ISOLATED
USED FOR HEAT
DISSIPATION

FIG. 6B

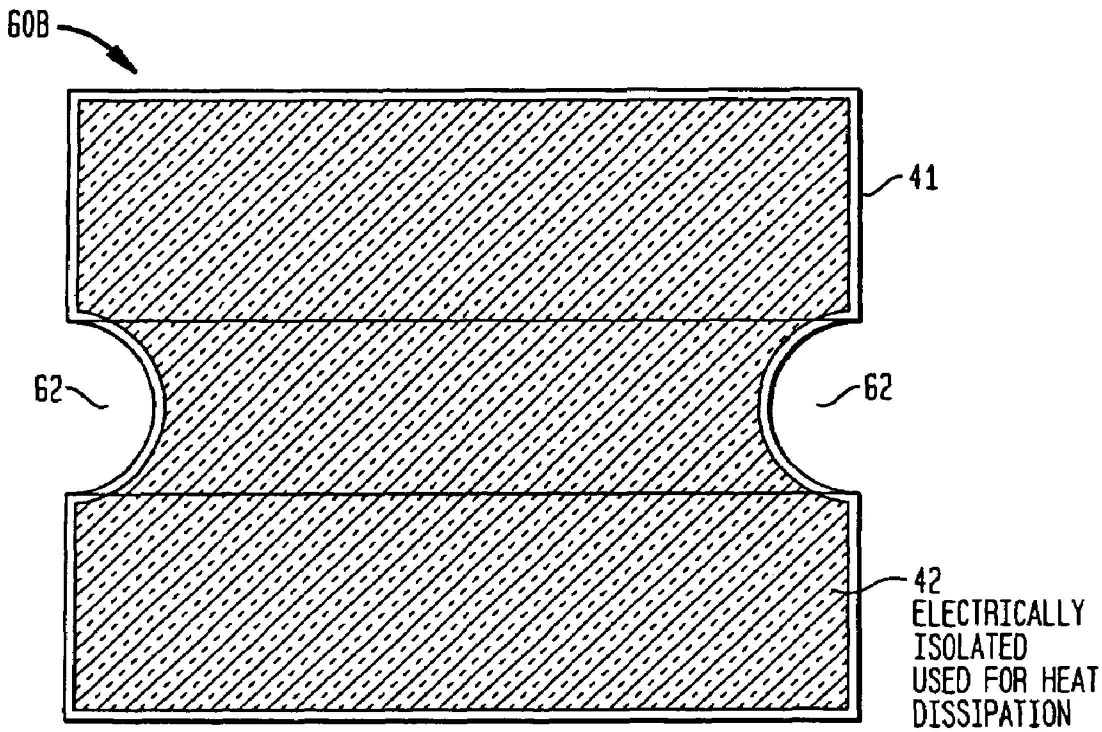

60B
41
62
62
42
ELECTRICALLY
ISOLATED
USED FOR HEAT
DISSIPATION

FIG. 7

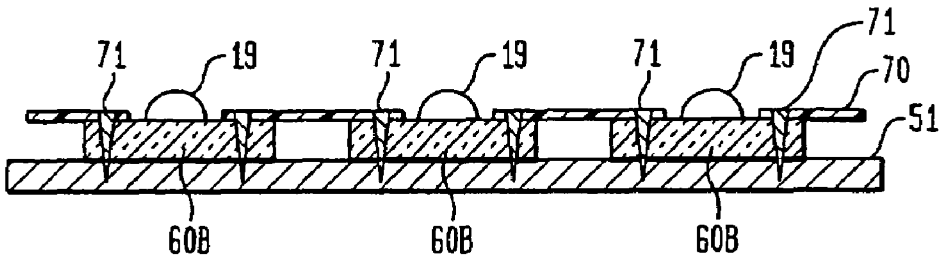

71
19
71
19
71
19
71
70
51
60B
60B
60B

FIG. 8

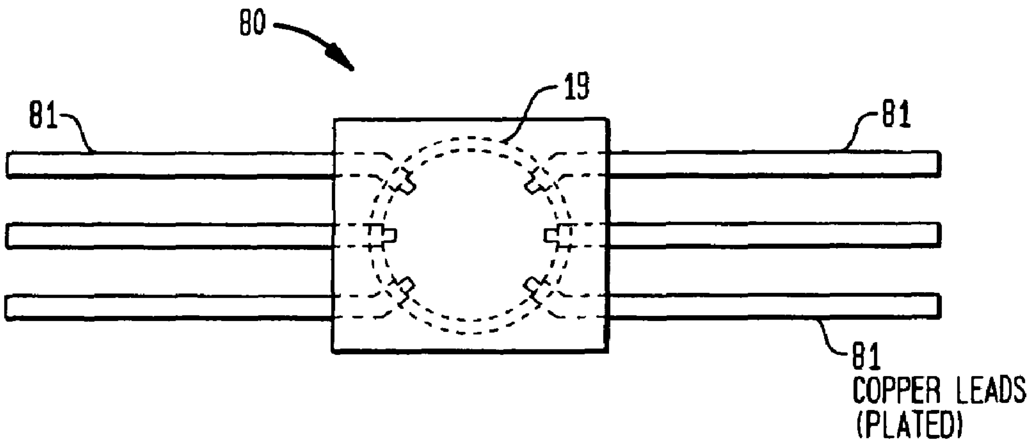
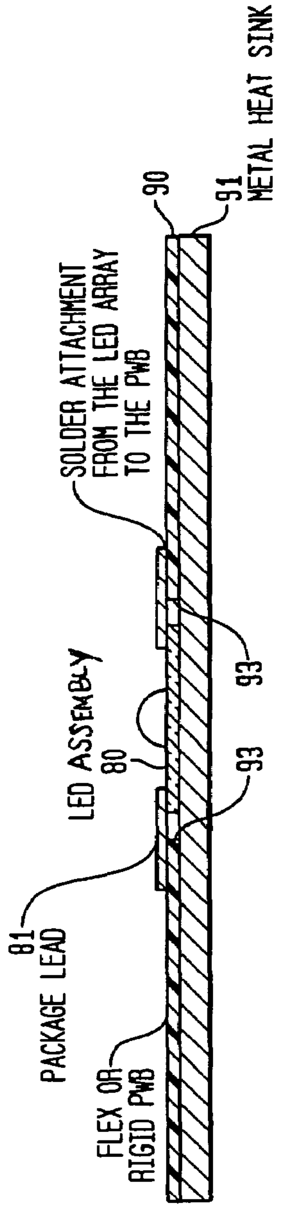
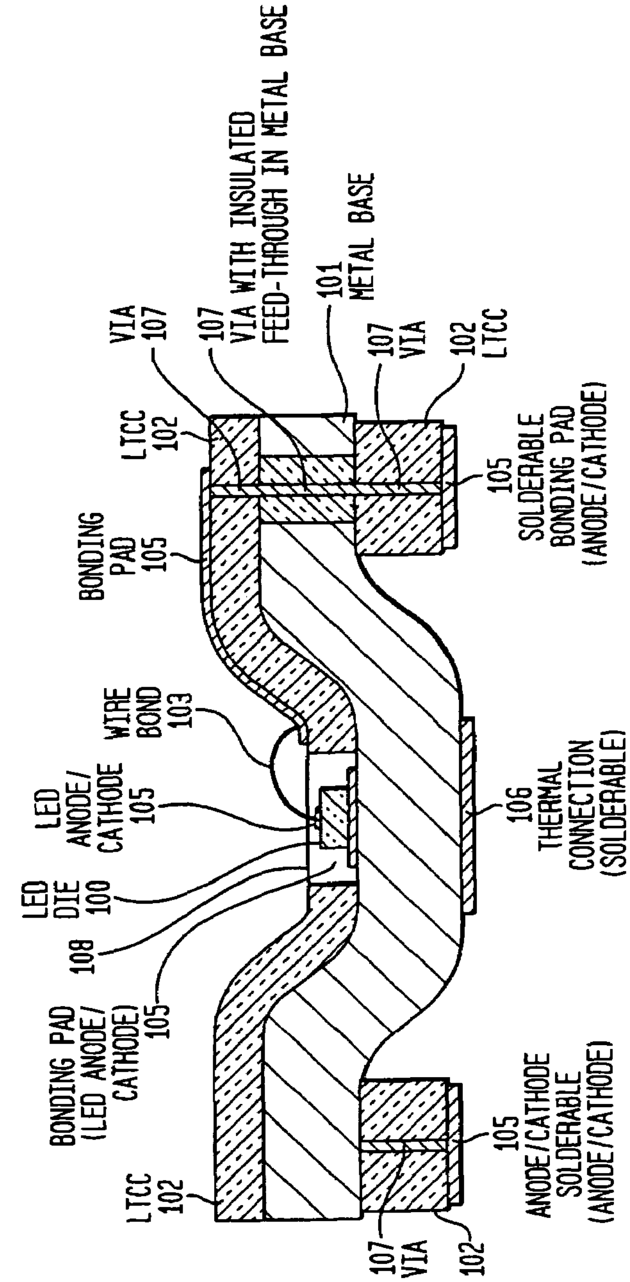

80
81
19
81
81
COPPER LEADS
(PLATED)

FIG. 9



FLEX OR RIGID PWB
PACKAGE LEAD
81
LED ASSEMBLY
80
93
93
SOLDER ATTACHMENT FROM THE LED ARRAY TO THE PWB
90
91
METAL HEAT SINK

FIG. 10



LTCC
102
BONDING PAD (LED ANODE/ CATHODE)
105
108
LED DIE
100
105
LED ANODE/ CATHODE
105
WIRE BOND
103
BONDING PAD
105
LTCC
102
VIA
107
107
VIA WITH INSULATED FEED-THROUGH IN METAL BASE
101
METAL BASE
107
VIA
102
LTCC
105
SOLDERABLE BONDING PAD (ANODE/CATHODE)
106
THERMAL CONNECTION (SOLDERABLE)
105
ANODE/CATHODE SOLDERABLE (ANODE/CATHODE)
107
VIA
102

SURFACE MOUNTABLE LIGHT EMITTING DIODE ASSEMBLIES PACKAGED FOR HIGH TEMPERATURE OPERATION

CROSS REFERENCE TO RELATED APPLICATION

This application is continuation-in-part of U.S. patent application Ser. No. 10/638,579, filed on Aug. 11, 2003 now U.S. Pat. No. 7,095,053. U.S. patent application Ser. No. 10/638,579 in turn claims the benifit of U.S. Provisional Application Ser. No. 60/467,857, filed on May 5, 2003. U.S. patent application Ser. No. 10/638,579 and U.S. Provisional Application Ser. No. 60/467,857 are incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to packaged assemblies of light emitting diodes (LEDs) and,in particular, to LED assemblies packaged for surface mounting and high temperature operation. The present invention further relates to number of arrangements for mounting the LED assemblies.

BACKGROUND OF THE INVENTION

Packaged light emitting diodes (packaged LEDs) are being used as light sources in an increasing variety of applications extending from communications and instrumentation to household and automotive lighting and image display. Packaged LEDs are now being considered for nearly all functions being performed by incandescent light bulbs.

One factor limiting the full potential of packaged LEDs is the thermal limits of conventional packaging. The commercially prevalent packaging assembly disposes semiconductor LED die in a plastic package. In these assemblies, both the die and the plastic package are temperature sensitive. The temperature sensitivity (reduced light generation) of the die has been ameliorated by refining the purity of the semiconductor materials. Improved LED die will now operate at about 120° C. But plastic LED packages typically have an operational limit of about 80° C. Meanwhile, the industry now seeks packaged LED assemblies that can operate at 200° C. Thus, the potential applications of LEDs are now limited by the thermal limits of packaging.

Another limiting factor is the relatively high cost of fabricating and mounting packaged LED assemblies. There exist highly promising fabrication techniques such as surface mount technology (SMT) and bolt down assembly (BDA), but these approaches typically require solder reflow temperatures that are too high for use with conventional plastic packaging and mounting. Thus, lower cost production of LED packages is also constrained by the thermal limits of conventional packaging. Accordingly, there is a need for an improved light emitting diode assembly packaged for surface mounting and higher temperature operation.

SUMMARY OF THE INVENTION

In accordance with the invention, a light emitting diode assembly packaged for surface mounting and high temperature operation comprises a thermally conducting base and one or more electrically insulating layers overlying the base and defining a surface cavity. According to an embodiment of the present invention, one or more electrical connection paths are disposed on the one or more electrically insulating layers. Each electrical connection path may include terminals and

connection pads. An assembly of LED die is disposed at least partially within the surface cavity. The assembly of LED die is thermally coupled to the thermally conducting base and electrically connected to the connection pads of the electrical connection paths. Advantageously, the thermally conducting base may include a high thermally-conductive metal and the insulating layers may be composed of ceramic. The packaged assemblies are mountable, particularly on circuit boards, using efficient surface mount technology or bolt down assembly techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments now to be described in detail in connection with the accompanying drawings. In the drawings:

FIGS. **1**(*a*) and **1**(*b*) illustrate a cross sectional view and a top view, respectively, of a packaged LED assembly for high temperature operation, in accordance with an embodiment of the present invention;

FIG. **2** is a bottom view of a packaged LED assembly for high temperature operation adapted for surface mount assembly, according to an embodiment of the present invention;

FIG. **3** schematically illustrates the packaged LED assembly of FIG. **2** surface mounted on a printed wiring board, according to an embodiment of the present invention;

FIG. **4** is a bottom view of a packaged LED assembly adapted for inverted attachment to a printed wiring board, according to an embodiment of the present invention;

FIG. **5** schematically shows a plurality of packaged LED assemblies mounted on a printed wiring board by inverted attachment, according to an embodiment of the present invention;

FIGS. **6**(*a*) and **6**(*b*) are bottom views of a packaged LED assembly adapted for bolt down assembly, according to an embodiment of the present invention;

FIG. **7** schematically illustrates a plurality of packaged LED assemblies mounted on a printed wiring board according to a bolt down assembly technique, according to an embodiment of the present invention;

FIG. **8** is a schematic top view of a packaged LED assembly including a plurality of metal leads, according to an embodiment of the present invention;

FIG. **9** schematically illustrates the packaged assembly of FIG. **8** mounted on a printed wiring board; and

FIG. **10** illustrates an LTCC-M packaged LED assembly including various optional features, according to an embodiment of the present invention.

DETAILED DESCRIPTION

This description is divided into two parts. Part I describes the structure and features of LED assemblies packaged for high temperature fabrication and/or operation. Part II provides further details of the low-temperature co-fired ceramic-metal ("LTCC-M") technology advantageously used in packaging the arrays.

I. Surface Mountable LED Assemblies Packaged for High Temperature Operation

Referring to the drawings, FIGS. **1**(*a*) and **1**(*b*) illustrate a cross section view and a top view, respectively, of an LED assembly **10** packaged for high temperature. The packaged LED assembly **10** includes a thermally conducting base **11** and one or more electrically insulating layers **12** overlying the base **11** and defining a surface cavity **13**. One or more electrical connection paths are disposed on the insulating layers **12**. According to an embodiment of the present invention, each electrical connection path includes a terminal **14**, a connection pad **15**, and connector paths (not shown) which connects each terminal **14** to its respective pad **15**. One or more LED die **16** are disposed within the surface cavity **13** such that each LED die **16** is in thermal contact with the base **11**. One having ordinary skill in the art will appreciate that thermal contact between the base **11** and the LED die **16** may be established by either mounting the LED die **16** directly on the base **11** or by mounting the LED die **16** on a relatively thin intervening layer of thermally conducting material. Furthermore, it is to be appreciated that the assembly may be arranged in order to achieve any desired degree of thermal contact between the LED die **16** and the base **11**, including a close thermal coupling between the components. The LED die **16** are electrically connected to the respective connection pads **15**, according to any known connecting means, such as, for example, by bonding wires **17**. One having ordinary skill in the art will appreciate that the bonding wires **17** may be composed of any suitable material, such as gold or aluminum.

According to an embodiment of the present invention, the LED die **16** may be attached to the base **11** using an epoxy, a conductive epoxy, a solder, an eutectic die attach, or other suitable adhesive. The LED die **16** are sealed in the surface cavity **13** and protected by filling the cavity **13** with an optically clear encapsulant **18**, such as, for example, a clear epoxy, silicone, polyurethane, or other clear material.

Optionally, an optical element **19**, such as a glass dome, may be attached overlying the LED die **16** using the adhesive properties of the encapsulant **18** or a separate adhesive material. The optical element **19** may be hemispherical, or any shape. One having ordinary skill in the art will appreciate that the shape of the optical element **19** may be selected according to the desired shape and beam width of the light output, and, accordingly, may be selected to improve light extraction and protect the LED assembly **10**. For convenience of mounting, the base **11** may include one or more screw or bolt mounting holes **9**, as shown in FIG. **1**B.

Optionally, each surface cavity **13** may include one or more LED die **16** disposed thereon. Each of the plurality of LED die **16** may be similar to one another, or may vary in size, light output, wavelength (color), electrical parameters, bandwidth, or etc. The plurality of LED die **16** may be electrically connected such that they operate together, separately, or in any desired combination.

One having ordinary skill in the art will appreciate that one or more additional devices (not shown) may be added to the LED assembly **10**. Such additional devices may include, for example, ESD protection circuits, driver circuits, light output detectors, temperature detectors, and/or compensation circuits. These additional devices may be used to control and maintain of any number of LED performance parameters, such as, light output, wavelength, color, and/or temperature.

FIG. **2** illustrates a bottom view of a LED assembly **20** adapted for surface mounting. The LED assembly **20** includes a bottom surface **20**A which includes a central region **21** composed of a thermally conductive material. The central region **21** may be an integral part of the base **11** or thermally coupled to the base **11**. According to an embodiment of the present invention, the central region **21** is composed of the same material as the base **11**. One having ordinary skill in the art will appreciate that the thermally conductive central region **21** advantageously provides for heat dissipation.

According to an embodiment of the present invention, one or more insulators **22** may be used to electrically isolate the central region **21** from the connection path between the one or more solderable terminals **23** and the LED die **16**. The insulators **22** also provide isolation between respective solderable terminals **23**. Also disposed on the bottom surface **20**A of the LED assembly **20** are one or more solderable terminals **23** which provide electrical connection to the LED die **16**. One having ordinary skill in the art will appreciate that the one or more solderable terminals **23** may be composed of any suitable material, including, for example, a silver palladium (AgPd) terminal.

According to an embodiment of the present invention, the surface mountable LED assembly package **20** may include electrically isolated terminals on the bottom surface **20**A of the package **20** that are connected to the LED die **16** in the LED assembly **20**. Optionally, the packaged LED assembly **20** may be readily connected to a printed wire board having appropriate pads for terminals **23** and a heat spreader for region **21**.

FIG. **3** schematically illustrates a plurality of LED assemblies **20** surface mounted on a printed wiring board (PWB) **30** including additional surface mounted components **31**. One having ordinary skill in the art will appreciate that the additional surface mounted components **31** may include, for example, integrated circuits, resistors, capacitors, etc. In addition, the PWB **30** may include one or more heat spreaders **32** in thermal contact with central regions **21** of the LED assemblies **20**, and/or a metal heat sink **33**. Accordingly, heat from the LED die **16** is transmitted by a high thermal conductivity path from the LED die **16** through the base **11** and heat spreader **32** to the heat sink **33**.

FIG. **4** illustrates a bottom view of a packaged LED assembly **40** adapted for inverted attachment to a printed wiring board, according to an embodiment of the present invention. The bottom surface of the LED assembly **40**, shown in FIG. **4**, includes a thermally conductive central region **42** adapted to be placed in thermal contact with a thermally conducting base (not shown in FIG. **4**), or that is part of the base. Preferably, the thermally conductive central region **42** is composed of the same material as the base. Advantageously, the thermally conductive central region **42** is electrically isolated by a peripheral region **41** which is composed of any suitable electrically insulating material. The bottom surface of the LED assembly **40** allows for the dissipation of heat from the LED die **16**.

FIG. **5** schematically illustrates a plurality of packaged LED assemblies **40** mounted on an apertured printed wiring board **50** by inverted attachment. As illustrated in FIG. **5**, each assembly **40** is mounted on a metal heat sink **51**. The thermally conductive region **42** of each LED assembly **40** is thermally coupled to the heat sink **51** via thermally conductive material. The encapsulated diode region under optical element **19** of each LED assembly **40** is mounted in registration with a respective aperture **52** in the apertured printed wiring board **50**.

Optionally, the LED assemblies **40** may be solder attached via terminals **14** (shown in FIG. **1**(*b*)) to corresponding pads (not shown) on the underside of the apertured printed wiring board **50**. The bottom surface of the LED assemblies **40** may be attached to the heat sink **51** using an suitable adhesive, such as, for example, an epoxy.

FIGS. **6**(*a*) and **6**(*b*) are bottom views of packaged assemblies **60**A, **60**B, respectively, adapted for bolt down assembly (BDA) on a printed circuit board, according to exemplary embodiments of the present invention. The bottom surface of the LED assemblies **60**A, **60**B includes a thermally conductive material **42**.

According to an embodiment of the present invention, the assembly **60**A shown in FIG. **6**(*a*), includes one peripheral bolt hole **62**. The term "bolt hole" as used herein is intended to encompass not only an opening but also a partial opening shaped to accommodate a bolt, screw, rivet, or similar fastener. According to another embodiment of the present invention, the LED assembly **60**B of FIG. **6**(*b*) includes two peripheral bolt holes **62**. One having ordinary skill in the art will appreciate that the LED assembly **60**A, **60**B, may include any number of bolt holes **62**, and, further, the bolt holes may be disposed peripherally or at any other location relative to the LED assembly **60**A, **60**B.

FIG. **7** shows a plurality of packaged LED assemblies **60**B mounted on a heat sink and attached to an apertured printed wiring board **70** according to a bolt down assembly technique. The apertured printed wiring board **70** is bolted to the heat sink **51** using bolts, screws, rivets, or any suitable fastener **71** that is capable of passing through one or more bolt holes **62** arranged in the assemblies **60**B.

It is to be appreciated that bolt down assembly does not require solder or adhesive for attachment to the heat sink **51**. One having ordinary skill in the art will appreciate that the heat sink may be composed of any suitable material, such as, for example, metal. Optionally, a thermal-conductivity promoter, such as a thermal grease, may be deposited between the bottom surfaces of assemblies **60**B and the heat sink **51**. Advantageously, the conductivity promoter reduces the thermal resistance in the connection between the surface of the LED assembly **60**B and the surface of the heat sink **51**.

FIG. **8** is a top view of an LED assembly **80** including one or more leads **81**, preferably composed of metal, extending beyond the periphery of the LED assembly **80**, according to an embodiment of the present invention. According to an embodiment of the present invention, the leads **81** may be wire bonded to LED die (not shown) at or near the peripheral edge of the surface cavity. Advantageously, the leads **81** may be sandwiched between a pair of insulating layers (e.g., insulating layers **12** shown in FIG. **1**) that overlie the metal base. Preferably, the leads **81** comprise copper.

FIG. **9** illustrates the mounting of an LED assembly **80** on an apertured printed circuit board **90** and a heat sink **91**. The apertured printed circuit board **90** may be disposed on the heat sink **91** in such a way that an aperture of the circuit board forms a surface cavity bounded by circuit board edges **93**. The LED assembly **80** is mounted at least partially within the cavity, and such that a thermally conductive base (not shown) is in thermal contact with the heat sink **91**. Further, the leads **81** may be soldered to corresponding conductive mating pads (not shown) on the board **90**.

Preferably, the packaged LED assemblies described in each of the above embodiments are low-temperature co-fired ceramic-metal ("LTCC-M") structures. The fabrication of LTCC-M structures is described in the section below.

II. LTCC-M Fabrication

Multilayer ceramic circuit boards are made from layers of green ceramic tapes. A green tape is made from particular glass compositions and optional ceramic powders, which are mixed with organic binders and a solvent, cast and cut to form the tape. Wiring patterns can be screen printed onto the tape layers to carry out various functions. Vias are then punched in the tape and are filled with a conductor ink to connect the wiring on one green tape to wiring on another green tape. The tapes are then aligned, laminated, and fired to remove the organic materials, to sinter the metal patterns and to crystallize the glasses. This is generally carried out at temperatures below about 1000° C., and preferably from about 750-950° C. The composition of the glasses determines the coefficient of thermal expansion, the dielectric constant and the compatibility of the multilayer ceramic circuit boards to various electronic components. Exemplary crystallizing glasses with inorganic fillers that sinter in the temperature range 700 to 1000° C. are Magnesium Alumino-Silicate, Calcium Boro-Silicate, Lead Boro-Silicate, and Calcium Alumino-Boricate.

More recently, metal support substrates (metal boards) have been used to support the green tapes. The metal boards lend strength to the glass layers. Moreover since the green tape layers can be mounted on both sides of a metal board and can be adhered to a metal board with suitable bonding glasses, the metal boards permit increased complexity and density of circuits and devices. In addition, passive and active components, such as resistors, inductors, and capacitors can be incorporated into the circuit boards for additional functionality. Where optical components, such as LEDs are installed, the walls of the ceramic layers can be shaped and/or coated to enhance the reflective optical properties of the package. Thus this system, known as low temperature cofired ceramic-metal support boards, or LTCC-M, has proven to be a means for high integration of various devices and circuitry in a single package. The system can be tailored to be compatible with devices including silicon-based devices, indium phosphide-based devices and gallium arsenide-based devices, for example, by proper choice of the metal for the support board and of the glasses in the green tapes.

The ceramic layers of the LTCC-M structure are advantageously matched to the thermal coefficient of expansion of the metal support board. Glass ceramic compositions are known that match the thermal expansion properties of various metal or metal matrix composites. The LTCC-M structure and materials are described in U.S. Pat. No. 6,455,930, "Integrated heat sinking packages using low temperature co-fired ceramic metal circuit board technology", issued Sep. 24, 2002 to Ponnuswamy et al. and assigned to Lamina Ceramics, Inc. U.S. Pat. No. 6,455,930 is incorporated by reference herein. The LTCC-M structure is further described in U.S. Pat. Nos. 5,581,876, 5,725,808, 5,953,203, and 6,518,502, all of which are assigned to Lamina Ceramics, Inc. and are also incorporated by reference herein.

The metal support boards used for LTCC-M technology do have a high thermal conductivity, but some metal boards have a high thermal coefficient of expansion, and thus a bare die cannot always be directly mounted to such metal support boards. However, some metal support boards are known that can be used for such purposes, such as metal composites of copper and molybdenum (including from 10-25% by weight of copper) or copper and tungsten (including 10-25% by weight of copper), made using powder metallurgical techniques. Copper clad Kovar®, a metal alloy of iron, nickel, cobalt and manganese, a trademark of Carpenter Technology, is a very useful support board. AlSiC is another material that can be used for direct attachment, as can aluminum or copper graphite composites.

In the simplest form, LTCC-M technology is used to provide an integrated package for a semiconductor LED die and accompanying circuitry, wherein the conductive metal support board provides a heat sink for the LED die. Referring to FIG. **10**, bare LED die **100**, for example, may be mounted directly onto a metal base **101** of the LTCC-M system having high thermal conductivity to cool the die **100**. In such case, the electrical signals used to operate the die **100** may be connected to the component from the ceramic **102**. In FIG. **10**, a wire bond **103** serves this purpose. Indirect attachment to the metal support board **101** may also be used.

According to an embodiment of the present invention, all of the components are mounted on the metal support board **101**, incorporating passive components such as electrodes and bonding pads **105**, thermal connector pads **106**, and conductive vias **107** into the multilayer ceramic portion, to connect the various components, i.e., semiconductor components, circuits, heat sink and the like, in an integrated package. Optionally, the package may be hermetically sealed within an encapsulant **108**.

For a more complex structure having improved heat sinking, the integrated package according to an embodiment of the present invention may combine a first and a second LTCC-M substrate. The first substrate may have mounted thereon a semiconductor device and/or a multilayer ceramic circuit board with embedded circuitry for operating the component. Further, the second substrate may have a heat sink or conductive heat spreader mounted thereon. Thermoelectric (TEC) plates (Peltier devices) and temperature control circuitry may be mounted between the first and second substrates to provide improved temperature control of semiconductor devices. Optionally, a hermetic enclosure may be adhered to the metal support board.

The use of LTCC-M technology marries the advantages of flip chip packaging with the advantages of integrated heat sinking. The LED assembly packages according to an embodiment of the present invention may be made smaller, cheaper and more efficient than existing present-day packaging. Advantageously, a metal substrate may serve as a heat spreader or heat sink. A flip chip may be mounted directly on the metal substrate, which is an integral part of the package, eliminating the need for additional heat sinking. A flexible circuit can be mounted over the bumps on the flip chip. The use of multilayer ceramic layers also allows for a fan-out and routing of traces to the periphery of the package, further improving heat sinking. The LTCC-M technology described herein may be used in many high power integrated circuits and devices that have high thermal management needs.

It is understood that the above-described embodiments are illustrative of only a few of the many possible specific embodiments, which can represent applications of the invention. Numerous and varied other arrangements can be made by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. A LED assembly adapted for surface mounting and high temperature operation, the LED assembly comprising:

a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar;

one or more electrically insulating layers overlying at least a portion of the planar portion of the thermally conducting base and defining a surface cavity, wherein the electrically insulating layers include one or more terminals;

one or more LED die disposed at least partially within the surface cavity, wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base, and electrically connected to the one or more terminals of the one or more insulating layers,

wherein a bottom surface of the LED assembly includes a thermally conductive region in solderable thermal contact with the thermally conducting base, for spreading heat transmitted to the base from the one or more LED die; and

further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.

2. The LED assembly of claim **1**, wherein the thermally conductive region is an integral part of the thermally conducting base.

3. The LED assembly of claim **1**, wherein the bottom surface of the LED assembly further comprises one or more electrically conductive regions adapted for electrical connection with the one or more terminals, and adapted for electrical insulation from the thermally conductive region.

4. The LED assembly of claim **1** further comprising one or more metal leads extending beyond a periphery of the LED assembly for providing an electrical path to the one or more LED die.

5. The LED assembly of claim **4**, wherein the one or more metal leads are vertically sandwiched between a pair of insulating layers overlying the thermally conducting base, the leads overhanging the edge of the LED assembly.

6. The LED assembly of claim **1**, wherein the thermally conducting base includes a metal base.

7. The LED assembly of claim **6**, wherein the metal base includes one or more holes.

8. The LED assembly of claim **1**, wherein the one or more electrically insulating layers include one or more layers of ceramic.

9. The LED assembly of claim **1**, wherein the thermally conducting base and the one or more electrically insulating layers comprise a ceramic-coated metal structure made according to a LTCC-M fabrication process.

10. The LED assembly of claim **1**, wherein the one or more LED die are at least partially encapsulated within the cavity.

11. A device comprising:

a heat sink;

an apertured board overlying the heat sink;

one or more LED assemblies mounted on the apertured board and thermally coupled to the heat sink by a heat spreader, wherein each of the one or more LED assemblies includes:

a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar,

one or more electrically insulating layers overlying at least a portion of the planar portion of the thermally conducting base and defining a surface cavity, wherein the electrically insulating layers include one or more terminals, and

one or more LED die disposed at least partially within the surface cavity, wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base and electrically connected to the one or more terminals of the one or more insulating layers,

wherein a bottom surface of the LED assembly includes a thermally conductive region in thermal contact with the thermally conducting base, for spreading heat transmitted to the base from the one or more LED die; and

further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.

12. The device according to claim **11**, wherein the heat spreader extends through the apertured board from the bottom of the LED assembly to the heat sink.

13. The device according to claim **11**, wherein the one or more LED assemblies each include one or more metal leads extending beyond a periphery of the LED assembly for providing an electrical path to the one or more LED die.

14. The device according to claim **13**, wherein the one or more metal leads are attached to the apertured board.

15. The device of claim **11**, wherein the one or more LED die are at least partially encapsulated within the cavity.

16. The device according to claim **11**, wherein the thermally conducting base and the one or more electrically insulating layers comprise a ceramic-coated metal structure made according to a LTCC-M fabrication process.

17. A device comprising:

an apertured board;

one or more LED assemblies mounted underlying the apertured board, wherein each of the one or more LED assemblies includes:

a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar,

one or more electrically insulating layers overlying at least a portion of the planar portion of the thermally conducting base and defining a surface cavity, wherein the electrically insulating layers include one or more terminals, and

one or more LED die disposed at least partially within the surface cavity, wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base and electrically connected to the one or more terminals of the one or more insulating layers,

wherein a bottom surface of the LED assembly includes a thermally conductive region in thermal contact with the thermally conducting base, for spreading heat transmitted to the base from the one or more LED die;

a heat sink thermally coupled to the bottom surface of each of the one or more LED assemblies; and

further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.

18. The device of claim **17**, wherein each of the one or more LED die are aligned with an aperture in the apertured board.

19. The device of claim **17**, wherein the one or more LED die are at least partially encapsulated within the cavity.

20. The device according to claim **17**, wherein the thermally conducting base and the one or more electrically insulating layers comprise a ceramic-coated metal structure made according to a LTCC-M fabrication process.

21. A device comprising:

an apertured board;

a heat sink;

one or more LED assemblies mounted between the apertured board and the heat sink, wherein each of the one or more LED assemblies includes:

a metal base including one or more holes, wherein at least a portion of the metal base is substantially planar,

one or more ceramic layers overlying at least a portion of the planar portion of the metal base and defining a surface cavity, wherein the ceramic layers include one or more terminals, and

one or more LED die disposed at least partially within the surface cavity, wherein the one or more LED die are in thermal contact with the planar portion of the metal base and electrically connected to the one or more terminals of the one or more ceramic layers,

wherein a bottom surface of the LED assembly includes a thermally conductive region in thermal contact with the metal base, for spreading heat transmitted to the base from the one or more LED die; and

further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.

22. The device of claim **21**, wherein the one or more LED assemblies are mounted between the apertured board and the heat sink by fasteners extending through the holes in the metal base, such that the one or more LED die are aligned with respective apertures in the apertured board.

23. The device of claim **21**, wherein the one or more LED die are at least partially encapsulated within the cavity.

24. The device according to claim **21**, wherein the thermally conducting base and the one or more electrically insulating layers comprise a ceramic-coated metal structure made according to a LTCC-M fabrication process.

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Exhibit 2

U.S. Patent No. 7,528,421
("'421 Patent")

Accused Products

The GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607) ("GE A19 LED Bulb") infringes at least Claims 1-2, 6 and 10 of the '421 Patent.

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[pre]. A LED assembly adapted for surface mounting and high temperature operation, the LED assembly comprising:	The GE A19 LED Bulb is a luminaire that contains an LED assembly adapted for surface mounting and high temperature operation. An image of the GE A19 LED Bulb (and its retail packaging) is shown below.  GE A19 LED Bulb Packaging

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	The GE A19 LED Bulb contains at least one LED assembly. As shown in the below image of the GE A19 LED Bulb, [redacted]. [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	One of the GE A19 LED Packages, shown in the optical image below, [redacted] [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	The GE A19 LED Package analyzed in this claim chart is an LED assembly adapted for surface mounting, at least because [redacted] [redacted] The remainder of the preamble is not limiting. The GE A19 LED Package analyzed in this claim chart is an LED assembly adapted for high temperature operation because [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[a]. a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar;	The GE A19 LED Package includes a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar. ***"a thermally conducting base"*** The GE A19 LED Package includes a thermally conducting base, [redacted] [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	"at least a portion of the thermally conducting base is substantially planar" As shown in the below [redacted] [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[b]. one or more electrically insulating layers overlying at least a portion of the planar portion of the thermally conducting base and defining a surface cavity,	***"one or more electrically insulating layers"*** The GE A19 LED Package includes one or more electrically insulating layers, as shown below in the images of the product. [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	[redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	[redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	"overlying at least a portion of the planar portion of the thermally conducting base" The electrically insulating layer in the GE A19 LED Package overlies at least a portion of the planar portion of the thermally conductive base, as shown in the images below. [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	"one or more electrically insulating layers . . . defining a surface cavity" The electrically insulating layer defines a surface cavity, as shown below. [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	[redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[c]. wherein the electrically insulating layers include one or more terminals;	The electrically insulating layer of the GE A19 LED Package identified above under claim limitation 1[b] includes one or more terminals. The electrically insulating layer includes a terminal, [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[d]. one or more LED die disposed at least partially within the surface cavity,	The GE A19 LED Package includes one or more LED die disposed at least partially within the surface cavity [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[e]. wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base, and electrically connected to the one or more terminals of the one or more insulating layers,	***"wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base"*** The GE A19 LED Package includes one or more LED die that are in thermal contact with the planar portion of the thermally conducting base. As shown in the below images of the product, [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	"wherein the one or more LED die are . . . electrically connected to the one or more terminals of the one or more insulating layers" The GE A19 LED Package includes one or more LED die that are electrically connected to one or more terminals of the insulating layer. As shown in the images below, [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[f]. wherein a bottom surface of the LED assembly includes a thermally conductive region in solderable thermal contact with the thermally conducting base, for spreading heat transmitted to the base from the one or more LED die; and	***"wherein a bottom surface of the LED assembly includes a thermally conductive region in solderable thermal contact with the thermally conducting base"*** The GE A19 LED Package contains a bottom surface that includes a thermally conductive region in solderable thermal contact with the thermally conducting base. As shown in the images below, [redacted]. [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	"for spreading heat transmitted to the base from the one or more LED die" The bottom surface of the GE A19 LED Package includes a thermally conductive region for spreading heat transmitted to the base from the LED die. For example, [redacted] [redacted]

Claim 1	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
1[g]. further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.	The GE A19 LED Package further includes an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad. In particular, [redacted] [redacted]

Claim 2	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
2. The LED assembly of claim 1, wherein the thermally conductive region is an integral part of the thermally conducting base.	The GE A19 LED Package includes a thermally conductive region that is an integral part of the thermally conducting base. As shown below, [redacted]

Claim 2	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
	[redacted]

Claim 6	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
6. The LED assembly of claim 1, wherein the thermally conducting base includes a metal base.	The GE A19 LED Package includes a thermally conducting base that includes a metal base, as shown below. [redacted] [redacted]

Claim 7	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
7. The LED assembly of claim 6, wherein the metal base includes one or more holes.	The GE A19 LED Package includes [redacted]

Claim 10	GE 6W (40W Replacement) Dimmable A19 LED Light Bulb (Soft White) (67607)
10. The LED assembly of claim 1, wherein the one or more LED die are at least partially encapsulated within the cavity.	The GE A19 LED Package includes one or more LED die that are at least partially encapsulated within the cavity. For example, as shown in the images below, [redacted]

Exhibit 3

US008506118B2

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

(10) **Patent No.: US 8,506,118 B2**
(45) **Date of Patent: *Aug. 13, 2013**

(54) **LIGHT FIXTURE AND ASSOCIATED LED BOARD AND MONOLITHIC OPTIC**

(75) Inventors: **Fredric S. Maxik**, Indialantic, FL (US); **Zach Gibler**, Granville, OH (US); **Eric Bretschneider**, Clarkston, MI (US); **David Henderson**, Indialantic, FL (US); **Addy Widjaja**, Palm Bay, FL (US)

(73) Assignee: **Lighting Sciene Group Corporation**, Satellite Beach, FL (US)

(*) 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.: **13/421,910**

(22) Filed: **Mar. 16, 2012**

(65) **Prior Publication Data**

US 2012/0176793 A1 Jul. 12, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/687,710, filed on Jan. 14, 2010, now Pat. No. 8,157,413.

(60) Provisional application No. 61/147,389, filed on Jan. 26, 2009.

(51) **Int. Cl.**
F21V 1/00 (2006.01)

(52) **U.S. Cl.**
USPC **362/235**; 362/237; 362/249.02; 362/294

(58) **Field of Classification Search**
USPC .... 315/185 R, 191, 192; 362/244, 326, 362/294, 373, 341, 145, 431
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,204,608	B2	4/2007	Beeman et al.	
7,566,150	B2	7/2009	Adrien	
7,959,331	B2 *	6/2011	Ho	362/373
8,157,413	B2 *	4/2012	Maxik et al.	362/244
8,382,347	B2 *	2/2013	McCanless	362/431
2003/0201874	A1	10/2003	Wu	
2004/0257006	A1	12/2004	Beeman et al.	
2009/0016055	A1	1/2009	Liu et al.	
2009/0034257	A1	2/2009	Liu et al.	

FOREIGN PATENT DOCUMENTS

FR 2908500 A1 5/2008

OTHER PUBLICATIONS

European Search Report for Application No. 10151159.0-1268; Date of Mailing: May 11, 2010; 6 pgs.

* cited by examiner

Primary Examiner — Ali Alavi
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

An embodiment of the invention is directed to a light fixture useful for area lighting. The light fixture includes a housing having a base and a top, and a light emitting diode (LED) light emission module disposed within the housing. The light emission module includes a centrally disposed aperture that receives a centrally disposed power lead for powering the light emission module.

20 Claims, 10 Drawing Sheets

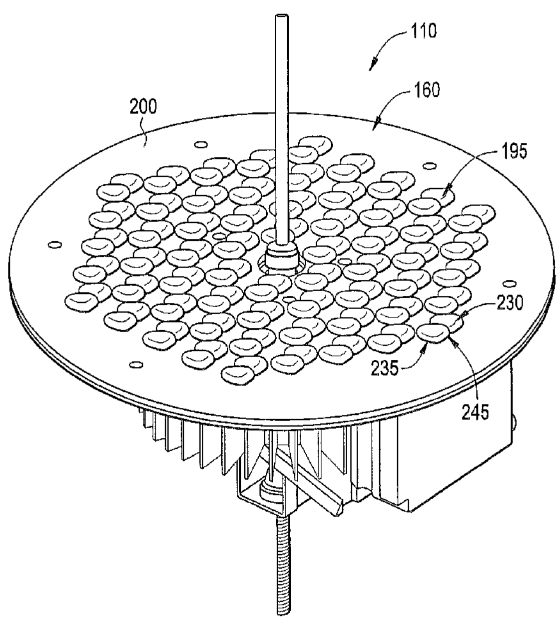


FIG. 1

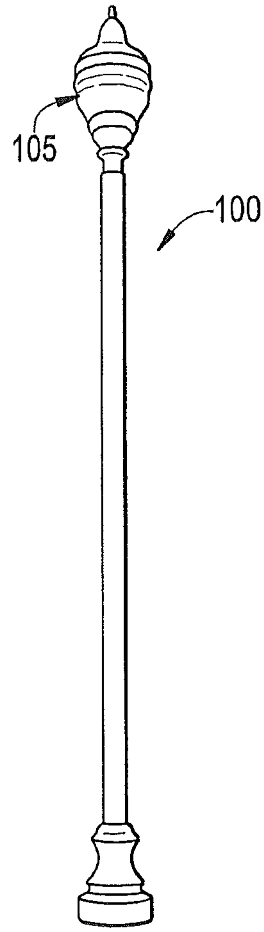
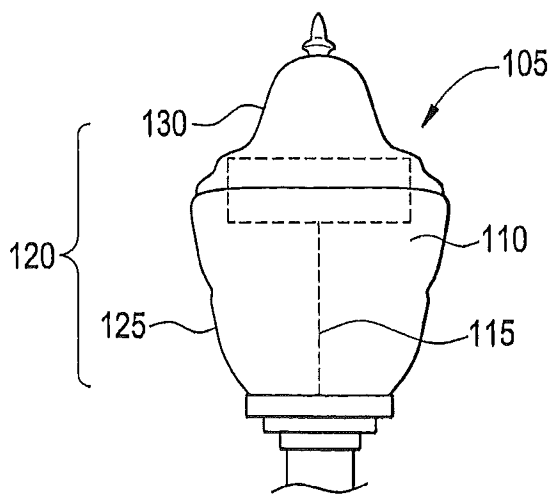
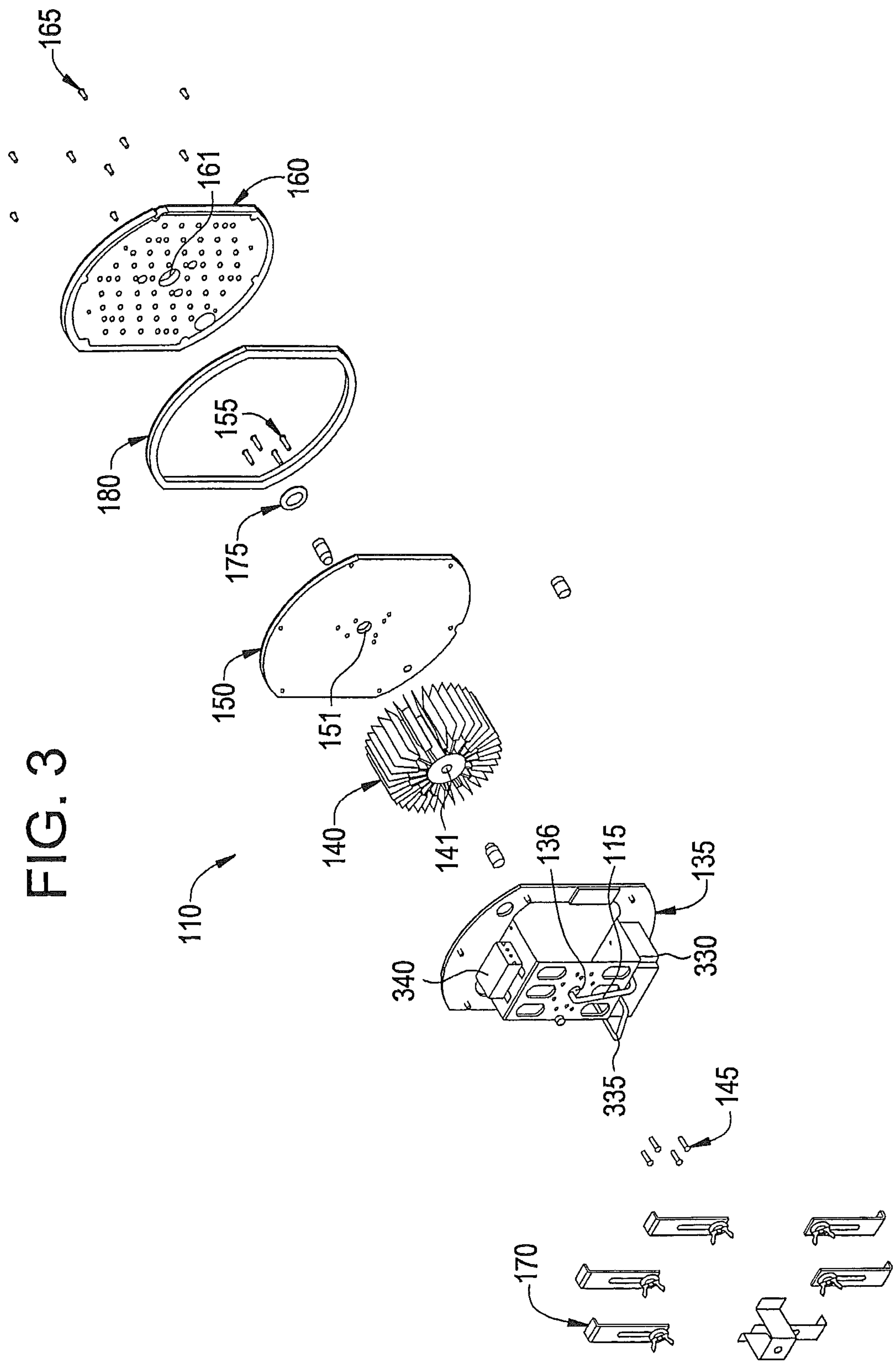


FIG. 2




165
161
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340
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170

FIG. 3

FIG. 4

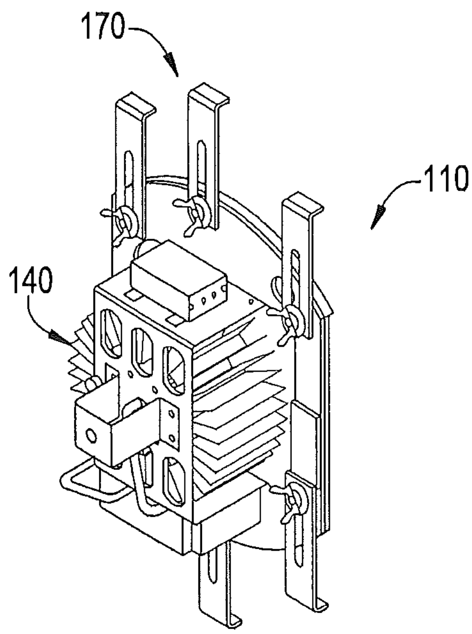


FIG. 5

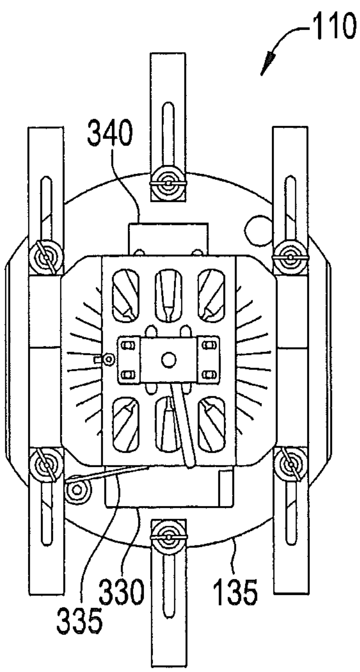


FIG. 6

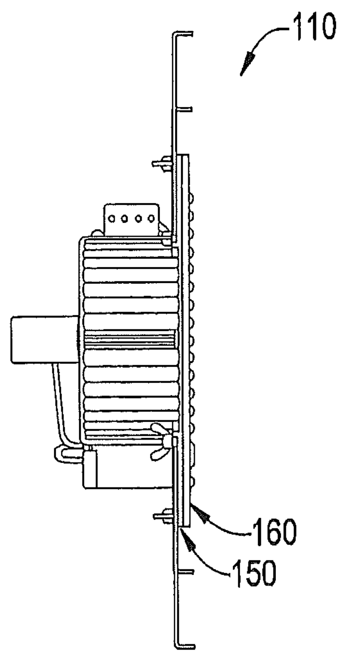


FIG. 7

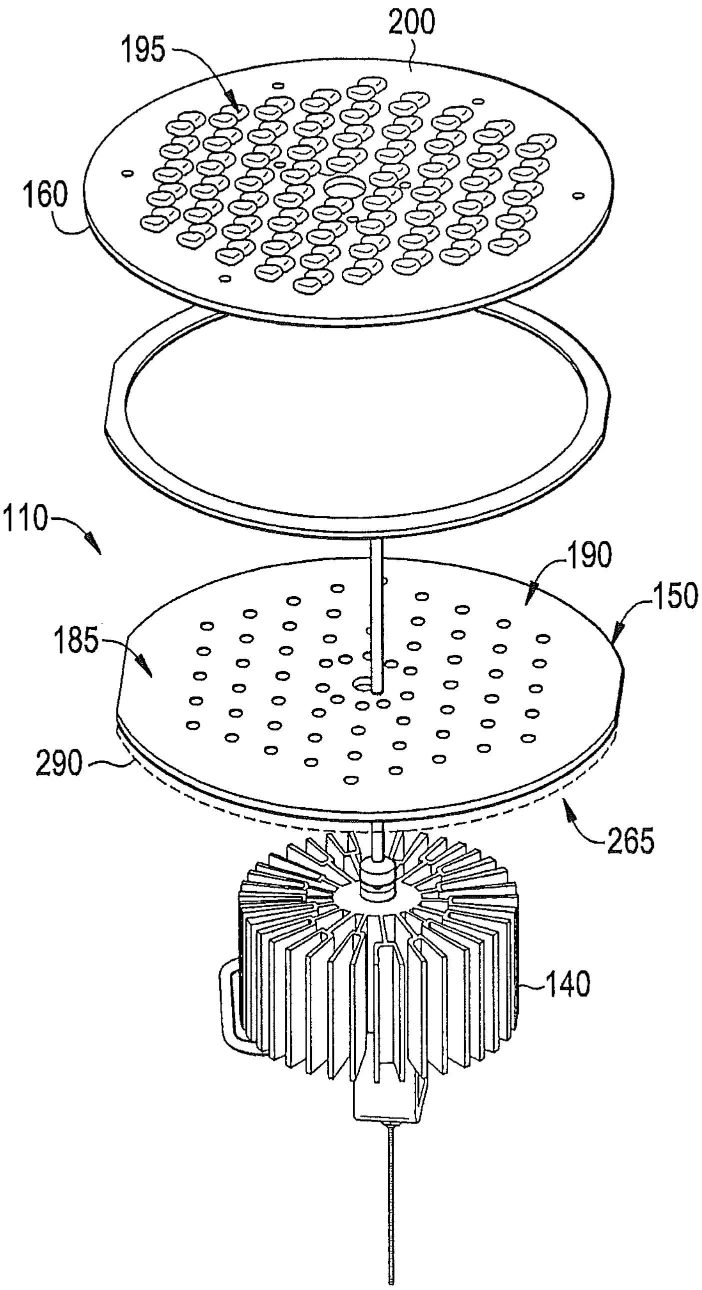


FIG. 8

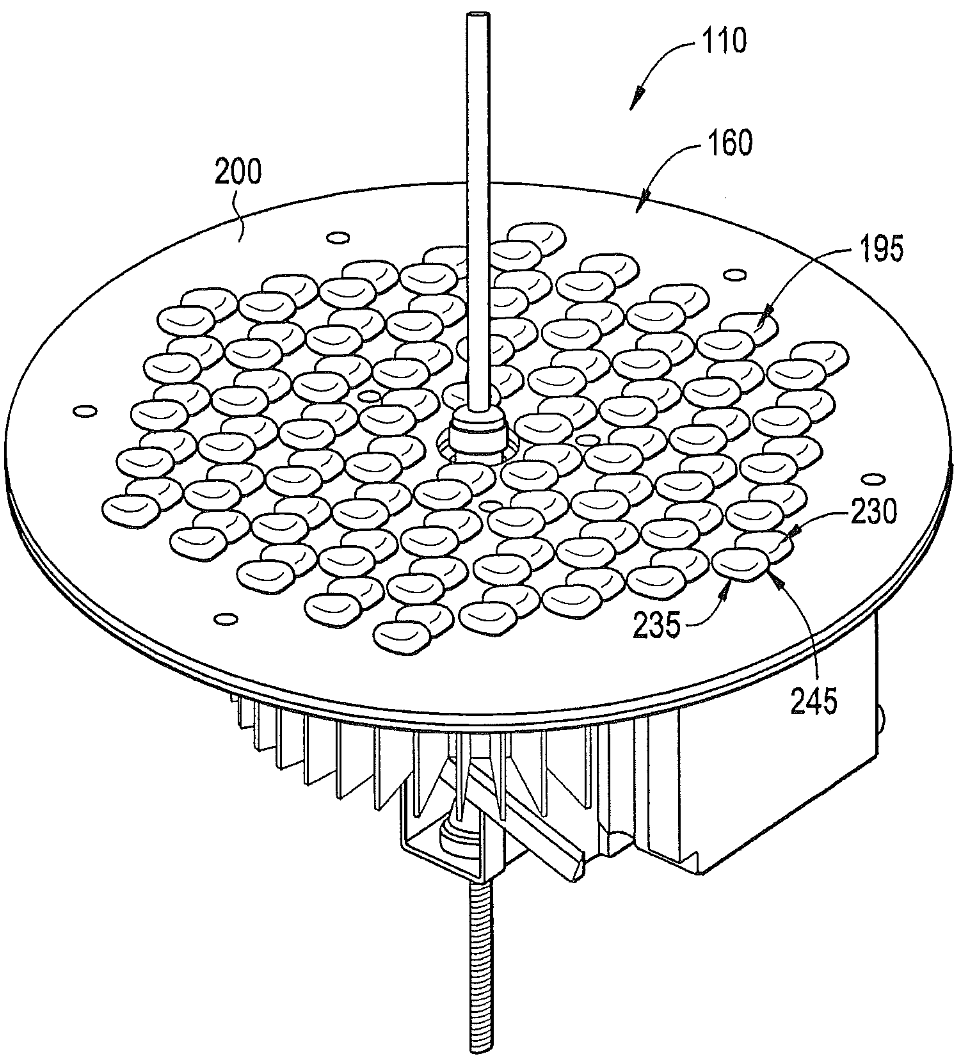


FIG. 9

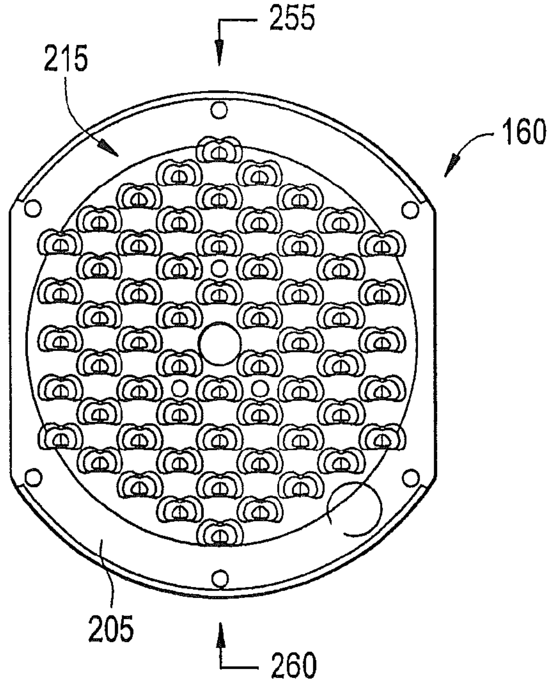
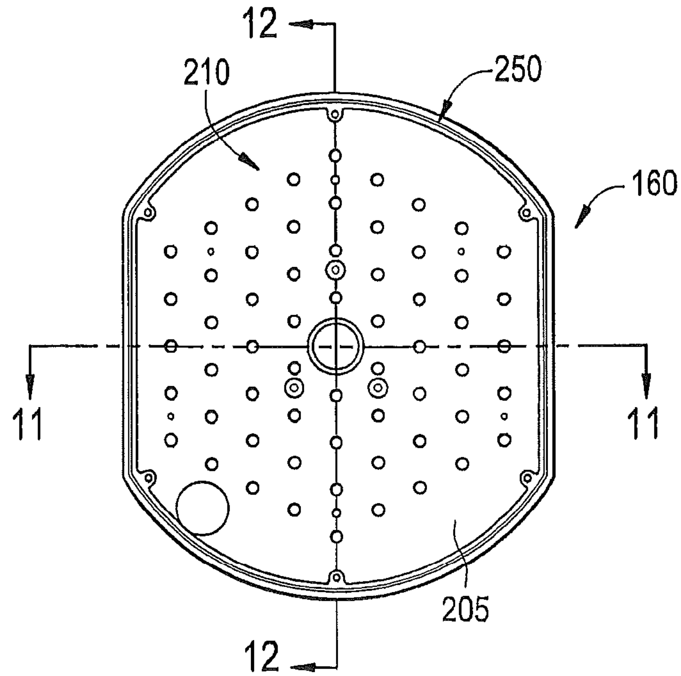


FIG. 10



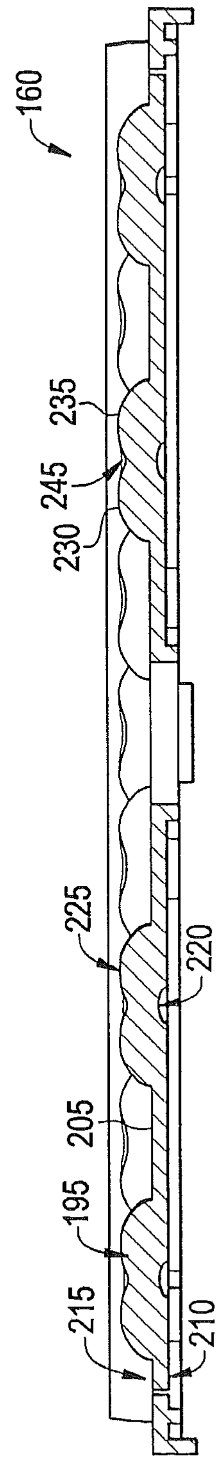


FIG. 11

FIG. 12

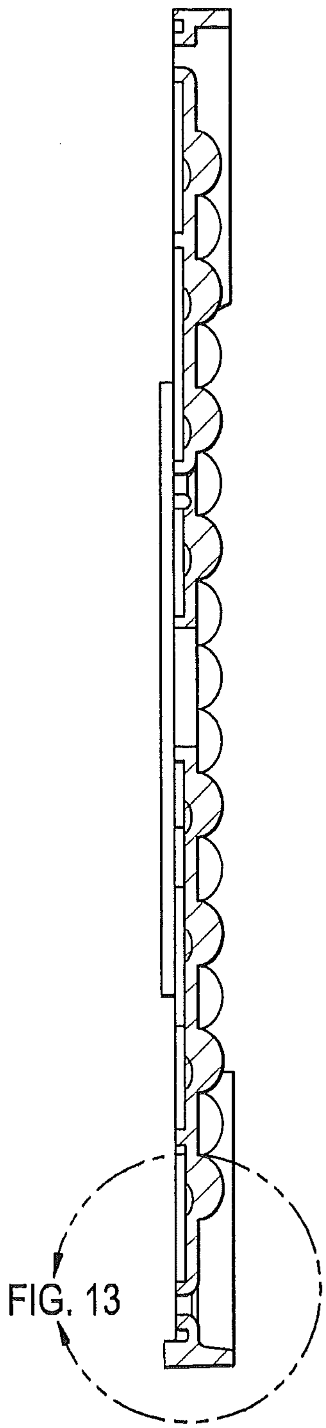


FIG. 13

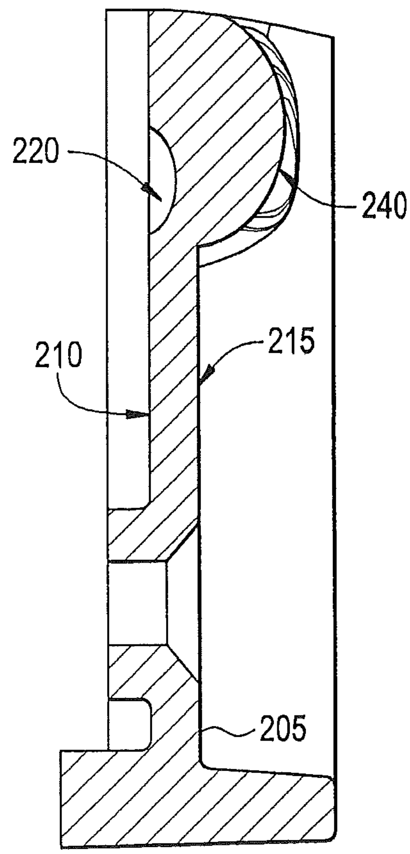


FIG. 14

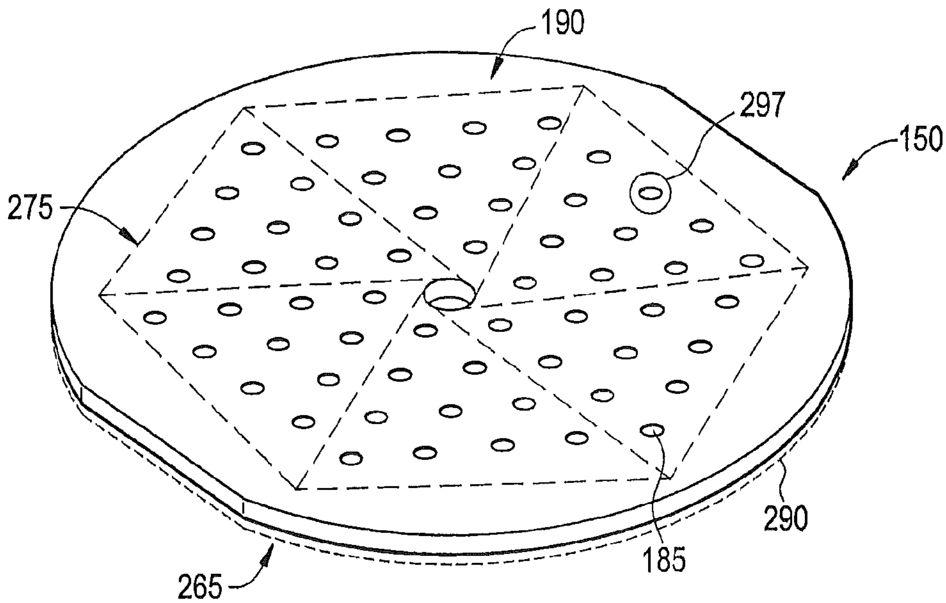


FIG. 15

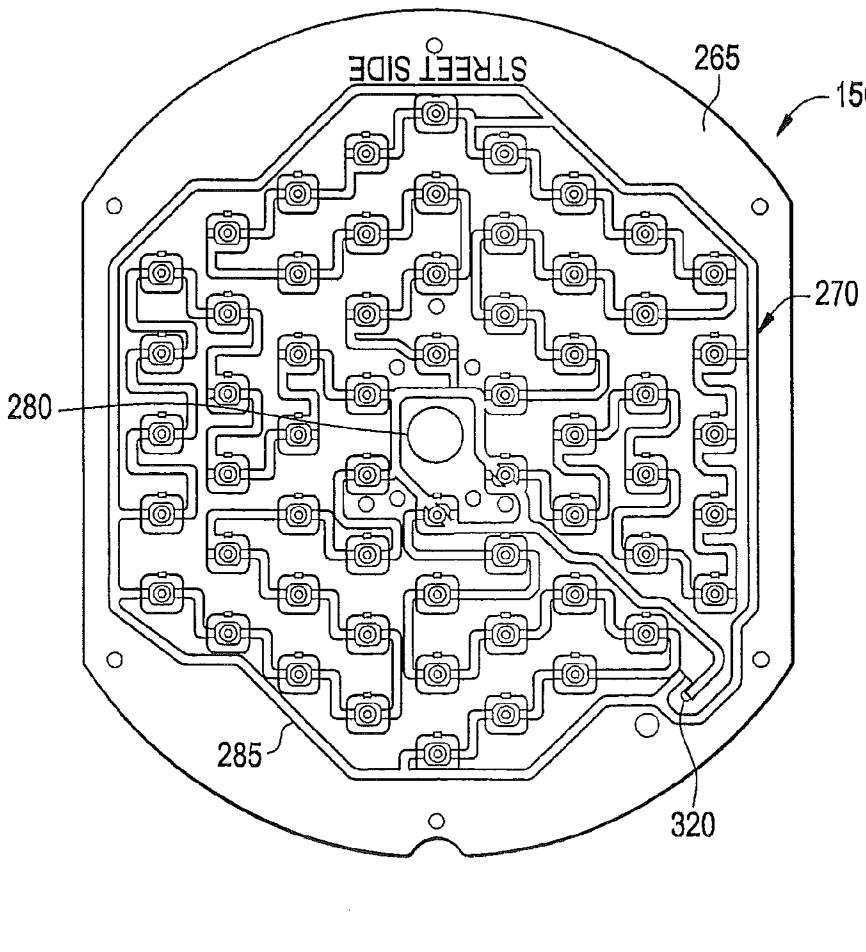


FIG. 16

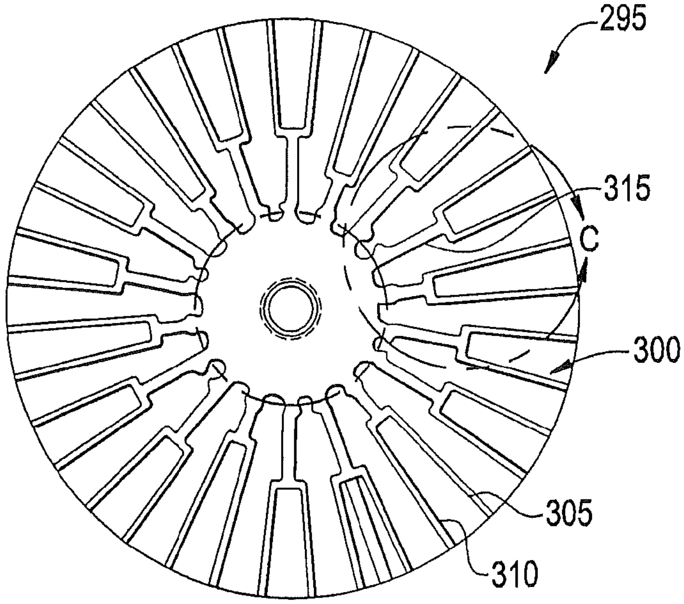
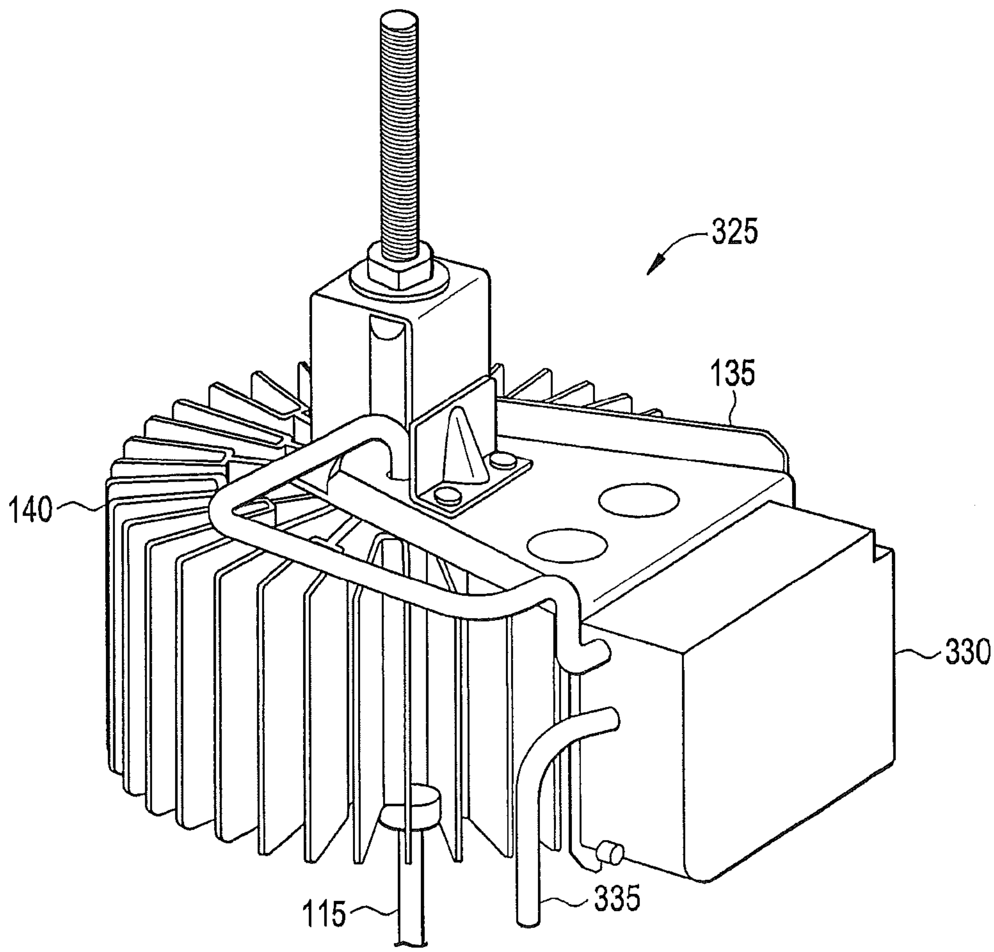


FIG. 17



LIGHT FIXTURE AND ASSOCIATED LED BOARD AND MONOLITHIC OPTIC

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 12/687,710 now U.S. Pat. No. 8,157,413, filed Jan. 14, 2010 and entitled "Light Fixture and Associated LED Board and Monolithic Optic" which, in turn, claims the benefit of U.S. Provisional Application Ser. No. 61/147,389, filed Jan. 26, 2009, which are both incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

The present disclosure relates generally to a light fixture and associated LED (light emitting diode) board and monolithic optic useful for area lighting or street lighting, and particularly to an LED-based street light fixture capable of generating a Type-III emission pattern at the ground level.

Conventional street lights include acorn type light fixtures and cobra type light fixtures, with the acorn type fixtures typically casting light from a light source in a uniform distribution around a central vertical axis (the lamp post for example) toward the street, and the cobra type fixtures typically casting light in a uniform downward distribution toward the street from an overhanging light source. With light fixtures having unmodified light distribution, the light emission pattern on one side of the fixture is substantially identical to the light emission pattern on an opposite side of the fixture. For acorn type light fixtures, such a uniform light emission pattern at the ground level is an inefficient use of light and energy where more light on the street side of the lamppost and less light on the house side of the lamppost is desired. Also with respect to energy usage, streetlights that employ high-pressure sodium (HPS) technology can still require a substantial amount of energy that can be overly burdensome to the tax base of municipalities employing many street light fixtures.

In an effort to overcome each of the aforementioned drawbacks, an LED solution employing a Type-III emission pattern (more light directed toward the street side and less light directed toward the house side) has been sought after, with the energy efficiency of LED's serving to keep energy demands under control, and the use of a specific emission pattern also serving to keep energy demands under control by directing the light to where it is more useful and less objectionable. For street lighting, however, and in view of the limited lumen output of a single LED compared with the cost of many LED's, an efficient arrangement utilizing a plurality of LED's within a single light fixture, such as an acorn light fixture, along with directed light emission, is desirable for advancing the art of LED street lighting and overcoming the aforementioned drawbacks.

BRIEF DESCRIPTION OF THE INVENTION

An embodiment of the invention is directed to a light fixture useful for area lighting. The light fixture includes a housing having a base and a top, and a light emitting diode (LED) light emission module disposed within the housing. The light emission module includes a centrally disposed aperture that receives a centrally disposed power lead for powering the light emission module.

Another embodiment of the invention is directed to an LED board useful for area lighting, which may be employed in the above-noted light fixture or another light fixture. The LED board includes a monolithic substrate having a first side and a second side, the first side having a plurality of LED's arranged in groups, each group being defined by a separate subset of the plurality of LED's, each group of LED's being electrically connected in parallel with each other group, and each of the LED's within a group being electrically connected in series with each other LED within the respective group.

Another embodiment of the invention is directed to a monolithic optic useful for area lighting employing a plurality of LED's, which may be employed in the above-noted light fixture or another light fixture. The monolithic optic includes a common platform having a first side configured to orient toward the LED's and a second side configured to orient toward the ground, and a plurality of convex lenses disposed on the second side in a one-to-one corresponding relationship with respect to the plurality of LED's. Each of the lenses has a same shape.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the exemplary drawings wherein like elements are numbered alike in the accompanying Figures:

FIG. **1** depicts an example embodiment of a light (fixture and pole) for use in accordance with an embodiment of the invention;

FIG. **2** depicts an example acorn light fixture, with a light emission module depicted in dashed lines, for use in accordance with an embodiment of the invention;

FIGS. **3**-**6** respectively depict an exploded assembly drawing, a back isometric drawing, a back view drawing, and a side view drawing, of an embodiment of a LED light emission module in accordance with an embodiment of the invention;

FIGS. **7** and **8** respectively depict an exploded assembly drawing and a front isometric drawing of an embodiment of the LED light emission module in accordance with an embodiment of the invention;

FIGS. **9**-**13** respectively depict a front plan view, a back plan view, a first section view, a second section view and a third section view, of a monolithic optic in accordance with an embodiment of the invention;

FIGS. **14** and **15** respectively depict an isometric front view and a back plan view of an LED board in accordance with an embodiment of the invention;

FIG. **16** depicts an example extrusion cross section for a heat sink in accordance with an embodiment of the invention; and

FIG. **17** depicts a portion of the light emission module showing a power supply and a secondary power lead in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of the invention, as shown and described by the various figures and accompanying text, provides an acorn LED light fixture useful for area lighting with a Type-III emission pattern at the ground level. While the embodiment described herein depicts an acorn light fixture as an exemplary light source, it will be appreciated that the disclosed invention is also applicable to other light sources, such as a cobra light fixture, for example. While embodiments described herein may be useful for providing Type-III light distribution, it will be appreciated that other emission patterns such as Types-I, II, IV and V may also be achieved by employing the teachings disclosed herein. While embodiments are described herein with reference to street lighting, it will be appreciated that such embodiments will also be applicable for the lighting of areas other than a street. As such, any reference herein to street lighting should not be construed as a limitation to the utility of embodiments of the invention.

FIG. **1** depicts an exemplary embodiment of a light (fixture and pole) **100** having an acorn type light fixture **105**. The acorn light fixture **105** is depicted further in FIG. **2** with a light emission module **110** depicted in dashed lines (to be discussed in more detail below), and with a centrally disposed power lead **115**, also depicted in dashed lines, for powering the light emission module **110**. In an embodiment, the light fixture **105** has a housing **120** that includes a base **125** and a top **130**, where the light emission module **110** is disposed within the housing **120** coupled to and supported by either of the base **125** or the top **130** by means that will be discussed further below. In an embodiment, the light emission module **110** is a light emitting diode (LED) light emission module having a centrally disposed aperture (best seen by referring to FIG. **3**) configured to receive the centrally disposed power lead **115**.

Reference is now made to FIGS. **3**-**6** collectively, where FIG. **3** is an exploded assembly drawing, FIG. **4** is a back isometric drawing, FIG. **5** is a back view drawing, and FIG. **6** is a side view drawing, of an embodiment of the LED light emission module **110**, which includes a support **135**, a radial fin heat sink **140** coupled to the support **135** via fasteners **145**, an LED board **150** coupled to the heat sink via fasteners **155**, and a monolithic optic **160** disposed proximate and coupled to the LED board **150** via fasteners **165**. In an embodiment, the monolithic optic **160** is formed of polycarbonate. One or more, and in an embodiment all, of the monolithic optic **160**, the LED board **150**, the heat sink **140** and the support **135**, include a centrally disposed aperture **161**, **151**, **141** and **136**, respectively, configured to receive the centrally disposed power lead **115** (only a segment being illustrated in FIG. **3**) for powering the light emission module **110**. Brackets **170** may be attached to support **135** for attaching the support **135**, and light emission module **110** generally, to the housing **120** of light fixture **105**, thereby providing universal mounting for a variety of light fixture designs. In an embodiment, the support **135** and brackets **170** are suitable for connecting the light emission module **110** to any shaped light fixture **105**, such as a circular, square, hexagonal or octagonal fixture for example, and are suitable for mounting the light emission module **110** at the top of the light fixture **105**, as illustrated in FIG. **2** for example, or at the bottom of the light fixture **105**. Gaskets **175**, **180** may be employed and disposed within respective gasket-receiving features to provide an adequate weather seal between the monolithic optic **160** and the LED board **150**, however, it is contemplated that adequate weather sealing may also be attainable using a curable sealant in place of one or both of the gaskets **175**, **180**.

Referring now to FIGS. **7** and **8**, where FIG. **7** is an exploded assembly drawing and FIG. **8** is a front isometric drawing of an embodiment of the LED light emission module **110**, the LED board **150** includes a plurality of LED's **185** disposed on a front side **190** of LED board **150**, and the monolithic optic **160** includes a plurality of lenses **195** disposed on a front side **200** (also herein referred to as the street side) of monolithic optic **160**, with each of the lenses **195** being associated and aligned with a corresponding one of the LED's **185**. Each lens **195** in combination with its corresponding LED **185** produces a same emission pattern oriented in a same direction as every other pair of lens **195** and LED **185** such that a Type-III emission pattern results on the ground at the street level from each pair of lens **195** and LED **185**, and from the aggregate of all pairs of lenses **195** and LED's **185**. As such, loss of light from a single or a group of LED's **185** does not change the overall emission pattern, but only slightly decreases the overall light intensity by a defined amount.

Further description of how the monolithic optic **160** produces this Type-III emission pattern will now be made with reference to FIGS. **9**-**13**, where FIG. **9** is a front plan view, FIG. **10** is a back plan view, and FIGS. **11**-**13** are various section views of the monolithic optic **160**. In an embodiment, monolithic optic **160** is formed with a common platform **205** having a first side **210** configured to orient toward the LED's **185** and a second side (street side) **215** configured to orient toward the street. In an embodiment, the common platform **205** defines a planar surface. The plurality of lenses **195** form concave lens profiles (dimples) **220** disposed on the first side **210**, and convex lens profiles **225** disposed on the second side **215**, in a one-to-one corresponding relationship with respect to the plurality of LED's **185**, with each of the lenses **195** having the same shape and the same respective optical portions that are configured to direct light in the same direction. More specifically, each of the lenses **195** has a same first cross-section (see FIG. **11** for example) and a same second cross-section (see FIGS. **12** and **13** for example), where the first and second cross-sections are orthogonal to each other. As can be seen in the first cross-section of FIG. **11**, each lens **195** has a centrally disposed dimple **220** (also referred to above as a concave lens profile) on the first side **210** of the common platform **205** with respect to two symmetrically disposed convex lobes **230**, **235** (also referred to above as a convex lens profile **225**) on the second side **215** of the common platform **205**. Also, as can be seen in the second cross-section of FIG. **12** and the expanded detail of FIG. **13**, each lens **195** has the aforementioned dimple **220** non-centrally disposed on the first side **210** of the common platform **205** with respect to a single asymmetrically disposed convex lobe **240** on the second side **215** of the common platform **205**. The overall shape formed by the convex lobes **230**, **235**, **240** and the concave dimple **220** is best seen by referring back to FIG. **8**, which illustrates in isometric view a plurality of lenses **195** each having two lobes **230**, **235** (see also FIG. **11**) symmetrically disposed about a valley **245** (see also FIG. **11**). The light from an LED **185** disposed at the first side **210** proximate a respective dimple **220** passes through the respective lens **195** (lobes **230**, **235**, **240**) in such a manner as to be directed more toward the street side **255** of the light fixture **105** than toward the house side **260** so as to provide a Type-III emission pattern, as discussed previously.

Notwithstanding the foregoing discussion of Type-III light distribution, it will be appreciated that alternative optics (not shown) may be used in place of optic **160** to provide any desired type of emission pattern, such as Type-I, II, III, IV or V light distribution for example. Accordingly, the scope of non-limiting inventions disclosed herein are not intended to be limited to Type-III light distribution only.

For weather sealing, also discussed previously, the first side **210** of common platform **205** optionally includes an endless gasket-receiving feature **250**, such as a recessed track for example, formed within and disposed proximate to the perimeter of the common platform **205**.

The LED board **150** will now be discussed with reference to FIGS. **14** and **15**, where FIG. **14** depicts an isometric view of the front (first) side **190** illustrating the plurality of LED's **185** aligned in one-to-one correlation with the dimples **220** on the first side **210** of monolithic optic **160**, and FIG. **14** depicts a plan view of the back (second) side **265** illustrating the electrical traces **270** for powering the LED's **185**. In an embodiment, the LED board **150** is made from a monolithic substrate, where the LED's **185** disposed on the first side **190** are arranged in groups **275**, with each group **275** being defined by a separate subset of the plurality of LED's **185**, with each group **275** of LED's **185** being electrically connected in parallel with each other group **275**, and with each of the LED's **185** within a group **275** being electrically connected in series with each other LED **185** within the respective group **275**. The electrical connection of LED's **185** within a group **275**, and between groups **275**, can be seen by careful examination of the electrical traces **270** depicted in FIG. **15**. For example, the central most LED **185** of a given group **275** is electrically connected on one side to a positive electrical bus **280**, and the outermost LED **185** of a respective given group **275** is electrically connected on an opposing side to a negative electrical bus **285**, with each LED **185** within the respective group being electrically connected in series. As such, light emission from all LED's **185** within a given group **275** will be lost in response to one of the LED's **185** within the given group **275** being non-functional (open circuited or burned out, for example). Power to the positive and negative electrical buses **280**, **285** is made via contact pad **320**, which is discussed further below in connection with FIG. **17**. In an embodiment, and as illustrated in FIGS. **14** and **15**, the plurality of LED's **185** are arranged in six triangular shaped groups **275** of LED's arranged in a hexagon pattern. As further illustrated in FIGS. **14** and **15**, an embodiment includes sixty LED's **185** arranged in six groups **275** of ten LED's each. In an embodiment, each group **275** of LED's **185** has the same number of LED's. While embodiments of the invention depict a certain arrangement of groups of LED's, and a certain number of LED's within a group, it will be appreciated that this is for illustrative purposes only, and that the scope of the invention contemplates and encompasses other counts of LED's within a group, and other arrangements of groups (pentagon, octagon, to name a few for example). To produce the Type-III emission pattern discussed above, an embodiment includes an arrangement of LED's **185** where each LED of the plurality of LED's all point in the same direction.

In an embodiment, the light emission module **110** disclosed herein does not include current regulation, which is typically employed in other existing LED light fixtures, and as discussed above, loss of light from a group of LED's **185** does not change the overall emission pattern, but only slightly decreases the overall light intensity by a defined amount. In an embodiment, such a defined amount can be determined from statistical averaging and the central limit theorem, where the forward voltage across each group of LED's (a group of ten LED's for example) remains fixed regardless of the number of parallel-connected groups of LED's that remain functional. For example, even though failure of a single LED within a group will eliminate the entire group (16.7% of all LED's for an arrangement of six groups of ten), the current increase in the remaining five strings (groups) increases the emission of those remaining groups so that the overall intensity loss is only 5%. Loss of two groups (33.3%) is estimated to result in only an 11% loss in overall intensity. As such, the embodiment disclosed herein provides for self-regulating light emission without the need for a current regulator.

To facilitate heat transfer from the LED's **185** to the heat sink **140**, a thermally conductive layer **290** (see FIGS. **7** and **14** for example), such as aluminum for example, may be disposed across the entire surface area of the second side **265** of the LED board **150**, where this thermally conductive layer **290** is disposed adjacent to and in intimate thermal communication with the heat sink **140**. In an embodiment, the heat sink **140** is a radial fin heat sink formed from an extrusion with planar cutoff ends. As seen by reference to FIG. **7**, one of the planar ends of heat sink **140** interfaces with the conductive layer **290** on the second side **265** of LED board **150**. At a plane defined by the interface of the LED board **150** and the heat sink **140**, the LED board **150** has an outside profile that shadows the outside profile of the heat sink **140**. That is, the LED board **150** has a larger girth than the heat sink **140**. The combination of a thermally conductive layer **290** and a smaller heat sink **140** provides for smaller packaging than other typical LED light fixtures suitable for street lighting. An example extrusion cross section **295** for heat sink **140** is depicted in FIG. **16**, which illustrates a plurality of fins **300** formed having two extension fins **305**, **310** extending off of a root fin **315**. As can be seen, the extension fins **305**, **310** may vary in length according to desired performance characteristics.

To provide for a desired color emission spectrum from the plurality of LED's **185**, a light transmissible encapsulate **297** (see FIG. **14** for example) possessing desired color rendition properties may be disposed over each of the LED's **185**.

Referring now to FIG. **17**, which depicts a portion **325** of light emission module **110** (heat sink **140**, partial support **135**, central power lead **115**, for example), in addition to a power supply **330** and a secondary power lead **335** (also illustrated in FIGS. **3** and **5**). The centrally disposed power lead **115**, which typically provides ac (alternating current) power from a utility, passes up through the center of light emission module **110**, as discussed above, and is connected to the power supply **330**, which in turn converts the ac power to dc (direct current) power for powering the LED's **185**. The secondary power lead **335** is connected to the LED board **150** via contact pad **320** (see FIG. **15**). In addition to the power supply **330**, a surge suppressor **340** (see FIGS. **3** and **5**) may be employed as part of the light emission module **110** in a manner known in the art for providing surge protection to the LED board **150**.

As illustrated in FIG. **17**, an embodiment includes the power supply **330** being structurally connected with support **135** of the light emission module **110**. However, it will be appreciated that the power supply **330** may be positioned at any location in association with and suitable for the purpose of powering light **100** without departing from embodiments of the invention disclosed herein. As such, all such locations for power supply **330** are contemplated and considered within the scope of inventions disclosed herein.

With regard to orientation, the light emission module **110** may be disposed in the base **125** of light fixture **105** with light emission therefrom being oriented in an upward direction away from the street or ground, or may be disposed in the top **130** of light fixture **105** with light emission therefrom being oriented in a downward direction toward the street or ground. In the base arrangement with light emission upward, the central power lead **115** may connect directly to the power supply **330** without having to pass through the heat sink **140**, LED board **150** or monolithic optic **160**, and in the top arrangement with light emission downward, the centrally disposed power lead **115** is disposed so as to minimize lead interference with light emission from the LED board **150** and monolithic optic **160**. In either orientation, the light emission module **110** configured to receive a centrally arranged power lead **115** as disclosed herein provides light emission advantages not otherwise provided by existing LED type light fixtures that may also be suitable for street lighting.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best or only mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

What is claimed is:

1. A light fixture useful for area lighting, the light fixture comprising:

a housing; and

a light emitting diode (LED) light emission module disposed within the housing, the light emission module having an LED board, the LED board comprising:

a monolithic substrate having a first side and a second side,

a first group of LEDs arranged on the first side, the first group of LEDs having a first plurality of LEDs electrically coupled in series;

a second group of LEDs arranged on the first side adjacent to the first group of LEDs, the second group of LEDs having a second plurality of LEDs electrically coupled in series, wherein the second group of LEDs is electrically coupled in parallel with the first group of LEDs.

2. The light fixture of claim **1**, wherein the housing includes a base and a top coupled to the base.

3. The light fixture of claim **2**, wherein the light emission module is disposed at least partially in the base with light emission therefrom being oriented in an upward direction away from the ground.

4. The light fixture of claim **2**, wherein the light emission module is disposed at least partially in the top with light emission therefrom being oriented in a downward direction toward the ground.

5. The light fixture of claim **1**, wherein the light emission module further comprises:

a support;

a heat sink coupled to the support;

the monolithic substrate coupled to the heat sink; and

a monolithic optic disposed proximate to the monolithic substrate.

6. The light fixture of claim **5**, wherein at least one of the monolithic optic, the monolithic substrate, the heat sink and the support has a centrally disposed aperture that receives a centrally disposed power lead for powering the light emission module.

7. The light fixture of claim **5**, wherein the monolithic substrate has a thermally conductive layer, the thermally conductive layer being disposed adjacent to and in thermal communication with the heat sink.

8. The light fixture of claim **5**, wherein at a plane defined by an interface of the monolithic substrate and the heat sink, the monolithic substrate has an outside profile that is equal to or greater than an outside profile of the heat sink.

9. The light fixture of claim **5**, wherein:

the light emission module is disposed in the housing with light emission therefrom being oriented downward toward the ground;

the monolithic optic has a plurality of lenses, each of the lenses being associated with a corresponding one of the LEDs in the first and second group of LEDs; and

each lens and corresponding LED has a same emission pattern oriented in a same direction that produces a Type-III emission pattern on the ground.

10. The light fixture of claim **1**, wherein each of the LEDs in the first and second group of LEDs are disposed such that light emission from each LED is directed in a same direction.

11. The light fixture of claim **1**, further comprising a thermally conductive layer disposed on the second side of the monolithic substrate.

12. The light fixture of claim **1**, wherein a number of LEDs in the first group of LEDs is equal to a number of LEDs in the second group of LEDs.

13. The light fixture of claim **1**, wherein the monolithic substrate has a centrally disposed aperture that receives a centrally disposed power lead for powering the first group of LEDs and the second group of LEDs.

14. The light fixture of claim **1**, further comprising a light transmissible encapsulate disposed over each of the LEDs.

15. A light fixture comprising:

a housing comprising a base and a top; and

a light emitting diode (LED) light emission module disposed within the housing, the light emission module comprising:

a plurality of LEDs;

a platform having a first side oriented towards the plurality of LEDs, and a second side oriented away from the plurality of LEDs; and

a plurality of convex lenses disposed on the second side, wherein each of the plurality of convex lenses is associated with one of the plurality of LEDs.

16. The light fixture of claim **15**, wherein the light emission module is disposed at least partially in the base with light emission therefrom being oriented in an upward direction away from the ground.

17. The light fixture of claim **15**, wherein the light emission module is disposed at least partially in the top with light emission therefrom being oriented in a downward direction toward the ground.

18. A light fixture comprising:

a housing comprising a base and a top; and

a light emitting diode (LED) light emission module disposed within the housing, the light emission module comprising:

a plurality of LEDs;

a platform having a first side oriented towards the plurality of LEDs, and a second side oriented away from the plurality of LEDs; and

a plurality of convex lenses disposed on the second side, wherein each of the plurality of convex lenses is associated with one of the plurality of LEDs;

wherein the light emission module further comprises:

a support;

a heat sink coupled to the support;

a monolithic substrate coupled to the heat sink; and

the platform disposed proximate to the monolithic substrate.

19. The light fixture of claim **18**, wherein at least one of the monolithic substrate, the heat sink and the support has a centrally disposed aperture that receives a centrally disposed power lead for powering the light emission module.

20. The light fixture of claim **18**, wherein at a plane defined by an interface of the monolithic substrate and the heat sink, the monolithic substrate has an outside profile that is equal to or greater than an outside profile of the heat sink.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,506,118 B2
APPLICATION NO. : 13/421910
DATED : August 13, 2013
INVENTOR(S) : Fredric S. Maxik et al.

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

On the Title Page, Item 73:

In Column 1, Line 1: delete “Lighting Sciene Group Corporation” and insert -- Lighting Science Group Corporation --, therefor.

Signed and Sealed this
Fifteenth Day of April, 2014

Michelle K. Lee

Michelle K. Lee
Deputy Director of the United States Patent and Trademark Office

Exhibit 4

U.S. Patent No. 8,506,118
("'118 Patent")

Accused Products

The GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073) ("GE Relax") infringes at least claim 1 and 5 of the '118 Patent.

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
1[pre]. A light fixture useful for area lighting, the light fixture comprising:	The preamble is not a limitation. To the extent the preamble is construed as a limitation, the GE Relax is a light fixture useful for area lighting. An image of the GE Relax is provided below.  Light fixture useful for area lighting

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
1[a] a housing; and	The GE Relax is a light fixture containing a housing, as indicated in the image below. REDACTED

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
1[b] a light emitting diode (LED) light emission module disposed within the housing, the light emission module having an LED board, the LED board comprising:	The GE Relax contains a light emitting diode (LED) light emission module disposed within the housing, the light emission module having an LED board. An image of the light emission module, after being removed from the housing, is shown below. REDACTED [redacted]

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
1[c] a monolithic substrate having a first side and a second side,	The light emission module of the GE Relax contains a monolithic substrate having a first side and a second side. [redacted] REDACTED [redacted]

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
1[d] a first group of LEDs arranged on the first side, the first group of LEDs having a first plurality of LEDs electrically coupled in series;	The light emission module of the GE Relax contains a first group of LEDs arranged on the first side, the first group of LEDs having a first plurality of LEDs electrically coupled in series. [redacted] [redacted] REDACTED

Claim 1	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
	REDACTED
1[e] a second group of LEDs arranged on the first side adjacent to the first group of LEDs, the second group of LEDs having a second plurality of LEDs electrically coupled in series, wherein the second group of LEDs is electrically coupled in parallel with the first group of LEDs.	The light emission module of the GE Relax contains a second group of LEDs arranged on the first side adjacent to the first group of LEDs, the second group of LEDs having a second plurality of LEDs electrically coupled in series, wherein the second group of LEDs is electrically coupled in parallel with the first group of LEDs. [redacted] Moreover, the first and second group of LEDs are electrically coupled in parallel with each other. [redacted] [redacted]

Claim 5	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
5[a]. The light fixture of claim 1, wherein the light emission module further comprises: a support;	The GE Relax fixture has a support, depicted below. REDACTED

Claim 5	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
5[b] a heat sink coupled to the support;	The GE Relax fixture has a heat sink, depicted below. [redacted] REDACTED

Claim 5	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
5[c] the monolithic substrate coupled to the heat sink; and	The LED board ("monolithic substrate") of the GE Relax is coupled to the heat sink [redacted] depicted below. REDACTED

Claim 5	GE Relax 8W (65W Replacement) Dimmable BR30 HD LED Light Bulb (Soft White) (43073)
5[d] a monolithic optic disposed proximate to the monolithic substrate.	The GE Relax includes a monolithic optic, shown below. [redacted] REDACTED [redacted]

Exhibit 5

US008674608B2

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

(10) **Patent No.: US 8,674,608 B2**
(45) **Date of Patent: Mar. 18, 2014**

(54) **CONFIGURABLE ENVIRONMENTAL CONDITION SENSING LUMINAIRE, SYSTEM AND ASSOCIATED METHODS**

(75) Inventors: **Eric Holland**, Indian Harbour Beach, FL (US); **Mark P. Boomgaarden**, Satellite Beach, FL (US); **Eric Thosteson**, Satellite Beach, FL (US)

(73) Assignee: **Lighting Science Group Corporation**, Satellite Beach, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 60 days.

(21) Appl. No.: **13/403,531**

(22) Filed: **Feb. 23, 2012**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
H05B 37/02 (2006.01)

(52) **U.S. Cl.**
USPC **315/155**; 315/154; 315/149

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,319,301 A 6/1994 Callahan et al.
5,523,878 A 6/1996 Wallace et al.
5,563,422 A 10/1996 Nakamura et al.
5,704,701 A 1/1998 Kavanagh et al.
5,936,599 A 8/1999 Reymond
5,997,150 A 12/1999 Anderson
6,140,646 A 10/2000 Busta et al.
6,211,626 B1 4/2001 Lys et al.
6,341,876 B1 1/2002 Moss et al.
6,356,700 B1 3/2002 Strobl
6,561,656 B1 5/2003 Kojima et al.
6,594,090 B2 7/2003 Kruschwitz et al.

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 02/16824 2/2002
WO WO 2006/095315 9/2006

(Continued)

OTHER PUBLICATIONS

Tannith Cattermole, "Smart Energy Glass controls light on demand", Gizmag.com, Apr. 18, 2010, accessed Nov. 1, 2011.

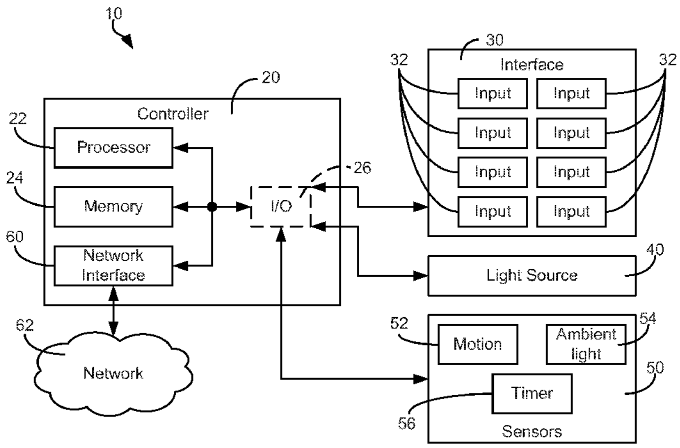
(Continued)

Primary Examiner — Crystal L Hammond
(74) *Attorney, Agent, or Firm* — Mark R. Malek; Daniel C. Pierron; Zies Widerman & Malek

(57) **ABSTRACT**

A luminaire with a light source, controller, and sensors to emit light into an environment is described. The controller may include a processor and memory to analyze data relating to conditions in the environment and to control the light source emitting light. The sensors may be in communication with the controller to detect conditions in the environment and generate data relating to same. The data may be receivable by the controller. Rules affect operation of the luminaire, which may be manipulated using an interface. The luminaire may communicate with devices connected through a network. Light and an auxiliary signal may be emitted substantially simultaneously to provide spatial awareness.

84 Claims, 21 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,733,135 B2 5/2004 Dho
6,767,111 B1 7/2004 Lai
6,817,735 B2 11/2004 Shimizu et al.
6,853,150 B2 2/2005 Clauberg et al.
6,870,523 B1 3/2005 Ben-David et al.
6,871,982 B2 3/2005 Holman et al.
6,876,007 B2 4/2005 Yamazaki et al.
6,967,761 B2 11/2005 Starkweather et al.
6,974,713 B2 12/2005 Patel et al.
7,042,623 B1 5/2006 Huibers et al.
7,066,628 B2 6/2006 Allen
7,070,281 B2 7/2006 Kato
7,072,096 B2 7/2006 Holman et al.
7,075,707 B1 7/2006 Rapaport et al.
7,083,304 B2 8/2006 Rhoads et al.
7,138,770 B2 11/2006 Uang et al.
7,178,941 B2 2/2007 Roberge et al.
7,184,201 B2 2/2007 Duncan
7,246,923 B2 7/2007 Conner
7,255,469 B2 8/2007 Wheatley et al.
7,261,453 B2 8/2007 Morejon et al.
7,289,090 B2 10/2007 Morgan
7,300,177 B2 11/2007 Conner
7,303,291 B2 12/2007 Ikeda et al.
7,325,956 B2 2/2008 Morejon et al.
7,342,658 B2 3/2008 Kowarz et al.
7,344,279 B2 3/2008 Mueller et al.
7,349,095 B2 3/2008 Kurosaki
7,400,439 B2 7/2008 Holman
7,427,146 B2 9/2008 Conner
7,429,983 B2 9/2008 Islam
7,434,946 B2 10/2008 Huibers
7,438,443 B2 10/2008 Tatsuno et al.
7,476,016 B2 1/2009 Kurihara
7,489,086 B2 2/2009 Miskin et al.
7,520,642 B2 4/2009 Holman et al.
7,530,708 B2 5/2009 Park
7,537,347 B2 5/2009 Dewald
7,540,616 B2 6/2009 Conner
7,567,040 B2 7/2009 Pong et al.
7,598,682 B2 10/2009 Grajcar
7,598,686 B2 10/2009 Lys et al.
7,604,378 B2 10/2009 Wolf et al.
7,605,971 B2 10/2009 Ishii et al.
7,607,798 B2 10/2009 Panotopoulos
7,626,755 B2 12/2009 Furuya et al.
7,677,736 B2 3/2010 Kasazumi et al.
7,684,007 B2 3/2010 Hull et al.
7,703,943 B2 4/2010 Li et al.
7,705,810 B2 4/2010 Choi et al.
7,708,452 B2 5/2010 Maxik et al.
7,709,811 B2 5/2010 Conner
7,719,766 B2 5/2010 Grasser et al.
7,728,846 B2 6/2010 Higgins et al.
7,732,825 B2 6/2010 Kim et al.
7,766,490 B2 8/2010 Harbers et al.
7,819,556 B2 10/2010 Heffington et al.
7,828,453 B2 11/2010 Tran et al.
7,828,465 B2 11/2010 Roberge et al.
7,832,878 B2 11/2010 Brukilacchio et al.
7,834,867 B2 11/2010 Sprague et al.
7,835,056 B2 11/2010 Doucet et al.
7,841,714 B2 11/2010 Gruber
7,845,823 B2 12/2010 Mueller et al.
7,852,017 B1 12/2010 Melanson
7,871,839 B2 1/2011 Lee et al.
7,880,400 B2 2/2011 Zhou et al.
7,889,430 B2 2/2011 El-Ghoroury et al.
7,906,789 B2 3/2011 Jung et al.
7,972,030 B2 7/2011 Li
7,976,205 B2 7/2011 Grotsch et al.
8,016,443 B2 9/2011 Falicoff et al.
8,040,070 B2 10/2011 Myers et al.
8,047,660 B2 11/2011 Penn et al.
8,049,763 B2 11/2011 Kwak et al.
8,061,857 B2 11/2011 Liu et al.
8,070,302 B2 12/2011 Hatanaka et al.
8,076,680 B2 12/2011 Lee et al.
8,083,364 B2 12/2011 Allen
8,096,668 B2 1/2012 Abu-Ageel
8,214,084 B2 7/2012 Simon et al.
8,232,745 B2 7/2012 Chemel et al.
8,253,338 B2 * 8/2012 Ashoff et al. 315/133
2003/0039036 A1 2/2003 Kruschwitz et al.
2004/0052076 A1 3/2004 Mueller et al.
2004/0218390 A1 11/2004 Holman et al.
2005/0134188 A1 * 6/2005 Lindqvist 315/149
2005/0174768 A1 8/2005 Conner
2005/0190430 A1 9/2005 Patel et al.
2006/0002101 A1 1/2006 Wheatley et al.
2006/0002108 A1 1/2006 Ouderkirk et al.
2006/0002110 A1 1/2006 Dowling et al.
2006/0138971 A1 6/2006 Uang et al.
2006/0164005 A1 7/2006 Sun
2006/0164607 A1 7/2006 Morejon et al.
2006/0232992 A1 10/2006 Bertram et al.
2006/0285078 A1 12/2006 Kasazumi et al.
2006/0285193 A1 12/2006 Kimura et al.
2006/0291269 A1 12/2006 Doucet et al.
2007/0013871 A1 1/2007 Marshall et al.
2007/0146639 A1 6/2007 Conner
2007/0159492 A1 7/2007 Lo et al.
2007/0188847 A1 8/2007 McDonald et al.
2007/0211449 A1 9/2007 Holman et al.
2007/0241340 A1 10/2007 Pan
2007/0263298 A1 11/2007 El-Ghoroury et al.
2007/0273794 A1 11/2007 Sprague et al.
2008/0143970 A1 6/2008 Harbers et al.
2008/0143973 A1 6/2008 Wu
2008/0198572 A1 8/2008 Medendorp
2008/0211421 A1 9/2008 Lee et al.
2008/0218992 A1 9/2008 Li
2008/0232084 A1 9/2008 Kon
2008/0258643 A1 10/2008 Cheng et al.
2008/0285271 A1 11/2008 Roberge et al.
2009/0009102 A1 1/2009 Kahlman et al.
2009/0046307 A1 2/2009 Kwak et al.
2009/0059099 A1 3/2009 Linkov et al.
2009/0059585 A1 3/2009 Chen et al.
2009/0079355 A1 3/2009 Zhou et al.
2009/0128781 A1 5/2009 Li
2009/0129079 A1 5/2009 Grotsch et al.
2009/0160370 A1 6/2009 Tai et al.
2009/0184662 A1 7/2009 Given et al.
2009/0184666 A1 7/2009 Myers et al.
2009/0261748 A1 10/2009 McKinney et al.
2009/0262516 A1 10/2009 Li
2009/0267085 A1 10/2009 Lee et al.
2009/0273918 A1 11/2009 Falicoff et al.
2010/0006762 A1 1/2010 Yoshida et al.
2010/0025700 A1 2/2010 Jung et al.
2010/0046234 A1 2/2010 Abu-Ageel
2010/0051976 A1 3/2010 Rooymans
2010/0060181 A1 3/2010 Choi et al.
2010/0061068 A1 3/2010 Geissler et al.
2010/0061078 A1 3/2010 Kim
2010/0072494 A1 3/2010 Lee et al.
2010/0103389 A1 4/2010 McVea et al.
2010/0109031 A1 5/2010 Lee et al.
2010/0110516 A1 5/2010 Penn et al.
2010/0117101 A1 5/2010 Kim et al.
2010/0128233 A1 5/2010 Liu et al.
2010/0141153 A1 * 6/2010 Recker et al. 315/149
2010/0165599 A1 7/2010 Allen
2010/0202129 A1 8/2010 Abu-Ageel
2010/0213859 A1 8/2010 Shteynberg et al.
2010/0231136 A1 9/2010 Reisenauer et al.
2010/0231863 A1 9/2010 Hikmet et al.
2010/0232134 A1 9/2010 Tran
2010/0244700 A1 9/2010 Chong et al.
2010/0244724 A1 9/2010 Jacobs et al.
2010/0270942 A1 10/2010 Hui et al.
2010/0277084 A1 11/2010 Lee et al.
2010/0295483 A1 * 11/2010 Ashoff et al. 315/312

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0302464	A1	12/2010	Raring et al.	
2010/0308738	A1	12/2010	Shteynberg et al.	
2010/0308739	A1	12/2010	Shteynberg et al.	
2010/0315320	A1	12/2010	Yoshida	
2010/0320927	A1	12/2010	Gray et al.	
2010/0320928	A1	12/2010	Kaihotsu et al.	
2010/0321641	A1	12/2010	Van Der Lubbe	
2010/0321933	A1	12/2010	Hatanaka et al.	
2011/0012137	A1	1/2011	Lin et al.	
2011/0193484	A1 *	8/2011	Harbers et al.	315/129
2012/0223646	A1 *	9/2012	Recker et al.	315/152
2013/0214687	A1 *	8/2013	Weaver	315/151

FOREIGN PATENT DOCUMENTS

WO	WO 2007/125477		11/2007
WO	2010/027459	A2	3/2010
WO	2010/098811	A2	9/2010
WO	2011/008251	A2	1/2011
WO	2011/016860	A1	2/2011

OTHER PUBLICATIONS

Gonzales, Rafael C., et al., "Digital Image Processing", Second Edition, ISBN-0-201-18075-8, 3 pages, 2002.

Lefaix, Gildas, et al., "Motion-based Obstacle Detection and Tracking for Car Driving Assistance," IAPR Int. Conf. on Pattern Recognition, ICPR'2002, vol. 4, pp. 74-77, Quebec, Canada, Aug. 2002.

Lyrtech Inc., "Intelligent occupancy sensor High-performance motion detection solution," Canada, 2 pages, Jun. 2009.

Texas Instruments, "Video and Vision Guide," pp. 1-81, 4Q 2009.

International Search Report and Written Opinion for PCT/US2013/027226 dated Nov. 18, 2013.

* cited by examiner

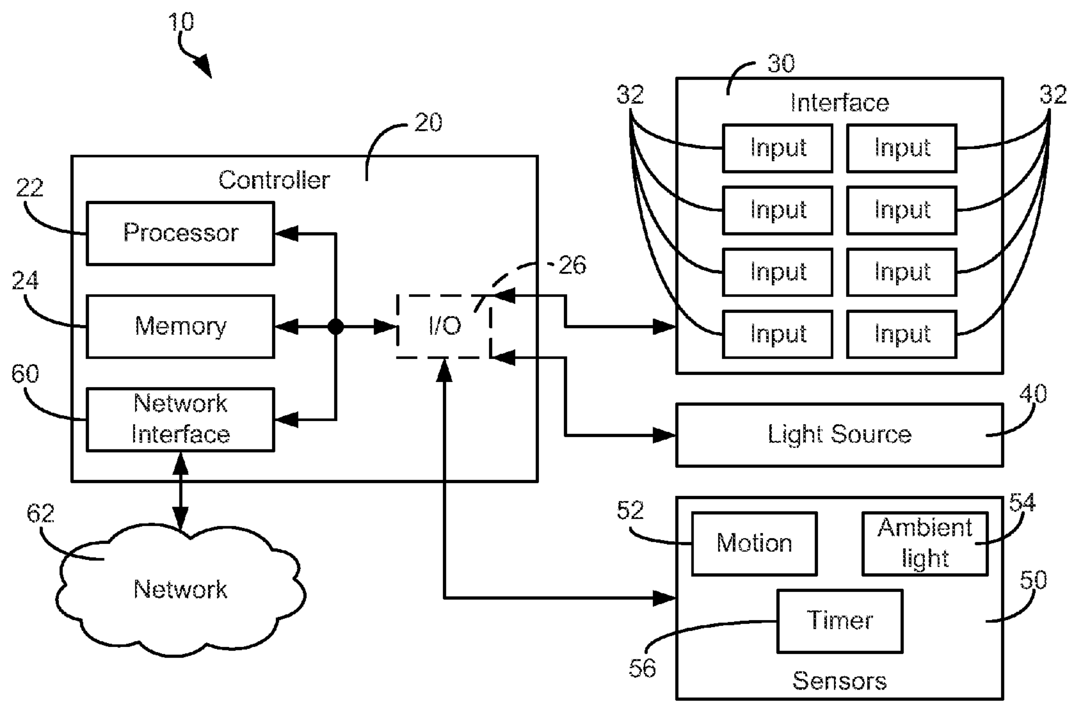

10
20
Controller
22
Processor
24
Memory
60
Network Interface
26
I/O
62
Network
30
Interface
32
Input
Input
Input
Input
Input
Input
Input
Input
32
40
Light Source
52
Motion
54
Ambient light
50
56
Timer
Sensors

FIG. 1

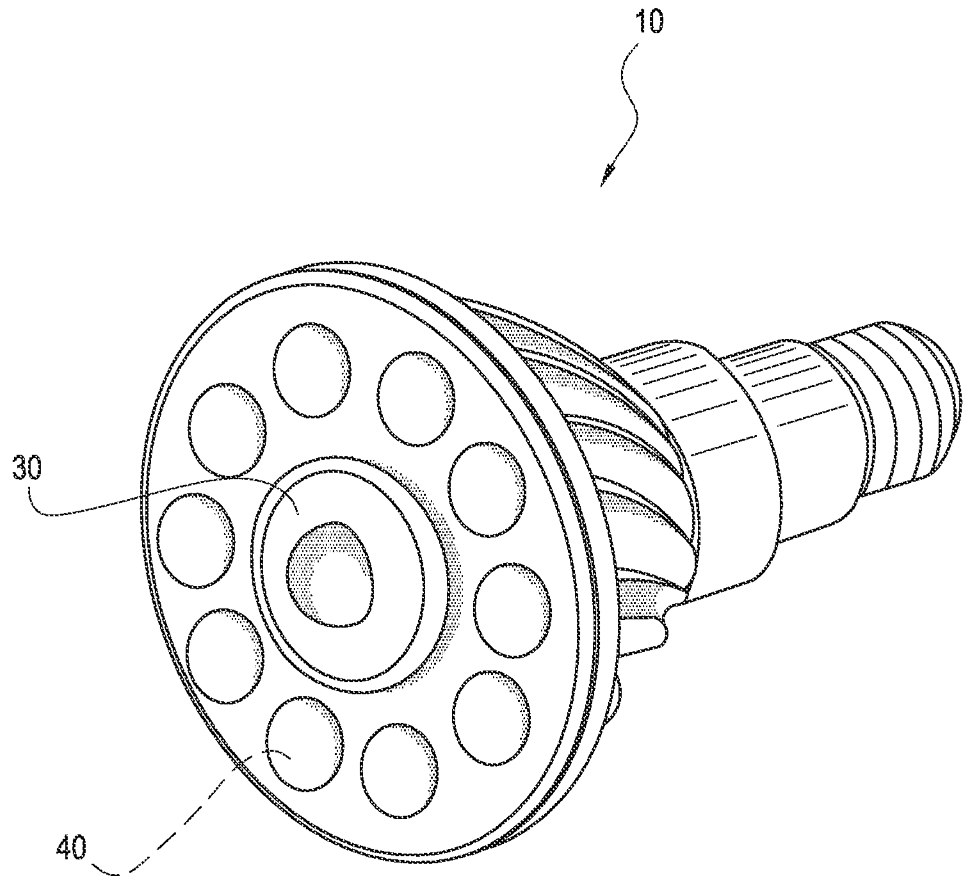
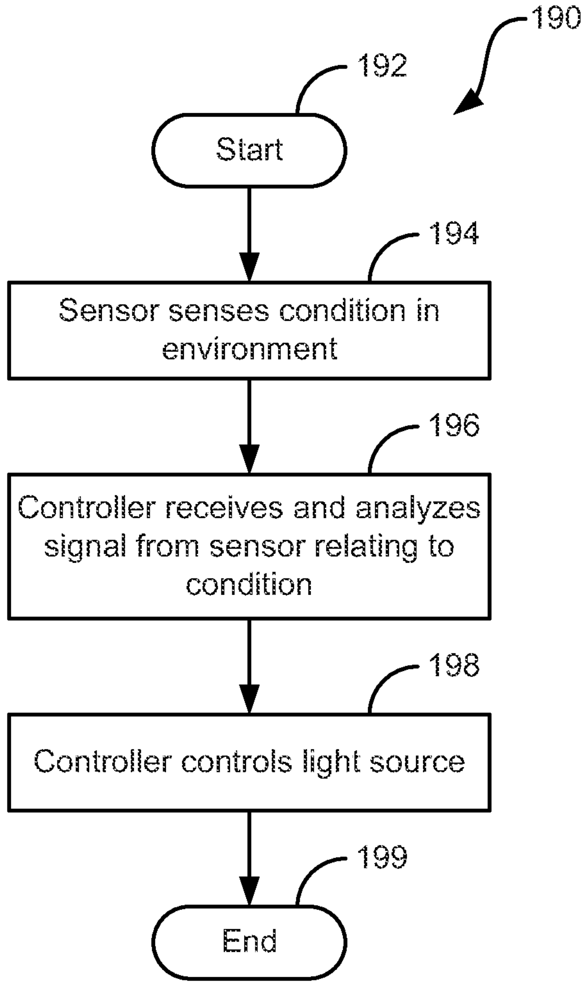


Fig. 2



190
192
Start
194
Sensor senses condition in environment
196
Controller receives and analyzes signal from sensor relating to condition
198
Controller controls light source
199
End

FIG. 3

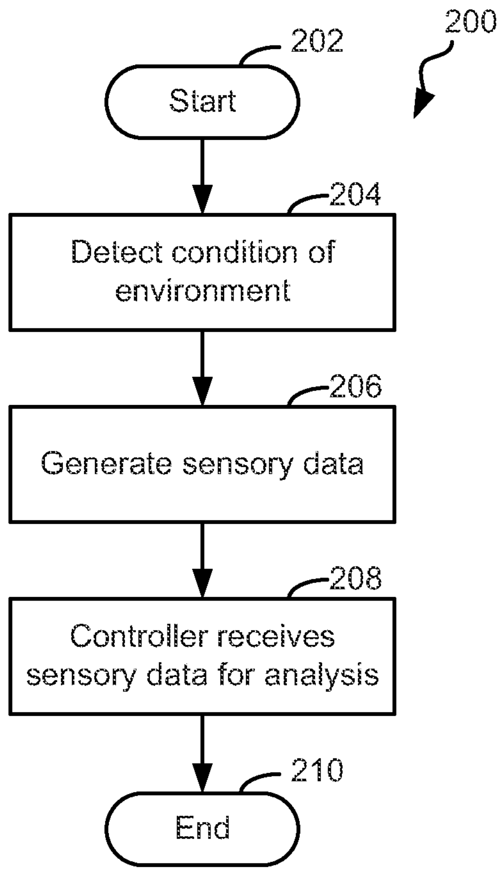

200
202
Start
204
Detect condition of environment
206
Generate sensory data
208
Controller receives sensory data for analysis
210
End

FIG. 4

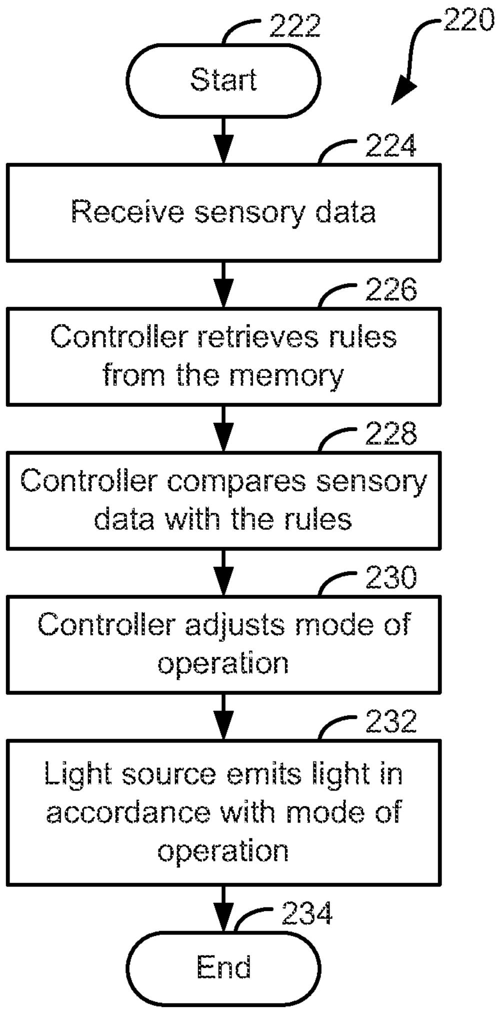

220
222
Start
224
Receive sensory data
226
Controller retrieves rules from the memory
228
Controller compares sensory data with the rules
230
Controller adjusts mode of operation
232
Light source emits light in accordance with mode of operation
234
End

FIG. 5

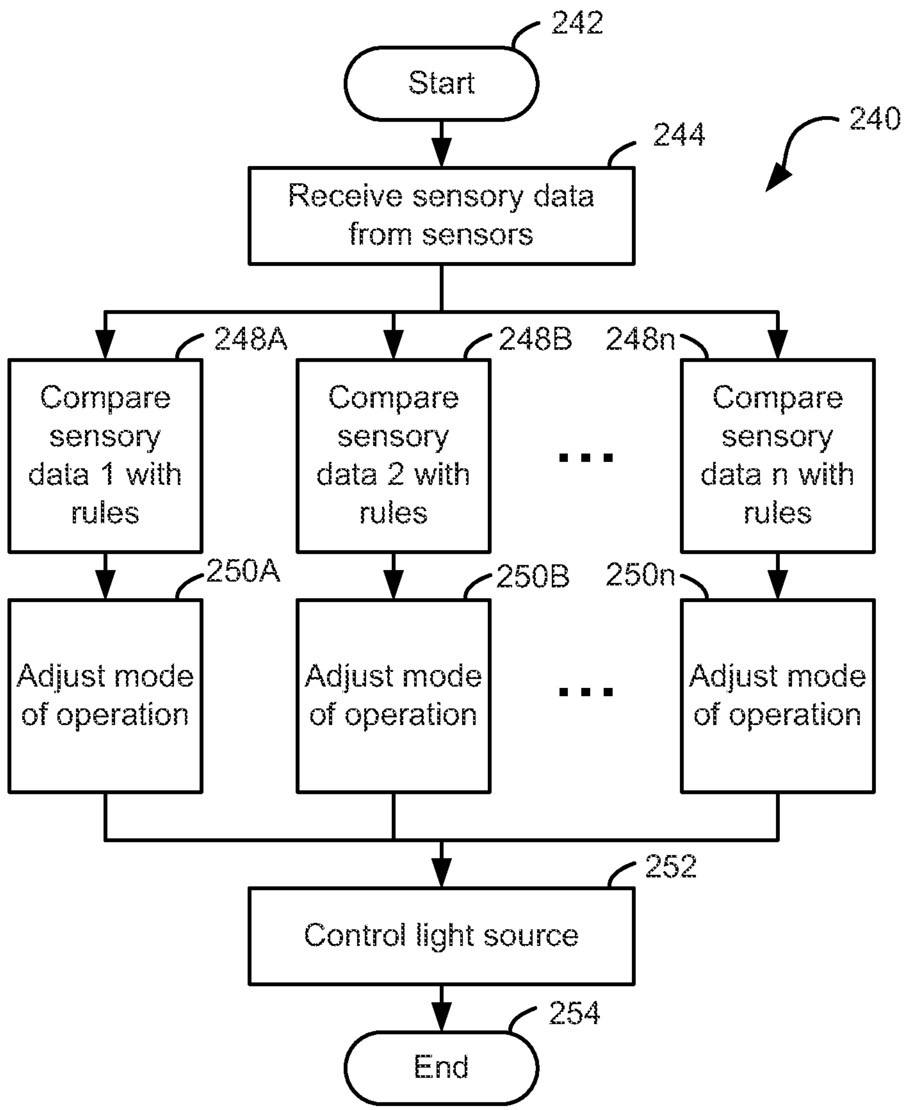

242
Start
244
240
Receive sensory data from sensors
248A
248B
248n
Compare sensory data 1 with rules
Compare sensory data 2 with rules
Compare sensory data n with rules
250A
250B
250n
Adjust mode of operation
Adjust mode of operation
Adjust mode of operation
252
Control light source
254
End

FIG. 6

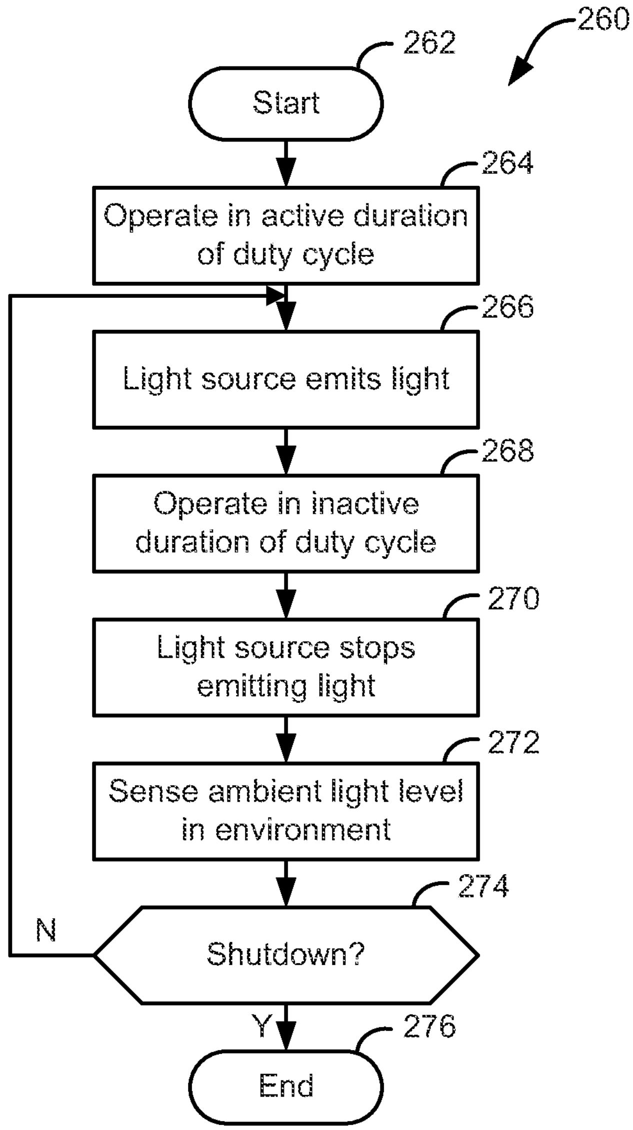

260
262
Start
264
Operate in active duration of duty cycle
266
Light source emits light
268
Operate in inactive duration of duty cycle
270
Light source stops emitting light
272
Sense ambient light level in environment
274
Shutdown?
N
Y
276
End

FIG. 7

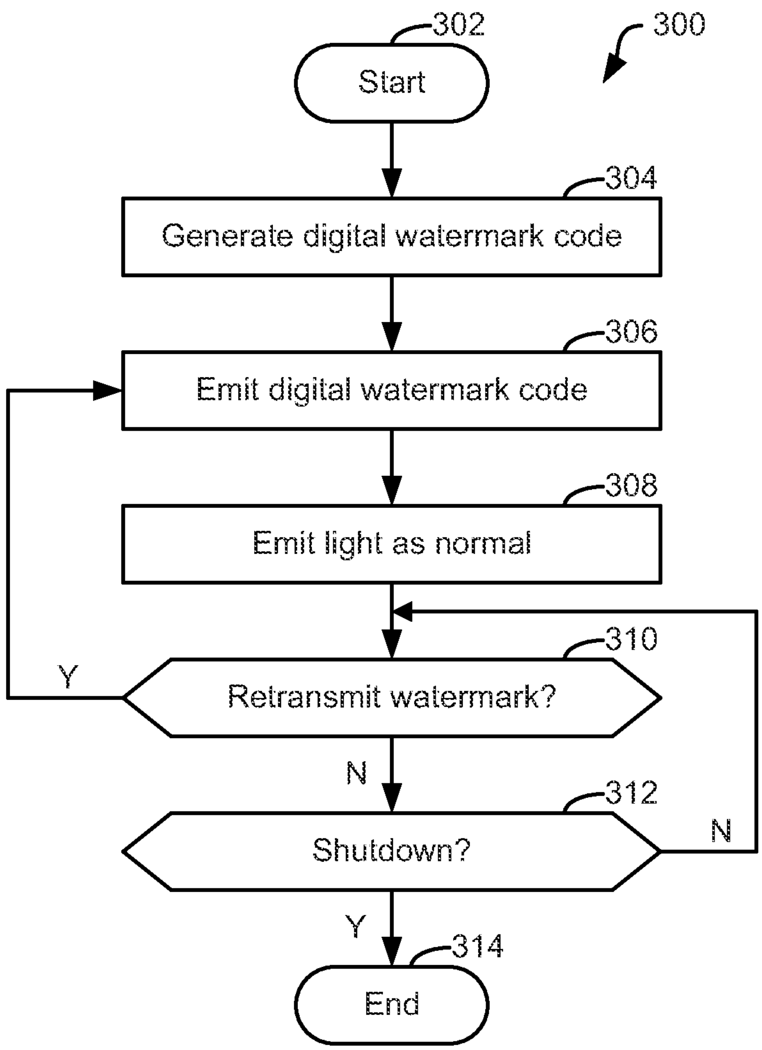

300
302
Start
304
Generate digital watermark code
306
Emit digital watermark code
308
Emit light as normal
310
Y
Retransmit watermark?
N
312
Shutdown?
N
Y
314
End

FIG. 8

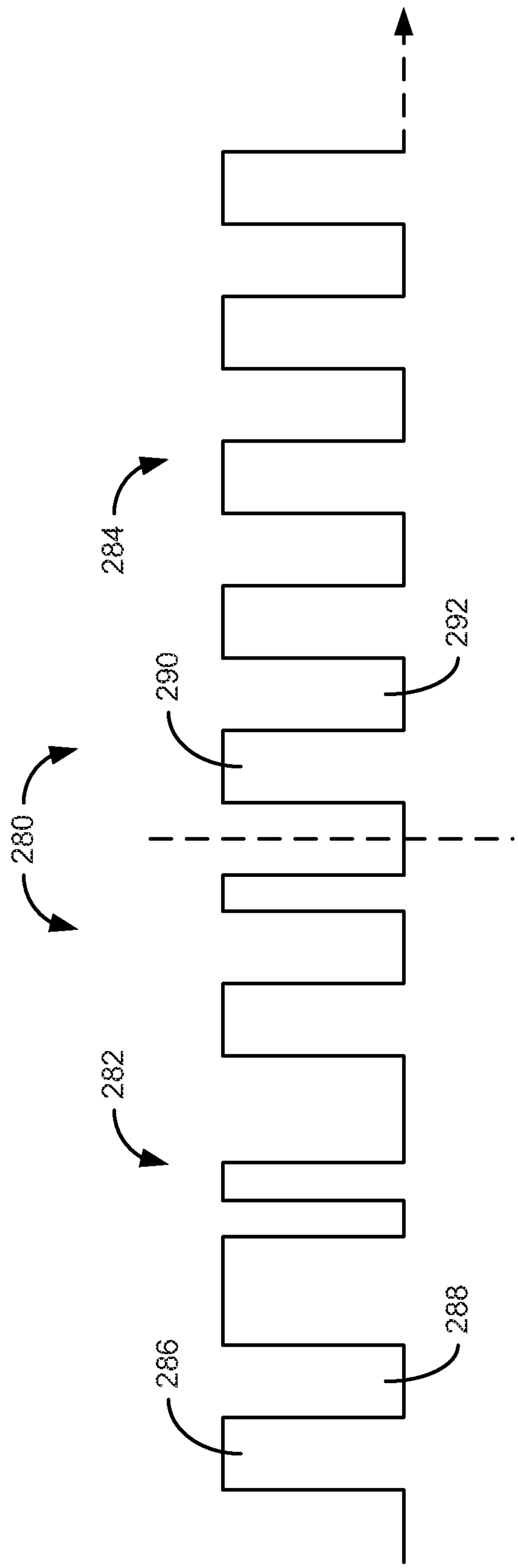
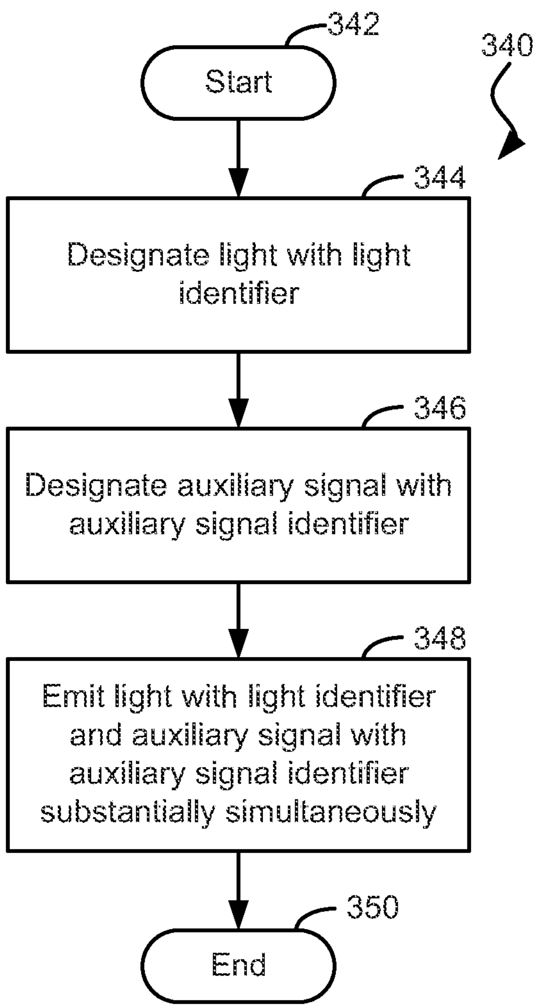


FIG. 9



340
342
Start
344
Designate light with light identifier
346
Designate auxiliary signal with auxiliary signal identifier
348
Emit light with light identifier and auxiliary signal with auxiliary signal identifier substantially simultaneously
350
End

FIG. 10

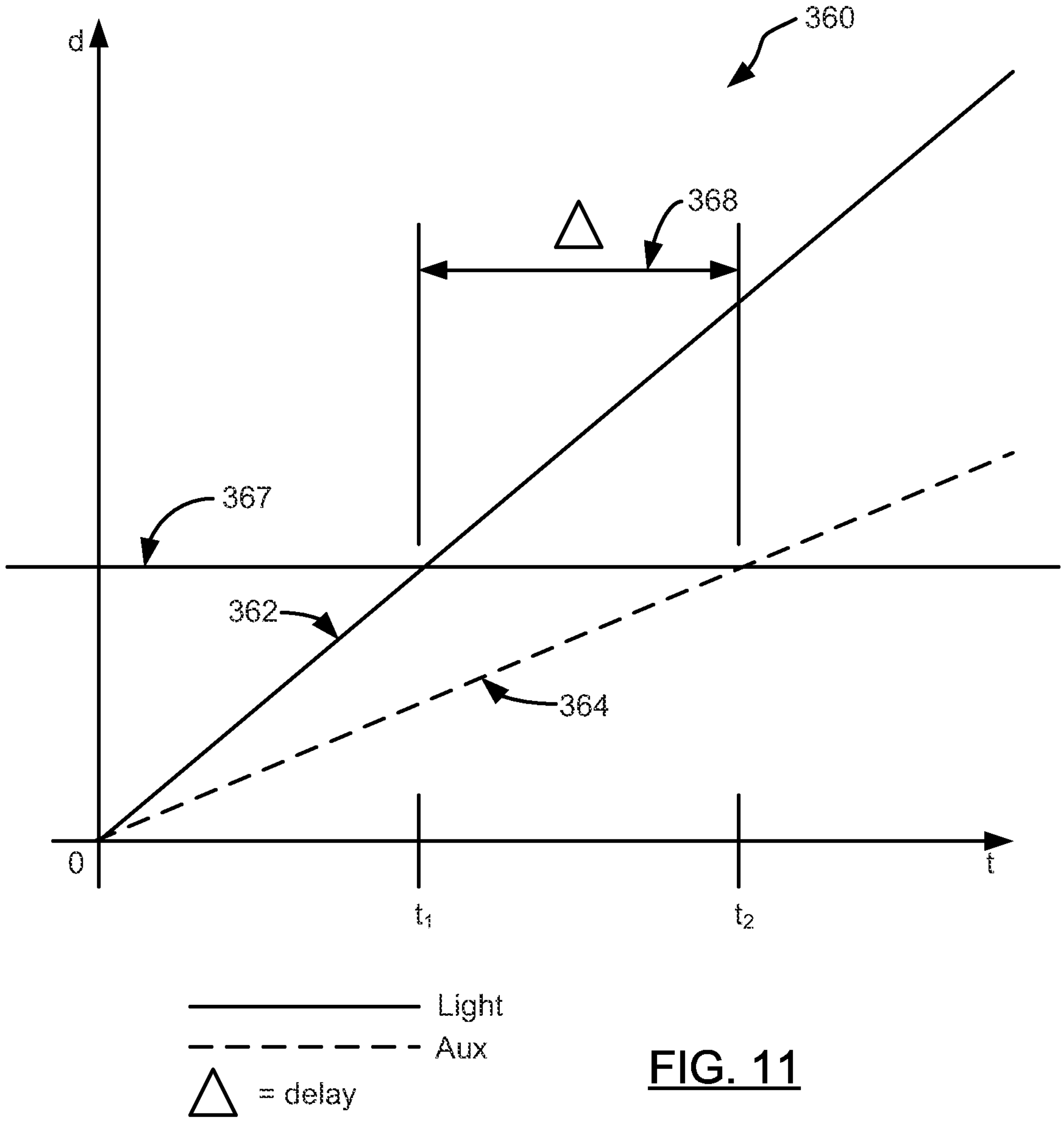


FIG. 11

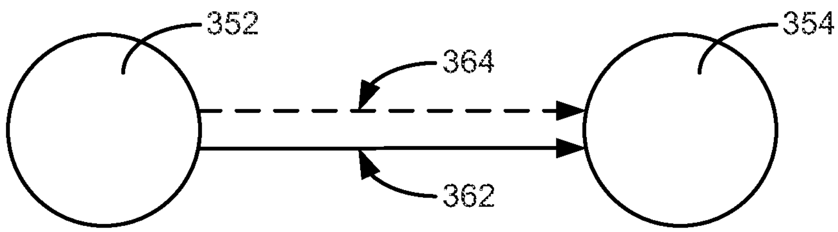


FIG. 12

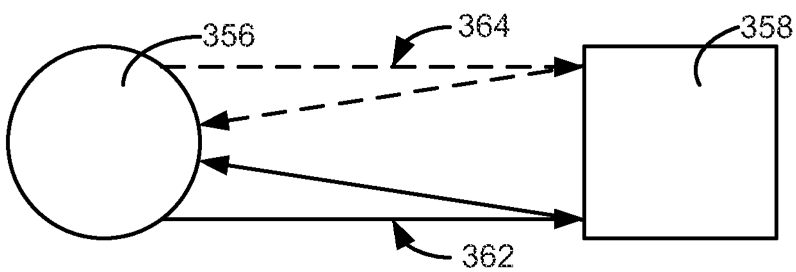


FIG. 13

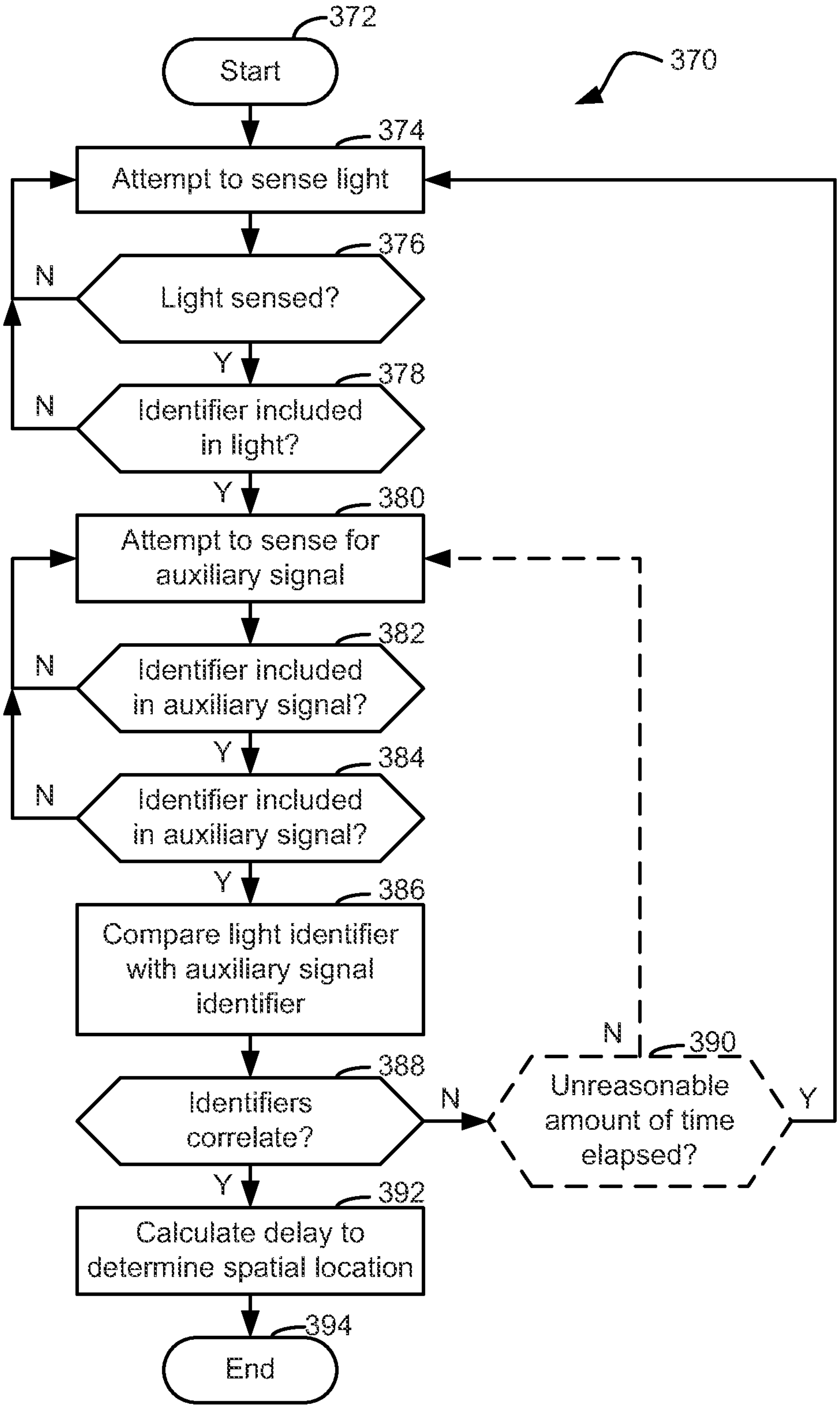
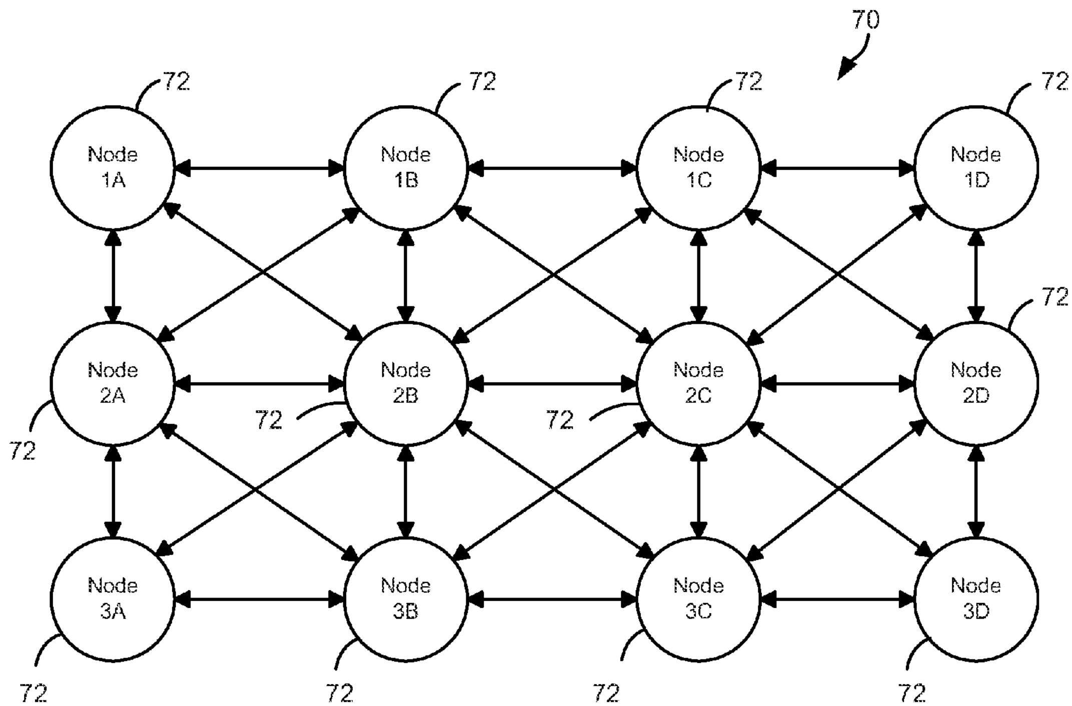

372
Start
370
374
Attempt to sense light
376
Light sensed?
N
Y
378
Identifier included in light?
N
Y
380
Attempt to sense for auxiliary signal
382
Identifier included in auxiliary signal?
N
Y
384
Identifier included in auxiliary signal?
N
Y
386
Compare light identifier with auxiliary signal identifier
388
Identifiers correlate?
N
390
Unreasonable amount of time elapsed?
N
Y
Y
392
Calculate delay to determine spatial location
394
End

FIG. 14



70
72
Node 1A
Node 1B
Node 1C
Node 1D
Node 2A
Node 2B
Node 2C
Node 2D
Node 3A
Node 3B
Node 3C
Node 3D

FIG. 15

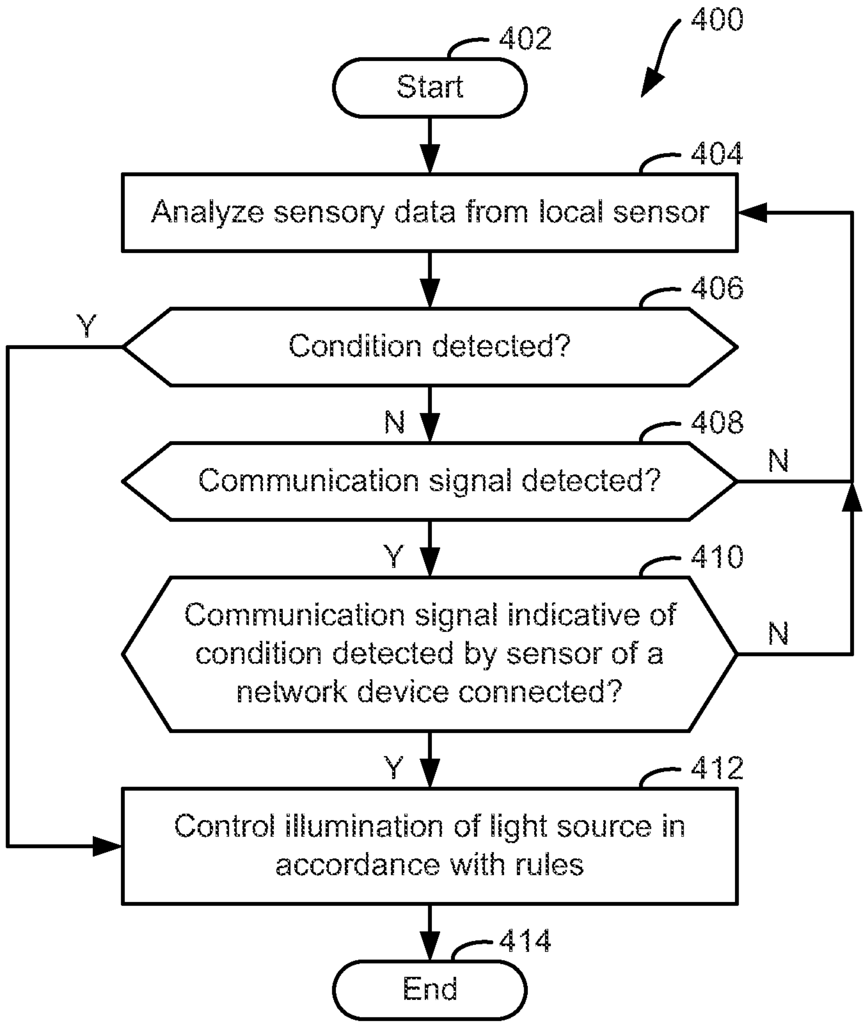

400
402
Start
404
Analyze sensory data from local sensor
406
Condition detected?
Y
N
408
Communication signal detected?
N
Y
410
Communication signal indicative of condition detected by sensor of a network device connected?
N
Y
412
Control illumination of light source in accordance with rules
414
End

FIG. 16

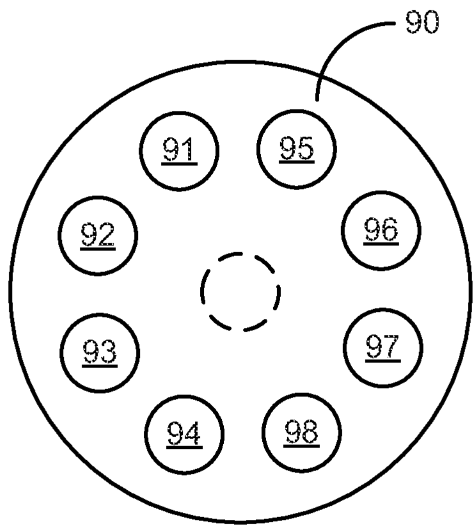
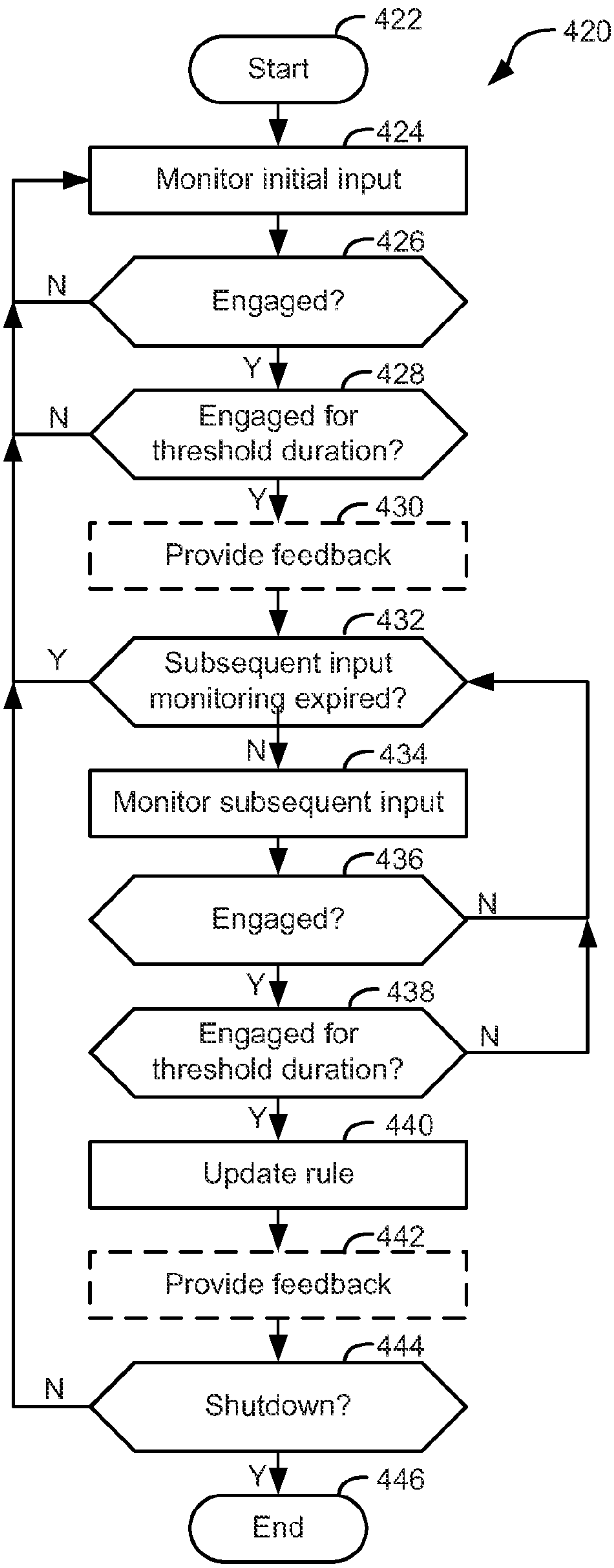


FIG. 17



420
422
Start
424
Monitor initial input
426
Engaged?
N
Y
428
Engaged for threshold duration?
N
Y
430
Provide feedback
432
Subsequent input monitoring expired?
Y
N
434
Monitor subsequent input
436
Engaged?
N
Y
438
Engaged for threshold duration?
N
Y
440
Update rule
442
Provide feedback
444
Shutdown?
N
Y
446
End

FIG. 18

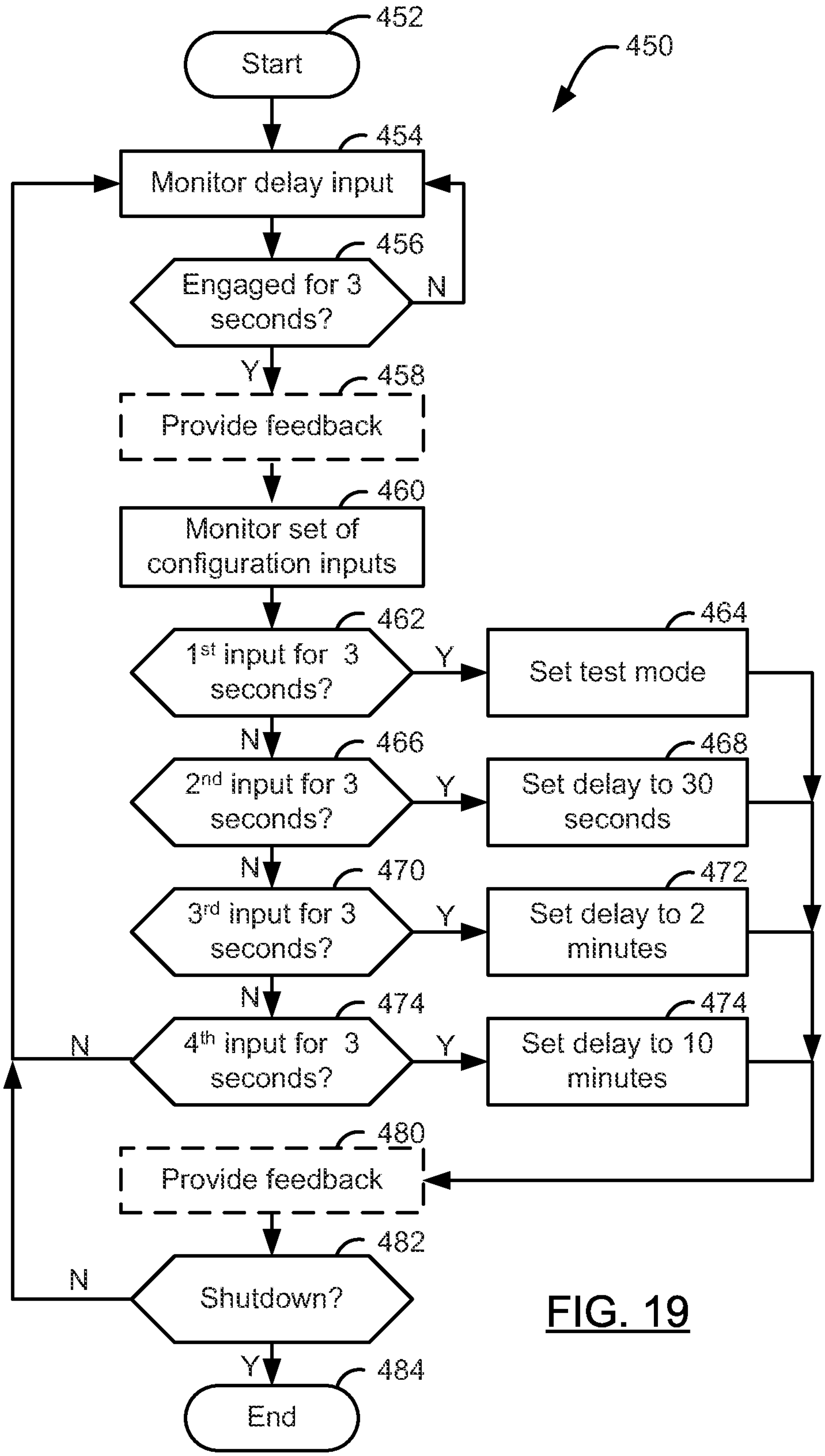
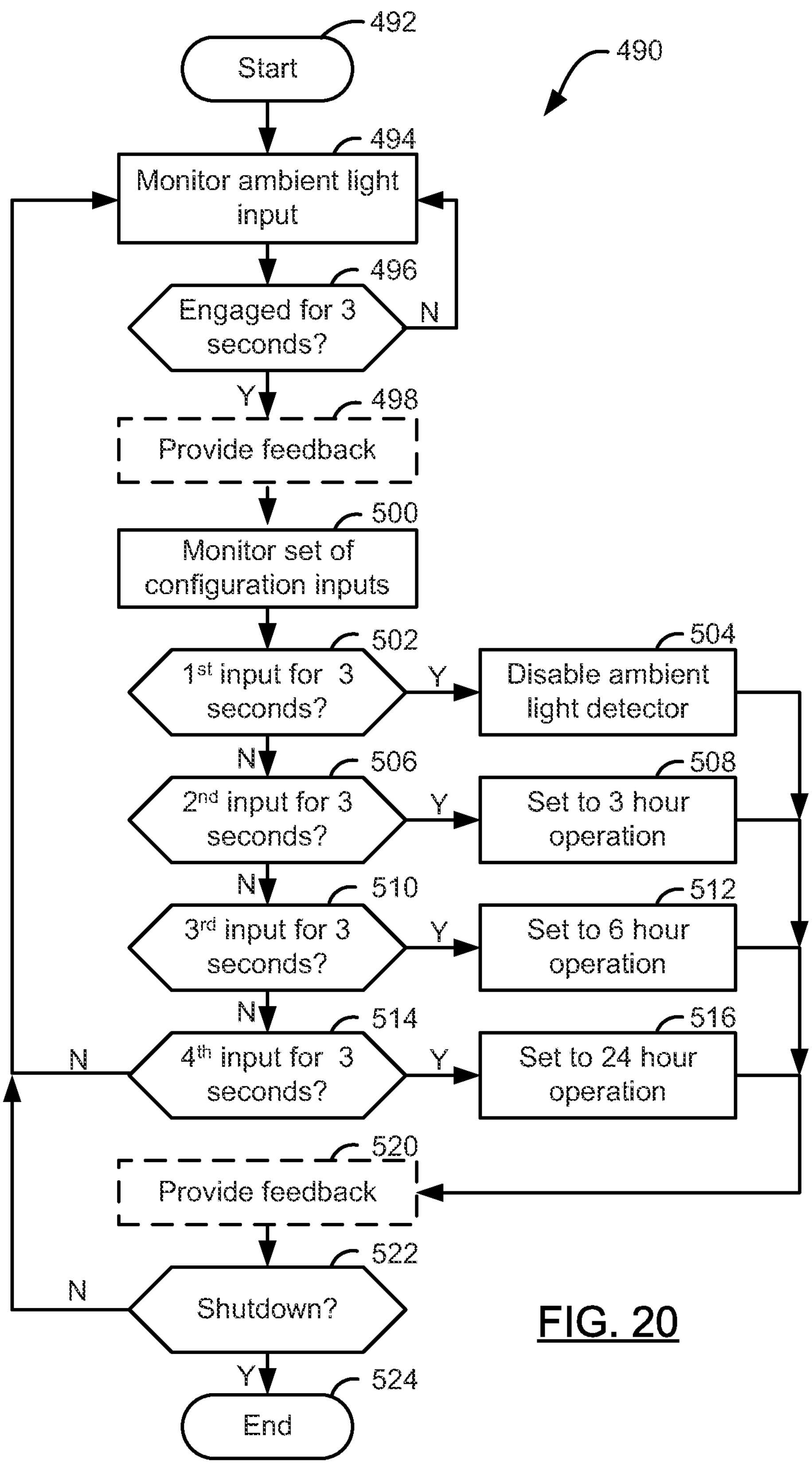

450
452
Start
454
Monitor delay input
456
Engaged for 3 seconds?
N
Y
458
Provide feedback
460
Monitor set of configuration inputs
462
1st input for 3 seconds?
Y
464
Set test mode
N
466
2nd input for 3 seconds?
Y
468
Set delay to 30 seconds
N
470
3rd input for 3 seconds?
Y
472
Set delay to 2 minutes
N
474
4th input for 3 seconds?
N
Y
474
Set delay to 10 minutes
480
Provide feedback
482
Shutdown?
N
Y
484
End

FIG. 19



490
492
Start
494
Monitor ambient light input
496
Engaged for 3 seconds?
N
Y
498
Provide feedback
500
Monitor set of configuration inputs
502
1st input for 3 seconds?
Y
504
Disable ambient light detector
N
506
2nd input for 3 seconds?
Y
508
Set to 3 hour operation
N
510
3rd input for 3 seconds?
Y
512
Set to 6 hour operation
N
514
4th input for 3 seconds?
N
Y
516
Set to 24 hour operation
520
Provide feedback
522
Shutdown?
N
Y
524
End

FIG. 20

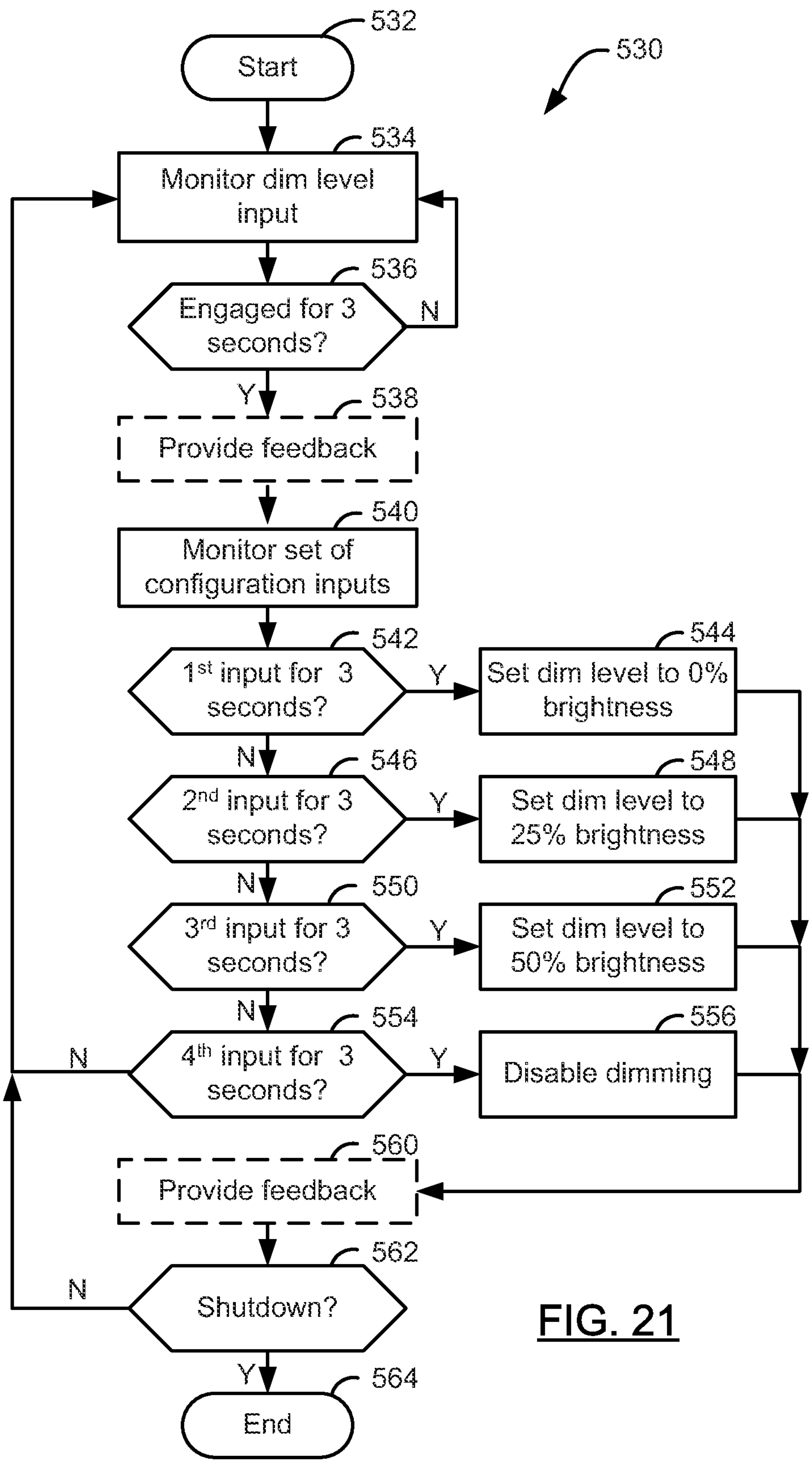

530
532
Start
534
Monitor dim level input
536
Engaged for 3 seconds?
N
Y
538
Provide feedback
540
Monitor set of configuration inputs
542
1st input for 3 seconds?
Y
544
Set dim level to 0% brightness
N
546
2nd input for 3 seconds?
Y
548
Set dim level to 25% brightness
N
550
3rd input for 3 seconds?
Y
552
Set dim level to 50% brightness
N
554
4th input for 3 seconds?
Y
556
Disable dimming
N
560
Provide feedback
562
Shutdown?
N
Y
564
End

FIG. 21

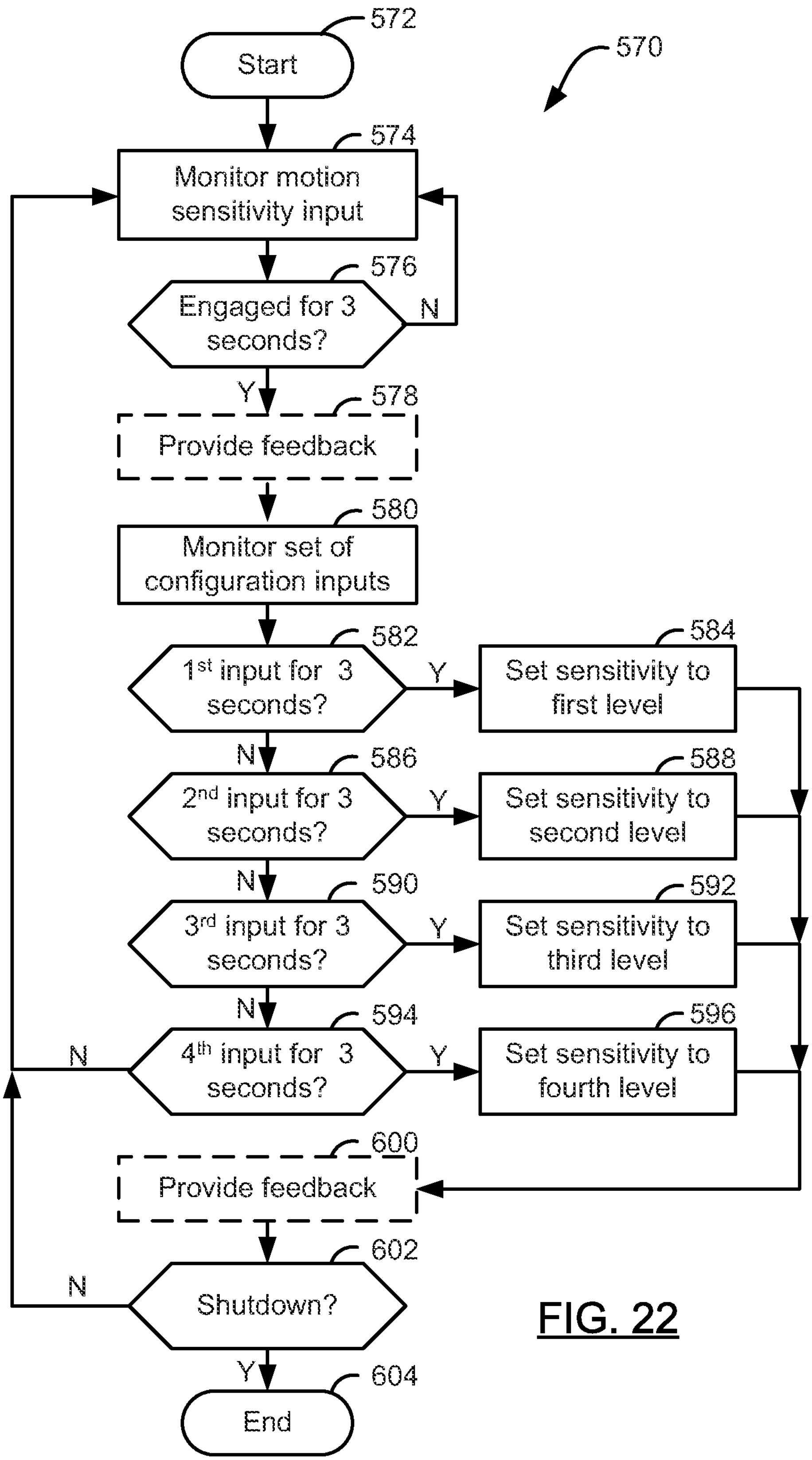

572
Start
570
574
Monitor motion sensitivity input
576
Engaged for 3 seconds?
N
Y
578
Provide feedback
580
Monitor set of configuration inputs
582
1st input for 3 seconds?
Y
584
Set sensitivity to first level
N
586
2nd input for 3 seconds?
Y
588
Set sensitivity to second level
N
590
3rd input for 3 seconds?
Y
592
Set sensitivity to third level
N
594
4th input for 3 seconds?
Y
596
Set sensitivity to fourth level
N
600
Provide feedback
602
Shutdown?
N
Y
604
End

FIG. 22

CONFIGURABLE ENVIRONMENTAL CONDITION SENSING LUMINAIRE, SYSTEM AND ASSOCIATED METHODS

RELATED APPLICATIONS

This application is related to and claims the benefit of U.S. Provisional Patent Application Ser. No. 61/486,316 titled MOTION DETECTING SECURITY LIGHT AND ASSOCIATED METHODS filed on May 15, 2011, the entire contents of which are incorporated herein by reference. This application is also related to and claims the benefit of U.S. Provisional Patent Application Ser. No. 61/486,314 titled WIRELESS LIGHTING DEVICE AND ASSOCIATED METHODS filed on May 15, 2011, the entire contents of which are incorporated herein by reference. This application is further related to and claims the benefit of U.S. Provisional Patent Application Ser. No. 61/486,322 titled VARIABLE LOAD POWER SUPPLY filed on May 15, 2011, the entire contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to the field of lighting devices. More specifically, the present invention relates to luminaires that include a light source to illuminate an environment in which a condition may be detected.

BACKGROUND OF THE INVENTION

Luminaries have traditionally been used to illuminate an area to deter the presence of trespassers, making an environment more secure. However, to illuminate an environment, the luminaire must be emitting light and consuming energy. Operating the luminaire during the day, when the environment may already be illuminated by the sunlight, may be inefficient and wasteful of energy.

As a result, proposed solutions in the prior art have included photoelectric sensors to detect the presence of light. By using a photoelectric sensor, a luminaire could automatically turn off during a time in which the environment may be illuminated by daylight.

However, a luminaire that includes a photoelectric sensor may lack operation control during the period between sunset and sunrise. Although the amount of energy consumed by the luminaire has been reduced, the luminaire may still be illuminating an environment when there are no objects, such as trespassers, or other conditions that would need illuminated. Additionally, a photoelectric sensor may sense the ambient light levels in an environment due to the light produced by the lighting device to which the sensor is attached. Furthermore, traditional ambient light sensors, such as photoelectric sensors, are typically bulky and aesthetically unappealing.

In an attempt to address the inefficiencies inherent to using a photoelectric sensor to control operation of the luminaire relative to ambient light conditions, devices in the prior art have included passive infrared sensors to detect motion. However, the addition of these motion sensors may add an undesirable amount of bulk to the lighting device to which it is attached. Also, due to the limited configurability of motion sensors in the prior art, numerous false detection of movement as well as low detection rates may occur depending on ambient conditions.

Additionally, luminaires of the prior art typically require sensors to be directly connected to each luminaire. In some configurations, multiple luminaires will be positioned throughout the environment. According to the prior art, each

of these luminaires would require independent sensors to detect motion, ambient light, and/or other conditions of the environment, which may operate inconsistently. There exists a need for an intelligent luminaire that may communicate with additional luminaires in the environment to create a network and share sensory data.

Furthermore, the luminaires of the prior art lack an ability to easily modify operation through a simplified and uniform interface. There exists a need for a configurable luminaire, the operation of which may be modifiable by a user through an accessible interface.

As a result, there exists a need for a luminaire that may illuminate an environment in which a condition is detected. There additionally exists a need for a lighting device that provides an interface to configure the operation of the luminaire. There further exists a need for a luminaire that combines illumination, motion detection, and ambient light detection in one device.

SUMMARY OF THE INVENTION

With the foregoing in mind, embodiments of the present invention are related to a luminaire that may illuminate an environment in which a condition is detectable, along with a related system and methods. The luminaire may additionally provide an interface to configure the operation of the luminaire. Furthermore, the luminaire may advantageously combine illumination, motion detection, and ambient light detection in one device. Moreover, the luminaire may communicate with additional luminaires in the environment to create a network and share data, such as sensory data. By providing a luminaire that advantageously combines these features, the present invention may beneficially possess characteristics of higher operational efficiency, increased product life, and reduced complexity, size, and manufacturing expense. Embodiments of the present invention also advantageously provide a configurable luminaire, the operation of which may be modifiable by a user through an accessible interface.

These and other features and advantages according to an embodiment of the present invention are provided by a luminaire that may comprise a light source, a controller, and sensors. Light may be emitted by the light source into an environment. The controller may include a processor and memory to analyze data relating to conditions in the environment and to control the light source. The sensors may be in communication with the controller to detect the conditions in the environment. The sensors may also generate data relating to the conditions. The data may be receivable by the controller.

Rules may be definable to affect operation of the light source. The rules may be stored in the memory, which may be compared with the data. The light source may be operable in a plurality of modes defined by the rules. Operation of the light source may be modifiable by the controller responsive to the data, which may relate to one or more of the conditions.

The light source may be operable having a duty cycle controlled by the controller. The duty cycle may have an active duration and an inactive duration. In the active duration, the light source may emit the light. Conversely, in the inactive duration, the light source may not emit the light.

The sensors may include a motion detector in communication with the controller to detect motion in the environment as the condition. The motion detector may transmit the data to the controller relating to motion that is detected. Additionally, ambient light levels in the environment may be detected by at least one of the sensors in communication with the controller as the condition. The data may be transmitted to the controller relating to the ambient light levels that are detected. The ambient light levels may be detected during the inactive duration of the duty cycle.

According to an embodiment of the present invention, the ambient light levels are detectable by an ambient light detector in communication with the controller. The ambient light detector may detect the ambient light levels in the environment as the condition. The controller may receive the data from the ambient light detector relating to the ambient light levels that are detected.

According to an embodiment of the present invention, a timer may be in communication with the controller to transmit data to the controller. The data may relate to an amount of time elapsed, which may be relative to an event definable by the ales. The timer may optionally be included in the controller.

According to an embodiment of the present invention, a network interface may be in communication with the controller. At least part of the data may be transmittable by the controller using the network interface. Additionally, data may be receivable by the controller using the network interface.

The controller, the light source, and at least one sensor may be included in a node. The node may be part of a network of nodes. Additionally, a plurality of nodes may be included in the network of nodes. Data may be transmittable and receivable between the nodes included in the network of nodes. In additional embodiments of the present invention, the node may be spatially aware relative to at least part of the nodes in the network of nodes.

The light source may be a light emitting semiconductor device. Light emitted by the light source may include a source wavelength range. At least part of the light in the source wavelength range may be received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range. The light in the converted wavelength range may be includable in the light.

Alight identifier may be included in the light and an auxiliary signal emitter may also be included in the luminaire. The auxiliary signal emitter may emit an auxiliary signal having a velocity that differs from the light. An auxiliary signal identifier may be included in the auxiliary signal. The light identifier and the auxiliary signal identifier are definable to identify the light that correlates with the auxiliary signal, both of which may be emitted substantially simultaneously.

The light with the light identifier and the auxiliary signal with the auxiliary signal identifier may be detectable by at least one of the sensors. The controller may analyze a delay between detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier to determine a spatial awareness. In an embodiment of the present invention, the auxiliary signal is ultrasonic.

According to an embodiment of the present invention, an interface may be used to define the rules. The interface may include inputs, which may be located on a surface of the luminaire. In some embodiments, the inputs may be manipulable to cause a signal to be sent to the controller. The signal may relate to a state of one or more input. Additionally, the states of the inputs may be independently altered upon being engaged by an object. The states to which the input is altered is definable by the rules.

The controller may be carried by a radio logic board, the luminaire may also include an antenna coupled to the radio logic board. The radio logic board may be separated from heat producing elements of the luminaire by a buffer distance.

The present invention is also directed to a system for controlling a luminaire. The system may include a controller including a processor and memory to analyze data and to control a light source to emit light and an interface that is manipulable to cause a signal to be sent to the controller. The signal may relate to a state of the interface. The system according to an embodiment of the present invention may also include sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition. The data may be transmittable to the controller for analysis.

Rules that are definable to affect operation of the light source may also be included. The rules may be stored in the memory to be comparable with the data, and the rules may be definable using the interface. The light source may be operable in a plurality of modes defined by the rules. At least one of the plurality of modes may be selectable and definable using the interface. For example, the light source may be operable by dimming the light source or moving the light source between an on position and an off position.

A method aspect of an embodiment of the present invention is for controlling a luminaire with an interface. The method may comprise receiving a signal by a controller from the interface. The interface may be manipulable to generate the signal. Additionally, the controller may include a processor and memory.

The method may also include analyzing the signal using the controller by comparing the signal to rules included in the memory. At least part of the rules may be definable using the interface to control operation of a light source to emit light. The method may additionally include receiving data from sensors in communication with the controller relating to a condition detected in the environment. The data may be receivable by the controller from the sensors for analysis. Moreover, the method may include comparing the data received by the sensor with at least part of the rules. The light source may be operated in a mode determined by comparing the data with the rules. An interface used with this method may include a plurality of inputs. In an embodiment, the inputs are locatable on a surface of the luminaire, such that the inputs are manipulable to cause the signal to be sent to the controller. The signal may relate to a state of one or more input.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating the components of a luminaire, according to an embodiment of the present invention.

FIG. **2** is a perspective view illustrating a luminaire including an lair interface, according to an embodiment of the present invention.

FIG. **3** is a flowchart illustrating operation of a luminaire, according to an embodiment of the present invention.

FIG. **4** is a flowchart illustrating detection of a condition in an environment, according to an embodiment of the present invention.

FIG. **5** is a flowchart illustrating an analysis of sensory data and controlling a light source, according to an embodiment of the present invention.

FIG. **6** is a flowchart illustrating an analysis of sensory data from a plurality of sensors and controlling a light source, according to an embodiment of the present invention.

FIG. **7** is a flowchart illustrating an operation of a light source with a duty cycle, according to an embodiment of the present invention.

FIG. **8** is a flowchart illustrating an inclusion of an identifier in a signal, according to an embodiment of the present invention.

FIG. **9** is a diagram illustrating inclusion of a light identifier in a light signal, according to an embodiment of the present invention.

FIG. **10** is a flowchart illustrating emission of signals with identifiers to determine a spatial awareness, according to an embodiment of the present invention.

FIG. **11** is a graph illustrating signals emittable by the luminaire with differing velocities, according to an embodiment of the present invention.

FIG. **12** is a block diagram illustrating signals being received by a luminaire to determine a spatial location, according to an embodiment of the present invention.

FIG. **13** is a block diagram illustrating signals reflected from an environmental object and being received by a luminaire to determine a spatial awareness, according to an embodiment of the present invention.

FIG. **14** is a flowchart illustrating a comparison of signals to determine a spatial awareness, according to an embodiment of the present invention.

FIG. **15** is a schematic diagram illustrating a network of nodes, according to an embodiment of the present invention.

FIG. **16** is a flowchart illustrating an analysis of sensory data sensed by a sensor and a network connected device, according to an embodiment of the present invention.

FIG. **17** is a schematic diagram illustrating an interface, according to an embodiment of the present invention.

FIG. **18** is a flowchart illustrating use of the interface of FIG. **17** to manipulate rules, according to an embodiment of the present invention.

FIGS. **19**-**22** are flowcharts illustrating examples of using the interface illustrated in FIG. **17** to manipulate rules, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Those of ordinary skill in the art realize that the following descriptions of the embodiments of the present invention are illustrative and are not intended to be limiting in any way. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Like numbers refer to like elements throughout.

In this detailed description of the present invention, a person skilled in the art should note that directional terms, such as "above," "below," "upper, e" and other like terms are used for the convenience of the reader in reference to the drawings. Also, a person skilled in the art should notice this description may contain other terminology to convey position, orientation, and direction without departing from the principles of the present invention.

Referring to FIGS. **1**-**22**, a luminaire **10** according to an embodiment of the present invention is now described in greater detail. Throughout this disclosure, the luminaire **10** may also be referred to as a system, device, lighting device, or the invention. Alternate references of the luminaire **10** in this disclosure are not meant to be limiting in any way.

As perhaps best illustrated in the block diagram of FIG. **1**, along with the perspective view of FIG. **2**, the luminaire **10**

according to an embodiment of the present invention may include a controller **20**, an interface **30** with inputs **32**, a light source **40**, and sensors **50**. Those of skill in the art will appreciate that the controller **20** may be a microcontroller, gate array, system-on-a-chip, general purpose processing element, or collections of electronic components capable of processing data. Preferably, but without limitation, the controller **20** may further include a central processor **22** (CPU), memory **24**, network interface **60** that may be connected to a network **62**, and/or an input/output (I/O) interface **26**. Skilled artisans will appreciate that one or more of the aforementioned elements of the controller **20** may be located outside of the controller, or omitted from the controller, as the embodiments of the present invention may vary. The light source **40** may include one or more light emitting semiconductor device, such as a light emitting diode (LED).

Skilled artisans will appreciate that although the light source **40** may be discussed in this disclosure as including light emitting diodes capable of emitting light in a source wavelength range, other light sources **40** may be used. In preferred embodiments, light emitting semiconductor devices may be used to provide illumination. Other embodiments of the present invention may include a light source **40** that is generated by a laser device. However, those of skill in the art will appreciate light sources **40** that are not semiconductor-based are intended to be included within the scope of the present invention. Those skilled in the art will appreciate that the light from the light source **40** could be provided by any number of lighting technologies, each of which are intended to be included within the scope and spirit of the present invention.

A controller **20** may be included in the luminaire **10**. As previously stated, the controller **20** may include a processor **22**, memory **24**, network interface **60**, and an I/O interface **26**. One or more of these components of the controller **20** may be located outside of the controller **20** and/or communicatively connected to the controller **20**. The processor **22** may be configured to receive a data signal from additional components of the luminaire **10**, such as a sensor **50** or the interface **30**. Those skilled in the art will also appreciate that the controller may be carried by a radio logic board, and that the luminaire may include an antenna coupled to the radio logic board. The antenna may, for example, be used to transmit a signal that caries data. The radio logic board may be separated from heat producing elements of the luminaire by a buffer distance. The buffer distance is a distance suitable to facilitation reduction of attenuation of the signal. Additional details and illustrations of the radio logic board, as well as the buffer distance where the radio logic board is positioned, are set forth in U.S. Provisional Patent Application No. 61/486,314 titled WIRELESS LIGHTING DEVICE AND ASSOCIATED METHODS filed on May 15, 2011, the entire contents of which are incorporated herein by reference.

The processor **22** may compute and perform calculations to the data that has been received from the additional components. As a non-limiting example, the processor **22** may receive sensory data from motion detector **52**, such as an infrared motion detecting sensor. The processor **22** may then analyze the data to determine whether the characteristics of the data are indicative of motion in the environment, if the processor **22** determines that the sensory data is indicative of motion, the processor **22** may generate a control signal indicating that motion has been detected. This control signal may be used to control a mode of operation for the luminaire **10**, which may include controlling the level of light emitted by the light source **40**, optionally further including controlling the duty cycle of one or more light source **40**.

The controller **20** may also include memory **24**. The memory **24** may include volatile and/or non-volatile memory modules. Volatile memory modules may include random access memory, which may temporarily store data and code being accessed by the processor **22**. The non-volatile memory may include flash based memory, which may store a computerized program to be operated on the processor **22**. The memory may also store sensory data detected by one or more of the sensors **50**.

Additionally, the memory **24** may include the computerized code used by the processor **22** to control the operation of the luminaire **10**. The memory **24** may also store feedback information related to the operation of additional components included in the luminaire **10**. In an embodiment of the present invention, the memory **24** may include an operating system, which may additionally include applications to be run from within the operating system, as will be appreciated by a person of skill in the art.

The memory **24** may include information to be analyzed by the processor **22**. This information may include the states of the various inputs **32**, data received from the sensors **50**, modes of operation, and rules to govern the analysis of the aforementioned information. The rules may be included in memory **24** to define an operation to be performed on the information, a comparison between various pieces of information, or otherwise define the operation of the various embodiments of the present invention. Preexisting rules may be programmed into the memory **24**. Additionally, rules may be defined or modified by a user. The rules may be defined or modified, for example, and without limitation, through an interface **30**.

The controller **20** may also include an I/O interface **26**. The I/O interface **26** may control the receipt and transmission of data and/or signals between the controller **20** and additional components. Provided as a non-limiting example, the I/O interface **26** may receive a sensory signal from a sensor, which may be indicative of a condition of the environment. After the processor **22** has analyzed the signal, it may use the I/O interface **26** to transmit a control signal to the light source **40** to affect the light emitted.

The sensors **50** may include any number of sensory devices to detect a condition in the environment. The sensors **50** may be directly connected to the controller **20** through a wired and/or wireless connection. In additional embodiments, sensors **50** may communicate with the controller **20** through a network **62**. These network **62** connected sensors **50** may be positioned independently of a luminaire **10**, or may alternatively be included and operated in another luminaire **10** within the network **62**. According to embodiments of the present invention, examples of motion detection, ambient light detection, and timing sensors **50** will be discussed throughout this disclosure. Those of skill in the art will appreciate that these specific example are discussed in the interest of clarity, and are not intended to limit the present invention to those examples.

According to an embodiment of the present invention, a motion detector **52** may be defined as an electronic device that detects motion in an environment and generates an electronic signal relative to that motion. The motion detector **52** may transmit and/or receive one or more signals to detect motion. These signals may include, but should not be limited to, infrared, ultrasonic, microwave, and radio waves. The detection may passive, such as with an infrared sensor **50** detecting body heat moving within an environment. The detection may alternatively be active, such as with an ultrasonic emitter emitting a wave and detecting its reflection from an object in the environment.

Provided as a specific example, without limitation, the motion detector **52** may include a passive infrared (PIR) sensor **50** for the detection of motion. The motion detector **52** may detect differing levels of motion, from which a signal may be analyzed. The sensitivity and operation of the motion detector **52** may be adjustable using the interface **30**. Additionally, the motion detector **52** may be enabled or disabled using the interface **30**. The motion detector **52** may additionally be configured to transmit a signal when motion may be absent from the field of view in the environment for a period of time, which may also be adjustable by the user.

According to an additional embodiment of the present invention, an ambient light detector **54** may include one or more photosensors and/or photodetectors to sense a level of ambient light in an environment. For the purpose of this disclosure, ambient light may be defined as the light existing in an environment that is not being provided by the luminaire **10**. Ambient light sensors **50** may include one of a plurality of sensors **50** that would be appreciated by those of skill in the art to detect a light level in the environment.

Example of ambient light detectors **54**, presented for clarity and without limitation, may include silicon light sensors, active pixel sensors, charge-coupled devices, CMOS sensors, LEDs configured in reverse-bias, optical detectors, photoresistors, photodiodes, photovoltaic cells, a combination of one or more of the aforementioned sensors, or any number of additional sensors that would be apparent to a skilled artisan. As will be discussed in greater detail below, the operation of the ambient light sensor **50** may be synchronized with the operation of the light source **40**. This synchronization may be controlled by the controller **20**.

Provided as a specific example, without limitation, the ambient light detector **54** may include a silicon light sensor. This non-limiting example of an ambient light detector **54** may estimate the ambient light conditions in the environment in which the luminaire **10** is operating. Differing signals may be transmitted to the controller **20** for analysis depending on the ambient light levels detected in the environment. In one embodiment, the luminosity of ambient light may be classified in as few as two levels, such as day and night. In other embodiments, the luminosity of ambient light may be classified in as many as a virtually limitless number of levels. These levels may be definable using the interface **30**. The interface may be used to add or remove levels, enable or disable the ambient light detector **54**, or otherwise configure the operation of the ambient light detector **54**.

A timer **56** may also be included as a sensor **50** to determine a quantity of time that may have elapsed from a starting point. The timer **56** may be configured to detect the amount of time that has elapsed since the occurrence of an event, the event being definable by the rules. The timer **56** may also begin counting down after an event has been detected, the expiration of which being definable to initiate another event. An example of an event may include a change in the state of the light source **40**, such as to provide additional or decreased illumination. Operation of the timer **56** will be discussed in greater detail below. The operation in the foregoing examples may be defined by the rules.

In an additional example of an embodiment including an ambient light sensor **50** and a timer **56**, the luminaire **10** may be operated in a part night operation. During part night operation, the luminaire **10** may operate normally upon the detection of low luminosity in the environment, such as a dark environment. Normal operation may include illuminating the environment with a medium to high output of light. Upon the detection of low luminosity, which may be defined as a triggering event by the rules, the timer **56** may begin counting.

Skilled artisans will appreciate that the timer **56** may count increment or decrement, as it may be definable in the rules, as would be consistent with the scope and spirit of the present invention. When the timer **56** reaches a limit, the luminaire **10** may further reduce the output of light emitting from the light source **40**. This output reduction may include adjusting at least one light source **40** to emit no light.

Continuing with the same example, the controller **20** of the luminaire **10** may additionally be configured to receive data from the motion detector **52**. The output of light provided by the light source **40** may be adjusted in further relation to the data received by the controller **20** from the motion detector **52**. For instance, the timer **56** may have expired, resulting in the controller controlling the light source to emit virtually no light. An object may cause motion in the environment, which may be detected by the motion detector **52**. The controller **20** of the luminaire **10** may analyze the data relating to detected motion and control the light source **40** to increase its output to approximately full output. The luminaire **10** may further be defined to reduce the output time after motion is no longer detected.

Still referring to FIG. **1**, the luminaire **10** may include a light source **40**. The light source **40** may include LEDs configured to illuminate an environment in which the luminaire **10** is located. A person of skill in the art will appreciate that, although the light source **40** may be discussed as an LED herein, any device capable of producing light to illuminate an area may be included within the scope of the present invention.

An LED may emit light when an electrical current is passed through the diode, typically in the forward bias. The LED may be driven by the passing electrical current to provide an electroluminescence, or emission of light. The color of the emitted light may be determined in part by the materials used in the construction of the light emitting semiconductor.

The light source **40** may emit a light in various spectrums of light. For example, the light source **40** may emit a light in the visible spectrum. This visible light may illuminate an environment, advantageously deterring the presence of trespassers. In another example, the light source **40** may emit a light in the infrared spectrum. This infrared light may illuminate an environment with a light that is not typically visible to the human eye, but may be visible to another device, such as a camera with a video sensor capable of detecting infrared light. The camera may be communicatively connected to the luminaire **10**, for example through a network **62**, or be provided as a stand-alone device separate from the luminaire **10**. The use of infrared light may advantageously allow the luminaire **10** to assist another device to monitor and detect motion in an area when light within the visible spectrum is not being emitted.

A conversion material may be applied to the LEDs to create a desired output color. The inclusion of a conversion material may advantageously allow the luminaire **10** of the present invention to include high efficacy LEDs, increasing the overall efficiency of the luminaire **10**. Additionally conversion materials may be included to convert the light emitted by a light source **40**, such as a conversion phosphor, delay phosphor, or quantum dot, to modify or increase the light outputted by the light source **40**.

An example of the inclusion of a conversion material will now be provided, without the intention to limit the luminaire **10** of the present invention to a single embodiment. In this example, the source wavelength range of the light generated by the light source **40** may be emitted in a blue wavelength range. However, a person of skill in the art, after having the benefit of this disclosure, will appreciate that LEDs capable of emitting light in any wavelength ranges may be used in the light source **40**, in accordance with this disclosure of the present invention. A skilled artisan will also appreciate, after having the benefit of this disclosure, additional light generating devices that may be used in the light source **40** that may be capable of creating an illumination.

Continuing with the present example of the light source **40** including a conversion material, the lighting source may generate a source light with a source wavelength range in the blue spectrum. The blue spectrum may include light with a wavelength range between 400 and 500 nanometers. A source light in the blue spectrum may be generated by a light emitting semiconductor that is comprised of materials that may emit a light in the blue spectrum. Examples of such light emitting semiconductor materials may include, but are not intended to be limited to, zinc selenide (ZnSe) or indium gallium nitride (InGaN). These semiconductor materials may be grown or formed on substrates, which may be comprised of materials such as sapphire, silicon carbide (SiC), or silicon (Si). A person of skill in the art will appreciate that, although the preceding semiconductor materials have been disclosed herein, any semiconductor device capable of emitting a light in the blue spectrum is intended to be included within the scope of the present invention.

Continuing with the present example, the conversion material may include a phosphor substance, which may be applied or located adjacent to the blue LEDs. The phosphorous substance may which may absorb wavelength ranges of emitted by the LEDs and emit light defined in additional wavelength ranges when energized. Energizing of the phosphor may occur upon exposure to light, such as the source light emitted from the light source. The wavelength of light emitted by a phosphor may depend on the materials from which the phosphor is comprised.

Referring back to FIG. **1**, the luminaire **10** according to an embodiment of the present invention may include a network interface **60**. A person of skill in the art will appreciate that the network interface **60** may be included within the controller **20** discussed above. Alternately, a skilled artisan will appreciate that the network interface **60** may be operatively connected to the controller **20**, wherein it may operate as an interface device between the controller **20** and a connected network **62**, such as for example, a home network, corporate network, or the Internet.

The network interface **60** may provide a channel for the electronic communication of data between the luminaire **10** and a connected device connected through the network **62**. Provided without the intent to be limiting, examples of network connected devices may include additional luminaires **10**, personal computers, tablets, smartphones, personal data assistants, a data center, remote, key fob, a light switch, or other electronic devices capable of connecting to a network **62**.

The network interface **60** may connect to a network **62** using a proprietary or standard connection protocol. With respect to embodiments of the present invention that include a proprietary network connection, the network interface **60** may perform handshake operations and exchange data with network **62** connected devices, as may be defined within the proprietary protocol. Alternately, the network interface **60** may connect to a network **62** using a standardized protocol. Examples of standardized protocols, provided without the intent to be limiting, may include 802.3 Ethernet, 802.11 Wi-Fi, 802.15.1 Bluetooth, 802.15.4 low rate personal area network **62** (PAN) environments, packet switching wide area networks (WAN), cellular relay WANs, or additional standardized data transmission protocols.

In additional embodiments, the data may be transmitted and received throughout a network **62** by emitting and detecting light. The light may be modulated such to include transmittable data. Preferably, the data will be transmitted in the light digitally by modulating between the emission and non-emission of light during a period. Alternatively, the data may be transmittable by modulating the analog frequency or amplitude of the light, or other emitted signal. The light may be detectable by a sensor, such as, for example, the ambient light sensor, during the periods of the duty cycle in which no light is being emitted. A person of skill in the art will appreciate that these periods may be short enough to be unperceivable by the human eye. Additionally, the network **62** may be transmittable using an auxiliary signal, such as an ultrasonic or Wi-Fi signal.

As illustrated in FIG. **1**, the luminaire **10** may additionally include an interface **30** to control its operation. The interface **30** may include a plurality of inputs **32**, which may be manipulated by a user to define the operation of the luminaire **10**. A person of skill in the art will appreciate that as few as one input **32** may be included in the interface **30** and be contemplated by the scope of this disclosure. Similarly, a skilled artisan will appreciate that the maximum number of inputs **32** may be virtually limitless. Preferably, a moderate number of inputs **32**, for example eight inputs **32**, may be included in the interface **30** to advantageously allow a diverse combination of controls to be selectable by the user without rendering the luminaire **10** overly complex.

With relation to the present invention, an input **32** may be defined as an element of the interface **30** through which the operation of the luminaire **10** may be modified. As will be discussed in greater detail herein, the input **32** may be provided by any number of means such as, for example, a mechanical toggle, a capacitive sensor, or any other system, device or apparatus suitable to cause the transmission of a signal to the controller **20**. In one embodiment, the input **32** may be a mechanical toggle, which may be physically engaged and mechanically altered to change the state of the toggle. For example, the mechanical toggle inputs **32** may be a switch that open or dose an electrical circuit upon being manipulated.

In another example, an input **32** may be a capacitive sensor. The state of a capacitive sensor input **32** may be altered upon the detection of an object located in proximity of the capacitive sensor. Skilled artisans will appreciate that a capacitive sensor may detect the proximity of an object using position, displacement, humidity, fluid level, acceleration, or other measurable changes in capacitance. Additional inputs **32** will be appreciated by a person of skill in the art. An example of an object may include the finger of a user, without limitation. The signal resulting from the touch may be received by the controller **20**, which may be analyzed to determine a state of operation for the luminaire **10**.

A person of skill in the art will appreciate that any number of components capable of altering a signal may be included as an input **32**, and should not limit the input **32** to the examples discussed above. Further examples for the operation of the inputs will be provided below.

The inputs **32** may be located on a surface of the luminaire **10**. Alternatively, the inputs **32** may be operatively connected to the luminaire **10**, such that the inputs **32** may be in communication with the controller **20**. In further embodiments, the inputs **32** may be remotely connected to the luminaire **10**, which may transmit a signal to be received by a sensor, network interface **60**, or other component. Skilled artisans will appreciate that the aforementioned examples of connective structures are provided in the interest of clarity, and should not limit the present invention to the preceding examples.

In an embodiment of the present invention, the network **62** connected device may be an additional luminaire **10**. In this example, if motion is sensed by sensors **50** included in one networked luminaire **10**, it may transmit an electronic signal to additional network connected luminaires **10** via the network interface **60**. Upon receiving the aforementioned electronic signal, the controllers **20** of the additional luminaires **10** may be controlled the operation of the additional luminaires **10** in response to the electronic signal transmitted over the network **62**. A person of skill in the art will appreciate additional devices that may be connected via the network interface **60**, such as devices with recording capabilities, sirens, indicators, or dialers that may contact police or a security department.

The luminaire **10**, according to embodiments of the present invention, may advantageously provide dynamic illumination of an environment with significant customizability in its operation. The luminaire **10** may detect one or more conditions present in an environment to affect how the environment may be illuminated by the luminaire **10**. A series of flowcharts will now be presented, along with accompanying descriptions, to illustrate various embodiments of the present invention. A person of skill in the art will appreciate that the follow flowcharts and descriptions are presented in the interest of clearly disclosing the invention, according to a number of its embodiments. Skilled artisans should not view the present invention to be limited to the embodiments discussed below.

Referring to flowchart **190** of FIG. **3**, operation of the luminaire **10** will be discussed generally, according to an embodiment of the present invention. Starting at Block **192**, a sensor **50** may sense a condition in the environment (Block **194**). The data generated by the sensor **50** relating to the detected condition may be received and analyzed by the controller **20** (Block **196**). The controller **20** may then control the light source **40** with respect to the analysis performed on the data (Block **198**). The operation may then terminate at Block **199**.

Referring now to flowchart **200** of FIG. **4**, operation of the sensor, according to an embodiment of the present invention, will be discussed in greater detail. Starting at Block **202**, a sensor **50** may detect a condition of the environment (Block **204**). As discussed above, the condition may include motion, ambient light levels, or additional conditions that would be apparent to a person of skill in the art. The sensor **50** may then generate sensory data relating to the detected condition (Block **206**). For example, and without limitation, the sensor **50** may be an ambient light detector **54** that senses a high level of ambient light in the environment. The ambient light detector **54** may generate a digital signal, such as a hex value of FE, to convey the condition to controller **20**. Skilled artisans will appreciate that analog signals may also be detectable by the controller **20**, for example by correlating voltage levels with the level in which the condition is detected in the environment.

The controller **20** may then receive the sensory data from the sensor **50** for analysis (Block **208**). The sensory data may have been made available by the sensor **50** to be received by the controller **20**. Skilled artisans will appreciate the data may be communicated between the sensor **50** and the controller **20** via transmission by the sensor, polling by the controller **20**, or other communications of data that would be readily apparent to after having the benefit of this disclosure. The operation may then terminate at Block **210**.

Referring now to flowchart **220** of FIG. **5**, operation of the controller **20**, according to an embodiment of the present invention, will now be discussed in greater detail. Starting at Block **222**, the controller **20** may receive sensory data from at least one of the sensors **50** (Block **224**). The controller **20** may then retrieve rules from the memory **24** (Block **226**). The memory **24** may be included in the controller **20**. Alternatively, the memory **24** including at least some of the rules may be operatively connected to the controller **20** and accessible by the controller **20**.

The controller **20** may then analyze the data, for example, by comparing the sensory data with the rules (Block **228**). After the data has been analyzed, the controller **20** may adjust the mode of operation of the luminaire **10** (Block **230**). Various modes, according to an embodiment of the present invention, may include full output, limited output, emission of light that includes data, emission of light that includes an identifier, flashing or blinking light, or other various operational modes that would be apparent to a skilled artisan after having the benefit of this disclosure. The controller **20** may then control the light source **40** to emit light in accordance with the mode of operation, as determined by analyzing the data (Block **232**). The operation may then terminate at Block **234**. The skilled artisan will appreciate that the light source may be operated in many different ways. Embodiments of the present invention specifically contemplate operation of the light source by dimming the light source and by moving the light source between an on position and an off position.

Referring now to flowchart **240** of FIG. **6**, the operation of the controller **20** communicative connected to a plurality of sensors **50**, according to an embodiment of the present invention, will now be discussed in greater detail. Starting at Block **242**, the controller **20** may receive sensory data from a plurality of the sensors **50** (Block **244**). The controller **20** may then retrieve rules from the memory **24** (Block **246**). The memory **24** may be included in the controller **20**. Alternatively, the memory **24** including at least some of the rules may be operatively connected to the controller **20** and accessible by the controller **20**.

The controller **20** may then analyze the data, for example, by comparing the sensory data with the rules, respective to each of the plurality of sensors **50** from which data has been received (Block **248**A, **248**B, . . . , **248***n*). After the data from the plurality of sensors **50** has been analyzed, the controller **20** may adjust the mode of operation of the luminaire **10**, respective to the analysis performed on the data that may have been received by each of the plurality of sensors (Block **250**A, **250**B, . . . , **250***n*). Various modes, according to an embodiment of the present invention, may include full output, limited output, emission of light that includes data, emission of light that includes an identifier, flashing or blinking light, or other various operational modes that would be apparent to a skilled artisan after having the benefit of this disclosure. The controller **20** may then control the light source **40** to emit light in accordance with the mode of operation, as determined by analyzing the data (Block **252**). The operation may then terminate at Block **254**.

The controller **20** may control the light source **40** to emit light with a duty cycle. The duty cycle may include an active duration and an inactive duration. During the active duration, the light source **40** may emit light. Conversely, during the inactive duration, the light source **40** may not emit light. The controller **20** may control the light source **40** to emit or to not emit light during the active and inactive durations of the duty cycle, respectively.

As discussed in greater detail above, one of the sensors **50** may be an ambient light detector **54** (see FIG. **1**). Referring now to flowchart **260** of FIG. **7**, operation of the ambient light detector **54** of the luminaire **10** according to an embodiment of the invention will now be discussed in greater detail. Generally, the ambient light detector **54** may detect ambient light levels in an inactive portion of the duty cycle. This discussion of an ambient light detector **54** being one of the sensors **50** of the luminaire **20** is provided as an example, and is not intended to limit the present invention in any way.

Starting at Block **262**, the light source **40** may be operating in the active duration of the duty cycle (Block **264**). During the active duration, one or more light sources **40** may emit light (Block **266**). Skilled artisans will appreciate that beginning this example with the light source **40** operating in the active or inactive duration of the duty cycle was made in the interest of clarity, and without the intent to limit the present invention. Accordingly, the present invention contemplates that this operation may begin with operation the light source in the inactive duration of the duty cycle.

The luminaire **10** may then change to operation in the inactive duration of the duty cycle (Block **268**). During the inactive duration, one or more light sources **40** may stop emitting light (Block **270**). The ambient light detector **54** may then detect the ambient light level in the environment (Block **272**). Since light is not being emitted by the light sources **40** during the inactive duration of the duty cycle, the ambient light sensor **50** may detect ambient light levels in the environment without interference from the light emitted by one or more light source **40**.

It may then be determined whether a shutdown command has been received by the controller **20** for the ambient light detector **54** at Block **274**. A shutdown command may be issued, for example, as a result of a configuration of the rules using the interface **30**. If no shutdown command has been received at Block **274**, the light source may continue to operate at Block **266**, wherein the light source **40** emits light while operating in the active duration of the duty cycle. Conversely, if a shutdown command is received at Block **274**, the operation may terminate at Block **276**. Effectively, the duty cycle may continually loop until a shutdown command is received.

Referring now to flowchart **300** of FIG. **8**, along with the signal **280** of FIG. **9**, the inclusion of an identifier in light or an auxiliary signal will now be discussed. In the following example, in the interest of clarity, inclusion of a light identifier in light will be discussed. Skilled artisans will appreciate similar operation for inclusion of an identifier in other signals, such as an auxiliary signal identifier being included in the auxiliary signal. Starting at Block **302** of flowchart **300**, the controller **20** may generate a digital identifier code (Block **304**). The digital identifier code is also referred to as a digital watermark. The controller **20** may control the light source **40** to emit the digital identifier code in the light (Block **306**).

Referring additionally to the signal **280** of FIG. **9**, an illustrative identifier will now be discussed. The identifier light **282** may be emitted by alternating the emission **286** and non-emission **288** of light in a pattern to indicate a digital signature, as will be appreciated by skilled artisans. For example, a luminaire **10** may be encoded with a serial number, which may be transmittable as the identifier in the light **282**. The controller **20** may include the identifier in the light at an interval, such as every minute, to identify the source of the light. In the example presented by the signal **280**, without limitation, the identifier may be interpreted by another device as "0011 0011 1010 0011 0010."

After the light including the light identifier has been emitted, the light source **40** may emit light with a standard, or otherwise defined, duty cycle, as illustrated, for example, at Block **308** of FIG. **8**. Referring additionally to FIG. **9**, light emitted without inclusion of an identifier light **284** may include a duty cycle that alters between the active duration **290** and the inactive duration **292**. The controller **20** may then determine if it should control the light source **40** to retransmit the light identifier, as illustrated at Block **310** of FIG. **8**. If retransmission of the identifier is desired, the light source **40** may again emit the digital identifier code in the light (Block **306**).

Conversely, if retransmission of the identifier is not desired at Block **310**, the controller **20** may determine whether a shutdown command has been received at Block **312**. If no shutdown command has been received at Block **312**, the controller **20** may continue to emit light as normal. If a shutdown command has been received at Block **312**, the operation may terminate at Block **314**.

The luminaire **10**, according to an embodiment of the present invention, may emit multiple signals that include multiple identifiers. The multiple identifiers may correlate the multiple signals. Additionally, the multiple signals may be transmittable substantially simultaneously, such that analysis on the transmission and or receipt of the signals may be performed by the controller **20**.

Referring now to flowchart **340** of FIG. **10**, the transmission of light with a light identifier and an auxiliary signal with an auxiliary signal identifier will now be discussed. The light and the auxiliary signal allow the luminaire to become spatially aware of an environment in which the luminaire is located. Similarly, the luminaire may use the light and the auxiliary signal to become aware of other objects and devices in the environment. Spatial awareness may include, but should not be limited to, geolocation, positioning, direction finding, and other analytical processes based on the spatial location of the luminaire in an environment.

According to an embodiment of the present invention, without limitation, the auxiliary signal may include acoustic energy. Acoustic energy may include signals with a frequency that is subsonic, audible, or ultrasonic. In the present example, provided in the interest of clarity, the auxiliary signal may be ultrasonic, or a sound with a frequency greater than the upper limits of human hearing. Starting at Block **342**, the controller **20** may designate light with a light identifier (Block **344**). The controller **20** may also designate an auxiliary signal with an auxiliary signal identifier (Block **346**). The light identifier and the auxiliary signal identifier may be correlated with one another.

Skilled artisans will appreciate that the designation of an identifier with light and an auxiliary signal may happen in any order, or substantially simultaneously. After the light has been designated with a light identifier and the auxiliary signal has been designated with an auxiliary signal identifier, the controller **20** may control the light source **40** to emit the light and the auxiliary signal emitter to emit auxiliary signal substantially simultaneously (Block **348**). The operation may then terminate at Block **350**.

Light, auxiliary signals, and other signals including one or more identifier, may be identifiable by luminaires **10** or other devices. This identification of signals, and an association to its source, may be used to perform analyses on the signals. For example, the detection of identified light by a luminaire **10** that has been emitted by another luminaire **10** in an environment may indicate the presence of a network **62** of luminaires **10**. As another example, receiving a plurality of signals associated with a source luminaire **10** may be used to calculate a distance between the devices. Skilled artisans will appreciate the following examples to be provided for illustrative purposes, and without limitation.

Referring now to graph **360** of FIG. **11**, the delay created between light **362**, represented by a solid line, and an auxiliary signal **364**, represented by a broken line, will now be discussed. Graph **360** plots the distance traveled by a signal along the y-axis and the time of travel along the x-axis. A desired travel distance has been indicated by the line labeled **367**.

The velocity at which light **362** and the auxiliary signal **364** travels through the environment may differ. For example, light **362** travels at approximately 3×10ˆ8 meters per second. In the present example, the light **362** may reach the desired travel distance **367** at time t_1. As another example, the auxiliary signal **364** may be a signal of acoustic energy, such as an ultrasonic signal that travels at approximately 340 meters per second. In the present example, the auxiliary signal **364** may reach the desired travel distance **367** at time t_2.

The difference between t_1 and t_2 may be a delay represented by the delta range **368**. As the distance the light and the auxiliary signals must travel increases, so will the delay between times when the light and an auxiliary signal reaching the desired travel distance **367**. This delay may be analyzed to determine the distance of the luminary from another device or object. The other device may be an additional luminaire **10**. According to an embodiment of the present invention, multiple luminaires **10** may be included as nodes in a network of nodes **70**, each of which being spatially aware with regard to the other nodes in the network of nodes.

Referring now to FIG. **12**, an example of acquiring spatial awareness will now be discussed. In FIG. **12**, light **362** and an auxiliary signal **364** may be emitted from a first luminaire **352** to be received by a second luminaire **10 354**. These signals **362**, **364** may be emitted substantially simultaneously from the first luminaire **352**. The delay between receiving the light **362** and the auxiliary signal **364** may be calculated by the second luminaire **354** to determine its distance from the first luminaire **352**. The delay may be calculated by the controller **20** of the luminaire **354**.

Referring now to FIG. **13**, an additional example of acquiring spatial awareness will now be discussed. In FIG. **13**, light **362** and an auxiliary signal **364** may be emitted from a luminaire **356** into an environment that includes an environmental object **358**. The light **362** and the auxiliary signal **364** may be reflected by the object and be received by the luminaire **356**. The luminaire **356** may then calculate the delay between the emission and the detection of the light **362** and the auxiliary signal **364** to determine the distance of the environmental object **358** from the luminaire **356**. The luminaire **356** may take in account the additional delay caused by the initial transmission and reflective transmission of the signals **362**, **364** to and from the environmental object **358**, respectively. A person of skill in the art will appreciate additional configurations of luminaires **10**, environmental objects **358**, and other devices that would allow the luminaire **10** to be spatially aware after having the benefit of this disclosure.

Referring now to flowchart **370** of FIG. **14**, an illustrative operation of calculating a delay between two signals will now be discussed. Starting at Block **372**, the luminaire **10** may attempt to sense light (Block **374**). The light may be sensed by a sensor **50** communicatively connected the controller **20**. The controller **20** may then determine whether light is sensed (Block **376**). Embodiments of the present invention contemplate use of an algorithm to conduct a delay/distance calculation. If light is sensed at Block **376**, the controller **20** may determine if a light identifier is included in the light (Block **378**). If no light is sensed at Block **376**, or if light is sensed that does not include a light identifier, the luminaire **10** may continue attempting to sense light (Block **374**).

If a light identifier is sense in the light, the luminaire **10** may attempt to sense an auxiliary signal, such as an ultrasonic signal (Block **380**). The auxiliary signal may be sensed by a sensor **50** communicatively connected the controller **20**. The controller **20** may determine whether an auxiliary signal is sensed (Block **382**). If an auxiliary signal is sensed at Block **382**, the controller **20** may determine if an auxiliary signal identifier is included in the auxiliary signal (Block **384**). If no auxiliary signal is sensed at Block **382**, or if auxiliary signal is sensed that does not include an auxiliary signal identifier, the luminaire **10** may continue attempting to sense an auxiliary signal (Block **380**).

After light with a light identifier and an auxiliary signal with an auxiliary signal identifier that has been sensed, the controller **20** may compare the identifiers for the light and the auxiliary signal (Block **386**). The controller **20** may then determine if the identifiers correlate at Block **388**. Embodiments of the present invention contemplate synchronization of the signals. This can be accomplished using time stamps, for example, that may be embedded in the signals.

If it is determined that the identifiers do not correlate at Block **388**, the controller **20** may optionally determine if an unreasonable amount of time has elapsed (Block **390**). An unreasonable amount of time may be relative to a time period wherein a delay between receiving light with a light indicator and an auxiliary signal with a correlating auxiliary signal indicator would be unreasonable given the space of the environment. Unreasonableness of time may be defined in the rules. Unreasonableness of time may also be defined or configured by a user, for example, using the interface **30**.

If it is determined that an unreasonable amount of time has not elapsed at Block **390**, the operation may again attempt to sense an auxiliary signal at Block **380**. If it is determined that an unreasonable amount of time has elapsed at Block **390**, the operation may again attempt to sense light at Block **374**, essentially restarting. If it is determined at Block **388** that the light identifier and the auxiliary signal identifier correlate, the controller **20** may calculate the delay between receiving the identified signals to determine a distance from the origin of the signals, and thus the spatial location of the luminaire **10** (Block **392**). The operation may terminate at Block **394**.

As previously mentioned, components included in the luminaire **10** may be included as a node within a network **62**, such as a network of nodes **70**. The luminaire **10** may communicate with one or more additional luminaires **10** over the network **62**. In an embodiment, luminaires **10** and additional devices may be connected over the network **62 69** by using a centralized hub or outer. In an additional embodiment, each device on the network **62 69** may be included in a network of nodes **70**, for example, and without limitation, a neural network **62**. A node may include a sensor, a controller **20**, and additional components of the luminaire **10** such as a light source **40** and/or an auxiliary signal emitter. The components of the node may be included in a luminaire **10**. Each node may operate as a master and a slave. Additionally, each node may act as a repeater to expand the range of the network **62 69**.

Referring now to FIG. **15**, an illustrative embodiment to a network of nodes **70** will now be discussed. In this embodiment a plurality of nodes may be positioned within communication range of additional nodes. A person of skill in the art will appreciate that the configuration of nodes illustrated in FIG. **15** has been chosen in the interest of clarity, as the nodes may be configured in a plethora of additional locations relative to one another.

As additional nodes are added to the neural network **62**, the range of the network **62** may be expanded. In the network of nodes **70** illustrated by FIG. **15**, each node may communicate with its neighboring nodes by sending and receive data directly with one another. For example, Node **2**A may transmit a direct data communication as a master to be received by Node **2**B as a slave. This data communication may not require involving additional nodes **72**. However, additional nodes **72** may still receive the data communication, analyze any information included in the data communication, and disregard any message to which the additional node **72** is not an intended recipient. A person of skill in the art will appreciate that communication of a node **72** with a non-neighboring node **72** is also contemplated by the scope of the present invention, and is intended to be included in this disclosure.

In an additional embodiment, nodes **72** may be configured to repeat messages that are addressed to another node **72** in the network of nodes **70**. For example, Node **2**A may intend to transmit a data communication as a master to Node **1**C as a slave. Node **2**A may broadcast the data transmission, even though Node **1**C is out of range to receive the transmission. However, the data may be received by Node **2**B as a slave, which may be in range of Node **2**A. After analyzing the data transmission, Node **2**B may determine that it is an unintended recipient, Node **2**B may then retransmit the data communication as the master, which may now be received by Node **1**C as the slave, since Node **1**C may now be in range of the transmitting master node.

Additionally, the controller **20** at each node may include memory **24**. The memory **24** of the node may maintain an at least partial log of data communication **80** that have been transmitted, received, and or rebroadcast by the node **72**. In this embodiment wherein the network of nodes **70** is a neural network, upon receipt of a data communication, the controller **20** of a node **72** may then access the memory **24** to compare the data included in the memory of that node **72** with the received data. The controller **20** of the node **72** may then make a logic based decision as a result of the analysis. An example of such a logic based decision may include declining to rebroadcast a data communication that has already been rebroadcast by the node **72**. An additional example of a logic based decision may include broadcasting a confirmation signal to a transmitting master node, such as node **3**B, indicating that the data transmission has been received from Node **3**C. In this example, the Node **3**C transmitting the data communication as a master node may receive the confirmation signal from Node **3**B as a slave node. Node **3**C may then analyze the confirmation signal to make a logic based decision to terminate further transmission of the original data communication.

As nodes **72** are added to the network of nodes **70**, each node **70** may receive and transmit multiple signal and data transmissions among each other. These signals may include, for example, the light and auxiliary signal transmissions usable to determine the spatial awareness between the nodes within the network of nodes **70**. As the nodes **72** become aware of one another, and as data is shared between the nodes **72**, advanced analysis of the data detected by the sensors **50** of each node **72** may be performed. Examples of such advanced analysis may include concatenation of the sensed environmental conditions with respect to the spatial location of each node **72**. This concatenation may create a map of conditions sensed throughout the environment, for example.

The sharing of data between nodes **72** within the network of nodes **70** may additionally allow a controller **20** of one node **72** analyze a condition sensed by another node **72**. An example of this distributed sensing, using both sensors **50** locally included within a node and distributed through a network of nodes **70**, will now be discussed with reference to flowchart **400** of FIG. **16**. Skilled artisans will appreciate that the following example is but one embodiment of the present invention, and thus should not be viewed as limiting.

Starting at Block **402**, the controller **20** may analyze sensory data from a local sensor, or a sensor **50** directly connected to the controller **20** (Block **404**). The controller **20** may then determine if a condition was detected by the local sensor (Block **406**). If a condition was detected, the operation may advance to Block **412**, wherein the controller **20** may control the light source **40** respective to the sensed conditions, as may be defined by the rules.

If a condition is not detected at Block **406**, the controller **20** may determine whether a communication signal is detected (Block **408**). A communication signal may be any signal that carries a communication from another device, such as an additional luminaire **10** that may be a node **72** in the network of nodes **70**. If no communication signal is detected at Block **408**, the operation may return to Block **404**, wherein the controller **20** may analyze sensed data from a local sensor. If a communication signal is detected at Block **408**, the controller **20** may determine whether the communication signal is indicative of a condition detected by a sensor **50** of a network **62** connected device (Block **410**). The network **62** connected device may be another luminaire **10** within the network **62**.

If the signal is not determined to be indicative of a condition detected by a sensor **50** of a network **62** connected device at Block **410**, the operation may return to Block **404**, wherein the controller **20** may analyze sensed data from a local sensor. If the signal is determined to be indicative of a condition detected by a sensor **50** of a network **62** connected device at Block **410**, the operation may advance to Block **412**, wherein the controller **20** may control the light source **40** with respect to the sensed conditions, as may be defined by the rules. The operation may then terminate at Block **414**.

In an embodiment of the present invention, as mentioned above, the luminaire **10** may include a network interface **60**. The luminaire **10** may communicate with network connected over a network **62** devices using the network interface **60**. Such communications may include receiving control instructions, firmware updates, or other data instructions that may affect the operation of the luminaire **10** of the present invention. The network interface **60** may also allow the luminaire **10** to transmit a data signal to a connected network device. Such data signals may include feedback information, status updates, identity, and other information detected by the luminaire **10**.

An embodiment of a network **62** connected device may include a computerized device capable of running computer programs. More specifically, the computerized network connected device may be connected to the network **62** to perform one or more analyses, which may result in the determination of operational statistics based at least partially upon feedback by the luminaire **10**. The network connected device may include, but should not be limited to, a server, a computer (i.e., desktop computer, laptop computer, netbook computer, or any machine having a processor), a dumb terminal that provides an visual interface with a computer or server, a personal digital assistant, mobile communications device such as a cellular phone, smart phone (such as an Google Android based phone), or other similar device that provides computer or quasi-computer functionality.

The network **62** communication may occur through an internal network **62**, an intranet, LAN, WAN, or global communications network **62** (such as the Internet). It should be noted that the method aspects of the present invention are preferably computer-implemented methods and, more particularly, at least one step is preferably carried out using a computerized device.

The analyses by the controller **20** may be performed as defined by the rules, which are storable in the memory **24**. The rules may be compared to data or other information to determine the operation of the luminaire **10**. The rules may also define the modes in which the luminaire **10** operates, sensitivity of the sensors, which of the modes should affect operation of the luminaire **10**, and other operation parameters that may relate to the operation of the luminaire **10**. Those skilled in the art will appreciate that the controller **20** of the luminaire **10** according to an embodiment of the invention is capable of several other functions, and that the above described functions are exemplary in nature and not intended to be limiting in any way.

The rules may be definable by a user. In an embodiment of the present invention, the rules may be definable using an interface **30**. The structure of an illustrative interface **30** has been discussed above. The interaction with the interface **30** to define and manipulate the rules will now be discussed in the following examples, presented without the intent to limit the present invention in any way.

Referring back to FIGS. **1-2**, the interface **30** may include a number of inputs **32** manipulable by a user. In the following examples, referring additionally to FIG. **17**, an illustrative interface **90** including eight inputs **91-98** will be discussed. Skilled artisans will appreciate that more or less inputs may be included and remain within the scope and spirit of the present invention. Also, in some of the following embodiments, a threshold duration value will be discussed. This threshold duration value is simply a variable quantity of time that may be predetermined or otherwise determined by a user. Additional embodiments will be apparent to a person of skill in the art after having the benefit of this disclosure.

Also, some of the following examples may include one or more steps wherein the luminaire **10** will provide feedback. These steps are optional. Feedback may be provided by emitting light from a light source **40**, emitting a sound, or otherwise providing an indication that an input has been received. Furthermore, the following examples include configurations wherein two inputs **32** are manipulated to interact with the interface **30**. A person of skill in the art appreciate that as few as one input **32** and as many as a virtually limitless number of inputs **32** may be manipulated within the scope of the present invention.

Referring now to flowchart **420** of FIG. **18**, modification of a rule, such as, for example, a delay between the detection of motion in the environment and illumination will now be discussed generally. Starting at Block **422**, the controller **20** may monitor an initial input (Block **424**). The initial inputs are illustrated as inputs **91-94** on the illustrative interface **90** of FIG. **17**. The controller **20** may then determine if the initial input has been engaged at Block **426**.

If the initial input has been engaged, the controller **20** may determine whether the initial input was engaged for a threshold duration (Block **428**). If the initial input has not been engaged, or has been engaged for a duration less than the threshold duration, the operation may return to Block **424** wherein the controller **20** will continue to monitor the initial input. If it is determined at Block **428** that the initial input has been engaged for the threshold duration, the luminaire **10** may optionally provide feedback that the initial input has been properly engaged (Block **430**). Those skilled in the art will appreciate that making the determination of whether or not the input has been engaged for the threshold duration advantageously prevents the inadvertent transmission of a signal upon an accidental engagement of one of the inputs. Those skilled in the art will further appreciate that the present invention contemplates transmitting a signal upon any engagement of the inputs and that the threshold duration may advantageously be manipulable for any desired duration, i.e., a minimal or no duration, to any desired length of duration.

Once the initial input has been engaged, as described above, the controller **20** may determine whether the period in which the subsequent input should be monitored has expired (Block **432**). The subsequent inputs are illustrated as inputs **96-98** on the illustrative interface **90** of FIG. **17**. The first time the operation makes this determination, the period will likely not have expired. If the period in which the subsequent input should be monitored has expired, the operation may return to Block **424**, wherein the initial input will again be monitored. If the period in which the subsequent input should be monitored has not expired at Block **432**, the controller **20** may then monitor a subsequent input (Block **434**).

The determination may then be made whether the initial input has been engaged at Block **436**. If the subsequent input has been engaged, the determination may be made whether the subsequent input has been engaged for a threshold duration (Block **438**). If the subsequent input has not been engaged, or has been engaged for a duration less than the threshold duration, the operation may return to Block **432** wherein a determination may again be made whether the period in which the subsequent input should be monitored has expired. Similar to the description of engaging the input above, embodiments of the present invention contemplates engaging the subsequent input for any duration, and that monitoring the duration may be optional, i.e., embodiments of the present invention contemplates that the signal may be transmitted upon immediate engagement of the input or upon engagement of the input for a duration.

If it is determined at Block **438** that the subsequent input has been engaged for the threshold duration, the operation may update the rule accordingly (Block **440**). The luminaire **10** may optionally provide feedback that the rule has been successfully updated (Block **442**). As indicated above, the feedback may be in any form, i.e., and audible feedback or a visual feedback. Those skilled in the art will appreciate that the feedback may be provided by sending a signal through the network that may result in delivery of a message indicating that the rule has been successfully updated. For example, it is contemplated that the feedback may result in delivery of an email, a text message, an instant message, or any other readily transmittable message that indicates that the rule has been successfully updated.

The controller **20** may then determine if a shutdown command has been received at Block **444**. If no shutdown command has been received, the operation may return to Block **424**, wherein the initial input will again be monitored. If a shutdown command has been received at Block **444**, the operation may terminate at Block **446**. A person of skill in the art will appreciate that this operation may be repeated for additional subsequent inputs.

Referring now to flowchart **450** of FIG. **19**, a specific modification of a delay between the detection of motion in the environment and illumination using the interface **30** will now be discussed, without limitation. Starting at Block **452**, the controller **20** may monitor a delay input (Block **454**). The controller **20** may then determine if the delay input has been engaged for a threshold duration, such as three seconds (Block **456**). If the delay input has not been engaged for the threshold duration, the operation may return to Block **454** wherein the controller **20** will continue to monitor the delay input. If it is determined at Block **456** that the delay input has been engaged for the threshold duration, the luminaire **10** may optionally provide feedback that the delay input has been properly engaged (Block **458**).

Once the delay input has been properly engaged, the controller **20** may monitor a set of configuration inputs (Block **460**). The set of configuration inputs may include one or more inputs that may be engaged by a user to manipulate the rules. Although the following example discusses four configuration inputs, a person of skill in the art will appreciate that any number of configuration inputs may be included in the set of configuration inputs, without limitation.

In determining if a configuration input has been engaged, the controller **20** may determine if a first input has been engaged for a threshold duration (Block **462**). If it is determined at Block **462** that the first input has been engaged for the threshold duration, the rule relating to the delay may be defined to operate in test mode (Block **464**). During test mode, the luminaire **10** may operate such that no delay is required and the luminaire **10** will react immediately to illuminate an environment with and without and motion in the field of view.

If the first input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **466** wherein the controller **20** may determine whether a second input has been engaged for a threshold duration. If it is determined at Block **466** that the second input has been engaged for the threshold duration, the rule relating to the delay may be defined to operate with a delay between detecting motion and emitting light being defined as thirty seconds (Block **468**). With the delay being defined as thirty seconds, the luminaire **10** may operate such to illuminate an environment in which motion is detected in the field of view for thirty seconds.

If the second input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **470** wherein the controller **20** may determine whether a third input has been engaged for a threshold duration. If it is determined at Block **470** that the third input has been engaged for the threshold duration, the rule relating to the delay may be defined to operate with a delay between detecting motion and emitting light being defined as two minutes (Block **472**). With the delay being defined as two minutes, the luminaire **10** may operate such to illuminate an environment in which motion is detected in the field of view for two minutes.

If the third input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **474** wherein the controller **20** may determine whether a fourth input has been engaged for a threshold duration. If it is determined at Block **474** that the fourth input has been engaged for the threshold duration, the rule relating to the delay may be defined to operate with a delay between detecting motion and emitting light being defined as ten minutes (Block **476**). With the delay being defined as ten minutes, the luminaire **10** may operate such to illuminate an environment in which motion is detected in the field of view for ten minutes.

If the fourth input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **454**, wherein the controller **20** may again monitor whether the delay input has been engaged.

If the rules have been defined in Blocks **464**, **468**, **472**, or **476**, the luminaire **10** may optionally provide feedback that the rule has been successfully changed (Block **480**). The controller **20** may then determine if a shutdown command has been received at Block **482**. If a shutdown command has not been received at Block **482**, the operation may proceed to Block **454**, wherein the controller **20** may again monitor whether the delay input has been engaged. If a shutdown command has been received at Block **482**, the operation may terminate at Block **484**.

Referring now to flowchart **490** of FIG. **20**, a specific modification of the ambient light detector **54** using the interface **30** will now be discussed, without limitation. Starting at Block **492**, the controller **20** may monitor an ambient light detector input (Block **494**). The controller **20** may then determine if the ambient light detector input has been engaged for a threshold duration, such as three seconds (Block **496**). Again, a threshold duration of three seconds (as illustrated in the flowchart **490**) is exemplary in nature and not meant to be limiting in any way. The threshold duration can be any duration, and a reading that the threshold duration is limited to three seconds is inappropriate and not intended in any way. If the ambient light detector input has not been engaged for the threshold duration, the operation may return to Block **494** wherein the controller **20** will continue to monitor the ambient light detector input. If it is determined at Block **496** that the ambient light detector **54** input has been engaged for the threshold duration, the luminaire **10** may optionally provide feedback that the ambient light detector input has been properly engaged (Block **498**).

Once the ambient light detector **54** input has been properly engaged, the controller **20** may monitor a set of configuration inputs (Block **500**). The set of configuration inputs may include one or more inputs that may be engaged by a user to manipulate the rules. Although the following example discusses four configuration inputs, a person of skill in the art will appreciate that any number of configuration inputs may be included in the set of configuration inputs, without limitation.

In determining if a configuration input has been engaged, the controller **20** may determine if a first input has been engaged for a threshold duration (Block **502**). If it is determined at Block **502** that the first input has been engaged for the threshold duration, the rule may be defined to disable the ambient light detector **54** (Block **504**). With the ambient light detector **54** disabled, the luminaire **10** may operate such to illuminate an environment with motion detected in the field of view, regardless of ambient light levels. This may provide for operation during daylight.

If the first input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **506** wherein the controller **20** may determine whether a second input has been engaged for a threshold duration. If it is determined at Block **506** that the second input has been engaged for the threshold duration, the rule relating to the ambient light detector **54** may be defined to operate during the first three hours that ambient light detector **54** detects low ambient light levels (Block **508**). In this operation, the luminaire **10** may illuminate an area with a dimmed brightness during the first three hours of low ambient light levels that no motion is detected. Again, the use of three hours as the time within which the luminaire may illuminate the area with a dimmed brightness is exemplary in nature and should not be read to limit any embodiment of the claimed invention in any way. Those skilled in the art, after having the benefit of this disclosure, will appreciate that the present invention contemplates that the luminaire may illuminate the area with a dimmed brightness for any amount of time. After the first three hours have expired, the luminaire **10** may emit no light in the subsequent hours and wherein no motion is detected. The luminaire **10** may emit light at full brightness upon the detection of motion.

If the second input has not been engaged for the threshold duration, for example three seconds (merely exemplary), the operation may proceed to Block **510** wherein the controller **20** may determine whether a third input has been engaged for a threshold duration. If it is determined at Block **510** that the third input has been engaged for the threshold duration, the rule relating to the ambient light detector **54** may be defined to operate during the first six hours that ambient light detector **54** detects low ambient light levels (Block **512**). In this operation, the luminaire **10** may illuminate an area with a first brightness during the first six hours of low ambient light levels that no motion is detected. After the first six hours have expired, the luminaire **10** may emit no light in the subsequent hours and wherein no motion is detected. The luminaire **10** may emit light at full brightness upon the detection of motion.

If the third input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **514** wherein the controller **20** may determine whether a fourth input has been engaged for a threshold duration. If it is determined at Block **514** that the fourth input has been engaged for the threshold duration, the rule relating to the ambient light detector **54** may be defined to operate during the all hours that ambient light detector **54** detects low ambient light levels (Block **516**). In this operation, the luminaire **10** may illuminate an area with a dimmed brightness during all hours of low ambient light levels and wherein no motion detected. The luminaire **10** may emit light at full brightness upon the detection of motion.

If the fourth input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **494**, wherein the controller **20** may again monitor whether the ambient light detector input has been engaged.

If the rules have been defined in Blocks **504**, **508**, **512**, or **516**, the luminaire **10** may optionally provide feedback that the rule has been successfully changed (Block **520**). The controller **20** may then determine if a shutdown command has been received at Block **522**. If a shutdown command has not been received at Block **522**, the operation may proceed to Block **494**, wherein the controller **20** may again monitor whether the ambient light detector input has been engaged. If a shutdown command has been received at Block **522**, the operation may terminate at Block **524**.

In the above examples, and has been previously indicated, there are several references to specific periods of time within which certain functions are carried out. These types of references appear throughout this specification. Such references to specific periods of time are not meant to be limiting in any way. For the sake of clarity and for ease of reading, the examples have been provided so that the user may readily appreciate the function of the luminaire **10** and the system of the various embodiments of the present invention. Those skilled in the art will appreciate that any disclosure of a specific time period, and any illustration indicating a specific time period, are not meant to be limiting in any way, and that the time periods may be readily manipulable, if so desired.

Referring now to flowchart **530** of FIG. **21**, a specific; modification of a dim level by which the luminaire **10** may be operated when no motion is detected in the environment will now be discussed, without limitation. The dim level may affect the brightness of light emitted by a light source **40** when a low ambient light level is detected without motion being detected in the environment. Skilled artisans will appreciate that the rules manipulable in association with the dim level may be applied in conjunction with other rules, such as the rules relating to ambient light or motion detection.

Starting at Block **532**, the controller **20** may monitor a dim input (Block **534**). The controller **20** may then determine if the dim input has been engaged for a threshold duration, such as three seconds (Block **536**). If the dim input has not been engaged for the threshold duration, the operation may return to Block **534** wherein the controller **20** will continue to monitor the dim input. If it is determined at Block **536** that the dim input has been engaged for the threshold duration, the luminaire **10** may optionally provide feedback that the dim input has been properly engaged (Block **538**).

Once the dim input has been properly engaged, the controller **20** may monitor a set of configuration inputs (Block **540**). The set of configuration inputs may include one or more inputs that may be engaged by a user to manipulate the rules. Although the following example discusses four configuration inputs, a person of skill in the art will appreciate that any number of configuration inputs may be included in the set of configuration inputs, without limitation.

In determining if a configuration input has been engaged, the controller **20** may determine if a first input has been engaged for a threshold duration (Block **542**). If it is determined at Block **542** that the first input has been engaged for the threshold duration, the rule relating to the dim level may be disabled (Block **544**). With the dim level disabled, the luminaire **10** may operate such that no light is emitted when motion is not sensed in the field of view, regardless of the ambient light levels sensed by an ambient light detector **54**.

If the first input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **546** wherein the controller **20** may determine whether a second input has been engaged for a threshold duration. If it is determined at Block **546** that the second input has been engaged for the threshold duration, the rule relating to the dim level may be defined to operate at, for example, twenty-five percent brightness (Block **548**). Similar to the time durations mentioned above, the percentage of brightness described with reference to Block **544**, **548**, **552**, and **556** are merely exemplary and those skilled in the art will appreciate that any brightness level is readily contemplated by the embodiments of the present invention. With the dim level being defined as twenty-five percent, the luminaire **10** may operate one or more light source **40** to illuminate an environment with approximately twenty-five percent brightness when no motion is detected in the environment.

If the second input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **550** wherein the controller **20** may determine whether a third input has been engaged for a threshold duration. If it is determined at Block **550** that the third input has been engaged for the threshold duration, the rule relating to the dim level may be defined to operate at fifty percent brightness (Block **552**). With the dim level being defined as fifty percent, the luminaire **10** may operate one or more light source **40** to illuminate an environment with approximately fifty percent brightness when no motion is detected in the environment.

If the third input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **554** wherein the controller **20** may determine whether a fourth input has been engaged for a threshold duration. If it is determined at Block **554** that the fourth input has been engaged for the threshold duration, the rule relating to the dim level may be defined to disable dimming (Block **556**). With the dimming being disabled, the luminaire **10** may operate such that it will not respond to motion detected in the field of view. However, in an embodiment, the sensors **50** may continue to detect ambient light levels, which may continue to affect operation of the luminaire **10**.

If the fourth input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **534**, wherein the controller **20** may again monitor whether the dim input has been engaged.

If the rules have been defined in Blocks **544**, **548**, **552**, or **556**, the luminaire **10** may optionally provide feedback that the rule has been successfully changed (Block **560**). The controller **20** may then determine if a shutdown command has been received at Block **562**. If a shutdown command has not been received at Block **562**, the operation may proceed to Block **534**, wherein the controller **20** may again monitor whether the dim input has been engaged. If a shutdown command has been received at Block **562**, the operation may terminate at Block **564**.

Referring now to flowchart **570** of FIG. **22**, a specific modification of motion detection sensitivity using the interlace **30** will now be discussed, without limitation. The sensitivity of motion detection definable in the rules may operate in conjunction with other rules, such as the rules relating to the delay or ambient light levels detected. Additionally, in the present example, levels of sensitivity are discussed between a first level and a fourth level, with each level offering increased sensitivity in motion detection. Increased sensitivity may be provided, for example, by increasing the distance in which motion is detectable. A person of skill in the art should appreciate that the present invention should not be limited to four levels of motion detecting sensitivity, and that any number of levels may be added or removed as the desired for the operation of the luminaire **10**.

Starting at Block **572**, the controller **20** may monitor a motion sensitivity input (Block **574**). The controller **20** may then determine if the motion sensitivity input has been engaged for a threshold duration, such as three seconds (Block **576**). If the motion sensitivity input has not been engaged for the threshold duration, the operation may return to Block **574** wherein the controller **20** will continue to monitor the motion sensitivity input. If it is determined at Block **576** that the motion sensitivity input has been engaged for the threshold duration, the luminaire **10** may optionally provide feedback that the motion sensitivity input has been properly engaged (Block **578**).

Once the motion sensitivity input has been properly engaged, the controller **20** may monitor a set of configuration inputs (Block **580**). The set of configuration inputs may include one or more inputs that may be engaged by a user to manipulate the rules. Although the following example discusses four configuration inputs, a person of skill in the art will appreciate that any number of configuration inputs may be included in the set of configuration inputs, without limitation.

In determining if a configuration input has been engaged, the controller **20** may determine if a first input has been engaged for a threshold duration (Block **582**). If it is determined at Block **582** that the first input has been engaged for the threshold duration, the rule relating to the sensitivity of motion detection may be defined to operate at a first level (Block **584**). With sensitivity being defined in the rules at the first level, the luminaire **10** may operate to detect motion in an environment with a small the field of view.

If the first input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **586** wherein the controller **20** may determine whether a second input has been engaged for a threshold duration. If it is determined at Block **586** that the second input has been engaged for the threshold duration, the rule relating to the sensitivity of motion detection may be defined to operate at a second level (Block **588**). With sensitivity being defined in the rules at the second level, the luminaire **10** may operate to detect motion in an environment with a field of view larger than the first level of sensitivity.

If the second input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **590** wherein the controller **20** may determine whether a third input has been engaged for a threshold duration. If it is determined at Block **590** that the third input has been engaged for the threshold duration, the rule relating to the sensitivity of motion detection may be defined to operate at a third level (Block **592**). With sensitivity being defined in the rules at the third level, the luminaire **10** may operate to detect motion in an environment with a field of view larger than the second level of sensitivity.

If the third input has not been engaged for the threshold duration, for example three seconds, the operation may proceed to Block **594** wherein the controller **20** may determine whether a fourth input has been engaged for a threshold duration. If it is determined at Block **594** that the fourth input has been engaged for the threshold duration, the rule relating to the sensitivity of motion detection may be defined to operate at a fourth level (Block **596**). With sensitivity being defined in the rules at the fourth level, the luminaire **10** may operate to detect motion in an environment with a field of view larger than the third level of sensitivity.

If the fourth input has not been engaged for a duration less than the threshold duration, for example three seconds, the operation may proceed to Block **574**, wherein the controller **20** may again monitor whether the motion sensitivity input has been engaged.

If the rules have been defined in Blocks **584**, **588**, **592**, or **596**, the luminaire **10** may optionally provide feedback that the rule has been successfully changed (Block **600**). The controller **20** may then determine if a shutdown command has been received at Block **602**. If a shutdown command has not been received at Block **602**, the operation may proceed to Block **574**, wherein the controller **20** may again monitor whether the motion sensitivity input has been engaged. If a shutdown command has been received at Block **602**, the operation may terminate at Block **604**.

The foregoing examples have been provided in the interest of clarity to illustrate an embodiment of the present invention in substantial detail. A person of skill in the art will appreciate that the interface **30** may include additional inputs, which may be used to define the rules relating to various sensors **50**. As examples, and without the intent to be limiting, additional sensors may detect temperature, humidity, barometric pressure, altitude, levels of certain gases, presence of vermin or other animals, seismic activity, electromagnetic radioactivity, or intensity of ultraviolet light.

Also, as discussed above, an alert may be provided upon detecting a condition of the environment, for example, using one of the sensors listed above. Alerts may include illumination, bunking, flashing, sound, transmitting a data signal, or other providing another form of indication that an condition has been detected or an event has occurred.

Furthermore, as additional sensors **50** may be included in the luminaire **10**, additional inputs may be provided to allow customization to the rules relating to the additional sensors. In additional embodiments of the present invention, the inputs **32** may be configured to manipulate the rules with different combinations of engagement. The rules relating to the operation of the inputs **32** may even be defined through engagement of the inputs. As such, skilled artisans should not view the present invention as limited to the examples discussed above.

A person of skill in the art will appreciate that one or more of the above provided embodiments may be included in the operation of the luminaire **10** of the present invention. Additionally, a person of skill in the art will appreciate additional embodiments that would be included within the scope and spirit of the present invention, after having the benefit of this disclosure. Furthermore, a skilled artisan will appreciate that the operations described above, along with additional operations that would be apparent to those in the art, may be performed exclusively, incrementally, sequentially, simultaneously, or any other operative configuration.

Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. A luminaire comprising:

a light source from which light is emittable into an environment;

a controller including a processor and memory to analyze data relating to conditions in the environment and to control the light source;

sensors in communication with the controller to detect the conditions in the environment and generate the data relating to the conditions, the data being transmittable to the controller;

rules definable to affect operation of the light source, the rules being stored in the memory to be comparable with the data;

wherein the light source is operable in a plurality of modes defined by the rules;

wherein operation of the light source is modifiable by the controller responsive to the data relating to at least one of the conditions;

wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light;

wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition;

wherein the motion detector transmits the data to the controller relating to the motion that is detected;

wherein ambient light levels in the environment are detectable by at least one of the sensors in communication with the controller as the condition; and

wherein data is transmitted to the controller relating to the ambient light levels that are detected, the ambient light levels being detectable during the inactive duration of the duty cycle.

2. A luminaire according to claim **1** further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.

3. A luminaire according to claim **1** further comprising a network interface in communication with the controller, wherein at least part of the data is trans table by the controller using the network interface, and wherein at least part of the data is receivable by the controller using the network interface.

4. A luminaire according to claim **1** wherein the controller, the light source, and the sensors are included in a node that is part of a network of nodes, wherein a plurality of nodes are includable in the network of nodes, and wherein data is transmittable and receivable between the nodes included in the network of nodes.

5. A luminaire according to claim **4** wherein the node is spatially aware relative to at least one of the nodes in the network of nodes.

6. A luminaire according to claim **1** wherein the light source is a light emitting semiconductor device.

7. A luminaire according to claim **1** wherein the light emitted by the light source includes a source wavelength range, wherein at least part of the light in the source wavelength range is received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range to be includable in the light.

8. A luminaire according to claim **1** wherein a light identifier is includable in the light.

9. A luminaire according to claim **8** further comprising:

an auxiliary signal emitter;

wherein the auxiliary signal emitter emits an auxiliary signal having a velocity that differs from the light;

wherein an auxiliary signal identifier is includable in the auxiliary signal;

wherein the light identifier and the auxiliary signal identifier are definable to identify the light that correlates with the auxiliary signal, wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are emitted substantially simultaneously;

wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are detectable by a device located in the environment;

wherein a delay between detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier is analyzed to determine a spatial awareness.

10. A luminaire according to claim **9** wherein the light identifier and the auxiliary signal identifier are detectable by at least one of the sensors, and wherein the controller analyzes the delay to determine the spatial awareness.

11. A luminaire according to claim **10** wherein the auxiliary signal includes acoustic energy.

12. A luminaire according to claim **1** further comprising an interface to define the rules.

13. A luminaire according to claim **12** wherein the interface is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface.

14. A luminaire according to claim **13** wherein inputs of the interface include capacitive sensors, the state of at least one of the capacitive sensors being independently alterable upon being engaged, and wherein the state to which the capacitive sensors are alterable is definable by the rules.

15. A luminaire according to claim **13** wherein inputs of the interface include mechanical toggles, the state of at least one of the mechanical toggles being independently alterable upon being engaged, and wherein the state to which the mechanical toggles are alterable is definable by the rules.

16. A luminaire according to claim **1** wherein the ambient light levels are detectable by an ambient light detector in communication with the controller to detect the ambient light levels in the environment as the condition, wherein the controller receives the data from the ambient light detector relating to the ambient light levels that are detected.

17. A luminaire according to claim **1** wherein the controller is carried by a radio logic board; and wherein the luminaire further comprises an antenna coupled to the radio logic board.

18. A luminaire according to claim **17** wherein the radio logic board is separated from heat producing elements of the luminaire by a buffer distance.

19. A luminaire according to claim **1** wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.

20. A system for controlling a luminaire comprising:

a controller including a processor and memory to analyze data and to control a light source to emit light;

an interface that is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface;

sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis;

rules definable to affect operation of the light source, the rules being stored in the memory to be comparable with the data, the rules being definable using the interface;

wherein the light source is operable in a plurality of modes defined by the rules, at least one of the plurality of modes being selectable and definable using the interface.

21. A system according to claim **20** wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition, wherein the motion detector transmits the data to the controller relating to the motion that is detected.

22. A system according to claim **20** wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light.

23. A system according to claim **22** wherein the sensors include an ambient light detector in communication with the controller to detect ambient light levels in the environment as the condition, wherein the ambient light detector transmits the data to the controller relating to the ambient light levels that are detected, the ambient light detector detecting the ambient light levels during the inactive duration of the duty cycle.

24. A system according to claim **20** further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.

25. A system according to claim **20** further comprising a network interface in communication with the controller, wherein at least part of the data is trans table by the controller using the network interface, and wherein at least part of the data is receivable by the controller using the network interface.

26. A system according to claim **20** wherein the controller, light source, and sensors are included in a node that is part of a network of nodes, wherein a plurality of nodes are includable in the network of nodes, wherein data is transmittable and receivable between the nodes included in the network of nodes.

27. A system according to claim **26** wherein the node is spatially aware relative to at least one of the nodes in the network of nodes.

28. A system according to claim **20** wherein the light source is a light emitting semiconductor device.

29. A system according to claim **20** wherein the light emitted by the light source includes a source wavelength range, wherein at least part of the light in the source wavelength range is received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range to be includable in the light.

30. A system according to claim **20** wherein inputs of the interface include capacitive sensors, the state of at least one of the capacitive sensors being independently alterable upon being engaged by an object, and wherein the state to which the capacitive sensor is alterable is definable by the rules.

31. A system according to claim **20** wherein inputs of the interface include mechanical toggles, the state of at least one of the mechanical toggles being independently alterable upon being engaged by an object, and wherein the state to which the mechanical toggles is alterable is definable by the rules.

32. A system according to claim **20** wherein a light identifier is includable in the light.

33. A system according to claim **32** further comprising:

an auxiliary signal emitter;

wherein the auxiliary signal emitter emits an auxiliary signal having a velocity that differs from the light;

wherein an auxiliary signal identifier is includable in the auxiliary signal;

wherein the light identifier and the auxiliary signal identifier are definable to identify the light that correlates with the auxiliary signal that is emitted substantially simultaneously;

wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are detectable by a device located in the environment;

wherein the controller analyzes a delay between detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier to determine a spatial awareness.

34. A system according to claim **33** wherein the auxiliary signal includes acoustic energy.

35. A system according to claim **20** wherein the controller, the sensors, and the interface are included in the luminaire.

36. A system according to claim **20** wherein the controller is carried by a radio logic board; wherein the system further comprises an antenna coupled to the radio logic board; and wherein the radio logic board is separated from heat producing elements of the luminaire by a buffer distance.

37. A system according to claim **20** wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.

38. A luminaire comprising:

a light source from which light is emittable into an environment;

a controller including a processor and memory to analyze data relating to conditions in the environment and to control the light source;

sensors in communication with the controller to detect the conditions in the environment and generate the data relating to the conditions, the data being transmittable to the controller;

rules definable to affect operation of the light source, the rules being stored in the memory to being comparable with the data; and

an auxiliary signal emitter;

wherein the light source is operable in a plurality of modes defined by the rules;

wherein the operation of the light source is modifiable by the controller responsive to the data relating to at least one of the conditions;

wherein the auxiliary signal emitter emits an auxiliary signal with a velocity that differs from the light;

wherein a light identifier is includable in the light and an auxiliary signal identifier is includable in the auxiliary signal;

wherein the light identifier and the auxiliary signal identifier are definable to identify the light that correlates with the auxiliary signal, wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are emitted substantially simultaneously;

wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are detectable by a device located in the environment;

wherein a delay between detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier is analyzed to determine a spatial awareness.

39. A luminaire according to claim **38** wherein the light identifier and the auxiliary signal identifier are detectable by at least one of the sensors, and wherein the controller analyzes the delay to determine the spatial awareness.

40. A luminaire according to claim **38** wherein the auxiliary signal includes acoustic energy.

41. A luminaire according to claim **38** wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition; and wherein the motion detector transmits data to the controller relating to the motion that is detected.

42. A luminaire according to claim **38** wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light; wherein the sensors include an ambient light detector in communication with the controller to detect ambient light levels in the environment as the condition; and wherein the ambient light detector transmits the data to the controller relating to the ambient light level detected, the ambient light detector detecting the ambient light level during the inactive duration of the duty cycle.

43. A luminaire according to claim **38** further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.

44. A luminaire according to claim **38** further comprising a network interface in communication with the controller, wherein at least part of the data is transmittable by the controller using the network interface, and wherein at least part of the data is receivable by the controller using the network interface.

45. A luminaire according to claim **38** wherein the controller, the light source, and the sensors are included in a node that is part of a network of nodes, wherein a plurality of nodes are includable in the network of nodes, wherein data is transmittable and receivable between the nodes included in the network of nodes.

46. A luminaire according to claim **45** wherein the node is spatially aware relative to at least one of the nodes in the network of nodes.

47. A luminaire according to claim **38** wherein the light source is a light emitting semiconductor device.

48. A luminaire according to claim **38** wherein the light emitted by the light source includes a source wavelength range, wherein at least part of the light in the source wavelength range is received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range to be includable in the light.

49. A luminaire according to claim **38** further comprising an interface to define the rules.

50. A luminaire according to claim **49** wherein the interface is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface.

51. A luminaire according to claim **50** wherein the inputs of the interface include capacitive sensors, the state of at least one of the capacitive sensors being independently alterable upon being engaged, and wherein the states to which the capacitive sensors are altered is definable by the rules.

52. A luminaire according to claim **50** wherein the inputs of the interface include mechanical toggles, the state of at least one of the mechanical toggles is being independently alterable upon being engaged by an object, and wherein the state to which the mechanical toggles is are alterable is definable by the rules.

53. A luminaire according to claim **38** wherein the controller is carried by a radio logic board; wherein the luminaire further comprises an antenna coupled to the radio logic board; and wherein the radio logic board is separated from heat producing elements of the luminaire by a buffer distance.

54. A luminaire according to claim **38** wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.

55. A method for controlling a luminaire with an interface, the method comprising:

receiving a signal by a controller from the interface, the interface being manipulable to generate the signal, the controller including a processor and memory;

analyzing the signal using the controller by comparing the signal to rules included in the memory, at least part of the rules being definable using the interface to control operation of a light source to emit light;

receiving data from sensors in communication with the controller relating to a condition detected in the environment, the data being receivable by the controller from the sensors for analysis; and

comparing the data received by the sensor with at least part of the rules to operate the light source in a mode determined by comparing the data with the rules;

wherein the interface is manipulable to cause the signal to be sent to the controller;

wherein the signal relates to a state of the interface.

56. A method according to claim **55** wherein inputs of the interface include capacitive sensors, the state of at least one of the capacitive sensors being independently alterable upon being engaged, and wherein the state to which the capacitive sensors are alterable is definable by the rules.

57. A method according to claim **55** wherein the inputs of the interface include mechanical toggles, the state of at least one of the mechanical toggles is being independently alterable upon being engaged by an object, and wherein the state to which the mechanical toggles is are alterable is definable by the rules.

58. A method according to claim **55** further comprising transmitting the data from a motion detector to the controller, wherein the data relates to motion that is detected by the motion detector.

59. A method according to claim **55** wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light.

60. A method according to claim **59** further comprising transmitting the data from an ambient light detector to the controller, wherein the data relates to ambient light levels that are detected during the inactive duration of the duty cycle by the ambient light detector.

61. A method according to claim **55** further comprising transmitting data from a timer to the controller, wherein the data includes an amount of time elapsed relating to an event definable by the rules.

62. A method according to claim **55** wherein a network interface is in communication with the controller, wherein at least part of the data is transmittable by the controller using the network interface, and wherein at least part of the data is receivable by the controller using the network interface.

63. A method according to claim **62** wherein the controller, light source, and sensors are included in a node that is part of a network of nodes, wherein a plurality of nodes are includable in the network of nodes, wherein data is transmittable and receivable between the nodes included in the network of nodes.

64. A method according to claim **63** wherein the node is spatially aware relative to at least one of the nodes in the network of nodes.

65. A method according to claim **63** wherein the light source is a light emitting semiconductor device.

66. A method according to claim **55** wherein the light source is a light emitting semiconductor device.

67. A method according to claim **55** wherein the light emitted by the light source includes a source wavelength range, wherein at least part of the light in the source wavelength range is received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range to be includable in the light.

68. A method according to claim **55** wherein a light identifier is includable in the light.

69. A method according to claim **68** wherein an auxiliary signal emitter is communicatively connected to the controller; wherein an auxiliary signal is emittable by the auxiliary signal emitter having a velocity that differs from the light; further comprising:

including an auxiliary signal identifier in the auxiliary signal, the light identifier and the auxiliary signal identifier being definable to identify the light that correlates with the auxiliary signal, wherein the light with the light identifier and the auxiliary signal with the auxiliary signal identifier are emitted substantially simultaneously;

detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier; and

analyzing a delay between detecting the light with the light identifier and detecting the auxiliary signal with the auxiliary signal identifier to determine a spatial awareness.

70. A method according to claim **69** wherein the auxiliary signal includes acoustic energy.

71. A method according to claim **55** wherein the controller is carried by a radio logic board that is separated from heat producing elements of the luminaire by a buffer distance.

72. A method according to claim **55** wherein operation of the light source is controlled by dimming the light source or moving the light source between an on position and an off position.

73. A method for detecting a condition in an environment using a luminaire connected to a network, the method comprising:

receiving data from sensors in communication with a controller, the sensors detecting the condition in the environment and generating the data in response to the conditions;

analyzing the data relating to the condition in the environment, wherein analyzing the data includes comparing the data to rules stored in the memory;

controlling a light source from which light is emittable to operate in a mode determined from the analysis of the data relating to the condition in the environment and the rules, the mode in which the light source is operable being defined by the rules;

communicating at east part of the data through the network using a network interface, emitting an auxiliary signal with a velocity that differs from the light using an auxiliary signal emitter;

including a light identifier in the light;

including an auxiliary signal identifier in the auxiliary signal;

defining the light identifier and the auxiliary signal identifier to identify the light that correlates with the auxiliary signal, the light with the light identifier and the auxiliary signal with the auxiliary signal identifier being emitted substantially simultaneously, the light with the light identifier and the auxiliary signal with the auxiliary signal identifier being detectable by a device in the environment; and

analyzing a delay between detecting the light with the light identifier and the auxiliary signal with the auxiliary signal identifier to determine a spatial awareness;

wherein the network interface is in communication with the controller, wherein at least part of the data is transmittable by the controller using the network interface, and wherein at least part of the data is receivable by the controller using the network interface.

74. A method according to claim **73** wherein the auxiliary signal includes acoustic energy.

75. A method according to claim **73** further comprising transmitting the data from a motion detector to the controller, wherein the data relates to motion that is detected by the motion detector.

76. A method according to claim **73** wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light; further comprising transmitting the data from an ambient light detector to the controller, wherein the data relates to ambient light level detected, the ambient light detector detecting the ambient light level during the inactive duration of the duty cycle by the ambient light detector.

77. A method according to claim **73** further comprising transmitting data from a timer is in communication with the controller, wherein the timer transmits data to the controller regarding an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.

78. A method according to claim **73** wherein the controller, the light source, and the sensors are included in a node that is part of a network of nodes, wherein a plurality of nodes are includable in the network of nodes, wherein data is transmittable and receivable between the nodes included in the network of nodes.

79. A method according to claim **78** wherein the node is spatially aware relative to at least one of the nodes in the network of nodes.

80. A method according to claim **73** wherein the light emitted by the light source includes a source wavelength range, wherein at least part of the light in the source wavelength range is received by a phosphorescent, fluorescent, or luminescent conversion material to be converted to a converted wavelength range to be includable in the light.

81. A method according to claim **73** further comprising manipulating an interface to define the rules.

82. A method according to claim **81** further comprising:

receiving a signal by the controller from the interface, the interface being manipulable to generate the signal; and

comparing the signal to the rules included in the memory, at least part of the rules being definable using the interface to control operation of the light source;

wherein the interface includes inputs that are manipulable to cause the signal to be sent to the controller;

wherein the signal relates to states of the inputs.

83. A method according to claim **73** wherein the controller is carried by a radio logic board that is separated from heat producing elements of the luminaire by a buffer distance that facilitates reduced attenuation of the signal.

84. A method according to claim **73** wherein operation of the light source is controlled by dimming the light source or moving the light source between an on position and an off position.

* * * * *

Exhibit 6

U.S. Patent No. 8,674,608 ("'608 Patent")

Accused Products

The GE C-Start Smart Switch and/or C-Reach in conjunction with one or more C by GE luminaires (e.g., bulbs and fixtures), sensors, and the C by GE App for mobile devices (e.g., Android and iOS) (collectively the "C by GE System") infringes at least claims 1, 2, 6, 12, 13, 16, 19, 20, 21, 22, 24, 28, and 37 of the '608 Patent.

Claim 1	C by GE System
1[pre]. A luminaire comprising:	The preamble is not a limitation. To the extent the preamble is construed as a limitation, the C by GE System includes luminaires (e.g., the GE C-Life 11W A19 Smart LED Light Bulb (44298)) as described in further detail below.
1[a] a light source from which light is emittable into an environment;	The C by GE System includes a light source from which light is emittable into an environment. [redacted] REDACTED

Claim 1	C by GE System
	REDACTED

Claim 1	C by GE System
1[b] a controller including a processor and memory to analyze data relating to conditions in the environment and to control the light source;	The C by GE System includes a controller including a processor and memory to analyze data and to control a light source to emit light. [redacted] [redacted] [redacted] REDACTED [redacted]

[1] *Available at* https://www.cbyge.com/products/c-reach.

Claim 1	C by GE System
	[redacted] REDACTED [redacted]

[2] *Available at* https://www.cbyge.com/pages/pdp-start-smart-switch.

Claim 1	C by GE System
1[c] sensors in communication with the controller to detect the conditions in the environment and generate the data relating to the conditions, the data being transmittable to the controller;	The C by GE System includes sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis. ***"sensors . . . to detect the conditions in the environment and generate the data relating to the conditions"*** [redacted] REDACTED

Claim 1	C by GE System
	[redacted] REDACTED [redacted] REDACTED

[3] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Senso.
[4] *Available at* https://www.cbyge.com/pages/pdp-reach.

Claim 1	C by GE System
	REDACTED [redacted] REDACTED

[5] *Available at* https://www.cbyge.com/pages/pdp-start-smart-switch.
[6] *Available at* https://www.amazon.com/Ge-Lighting-CbyGE/dp/B0747GRGWH.

Claim 1	C by GE System
	"sensors in communication with the controller" [redacted] REDACTED

[7] *Available at* https://www.cbyge.com/pages/pdp-start-smart-switch.

Claim 1	C by GE System
	[redacted] REDACTED

[8] *Available at* https://www.cbyge.com/pages/pdp-reach.

Claim 1	C by GE System
	REDACTED

[9] *Available at* https://www.cbyge.com/pages/pdp-start-smart-switch.

Claim 1	C by GE System
	"the data being transmittable to the controller" The data [redacted] is transmittable to the controller. [redacted]:[10] [redacted] REDACTED [redacted] REDACTED

[10] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Senso.
[11] *Available at* https://www.amazon.com/Ge-Lighting-CbyGE/dp/B0747GRGWH.

Claim 1	C by GE System
1[d] rules definable to affect operation of the light source, the rules being stored in the memory to be comparable with the data;	The C by GE System includes rules definable to affect operation of light sources, the rules being stored in memory to be comparable with the data, [redacted]

Claim 1	C by GE System
	REDACTED

[12] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Sensor, at 0:52 time stamp.
[13] *Available at* https://www.cbyge.com/pages/pdp-app.

Claim 1	C by GE System
	REDACTED

[14] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Sensor, at 0:21-26 time stamp.

Claim 1	C by GE System
	REDACTED

[15] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Sensor, at 1:10 time stamp.
[16] *Available at* https://www.amazon.com/Ge-Lighting-CbyGE/dp/B0747GRGWH.

Claim 1	C by GE System
	[redacted] REDACTED [redacted] REDACTED

[17] *Available at* https://www.cbyge.com/pages/pdp-start-smart-switch.
[18] *Available at* https://www.cbyge.com/pages/pdp-reach.

Claim 1	C by GE System
1[e] wherein the light source is operable in a plurality of modes defined by the rules;	The C by GE System includes light sources operable in a plurali [redacted] REDACTED

[19] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Sensor, at 0:21 time stamp.

Claim 1	C by GE System
1[f] wherein operation of the light source is modifiable by the controller responsive to the data relating to at least one of the conditions;	The C by GE System enables operation of the light source that is modifiable by the controller responsive to the data relating to at least one of the conditions. [redacted] (the controller) modify operation of the light source responsive to the data relating to at least one of the conditions [redacted]
1[g] wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light;	The C by GE System is operable to have a duty cycle controlled by the controller, the duty cycle having an active duration wherein light bulbs emit light and inactive durations wherein the light source does not emit light. [redacted] REDACTED

[20] *Available at* https://support.cbyge.com/hc/en-us/articles/360015700951-How-To-Create-a-Room-Automation-Within-the-App.

Claim 1	C by GE System
	[redacted] REDACTED

[21] *Available at* https://support.cbyge.com/hc/en-us/articles/360015700951-How-To-Create-a-Room-Automation-Within-the-App at 1:44 time stamp.

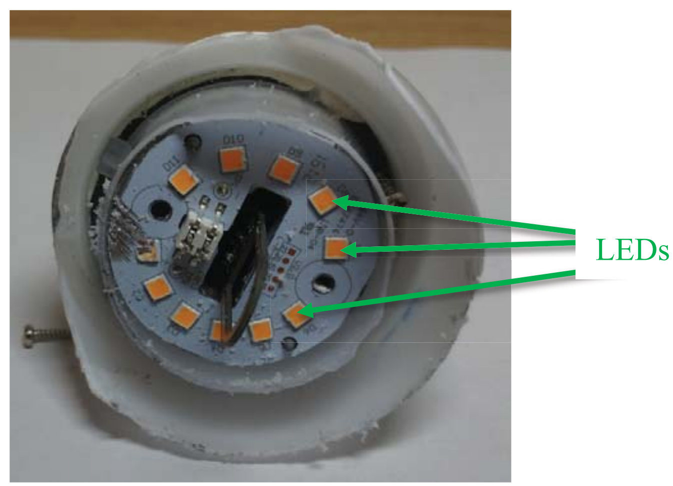
Claim 1	C by GE System
1[h] wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition;	The sensors in the C by GE System include a motion detector in communication with the controller to detect motion in the environment as the condition [redacted] REDACTED

Claim 1	C by GE System
1[i] wherein the motion detector transmits the data to the controller relating to the motion that is detected;	The motion detector in the C by GE System transmits the data to the controller relating to the motion that is detected. [redacted] REDACTED
1[j] wherein ambient light levels in the environment are detectable by at least one of the sensors in communication with the controller as the condition; and	Ambient light levels in the environment are detectable as the condition by a sensor [redacted] - [redacted] by GE System, which is in communication with the controller [redacted]

Claim 1	C by GE System
1[k] wherein data is transmitted to the controller relating to the ambient light levels that are detected, the ambient light levels being detectable during the inactive duration of the duty cycle.	Data relating to the ambient light levels that are detected is transmitted to the controller in the C by GE System, as described above with respect to claim limitations 1[c] and 1[j]. During the inactive duration of the duty cycle [redacted], [redacted] can detect ambient light levels [redacted] REDACTED REDACTED

Claim 2	C by GE System
2. A luminaire according to claim 1 further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.	The C by GE System includes a timer in communication with the controller [redacted], wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller. [redacted] REDACTED

[22] *Available at* https://support.cbyge.com/hc/en-us/articles/360020877591-How-To-Activate-Your-Smart-Switch-Motion-Sensor at 0:44 time stamp.

Claim 6	C by GE System
6. A luminaire according to claim 1 wherein the light source is a light emitting semiconductor device.	As described *supra* for claim 1, various lighting devices can be used in the C by GE System, including LED-based light bulbs and other LED light sources. For example: **C by GE Sol lamp (https://www.cbyge.com/pages/pdp-sol):**  **C-Life Bulb (https://www.cbyge.com/pages/pdp-life):**  

Claim 12	C by GE System
12. A luminaire according to claim 1 further comprising an interface to define the rules.	As described *supra* in claim 1[d], the C by GE App of the C by GE System includes a user interface to define the rules [redacted] An exemplary image of the user interface of the C by GE App is shown below: REDACTED

Claim 13	C by GE System
13. A luminaire according to claim 12 wherein the interface is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface.	As described *supra* in claim 1[d], the C by GE App within the C by GE System includes a user interface manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the user interface. [redacted]

Claim 16	C by GE System
16. A luminaire according to claim 1 wherein the ambient light levels are detectable by an ambient light detector in communication with the controller to detect the ambient light levels in the environment as the condition, wherein the controller receives the data from the ambient light detector relating to the ambient light levels that are detected.	As described *supra* in claim 1[c], the C by GE System uses an ambient light sensor to detect ambient light levels as the claimed "condition." [redacted]

Claim 19	C by GE System
19. A luminaire according to claim 1 wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.	The C by GE System allows the light source to be operable by dimming the light or moving the light source between an on position and an off position. [redacted] REDACTED

[23] *Available at* https://www.cbyge.com/pages/pdp-app.

Claim 20	C by GE System
20. A system for controlling a luminaire comprising:	The preamble is not a limitation. To the extent the preamble is construed as a limitation, the C by GE System is a system for controlling luminaires. The C by GE System, as set forth *supra* in claim 1, includes a [redacted]
20[a] a controller including a processor and memory to analyze data and to control a light source to emit light;	The C by GE System includes a controller including a processor and memory to analyze data and to control a light source to emit light. *See, e.g.*, *supra* claim 1[b].
20[b] an interface that is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface;	The C by GE System includes an interface that is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the inter [redacted] *See, e.g.*, *supra* claim 1[d] and claim 13.
20[c] sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis;	The C by GE System includes sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis. As set forth *supra* in claim 1[c]-1[i [redacted]
20[d] rules definable to affect operation of the light source, the rules being stored in the memory to be comparable with the data, the rules being definable using the interface;	The C by GE System uses rules definable to affect operation of light sources, the rules being stored in memory to be comparable with the data from connected sensors. Such rules are described *supra* in claim 1[d] and 1[e].

Claim 20	C by GE System
20[e] wherein the light source is operable in a plurality of modes defined by the rules, at least one of the plurality of modes being selectable and definable using the interface.	The C by GE System includes light sources operable in a plurality of modes defined by the rules, at least one of the plurality of modes being selected and definable using the interface. As set forth *supra* in claim 1[e], a user may operate the C by GE System [redacted]

Claim 21	C by GE System
21. A system according to claim 20 wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition, wherein the motion detector transmits the data to the controller relating to the motion that is detected.	The C by GE System includes a motion detector in communication with the controller to detect motion in the environment as the condition, wherein the motion detector transmits the data to the controller relating to the motion that is detected. *See supra* claim 1[c] (describing motion sensing functionality of C by GE System devices).

Claim 22	C by GE System
22. A system according to claim 20 wherein the light source is operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light.	The C by GE System's light sources are operable having a duty cycle controlled by the controller, the duty cycle having an active duration wherein the light source emits the light and an inactive duration wherein the light source does not emit the light. [redacted]

Claim 24	C by GE System
24. A system according to claim 20 further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.	The C by G System includes a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller. *See supra* claim 2.

Claim 28	C by GE System
28. A system according to claim 20 wherein the light source is a light emitting semiconductor device.	The light sources of the available luminaire devices for the C by GE System are LED-based. *See, e.g.*, *supra* claim 6.

Claim 37	C by GE System
37. A system according to claim 20 wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.	As set forth in claim 19, lights in the C by GE System are operable by dimming, [redacted] and on/off switching. *See supra* claim 19.

Exhibit 7

US007098483B2

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

(10) **Patent No.: US 7,098,483 B2**
(45) **Date of Patent: Aug. 29, 2006**

(54) **LIGHT EMITTING DIODES PACKAGED FOR HIGH TEMPERATURE OPERATION**

(75) Inventors: **Joseph Mazzochette**, Cherry Hill, NJ (US); **Greg Blonder**, Summit, NJ (US)

(73) Assignee: **Lamina Ceramics, Inc.**, Westampton, NJ (US)

(*) 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.: **10/933,096**

(22) Filed: **Sep. 2, 2004**

(65) **Prior Publication Data**

US 2005/0029535 A1 Feb. 10, 2005

Related U.S. Application Data

(62) Division of application No. 10/638,579, filed on Aug. 11, 2003.

(60) Provisional application No. 60/467,857, filed on May 5, 2003.

(51) **Int. Cl.**

H01L 27/15	(2006.01)
H01L 31/12	(2006.01)
H01L 33/00	(2006.01)

(52) **U.S. Cl.** **257/81**; 257/98; 257/99

(58) **Field of Classification Search** 257/79, 257/81, 99, 98, 82, 676, 80
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,886,709	A	12/1989	Sasame et al.	428/552
5,122,781	A	6/1992	Saubolle	340/473
5,140,220	A	8/1992	Hasegawa	313/512
5,581,876	A	12/1996	Prabhu et al.	
5,725,808	A	3/1998	Tormey et al.	
5,745,624	A	4/1998	Chan et al.	
5,847,935	A *	12/1998	Thaler et al.	361/761
5,953,203	A	9/1999	Tormey et al.	
5,977,567	A	11/1999	Verdiell	
6,045,240	A *	4/2000	Hochstein	362/294
6,220,722	B1	4/2001	Begemann	362/231
6,325,524	B1	12/2001	Weber et al.	362/245
6,376,268	B1	4/2002	Verdiell	
6,428,189	B1	8/2002	Hochstein	362/373
6,455,930	B1	9/2002	Palanisamy et al.	
6,518,502	B1 *	2/2003	Hammond et al.	174/52.4
6,634,750	B1	10/2003	Neal et al.	351/211
6,634,770	B1	10/2003	Cao	362/294
6,692,252	B1	2/2004	Scott	463/29
2002/0034834	A1	3/2002	Verdiell	
2002/0163006	A1 *	11/2002	Yoganandan et al.	257/81

(Continued)

FOREIGN PATENT DOCUMENTS

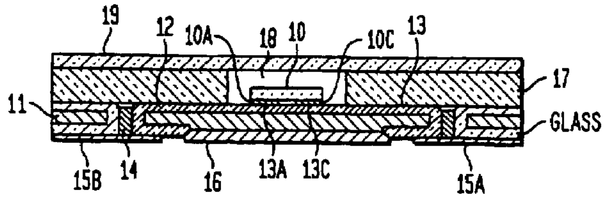
JP	2000-294701	10/2000	257/712

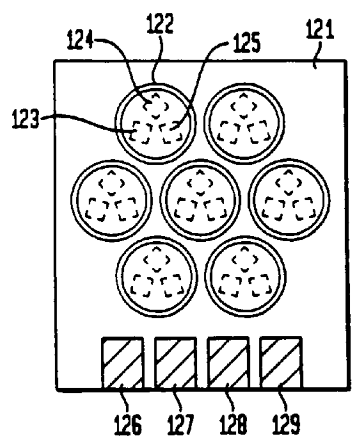
Primary Examiner—Phat X. Cao
(74) *Attorney, Agent, or Firm*—Lowenstein Sandler PC

(57) **ABSTRACT**

In accordance with the invention, an LED packaged for high temperature operation comprises a metal base including an underlying thermal connection pad and a pair of electrical connection pads, an overlying ceramic layer, and a LED die mounted overlying the metal base. The LED is thermally coupled through the metal base to the thermal connection pad, and the electrodes are electrically connected to the underlying electrical connection pads. A low thermal resistance insulating layer can electrically insulate other areas of die from the base while permitting heat passage. Heat flow can be enhanced by thermal vias to the thermal connector pad. Ceramic layers formed overlying the base can add circuitry and assist in distributing emitted light. The novel package can operate at temperatures as high as 250° C.

20 Claims, 13 Drawing Sheets





U.S. PATENT DOCUMENTS

2002/0175621	A1	11/2002	Song et al.	
2002/0176250	A1	11/2002	Bohler et al.	
2003/0057421	A1*	3/2003	Chen	257/79
2004/0026706	A1*	2/2004	Bogner et al.	257/99

* cited by examiner

FIG. 1A

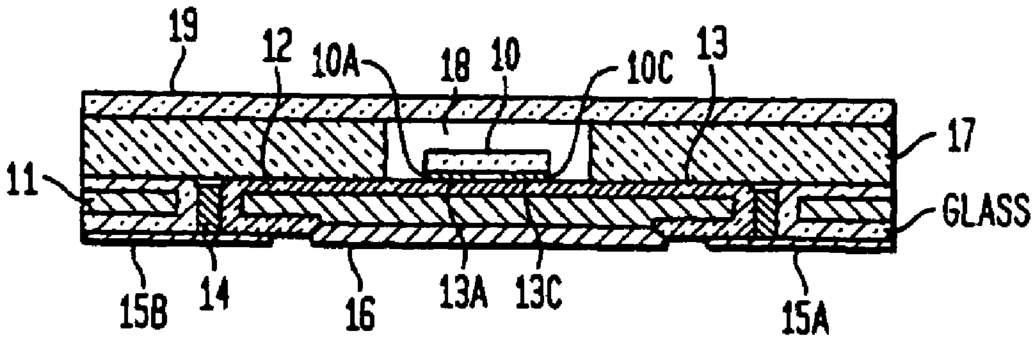


FIG. 1B

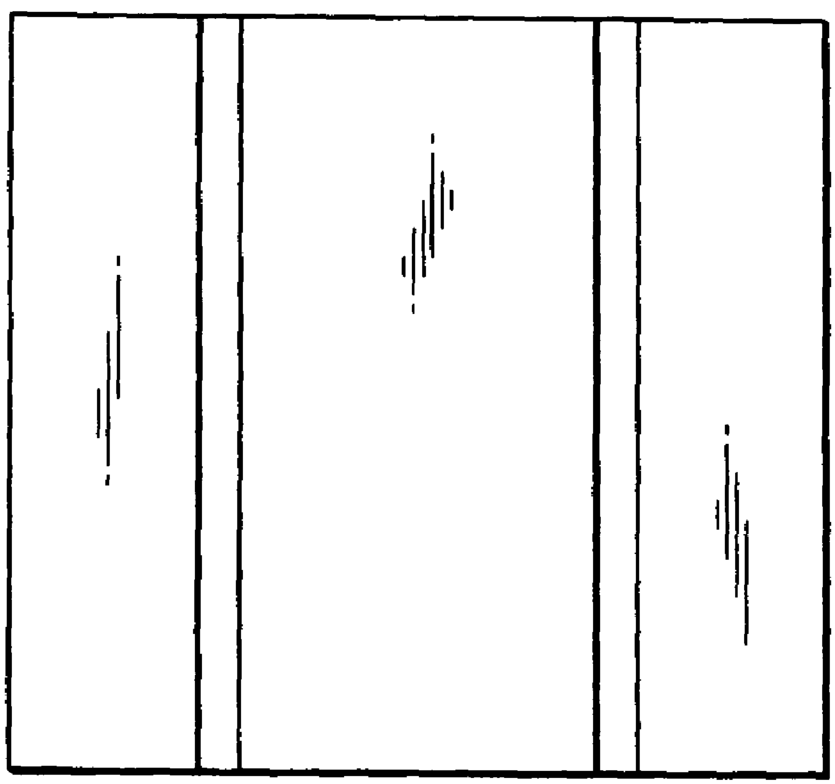


FIG. 2

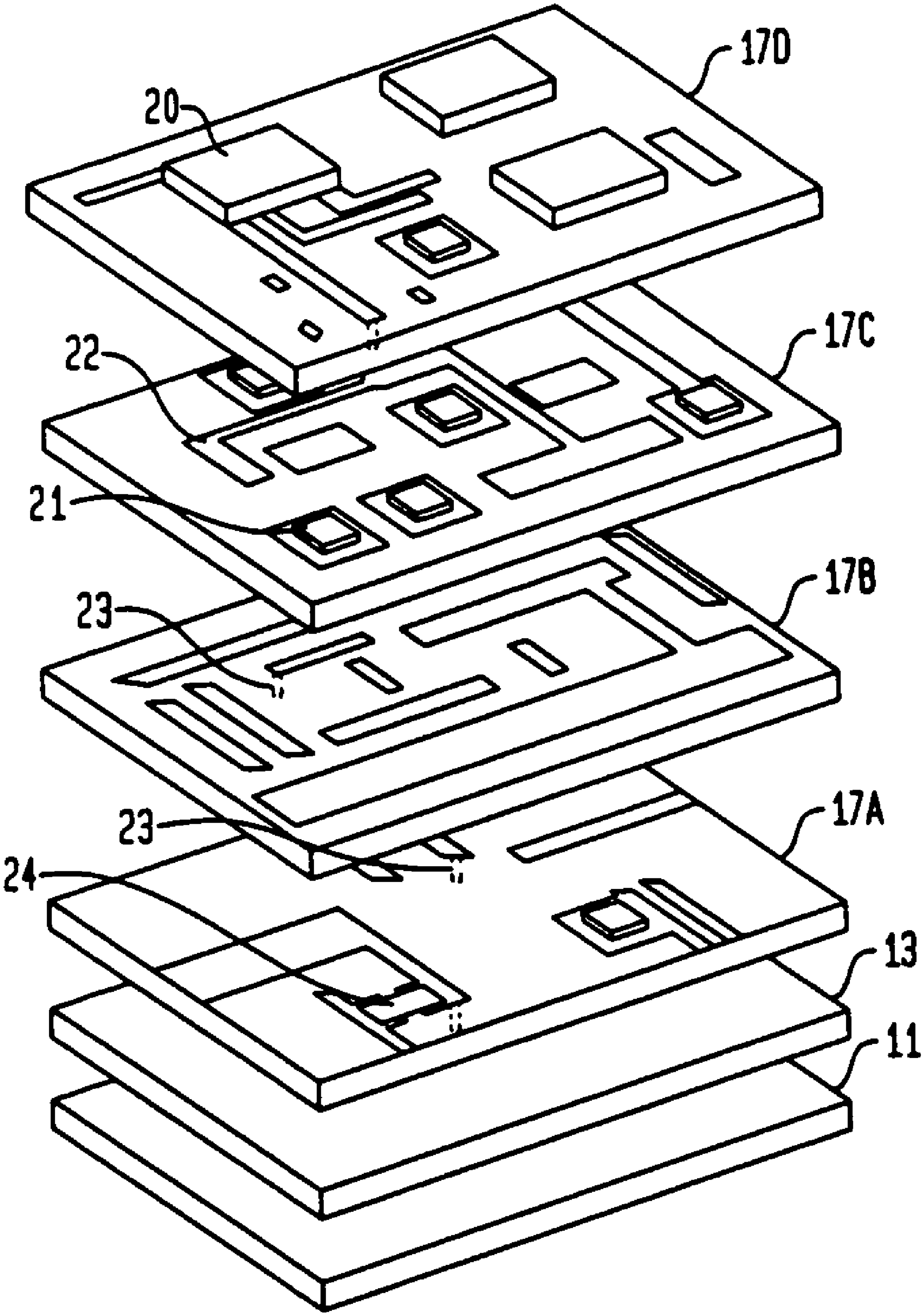


FIG. 3A

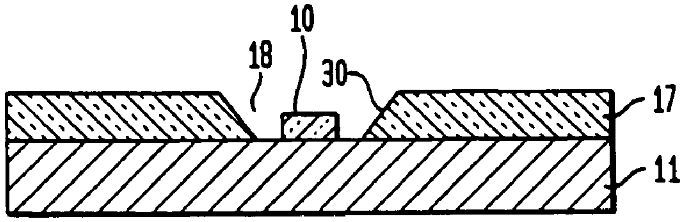


FIG. 3B

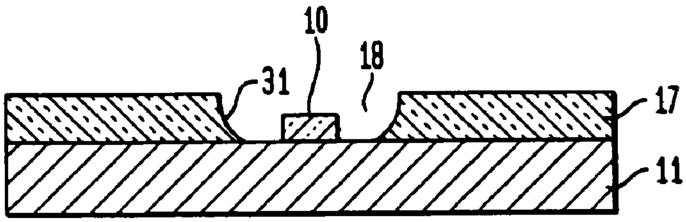


FIG. 4

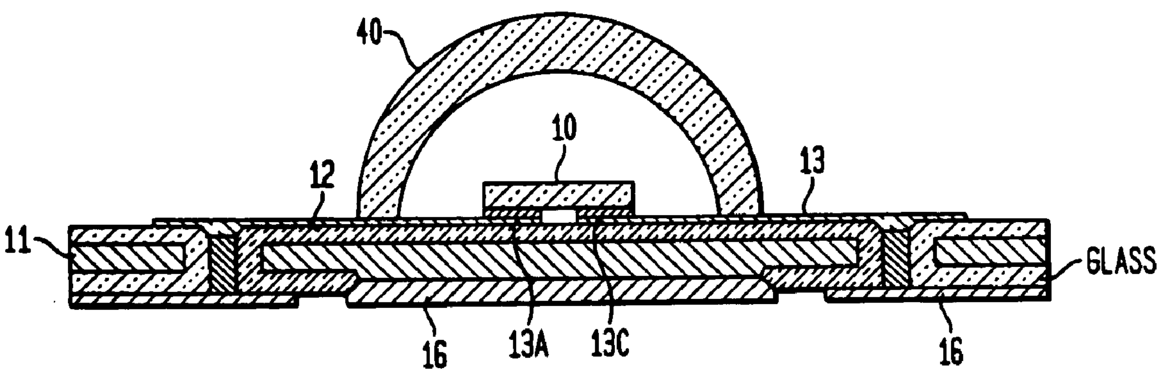
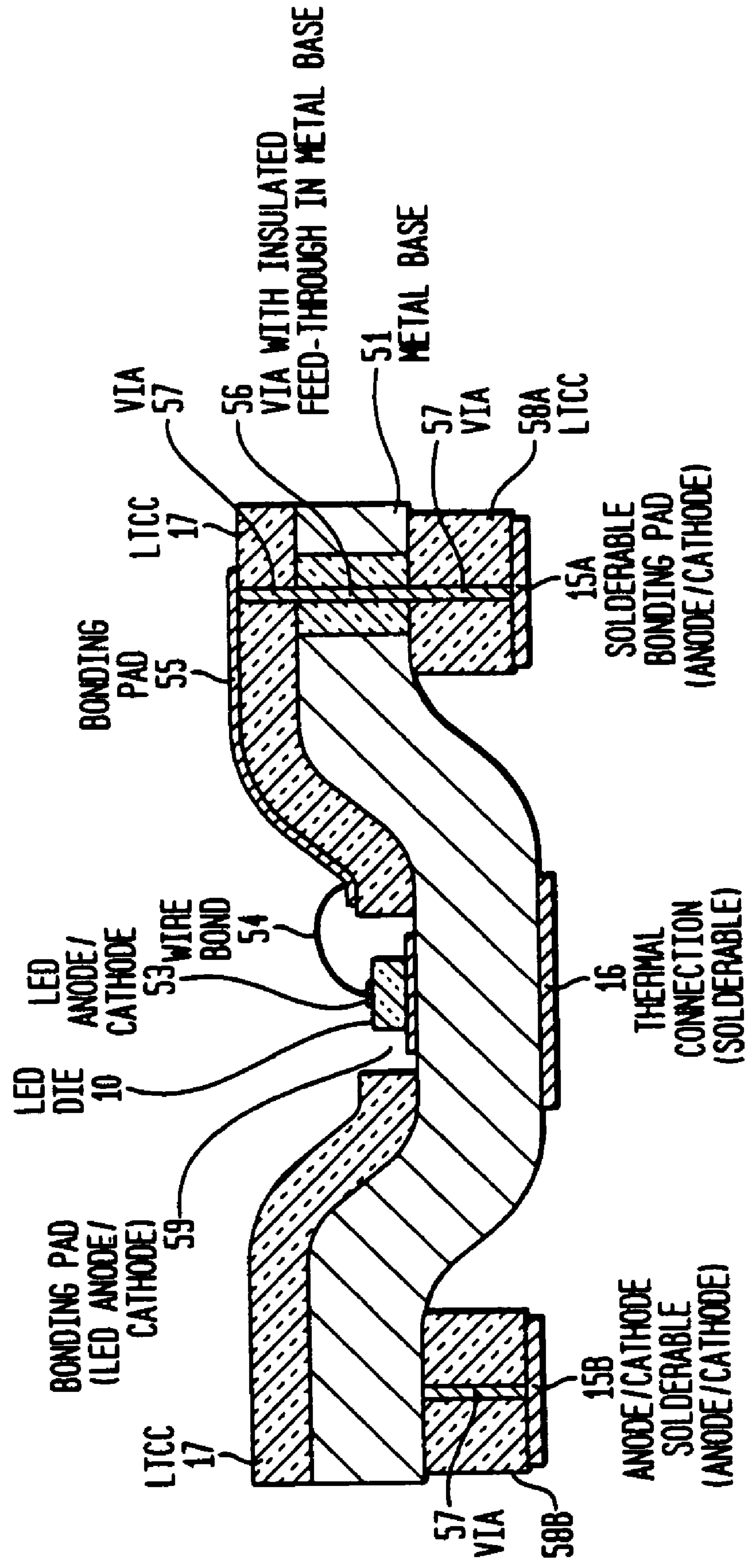


FIG. 5


VIA
57
56
VIA WITH INSULATED
FEED-THROUGH IN METAL BASE
51
METAL BASE
57
VIA
58A
LTCC
LTCC
17
BONDING
PAD
55
15A
SOLDERABLE
BONDING PAD
(ANODE/CATHODE)
LED
ANODE/
CATHODE
53
WIRE
BOND
54
16
THERMAL
CONNECTION
(SOLDERABLE)
LED
DIE
10
59
BONDING PAD
(LED ANODE/
CATHODE)
LTCC
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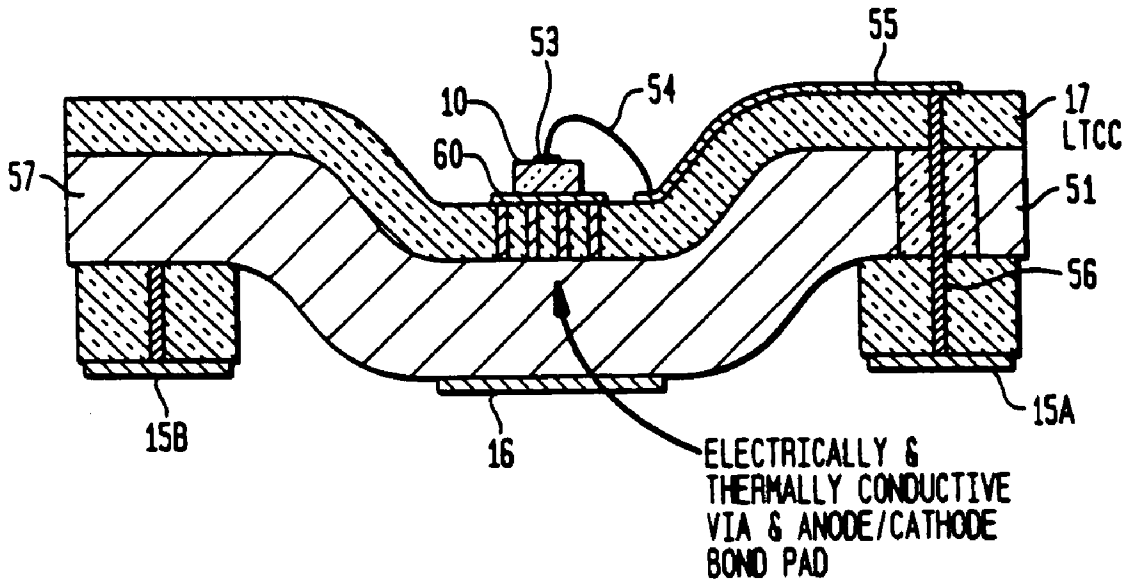
(ANODE/CATHODE)
57
VIA
58B

FIG. 6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LTCC
60
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15B
16
ELECTRICALLY &
THERMALLY CONDUCTIVE
VIA & ANODE/CATHODE
BOND PAD

FIG. 7

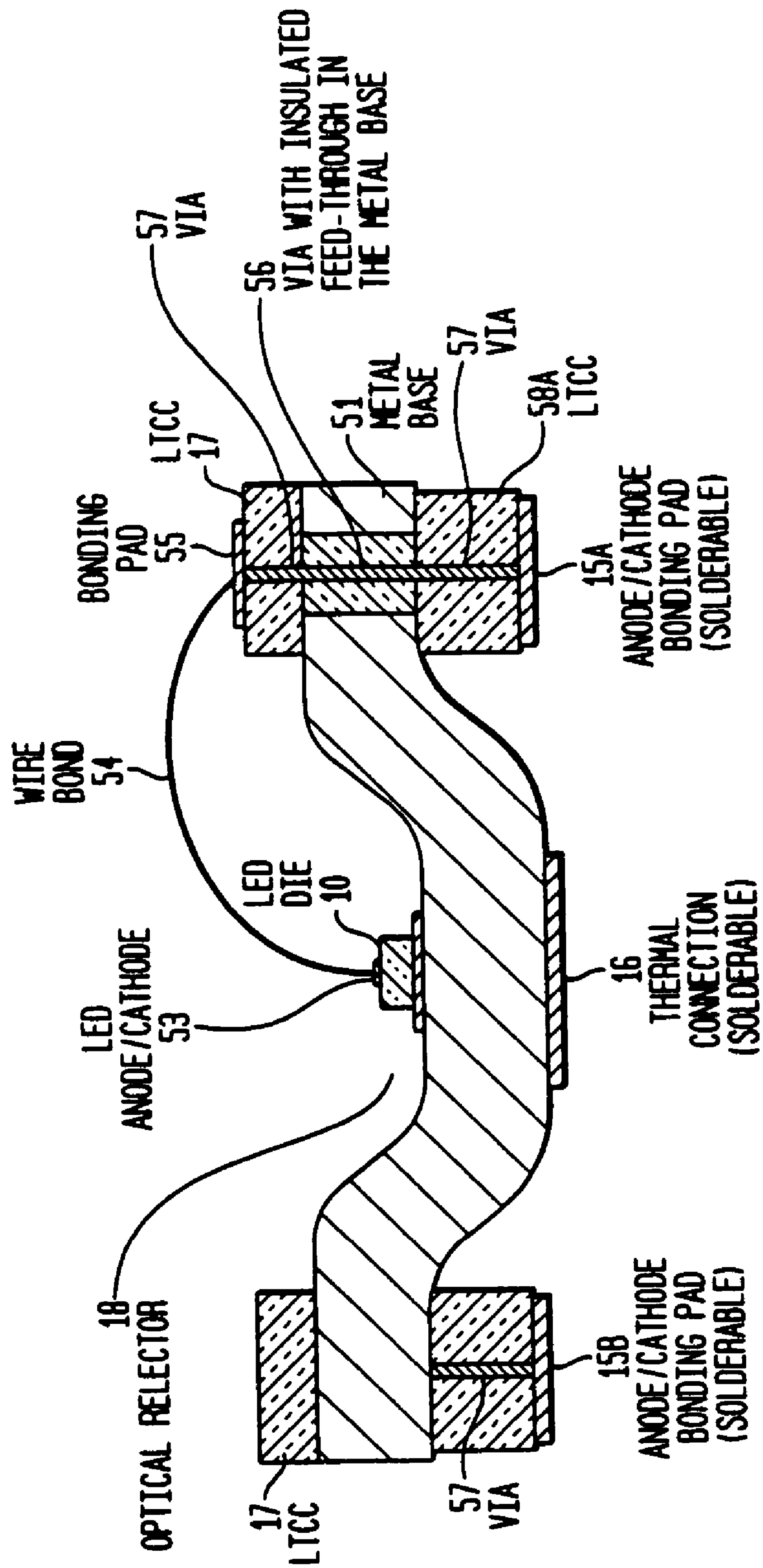

57 VIA
56 VIA WITH INSULATED FEED-THROUGH IN THE METAL BASE
57 VIA
51 METAL BASE
58A LTCC
LTCC 17
BONDING PAD 55
15A ANODE/CATHODE BONDING PAD (SOLDERABLE)
WIRE BOND 54
LED DIE 10
LED ANODE/CATHODE 53
16 THERMAL CONNECTION (SOLDERABLE)
18 OPTICAL RELECTOR
17 LTCC
57 VIA
15B ANODE/CATHODE BONDING PAD (SOLDERABLE)

FIG. 8

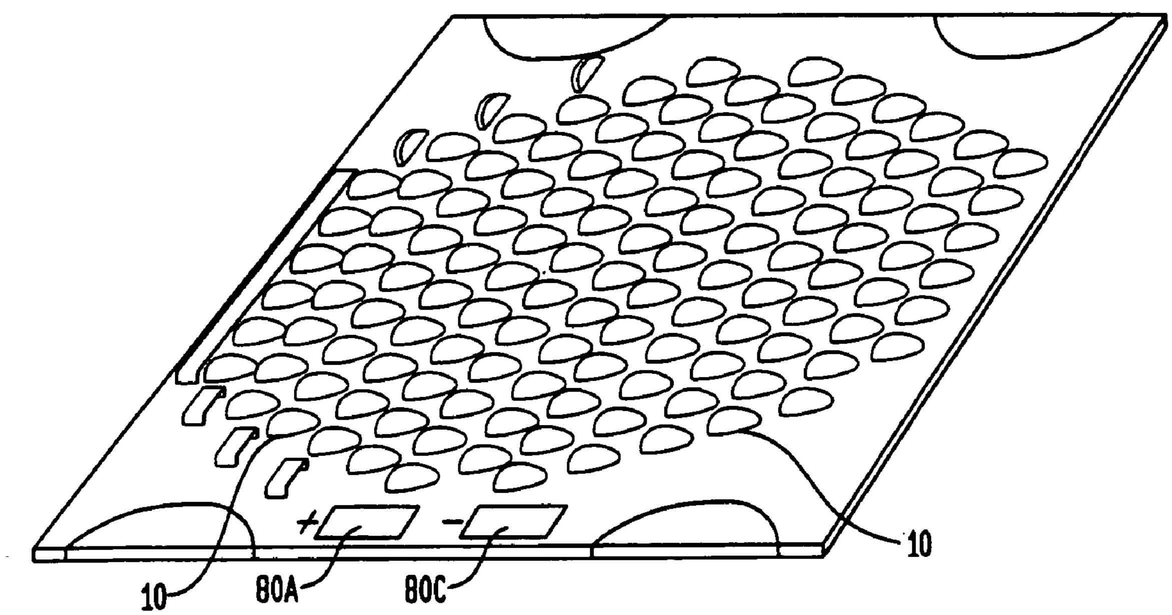


FIG. 9

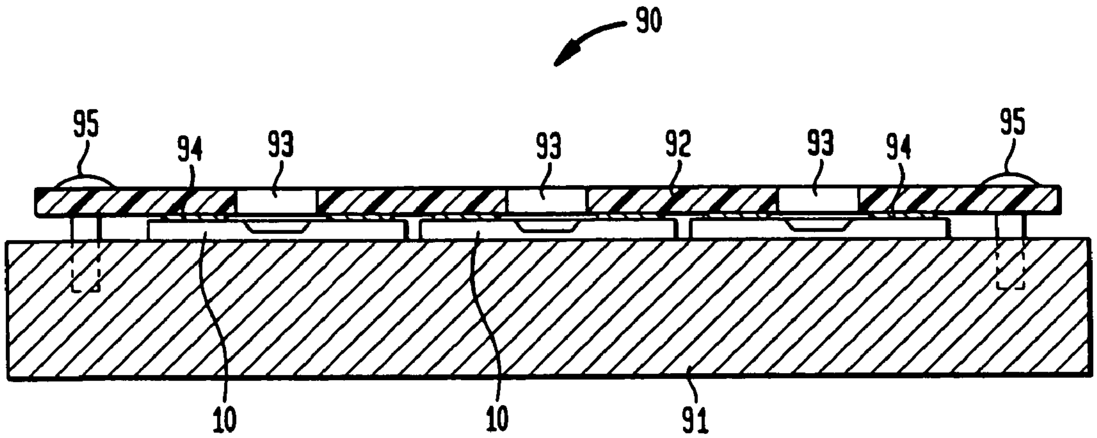


FIG. 10

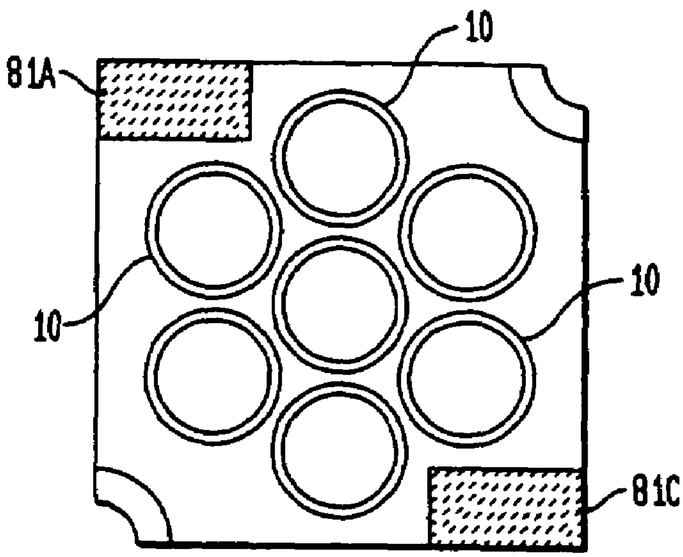


FIG. 11

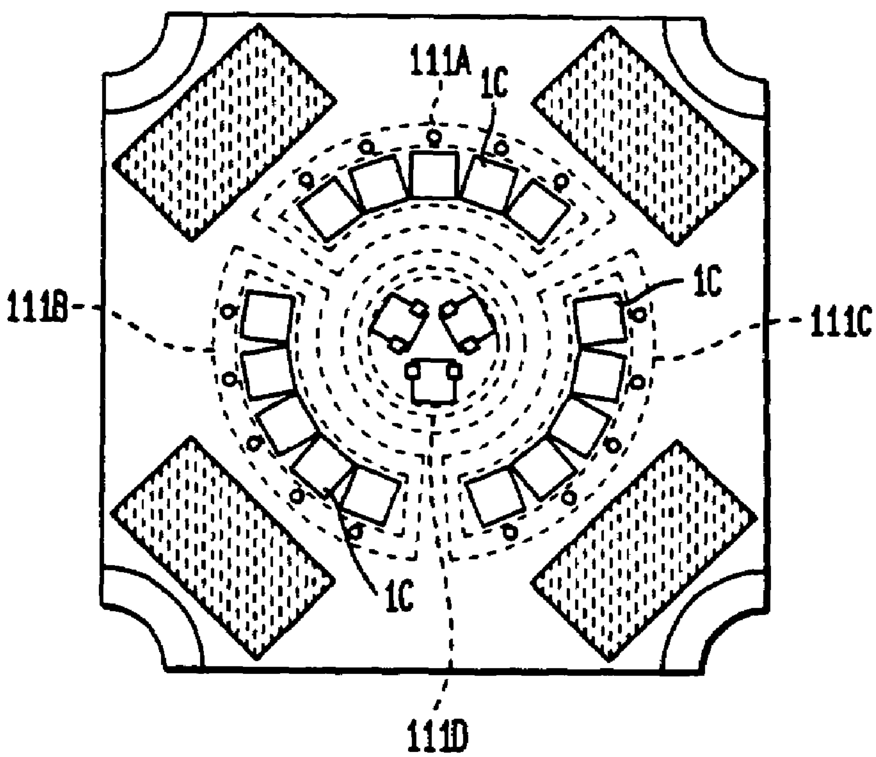


FIG. 12

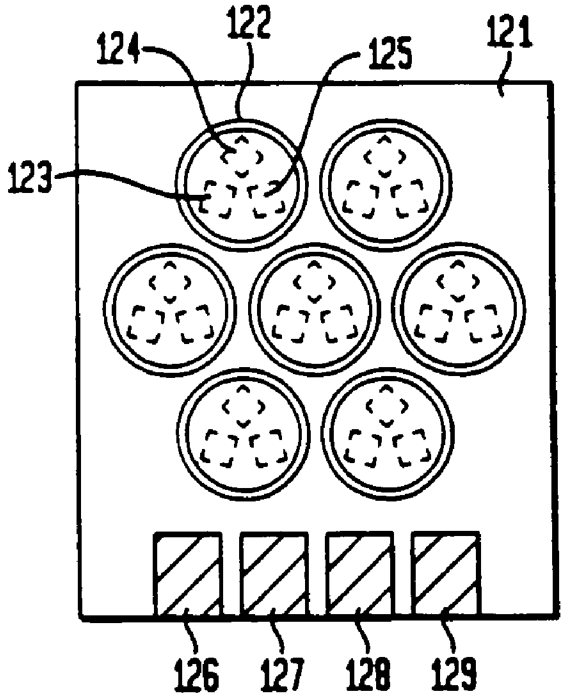


FIG. 13

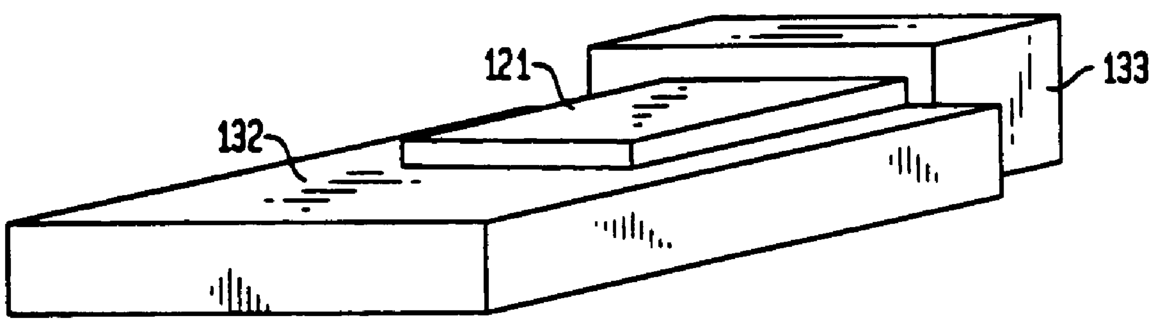


FIG. 14

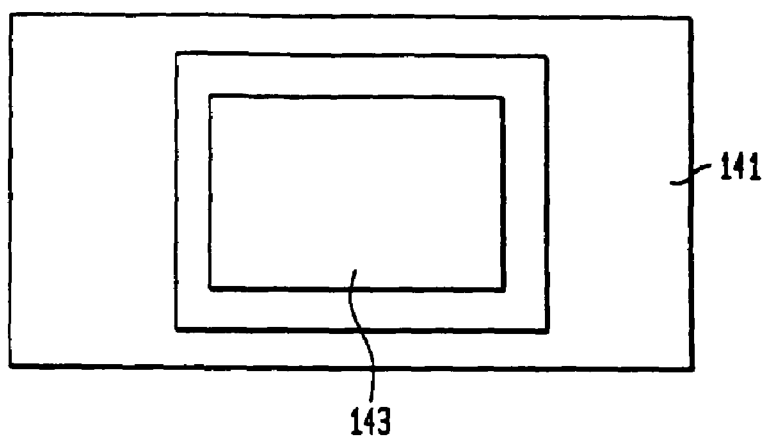


FIG. 15

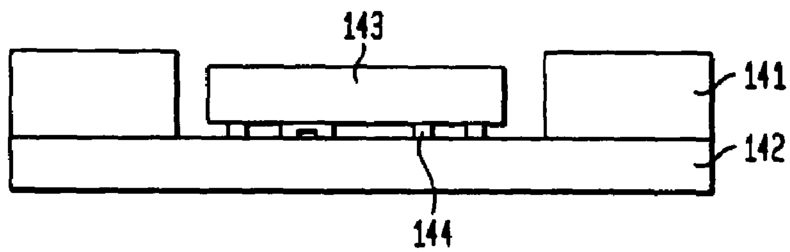


FIG. 16

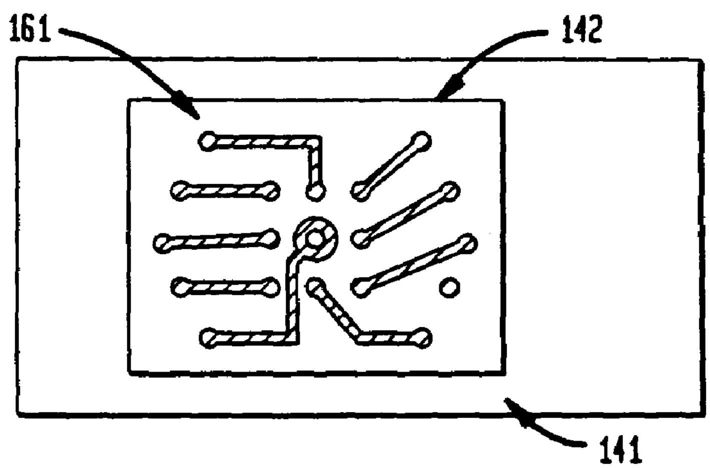


FIG. 17

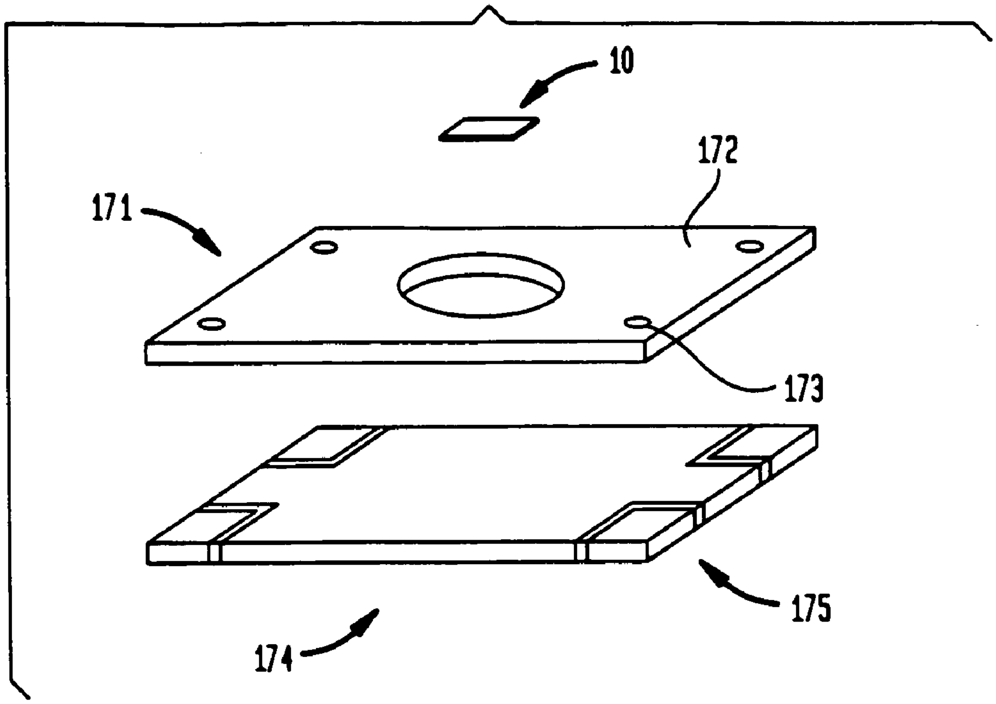


FIG. 18

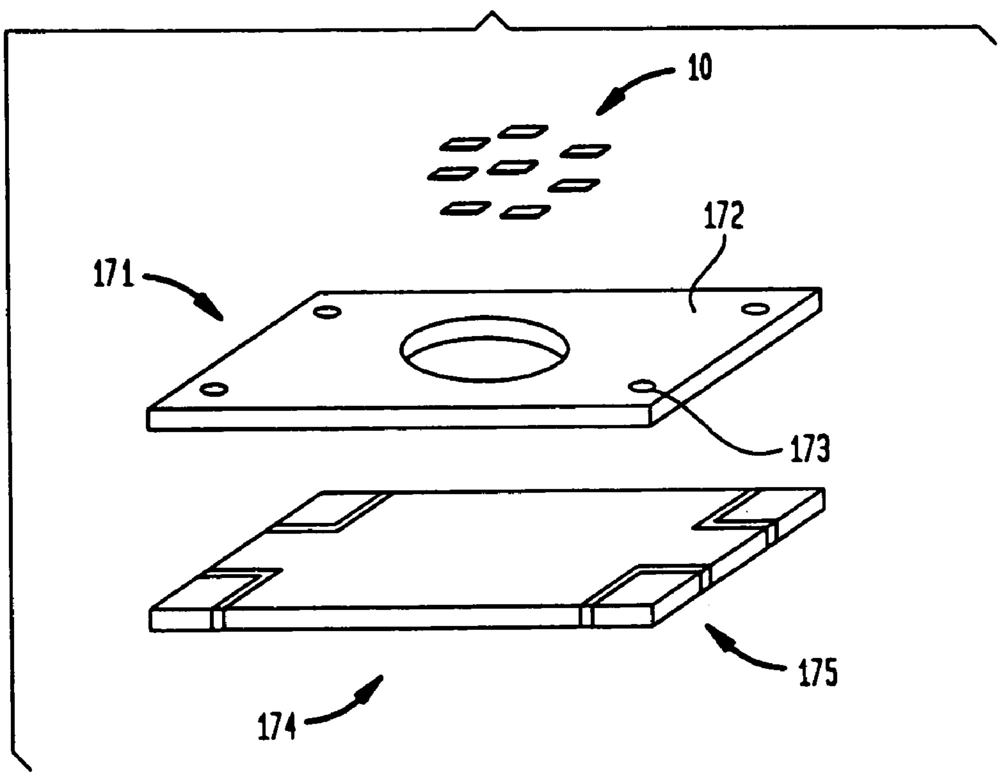
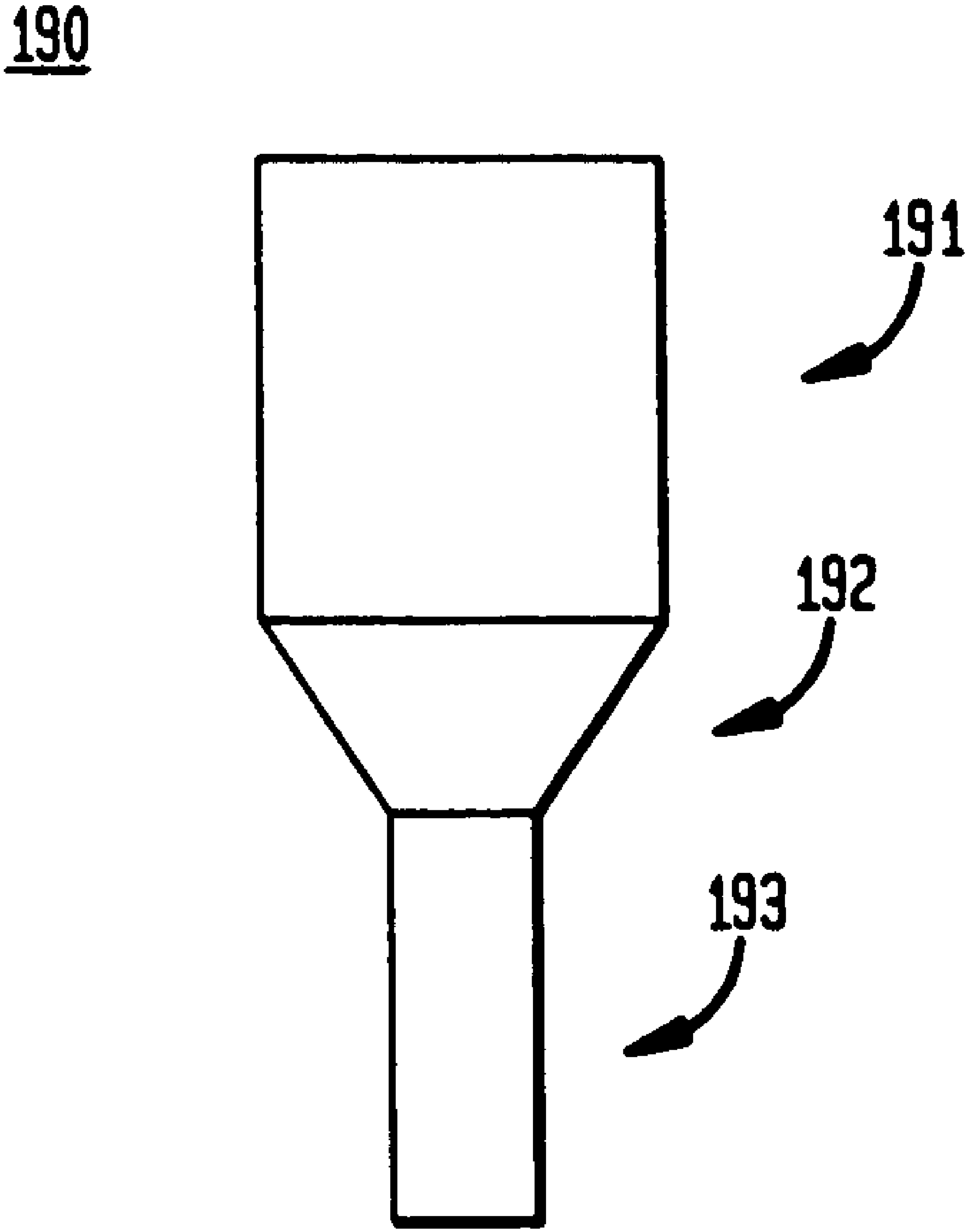


FIG. 19



LIGHT EMITTING DIODES PACKAGED FOR HIGH TEMPERATURE OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

This is a divisional of U.S. patent application Ser. No. 10/638,579, by Joseph Mazzochette and Greg. E. Blonder, filed on Aug. 11, 2003, entitled "Light Emitting Diodes Packaged For High Temperature Operation", which application is hereby incorporated herein by reference. U.S. patent application Ser. No. 10/638,579 in turn claims the benefit of U.S. Provisional Application Ser. No. 60/467,857, "Light Emitting Diodes Packaged for High Temperature Operation", filed May 5, 2003. The 60/467,857 application is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to light emitting diodes and, in particular, to light emitting diodes packaged for high temperature operation.

BACKGROUND OF THE INVENTION

Light emitting diodes (LEDs) are being used as light sources in an increasing variety of applications extending from communications and instrumentation to household, automotive and visual display. Many of these applications require higher levels of power or subject the LEDs to higher temperature operating environments. In response, LED manufacturers have improved the purity of the semiconductor materials in order to keep the LED output intensity high as temperature increases. As a result, desired applications of LEDs are now constrained by the thermal limits of their packaging.

The currently prevalent plastic LED packages have an operational temperature limit of about 80° C. Some LED die, however, will operate at 120° C., and industry preference is for an operational temperature of about 200° C. Accordingly there is a need for an improved light emitting diode packaged for high temperature operation.

SUMMARY OF THE INVENTION

In accordance with the invention, an LED packaged for high temperature operation comprises a metal base including an underlying thermal connection pad and a pair of electrical connection pads, an overlying ceramic layer, and a LED die mounted overlying the metal base. The LED is thermally coupled through the metal base to the thermal connection pad, and the electrodes are electrically connected to the underlying electrical connection pads. A low thermal resistance insulating layer can electrically insulate other areas of die from the base while permitting heat passage. Heat flow can be enhanced by thermal vias to the thermal connector pad. Ceramic layers formed overlying the base can add circuitry and assist in distributing emitted light. The packaged diode can be made by the low temperature co-fired ceramic on metal technique (LTCC-M). The LTCC-M packaged diode can operate at temperatures as high as 250° C.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments now to be described in detail in connection with the accompanying drawings. In the drawings:

FIG. **1** is a schematic cross section of a first embodiment of an LED packaged for high temperature operation;

FIG. **2** illustrates how circuit components can be added to the overlying ceramic layer;

FIGS. **3**A and **3**B illustrate exemplary light dispersive cavities in the ceramic layer;

FIG. **4** is a schematic cross section of an alternative embodiment of an LED;

FIGS. **5**, **6** and **7** show alternative embodiments of the packaged LED;

FIG. **8** depicts an array of LEDs in accordance with the embodiment of FIG. **1**;

FIG. **9** illustrates, in schematic cross section an array that is particularly easy to fabricate;

FIGS. **10** and **11** are top views of advantageous arrays;

FIG. **12** shows the inventive LED array as a plug in card;

FIG. **13** shows the card of FIG. **12** mounted on an additional external heatsink;

FIGS. **14** and **15** are a top and side view of flip-chip die bonded to the traces of an LTCC-M package by solder or gold balls;

FIG. **16** shows conductive traces in an LTCC-M package;

FIG. **17** shows a single LED package having isolated base terminals and vias;

FIG. **18** shows the package of FIG. **17** adapted for a plurality of LED die; and

FIG. **19** shows a round punch tool for forming a tapered cavity.

It is to be understood that these drawings are for illustrating the concepts of the invention and are not to scale.

DETAILED DESCRIPTION

This description is divided into two parts. In Part I describes the structure and features of light emitting diodes (LEDs) packaged for high temperature operation in accordance with the invention and illustrate exemplary embodiments. In Part II we provide further details of the LTCC-M technology used in packaging the LEDs.

I. LEDs Packaged for High Temperature Operation

Referring to the drawings, FIG. **1** is a schematic cross section of an LED **10** packaged for high temperature operation. LED **10** is mounted overlying and thermally coupled to a metal base **11**. Advantageously the metal base **11** includes a patterned low thermal resistance, electrically insulating layer **12** to provide electrical insulation from the base **11** and a patterned conductive layer **13** to provide thermal coupling and electrical connection. The layers **12** and **13** can be patterned to provide insulation or electrical connection regions as desired. An LED **10** having an anode **10**A and a cathode **10**C can be mounted overlying the base **11** by solder bonding the electrodes **10**A and **10**C to conductive pad regions **13**A and **13**C of patterned conductive layer **13**.

Electrical connections may be made through the metal base **11** to underlying electrical connection pads **15**A and **15**B using electrically insulated vias **14** or the metal of the base **11**. Solderable electrical connection pads **15**A and **15**B may be deposited on the underside of metal base **11** to permit surface mounting of the base **11** on a printed circuit board (not shown). The remaining areas of the base **11** may be provided with one or more thermal connector pads **16** to carry heat from the LED package to the printed circuit board. Advantageously the base **11** makes contact with plated through holes (not shown) in a printed circuit board during solder assembly. Such through holes would transfer heat from the diode package into the PCB carrier (typically aluminum or copper).

Overlying the base **11**, one or more ceramic layers **17** can be added to the surface of the package. The ceramic layers on the base **11** form a cavity **18** around the LED **10**. The shape of the cavity walls, as will be discussed below, can affect the distribution of light from the LED **10**. The ceramic layer **17** can include circuitry for connecting multiple diodes in an array, electrostatic discharge protection circuitry, diode control and power supply connections and other surface mount components (not shown in FIG. **1**).

A transparent cover **19** can be provided by bonding a transparent clear cover or lens over the cavity **18** (as by epoxy). The seal can be made hermetic by addition of a bonding pad and brazed seal ring (not shown).

In an advantageous embodiment, the metal base **11** is copper/molybdenum/copper (CMC), the low thermal resistance electrical insulating layer **12** (about 2 micrometers) can be an oxidized layer of the metal base, deposited glass or another deposited insulator such as nickel oxide (about 2 micrometers), and the conductive layer **13** can be gold, silver or other suitable conductor. The LED electrodes **10**A, **10**C can be solder bonded to the gold bonding pads **13**A, **13**C by AuSn solder. The underlying pads **15** and **16** for electrical connection and heat sinking are preferably PdAg and Ag, respectively.

As shown in FIG. **2**, the ceramic layer **17** overlying base **11** can be composed of a plurality of ceramic layers **17**A, **17**B, **17**C and **17**D. Each ceramic layer can include circuit components for powering, controlling, protecting and interconnecting LEDs. While the circuitry will vary for different applications, FIG. **2** illustrates how to add surface mounted active devices **20**, buried capacitors **21**, connectors **22**, interconnecting vias **23**, and buried resistors **24**. The metal base **11** with overlying ceramic layer **17** incorporating circuitry can be fabricated using the low temperature co-fired ceramic on metal technique (LTCC-M) described, for example, in U.S. Pat. No. 6,455,930 issued Sep. 24, 2002 and incorporated herein by reference.

Since a good amount of light is emitted from the edges of LED die, the shape of the ceramic cavity is an important factor in the total light efficiency. The ceramic cavity walls can be formed in a variety of ways including embossing, coining, stamping, forming by lamination, or routing the ceramic in the "green" or unfired state.

FIGS. **3**A and **3**B illustrate exemplary light dispersive cavities for the LED of FIG. **1**. In FIG. **3**A the cavity **18** is provided with walls **30** having straight taper. In FIG. **3**B, the walls **31** have a parabolic taper. In general, each diode cavity **18** can be shaped to improve the light output and focus. White fired glass ceramic is reflective and disperses light to reduce the appearance of bright spots. The reflectivity of the cavity surface can be increased by polishing the surface or by applying a reflective coating such as silver, as by spraying, painting, sputtering or chemical vapor disposition. It is advantageous to smooth the side walls so that applied materials such as epoxy will shrink back and form a reflective gap.

FIG. **4** is a schematic cross section of an alternative embodiment of a single LED packaged for high temperature operation. In this embodiment a lens **40** overlying the LED **10** replaces the ceramic layer **17**, cavity **18** and lens cover **19**. The other features of the FIG. **4** device are substantially the same as described for the FIG. **1** device.

Other variations of the high temperature LED would include a LED die with a single electrode on the bottom of the package with the second electrode as a wire bondable pad on the top side. Or both electrodes could be on the top surface with wire bonding to each.

FIG. **5** is a schematic cross section of an alternative LED packaged for high temperature applications. The FIG. **5** device is similar to FIG. **1** device except that the metal base **51** is formed, as by coining, to include a concave light reflecting cavity **52** around the LED die **10**. FIG. **5** also illustrates that the LED die **10** can have one of its electrodes **53** on its top surface. The top electrode **53** can be connected, for example by a bonding wire **54** to a top bonding pad **55** on the ceramic **17** and through via **57** including insulated via section **56** to the bonding pad **15**A underlying the formed metal base **51**. The other LED electrode can be on the bottom surface connected to bonding pad **59** and further connected by way of the metal base and via **57** to the second underlying bonding pad **15**B. The formed metal base **51** can be provided with underlying ceramic supports **58**A, **58**B so that underlying bonding pads **15**A, **15**B are coplanar with thermal base connector **16**. This arrangement presents pads **15**A, **15**B and connector **16** in a single plane for surface mount connection onto a PC board.

The embodiment of FIG. **6** is similar to that of FIG. **5** except that the LED **10** is mounted on the ceramic layer **17** rather than on the formed metal base **51**. Here the ceramic layer **17**, conforming to the coined metal base, acts as a light reflector. The bottom electrode of the LED **10** can be connected to metal base **51** by way of a bonding pad **60** and conductive vias **61** through the ceramic to the base **51**. The vias **61** are numbered and dimensioned to conduct heat as well as electricity.

The FIG. **7** embodiment is similar to the FIG. **5** embodiment except that the cavity **18** in the ceramic layer **17** is enlarged so that the shaped region of formed metal base **51** is more widely exposed for acting as a layer area reflector.

The LED structure of FIG. **1** may easily be replicated to form an array of LEDs. FIG. **8** illustrates an exemplary array **80** of diodes **10**, with buried interconnection circuitry (not shown) added to the ceramic (**17** of FIG. **1**) connected to common electrodes **81**A, **81**C.

FIG. **9** is a schematic cross section of an array **90** of LTCC-M packaged LED diodes **10** that is particularly easy to fabricate. In essence array **90** comprises a plurality of diodes **10** disposed between a heat sink **91** and an apertured PC board **92**. The light emitting portion of each LED **10** is aligned with a corresponding window aperture **93** of PC board **92**. The PC board **92** advantageously contains the control and driver circuits (not shown) and electrical connections between the circuits and the LED's, e.g. connections **94**. The PC Board **92** can be conveniently secured to the heat sink (which can be a sheet of aluminum), as by screws **95**, to hold the diodes **10** in thermal contact with the heat sink. Advantageously thermal coupling between the diodes and the heat sink can be facilitated by thermal grease.

The array **90** is particularly easy to fabricate. After forming PC board **92** and providing a plurality of LTCC-M packaged diodes **10** as described herein, the diodes can be surface mounted on the PC board with the light emitting portions aligned with apertures, and LED contacts aligned with PC board contacts. After solder reflow connection, the PC board **92** can be secured to the heat sink **91** by screws **95**. The apertures and LEDs can be arranged across the surface of the board to achieve any desired configuration of a two-dimensional array of LEDs.

FIG. **10** is a top view illustrating a first advantageous configuration of LEDs **10** forming a closely packed hexagonal array. The PC board **92** includes common electrodes **81**A and **81**C.

FIG. **11** is a top view of a second advantageous configuration. The LEDs are distributed in a plurality of sets **111**A, **111**B, and **111**C in respective sectors around the circumference of a circle and in a set **111**D in the center of the circle, all to emulate a concentrated light source.

FIG. **12** shows an embodiment of the invention suitable for use as a plug in card. A plurality of cavities **122** includes a plurality LED die **123**, **124**, and **125**. LED die **123**, **124**, and **125** can be identical die (for increased luminosity), or they can be individual colors and lit in various patterns for single, or mixed color displays. They can also be lit in various combinations to give variable intensity or to show patterns. Card contact fingers **126**, **127**, **128**, and **129** show an exemplary embodiment to control the displayed color. Here, finger **129** is an electrical common (common cathode or common anode), and fingers **126**, **127**, and **128** are each connected to a single color die in each well to cause the card to light red, green, or blue respectively. In the example, each LED die is wired to the respective LED die of the same color in each well and to the respective control finger for that color. In another version of this embodiment, decoding/driver electronics can be embedded directly in the layers of the card and can control individual LED die or groups of die.

FIG. **13** shows card advantageously mounted on heat sink **132** for additional cooling. Also the card is shown plugged into edge connector **133** showing how contact is made with contact fingers **126**, **127**, **128**.

Semiconductor die can also be directly connected as flip-chips to any of the described LED assemblies. In this embodiment, surfaces of the package can be bumped with a bondable material such as gold or solder. The bumps can be applied to correspond to the metal terminals of the semiconductor die. The die can then be attached to the package by applying heat and/or thermosonic agitation to create metallurgical connections between the bumped terminals on the package and the die terminals. This embodiment is shown in FIGS. **14** and **15**. FIG. **14** is a top view showing flip-chip die **143** in LTCC-M package **141**. FIG. **15** is a side view of the same assembly showing flip chip **143** connected to a wiring plane on surface **142** by bumps **144**. FIG. **16** shows a top view of a package before the die is installed. Wiring traces **161** can be seen residing on surface **142**.

In another embodiment of the invention, as shown in FIG. **17**, connections to the LED assembly can be made by isolated terminals **175** on base **174**. Openings in insulating layer **171** form wells for the LEDs as before. Insulating layer **171** can optionally include ground plane **172**. Metal vias **173** can facilitate electrical connections from isolated terminals **175** to the die via conductive traces (not shown). FIG. **18** shows a version of this embodiment designed to house a plurality of die **10**.

The invention may now be more clearly understood by consideration of the following specific example.

EXAMPLE

This part was built using a 13% copper, 74% molybdenum, 13% copper (CMC) metal laminate produced by H.C. Starck Corp. Thick film gold bonding pads are fired on the metal base to correspond to the location of each diode electrode. The pads are connected electrically and thermally to the CMC base. 4 layers of CMC-compatible ceramic tape are used to form the LED cavities, make the electrical

connections, and form the array housing. The ceramic tape is composed of glasses and resins supplied by Ferro Corp. and others. The tape materials are ground, mixed, and cast into flat sheets. The sheets are then processed using common "green" tape processing including punching, printing, collating, and laminating.

The cavities are formed by routing (cutting away material with a rotary tool), pressing the shape using a rigid tool during lamination in the green state, or by punching the cavity in each ceramic layer (green-state punching) using a round punch tool **190** with punch shaft **191** and tapered shaft **192** (FIG. **19**). Round Punch **193** pushes out the ceramic tape chad, then the tapered shaft **192** presses a taper into the green tape. The surface is optionally coated with a silver or aluminum metal powder prior to each punch. During the punching operation the metal powder is transferred to the ceramic tape. When fired, the metal sinters into the ceramic. The surface of the taper can also be polished after firing using a rotary polishing tool. A polished surface can also result by using a ceramic powder with a finer grain size in the production of the ceramic tape. The finer grain size reduces the surface roughness of the finished part.

The CMC base is attached during lamination and joined to the tape layers during firing at ~900° C. Multiple arrays are processed on a single wafer, which is then singulated by dicing after firing. After the package is complete, individual diodes are connected to the gold pads in the bottom of each cavity by soldering using 80% Au/20% Sn solder, or using electrically conductive epoxy such as Ablebond 84LMI. The gold pads are connected to the metal base. Conductive vias connect an electrical terminal on the top ceramic layer to the metal base. The anode or cathode are commonly connected to the back side of the diode which is in-turn connected to the gold bonding pad The opposite side of the diode is electrically connected to the array using a wire bond. The bond is connected from the diode to a bonding pad on one of the ceramic layers. Thick film, conductive traces are deposited onto the surface of the ceramic layer containing the bonding pads. The traces are connected to an electrical terminal on the top ceramic layer through electrically conductive vias. A variety of diode connections are possible including series, parallel, and combined series-parallel. Voltage dropping and current limiting resistors, inductors, and capacitors may be added as components buried in between the ceramic layers, or as discrete components mounted on the top surface of the package. Additional control, ESD protection, and voltage regulation semiconductors may be added in die or packaged form. Finally, an index matching epoxy, such as Hysol 1600, may be added to each diode cavity to improve the light output of each device, followed by a cover or lens that may be attached using clear Hysol 1600.

II. LTCC-M Packaging

Multilayer ceramic circuit boards are made from layers of green ceramic tapes. A green tape is made from particular glass compositions and optional ceramic powders, which are mixed with organic binders and a solvent, cast and cut to form the tape. Wiring patterns can be screen printed onto the tape layers to carry out various functions. Vias are then punched in the tape and are filled with a conductor ink to connect the wiring on one green tape to wiring on another green tape. The tapes are then aligned, laminated, and fired to remove the organic materials, to sinter the metal patterns and to crystallize the glasses. This is generally carried out at temperatures below about 1000° C., and preferably from about 750–950° C. The composition of the glasses determines the coefficient of thermal expansion, the dielectric constant and the compatibility of the multilayer ceramic circuit boards to various electronic components. Exemplary crystallizing glasses with inorganic fillers that sinter in the temperature range 700 to 1000° C. are Magnesium Alumino-Silicate, Calcium Boro-Silicate, Lead Boro-Silicate, and Calcium Alumino-Boricate.

More recently, metal support substrates (metal boards) have been used to support the green tapes. The metal boards lend strength to the glass layers. Moreover since the green tape layers can be mounted on both sides of a metal board and can be adhered to a metal board with suitable bonding glasses, the metal boards permit increased complexity and density of circuits and devices. In addition, passive and active components, such as resistors, inductors, and capacitors can be incorporated into the circuit boards for additional functionality. Where optical components, such as LEDs are installed, the walls of the ceramic layers can be shaped and/or coated to enhance the reflective optical properties of the package. Thus this system, known as low temperature cofired ceramic-metal support boards, or LTCC-M, has proven to be a means for high integration of various devices and circuitry in a single package. The system can be tailored to be compatible with devices including silicon-based devices, indium phosphide-based devices and gallium arsenide-based devices, for example, by proper choice of the metal for the support board and of the glasses in the green tapes.

The ceramic layers of the LTCC-M structure must be matched to the thermal coefficient of expansion of the metal support board. Glass ceramic compositions are known that match the thermal expansion properties of various metal or metal matrix composites. The LTCC-M structure and materials are described in U.S. Pat. No. 6,455,930, "Integrated heat sinking packages using low temperature co-fired ceramic metal circuit board technology", issued Sep. 24, 2002 to Ponnuswamy, et al and assigned to Lamina Ceramics. U.S. Pat. No. 6,455,930 is incorporated by reference herein. The LTCC-M structure is further described in U.S. Pat. Nos. 5,581,876, 5,725,808, 5,953,203, and 6,518,502, all of which are assigned to Lamina Ceramics and also incorporated by reference herein.

The metal support boards used for LTCC-M technology do have a high thermal conductivity, but some metal boards have a high thermal coefficient of expansion, and thus a bare die cannot always be directly mounted to such metal support boards. However, some metal support boards are known that can be used for such purposes, such as metal composites of copper and molybdenum (including from 10–25% by weight of copper) or copper and tungsten (including 10–25% by weight of copper), made using powder metallurgical techniques. Copper clad Kovar®, a metal alloy of iron, nickel, cobalt and manganese, a trademark of Carpenter Technology, is a very useful support board. AlSiC is another material that can be used for direct attachment, as can aluminum or copper graphite composites.

Another instance wherein good cooling is required is for thermal management of flip chip packaging. FIGS. **14** and **15**, for example show the inventive LED system where the LTCC-M package house LED die. Densely packed microcircuitry, and devices such as decoder/drivers, amplifiers, oscillators and the like which generate large amounts of heat, can also use LTCC-M techniques advantageously. Metallization on the top layers of an integrated circuit bring input/output lines to the edge of the chip so as to be able to wire bond to the package or module that contains the chip. Thus the length of the wirebond wire becomes an issue; too

long a wire leads to parasitics. The cost of very high integration chips may be determined by the arrangement of the bond pads, rather than by the area of silicon needed to create the circuitry. Flip chip packaging overcomes at least some of these problems by using solder bumps rather than wirebond pads to make connections. These solder bumps are smaller than wire bond pads and, when the chip is turned upside down, or flipped, solder reflow can be used to attach the chip to the package. Since the solder bumps are small, the chip can contain input/output connections within its interior if multilayer packaging is used. Thus the number of transistors in it, rather than the number and size of bond pads will determine the chip size.

However, increased density and integration of functions on a single chip leads to higher temperatures on the chip, which may prevent full utilization of optimal circuit density. The only heat sinks are the small solder bumps that connect the chip to the package. If this is insufficient, small active or passive heat sinks must be added on top of the flip chip. Such additional heat sinks increase assembly costs, increase the number of parts required, and increase the package costs. Particularly if the heat sinks have a small thermal mass, they have limited effectiveness as well.

In the simplest form of the present invention, LTCC-M technology is used to provide an integrated package for a semiconductor component and accompanying circuitry, wherein the conductive metal support board provides a heat sink for the component. A bare semiconductor die, for example, can be mounted directly onto a metal base of the LTCC-M system having high thermal conductivity to cool the semiconductor component. In such case, the electrical signals to operate the component must be connected to the component from the ceramic. In FIGS. **5**, **6**, and **7**, wire bond **54** serves this purpose. Indirect attachment to the metal support board can also be used. In this package, all of the required components are mounted on a metal support board, incorporating embedded passive components such as conductors and resistors into the multilayer ceramic portion, to connect the various components, i.e., semiconductor components, circuits, heat sink and the like, in an integrated package. The package can be hermetically sealed with a lid.

For a more complex structure having improved heat sinking, the integrated package of the invention combines a first and a second LTCC-M substrate. The first substrate can have mounted thereon a semiconductor device, and a multilayer ceramic circuit board with embedded circuitry for operating the component; the second substrate has a heat sink or conductive heat spreader mounted thereon. Thermoelectric (TEC) plates (Peltier devices) and temperature control circuitry are mounted between the first and second substrates to provide improved temperature control of semiconductor devices. A hermetic enclosure can be adhered to the metal support board.

The use of LTCC-M technology can also utilize the advantages of flip chip packaging together with integrated heat sinking. The packages of the invention can be made smaller, cheaper and more efficient than existing present-day packaging. The metal substrate serves as a heat spreader or heat sink. The flip chip can be mounted directly on the metal substrate, which is an integral part of the package, eliminating the need for additional heat sinking. A flexible circuit can be mounted over the bumps on the flip chip. The use of multilayer ceramic layers can also accomplish a fan-out and routing of traces to the periphery of the package, further improving heat sinking. High power integrated circuits and devices that have high thermal management needs can be used with this new LTCC-M technology.

It is understood that the above-described embodiments are illustrative of only a few of the many possible specific embodiments, which can represent applications of the invention. Numerous and varied other arrangements can be made by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A low temperature co-fired ceramic on metal (LTCC-M) light emitting diode (LED) assembly for high temperature operation comprising:

a metal base, the metal base including a thermal connection surface;

at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die thermally coupled through the metal base to the thermal connection surface;

a layer of ceramic overlying the metal base, the layer of ceramic having at least one opening to house the LED die;

a plurality of conductive traces insulated from the metal base, the LED electrodes electrically connected to the conductive traces; and

one or more isolated terminals formed on the metal base, the one or more isolated terminals electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly.

2. The LED assembly of claim **1** further comprising a plurality of edge connector fingers, wherein the fingers are connected to the LED electrodes.

3. The LED assembly of claim **1** further comprising an additional metal block on which the LED assembly is mounted to further improve heat dissipation.

4. The LED assembly of claim **1** wherein the LED die is a flip-chip.

5. The LED assembly of claim **4** wherein the flip-chip is bonded to the traces by conductive balls comprising solder or gold.

6. The LED assembly of claim **1** further comprising vias in the insulating layer, the vias electrically connecting the traces to the isolated terminals.

7. A low temperature co-fired ceramic on metal (LTCC-M) light emitting diode (LED) assembly for high temperature operation comprising:

a metal base, the metal base including a thermal connection surface;

at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die thermally coupled through the metal base to the thermal connection surface;

a layer of ceramic overlying the metal base, the layer of ceramic having at least one opening to house the LED die;

a plurality of conductive traces insulated from the metal base, the LED electrodes electrically connected to the conductive traces; and

a plurality of edge connector fingers, wherein the fingers are connected to decoder/driver electronics embedded in the assembly that control the LED electrodes.

8. The LED assembly of claim **7** further comprising an additional metal block on which the LED assembly is mounted.

9. The LED assembly of claim **7**, wherein the LED die is a flip-chip.

10. The LED assembly of claim **9**, wherein the flip-chip is bonded to the traces by one or more conductive balls.

11. A light emitting diode (LED) assembly for high temperature operation comprising:

a metal base, the metal base including a thermal connection surface;

at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die thermally coupled through the metal base to the thermal connection surface;

a layer of electrically insulating material overlying the metal base, wherein the layer of electrically insulating material includes at least one opening to house the LED die;

a plurality of conductive traces insulated from the metal base, the LED electrodes electrically connected to the conductive traces; and

one or more isolated terminals formed on the metal base, the one or more isolated terminals electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly.

12. The LED assembly of claim **11** further comprising a plurality of edge connector fingers, wherein the fingers are connected to the LED electrodes.

13. The LED assembly of claim **11** further comprising an additional metal block on which the LED assembly is mounted to further improve heat dissipation.

14. The LED assembly of claim **11** wherein the LED die is a flip-chip.

15. The LED assembly of claim **13** wherein the flip-chip is bonded to the traces by conductive balls comprising solder or gold.

16. The LED assembly of claim **11** further comprising vias in the insulating layer, the vias electrically connecting the traces to the isolated terminals.

17. A light emitting diode (LED) assembly for high temperature operation comprising:

a metal base, the metal base including a thermal connection surface;

at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die thermally coupled through the metal base to the thermal connection surface;

a layer of electrically insulating material overlying the metal base, the layer of electrically insulating material having at least one opening to house the LED die;

a plurality of conductive traces insulated from the metal base, the LED electrodes electrically connected to the conductive traces; and

a plurality of edge connector fingers, wherein the fingers are connected to decoder/driver electronics embedded in the assembly that control the LED electrodes.

18. The LED assembly of claim **17** further comprising an additional metal block on which the LED assembly is mounted.

19. The LED assembly of claim **17**, wherein the LED die is a flip-chip.

20. The LED assembly of claim **19**, wherein the flip-chip is bonded to the traces by one or more conductive balls.

* * * * *

Exhibit 8

U.S. Patent No. 7,098,483
("'483 Patent")

Accused Products

The General Electric ("GE") Infusion LED (M1000/830/W/N) ("GE Infusion") Module infringes at least Claims 11 and 16 of the '483 Patent.

Claim 11	GE Infusion M1000/830/W/N LED Module
11[pre]. A light emitting diode (LED) assembly for high temperature operation comprising:	The GE Infusion Module contains at least one LED assembly. As shown in the below image of the GE Infusion Module, the product contains several LED packages ("GE Infusion LED Package(s)"), at least one of which is an embodiment of an LED assembly. GE Infusion LED Package  Optical Image of the GE Infusion LED Module

Claim 11	GE Infusion M1000/830/W/N LED Module
	The remainder of the preamble is not limiting. The GE Infusion LED Package analyzed in this claim chart is an assembly for high temperature operation because it meets the structural limitations recited in claim elements 11[a]-11[e], as shown in further detail below. One of the GE Infusion LED Packages, shown in the optical image below, was removed from the GE Infusion LED Module and was analyzed to demonstrate that the relevant limitations of claim 11 and its asserted dependent claims are met. REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
11[a]. a metal base, the metal base including a thermal connection surface;	The GE Infusion LED Package contains a metal base including a thermal connection surface, as shown in the optical and x-ray images of the package below. ***"a metal base"*** The [redacted] metal at the bottom of the GE Infusion LED Package, shown in the optical and x-ray images below, is the "metal base" recited in claim 11. **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
	REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"the metal base including a thermal connection surface" The metal base of the GE Infusion LED Package includes a thermal connection surface, as shown in the optical and x-ray images below. [redacted] **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
11[b]. at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die thermally coupled through the metal base to the thermal connection surface;	The GE Infusion LED Package contains at least one LED die, the LED die having a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer, the die is thermally coupled through the metal base to the thermal connection surface. ***"at least one LED die"*** As shown in the x-rays of the GE Infusion LED Package below, the product contains at least one LED die. REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"the LED die having a pair of electrodes" As shown in the x-ray image of the GE Infusion LED Package below, the at least one LED die has a pair of electrodes: [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"a pair of electrodes overlying and electrically insulated from the metal base by an insulating layer" As shown in the x-ray image of the GE Infusion LED Package below, the pair of electrodes of the LED die are overlying and electrically insulated from the metal base by an insulating layer. The pair of electrodes are overlying the metal base because, as shown in the x-ray below, they are [redacted] The pair of electrodes of the LED die are also electrically insulated from the metal base through the below-indicated insulating layer. [redacted] **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
	"the die is thermally coupled through the metal base to the thermal connection surface" The LED die is thermally coupled through the metal base to the thermal connection surface by way of the [redacted] [redacted] Thus, the LED die is thermally coupled to the metal base [redacted] Furthermore, [redacted], the LED die is thermally coupled through the metal base to the thermal connection surface. REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
11[c]. a layer of electrically insulating material overlying the metal base, wherein the layer of electrically insulating material includes at least one opening to house the LED die;	The GE Infusion LED Package contains a layer of electrically insulating material overlying the metal base, wherein the layer of electrically insulating material includes at least one opening to house the LED die. ***"a layer of electrically insulating material"*** In addition to the insulating layer between the metal base and the LED discussed in limitation 11[b] above, the GE Infusion LED Package also contains a "layer of electrically insulating material" that surrounds and houses the LED die. This layer of electrically insulating material is shown below in the x-ray and optical images of the GE Infusion LED Package. [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	REDACTED ***"overlying the metal base"*** The layer of electrically insulating material identified in the x-ray and optical images above is overlying the metal base [redacted]

Claim 11	GE Infusion M1000/830/W/N LED Module
	"the layer of electrically insulating material includes at least one opening to house the LED die" The layer of electrically insulating material overlying the metal base includes at least one opening to house the LED die. As shown in the x-ray and optical images of the GE Infusion LED Package below, the layer of electrically insulating material [redacted] has an opening where the LED die is housed. **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
	[redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
11[d]. a plurality of conductive traces insulated from the metal base, the LED electrodes electrically connected to the conductive traces; and	The GE Infusion LED Package contains a plurality of conductive traces insulated from the metal base, and the LED electrodes are electrically connected to the conductive traces. ***"a plurality of conductive traces"*** The GE Infusion LED Package contains a plurality of conductive traces. As shown in the below x-rays of the GE Infusion LED Package, the product contains [redacted]. REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	REDACTED ***"insulated from the metal base"*** As shown in the x-ray of the GE Infusion LED Package below, the plurality of conductive traces are insulated from the metal base [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	Further, as shown in the x-ray of the GE Infusion LED Package below, [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"the LED electrodes electrically connected to the conductive traces" As shown in the x-ray of the GE Infusion LED Package below, the LED electrodes are electrically connected to the identified conductive traces. The LED electrode on top of the LED die is electrically connected to the conductive traces by bonding wire. The LED electrode [redacted] is electrically connected to the conductive traces that [redacted] The traces are each connected [redacted] of the product, and thus form part of the electrical path. **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
11[e]. one or more isolated terminals formed on the metal base, the one or more isolated terminals electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly.	The GE Infusion LED Package contains one or more isolated terminals formed on the metal base, the one or more isolated terminals electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly. "***one or more isolated terminals***" The isolated terminals of the GE Infusion LED Package are identified in the below x-ray and optical images of the product. [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"formed on the metal base" The isolated terminals of the GE Infusion LED Package are "formed on the metal base." As shown in the optical image of the GE Infusion LED Package below, [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	[redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	"***the one or more isolated terminals electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly***" The one or more isolated terminals of the GE Infusion LED Package are electrically connected to decoder/driver electronics that control the LED electrodes, wherein the electronics are mounted within the assembly. For instance, the GE Infusion LED Package contains [redacted] mounted within the assembly and electrically connected to the isolated terminals ([redacted] This [redacted] controls the LED electrodes. The below x-ray images of the GE Infusion LED Package show the [redacted] in the product. **REDACTED**

Claim 11	GE Infusion M1000/830/W/N LED Module
	REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	The one or more isolated terminals are electrically connected to the [redacted]. As shown in the below x-rays of the GE Infusion LED Package, the [redacted] are electrically connected to the isolated terminals [redacted] REDACTED

Claim 11	GE Infusion M1000/830/W/N LED Module
	REDACTED

Claim 16	GE Infusion LED Module M1000/830/W/N
16. The LED assembly of claim 11 further comprising vias in the insulating layer, the vias electrically connecting the traces to the isolated terminals.	The GE Infusion LED Package contains vias in the insulating layer which electrically connect the traces to the isolated terminals. ***"The LED assembly of claim 11 further comprising vias in the insulating layer"*** As shown in the x-ray image of the GE Infusion LED Package below, the product contains vias in the insulating layer. REDACTED

Claim 16	GE Infusion LED Module M1000/830/W/N
	"the vias electrically connecting the traces to the isolated terminals" The vias electrically connect the conductive traces to the isolated terminals. [redacted] REDACTED

Exhibit 9

US007095053B2

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

(10) **Patent No.: US 7,095,053 B2**
(45) **Date of Patent: Aug. 22, 2006**

(54) **LIGHT EMITTING DIODES PACKAGED FOR HIGH TEMPERATURE OPERATION**

(75) Inventors: **Joseph Mazzochette**, Cherry Hill, NJ (US); **Greg Blonder**, Summit, NJ (US)

(73) Assignee: **Lamina Ceramics, Inc.**, Westampton, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 24 days.

(21) Appl. No.: **10/638,579**

(22) Filed: **Aug. 11, 2003**

(65) **Prior Publication Data**

US 2004/0222433 A1 Nov. 11, 2004

Related U.S. Application Data

(60) Provisional application No. 60/467,857, filed on May 5, 2003.

(51) **Int. Cl.**
H01L 27/15 (2006.01)
H01L 31/12 (2006.01)
H01L 33/00 (2006.01)

(52) **U.S. Cl.** **257/81**; 257/98; 257/99

(58) **Field of Classification Search** 257/79, 257/80, 81, 98, 99, 82, 676
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,886,709 A 12/1989 Sasame et al. 428/552
5,117,281 A 5/1992 Katsuraoka
5,122,781 A 6/1992 Saubolle 340/473
5,140,220 A 8/1992 Hasegawa 313/512
5,482,898 A 1/1996 Marrs
5,485,037 A 1/1996 Marrs
5,581,876 A 12/1996 Prabhu et al.
5,725,808 A 3/1998 Tormey et al.
5,745,624 A 4/1998 Chan et al.
5,847,935 A * 12/1998 Thaler et al. 361/761
5,857,767 A 1/1999 Hochstein
5,953,203 A 9/1999 Tormey et al.
5,977,567 A 11/1999 Verdiell
6,045,240 A * 4/2000 Hochstein 362/294
6,220,722 B1 4/2001 Begemann 362/231
6,325,524 B1 12/2001 Weber et al. 362/245
6,376,268 B1 4/2002 Verdiell
6,428,189 B1 8/2002 Hochstein 362/373
6,455,930 B1 9/2002 Palanisamy et al.
6,480,389 B1 11/2002 Shie et al.
6,483,623 B1 11/2002 Maruyama
6,518,502 B1 * 2/2003 Hammond et al. 174/52.4

(Continued)

FOREIGN PATENT DOCUMENTS

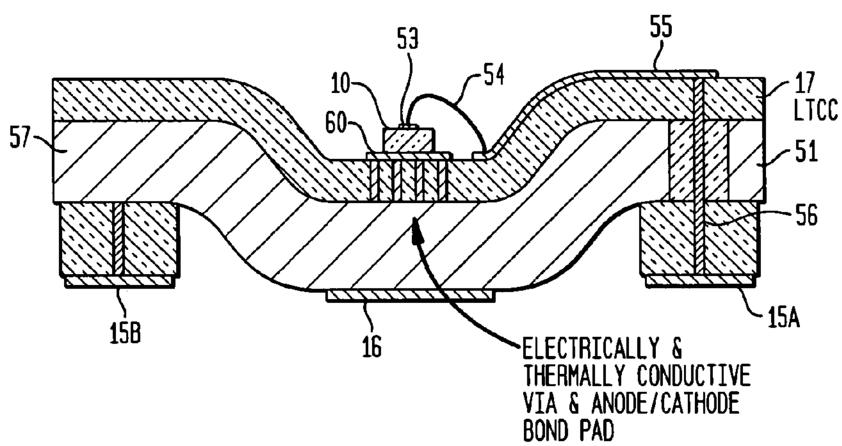
JP 2000-294701 10/2000 .... 257/712

Primary Examiner—Phat X. Cao
(74) *Attorney, Agent, or Firm*—Lowenstein Sandler P.C.

(57) **ABSTRACT**

In accordance with the invention, an LED packaged for high temperature operation comprises a metal base including an underlying thermal connection pad and a pair of electrical connection pads, an overlying ceramic layer, and a LED die mounted overlying the metal base. The LED is thermally coupled through the metal base to the thermal connection pad, and the electrodes are electrically connected to the underlying electrical connection pads. A low thermal resistance insulating layer can electrically insulate other areas of die from the base while permitting heat passage. Heat flow can be enhanced by thermal vias to the thermal connector pad. Ceramic layers formed overlying the base can add circuitry and assist in distributing emitted light. The novel package can operate at temperatures as high as 250° C.

30 Claims, 13 Drawing Sheets



U.S. PATENT DOCUMENTS

6,634,750	B1	10/2003	Neal et al.	351/211
6,634,770	B1	10/2003	Cao	362/294
6,692,252	B1	2/2004	Scott	433/29
2002/0004251	A1	1/2002	Roberts et al.	
2002/0034834	A1	3/2002	Verdiell	
2002/0163006	A1 *	11/2002	Yoganandan et al.	257/81
2002/0175621	A1	11/2002	Song et al.	
2002/0176250	A1	11/2002	Bohler et al.	
2003/0057421	A1 *	3/2003	Chen	257/79
2004/0026706	A1 *	2/2004	Bogner et al.	257/99

* cited by examiner

FIG. 1A

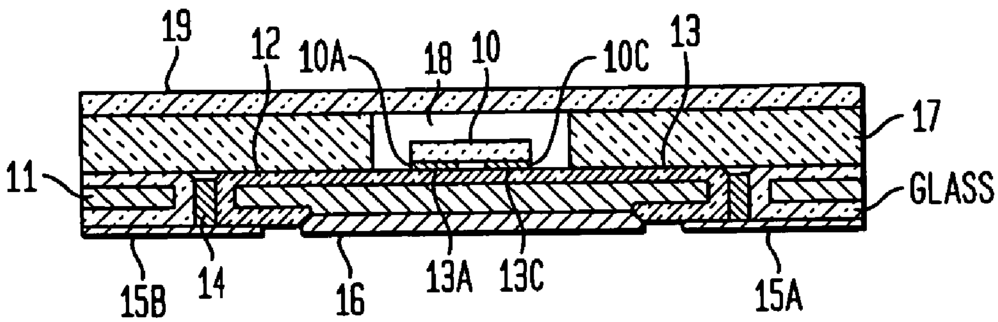


FIG. 1B

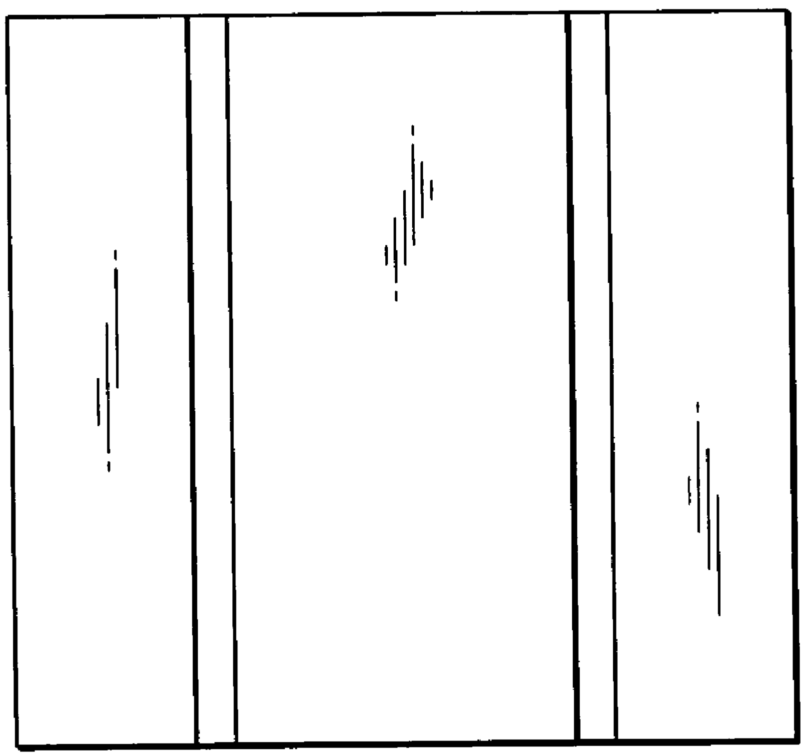


FIG. 2

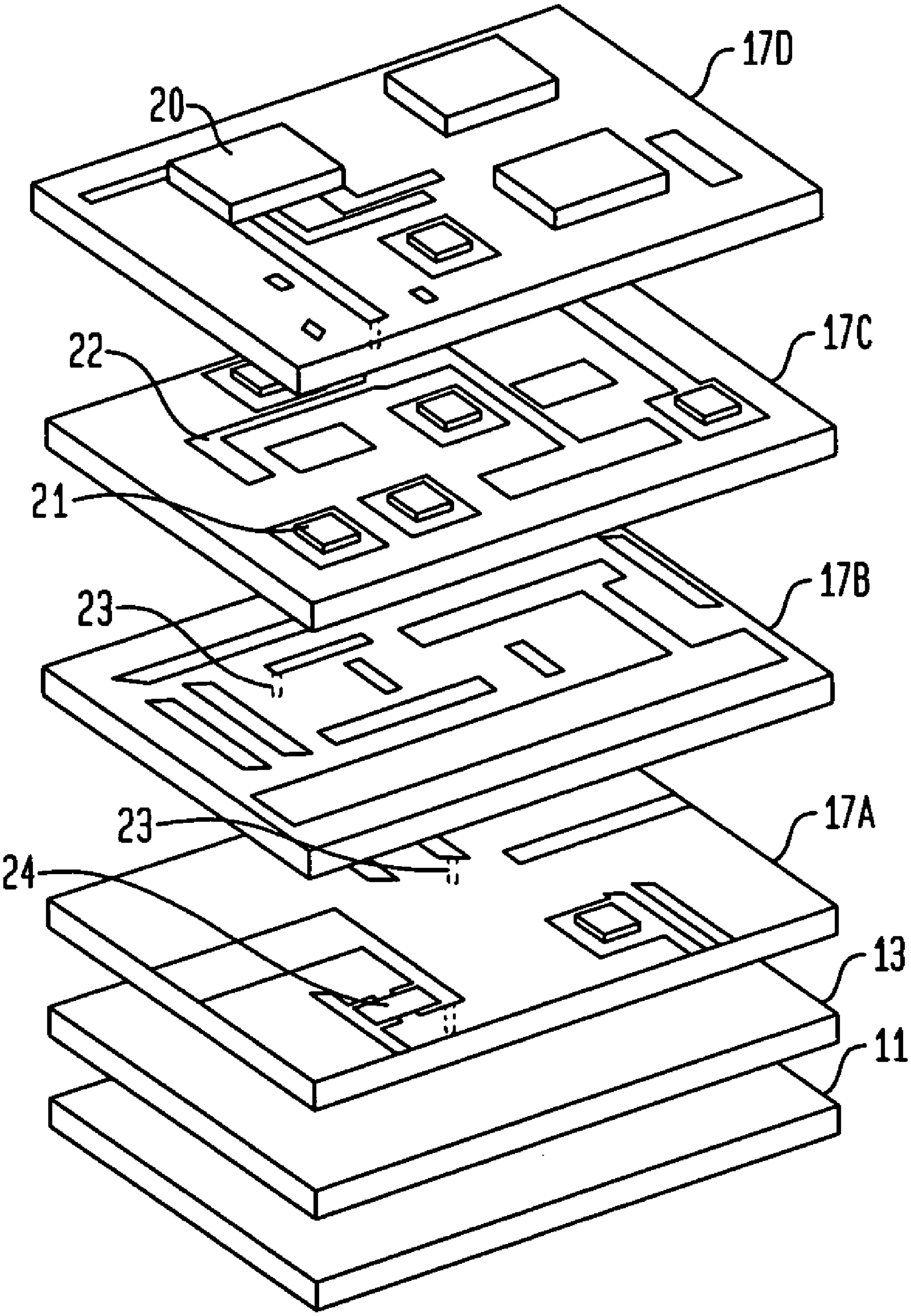


FIG. 3A

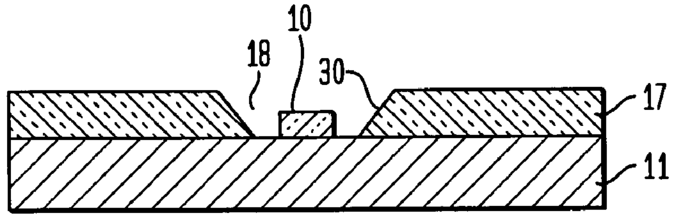


FIG. 3B

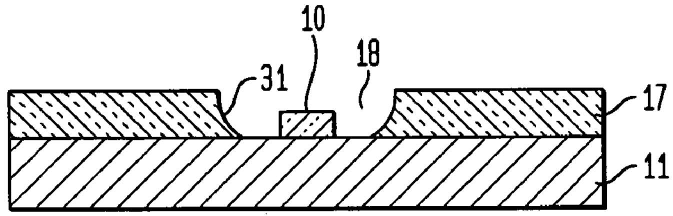


FIG. 4

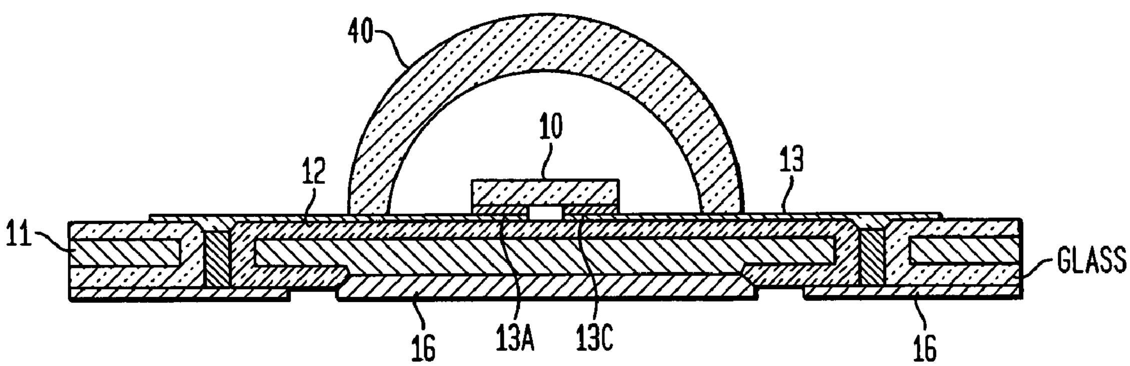


FIG. 5

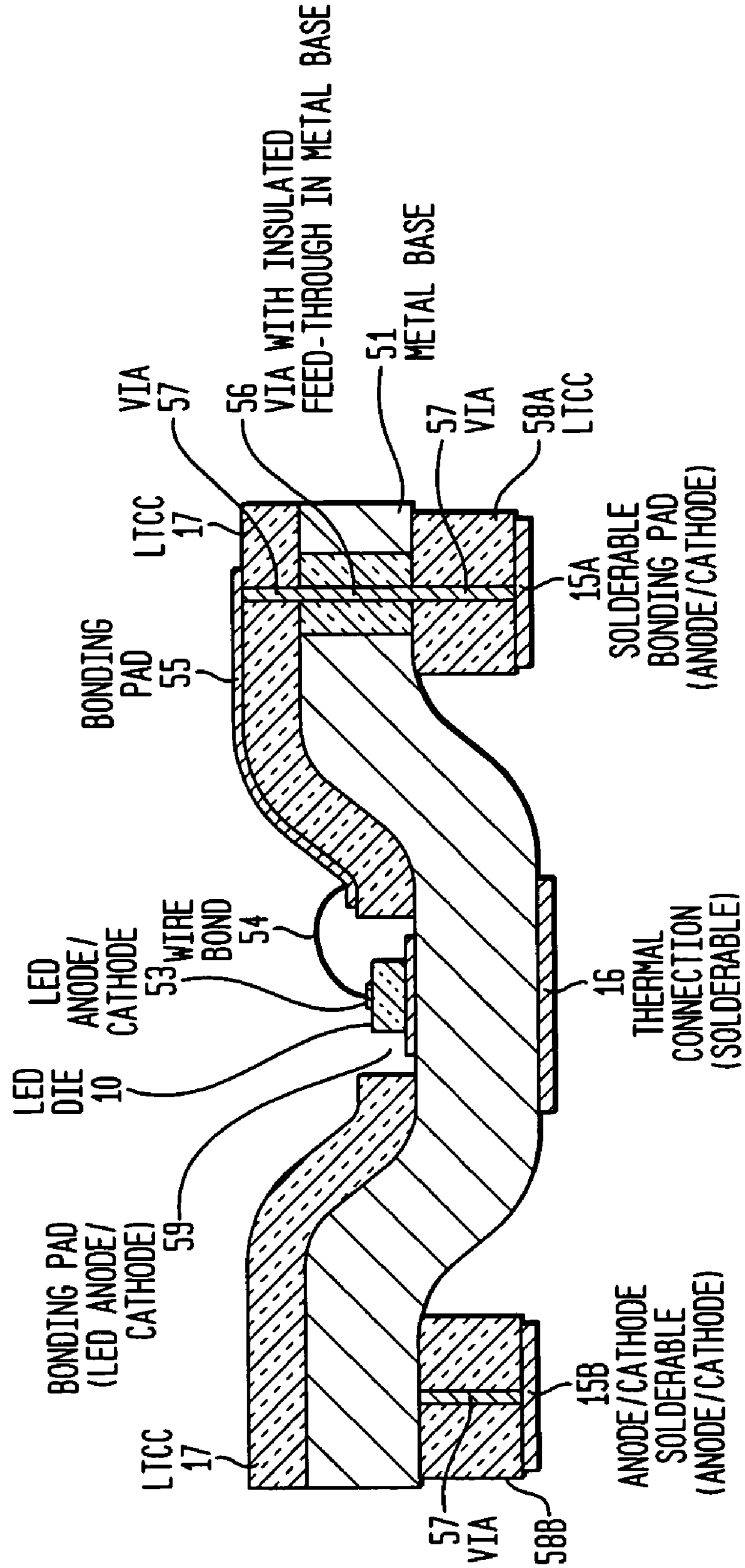
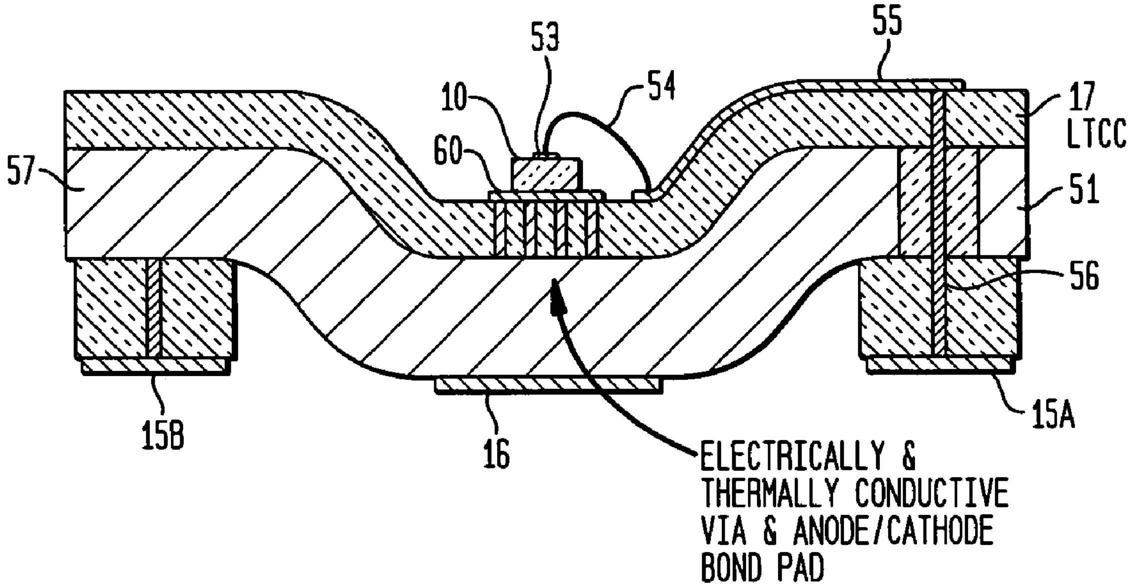
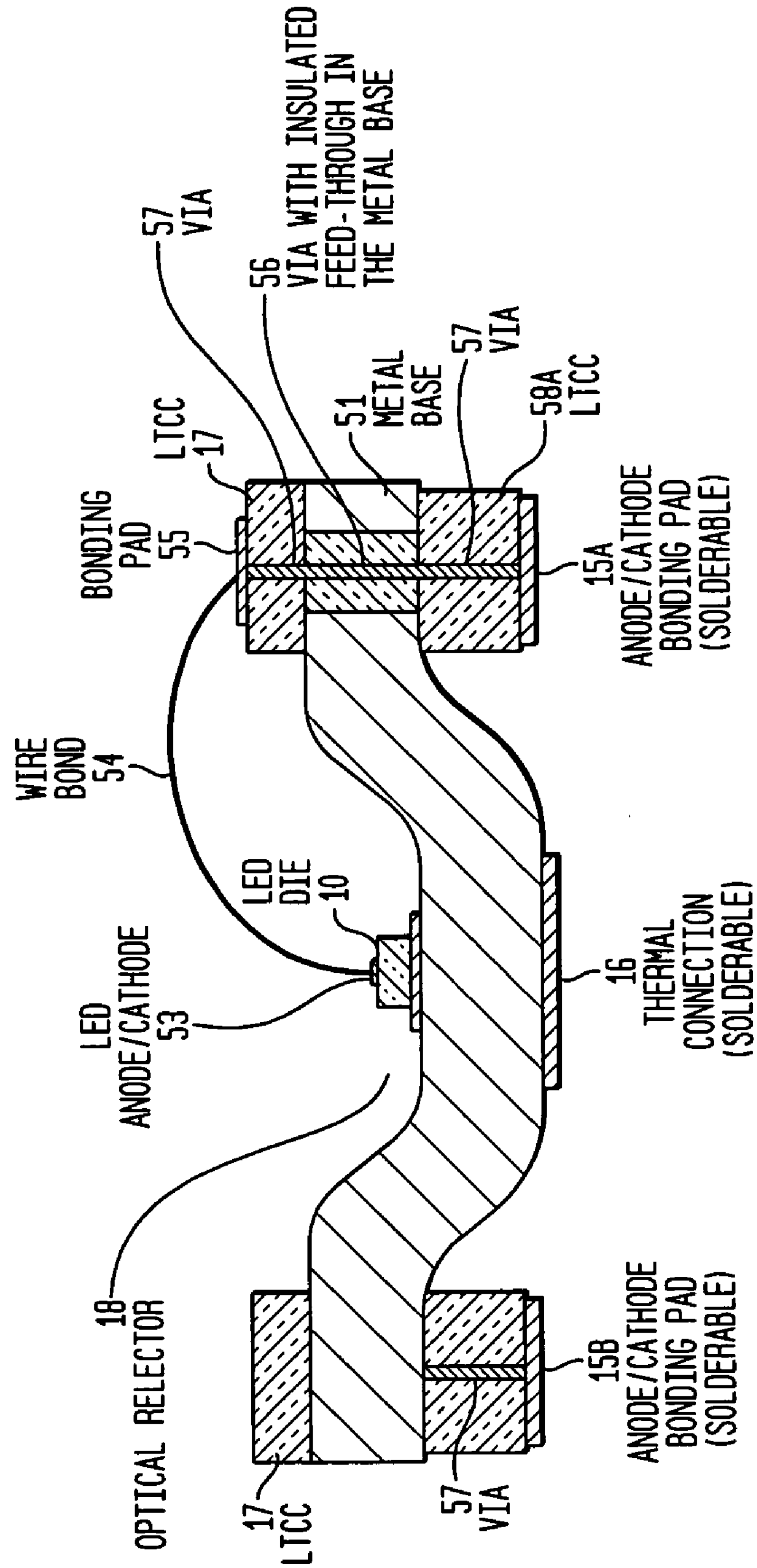

VIA 57
56 VIA WITH INSULATED FEED-THROUGH IN METAL BASE
51 METAL BASE
57 VIA
58A LTCC
LTCC 17
BONDING PAD 55
15A SOLDERABLE BONDING PAD (ANODE/CATHODE)
LED ANODE/CATHODE 53
WIRE BOND 54
LED DIE 10
16 THERMAL CONNECTION (SOLDERABLE)
BONDING PAD (LED ANODE/CATHODE) 59
LTCC 17
15B ANODE/CATHODE SOLDERABLE (ANODE/CATHODE)
57 VIA
58B

FIG. 6


53
55
10
54
17
LTCC
60
57
51
56
15B
16
15A
ELECTRICALLY &
THERMALLY CONDUCTIVE
VIA & ANODE/CATHODE
BOND PAD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56 VIA WITH INSULATED FEED-THROUGH IN THE METAL BASE
51 METAL BASE
57 VIA
58A LTCC
LTCC 17
BONDING PAD 55
15A ANODE/CATHODE BONDING PAD (SOLDERABLE)
WIRE BOND 54
LED DIE 10
LED ANODE/CATHODE 53
16 THERMAL CONNECTION (SOLDERABLE)
18 OPTICAL RELECTOR
17 LTCC
57 VIA
15B ANODE/CATHODE BONDING PAD (SOLDERABLE)

FIG. 7

FIG. 8

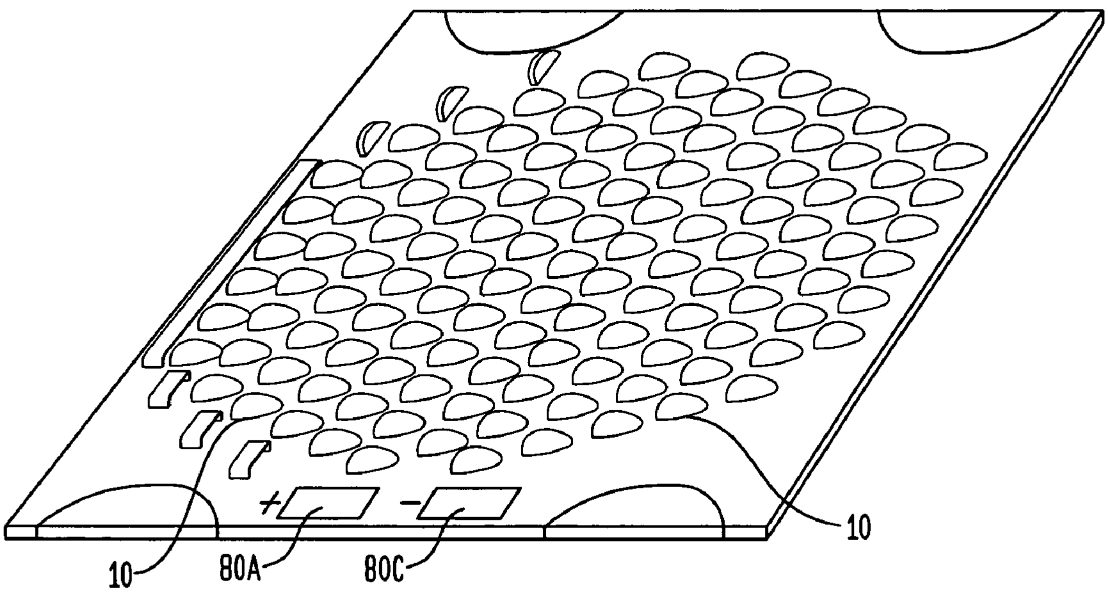


FIG. 9

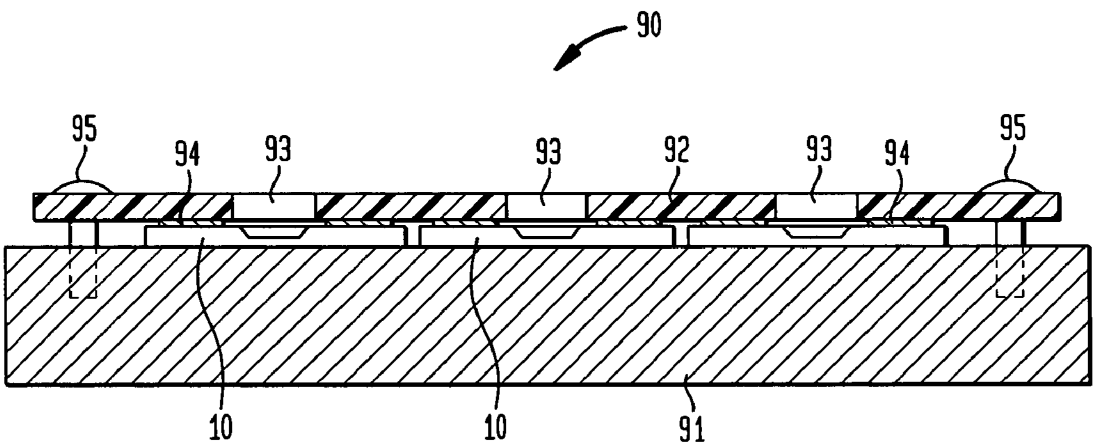


FIG. 10

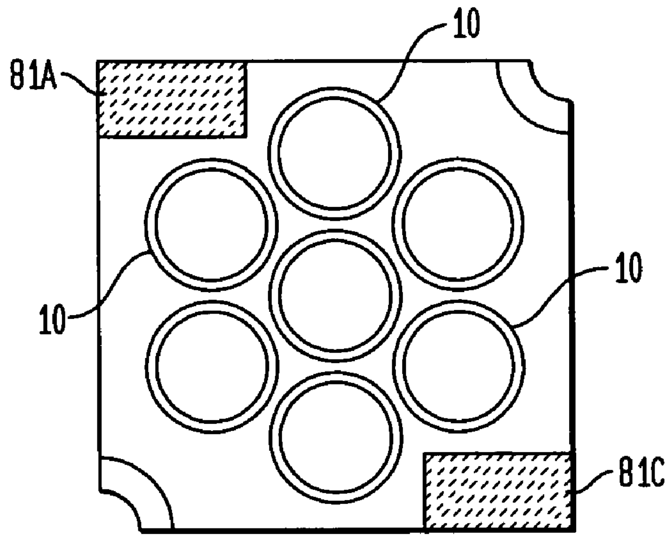


FIG. 11

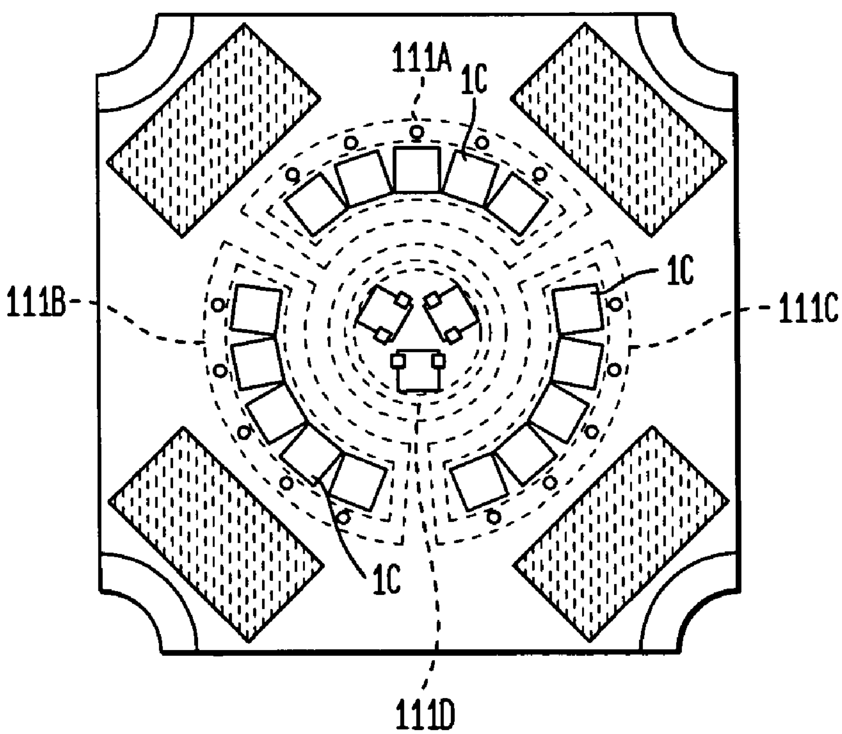


FIG. 12

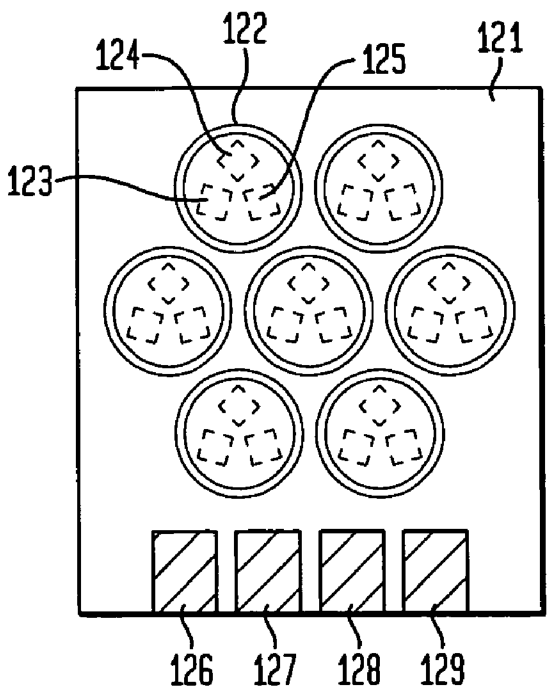


FIG. 13

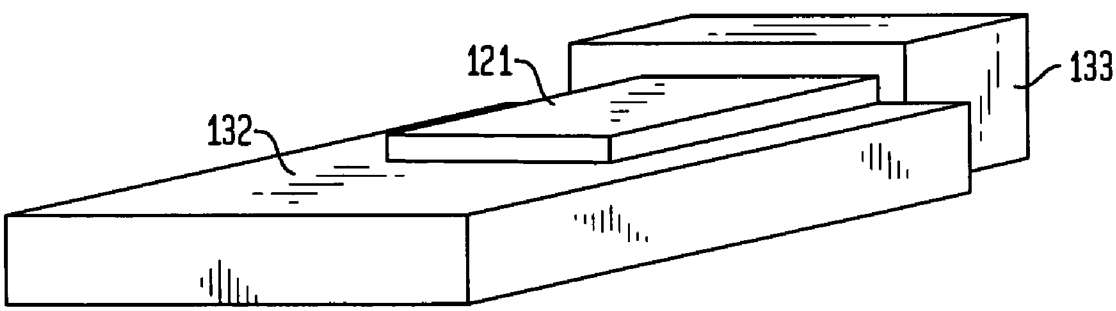


FIG. 14

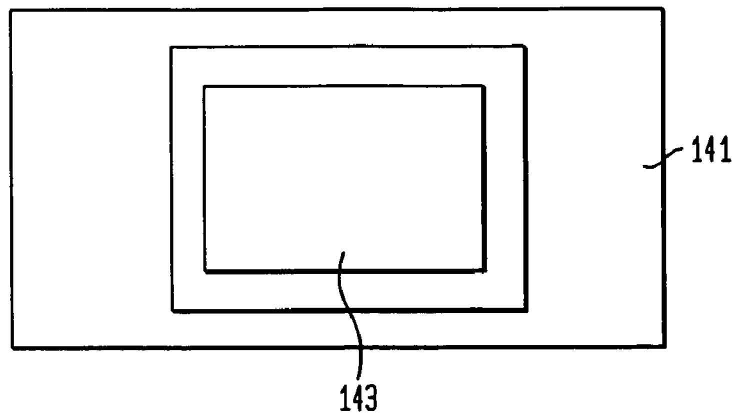


FIG. 15

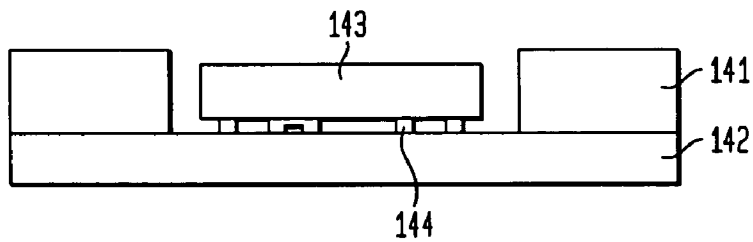


FIG. 16

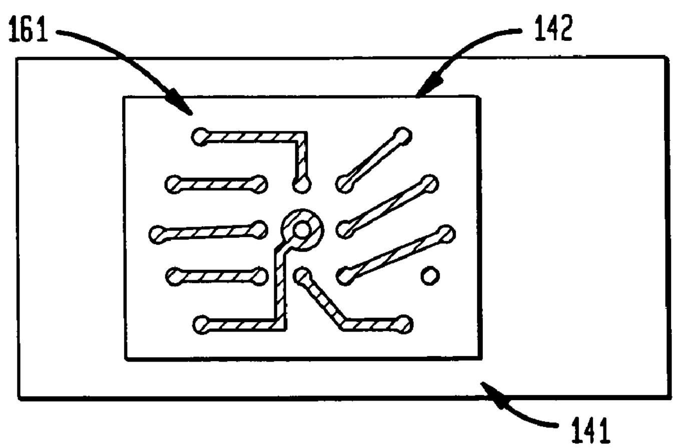


FIG. 17

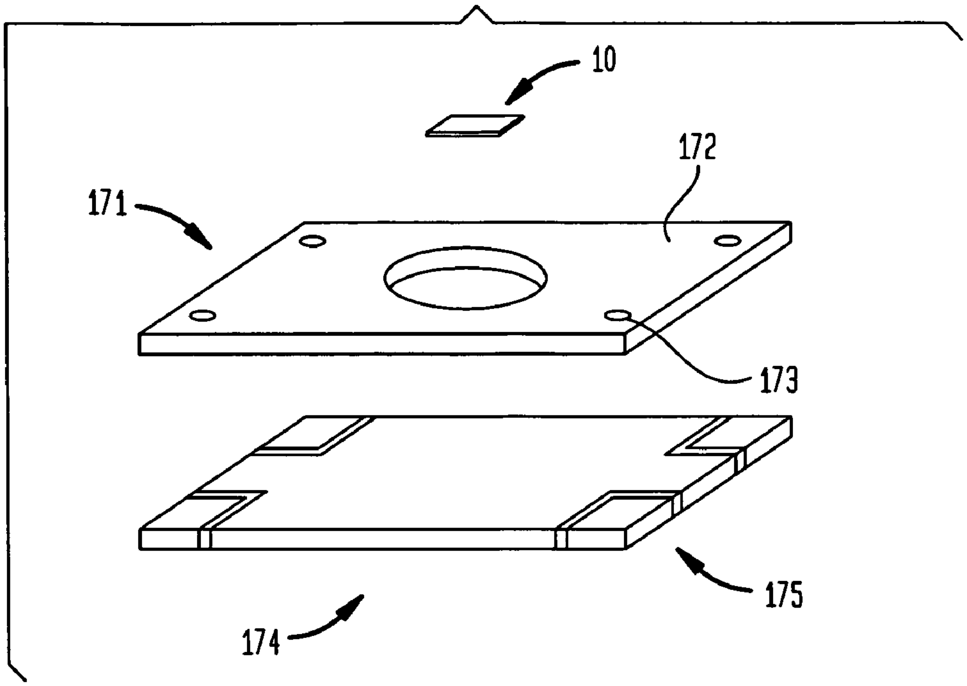


FIG. 18

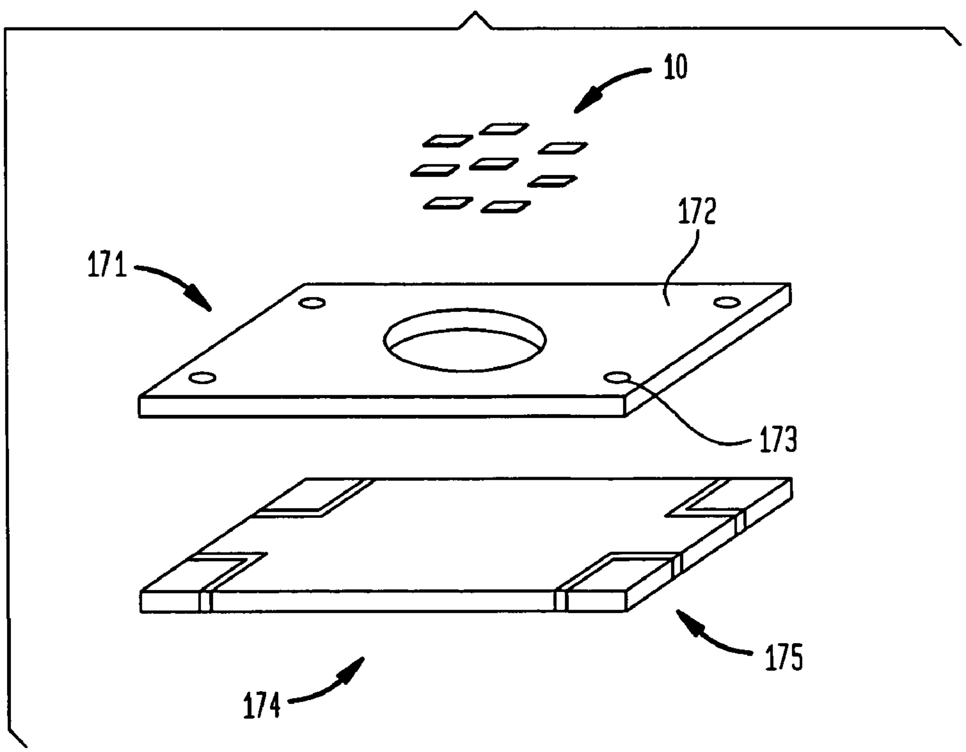
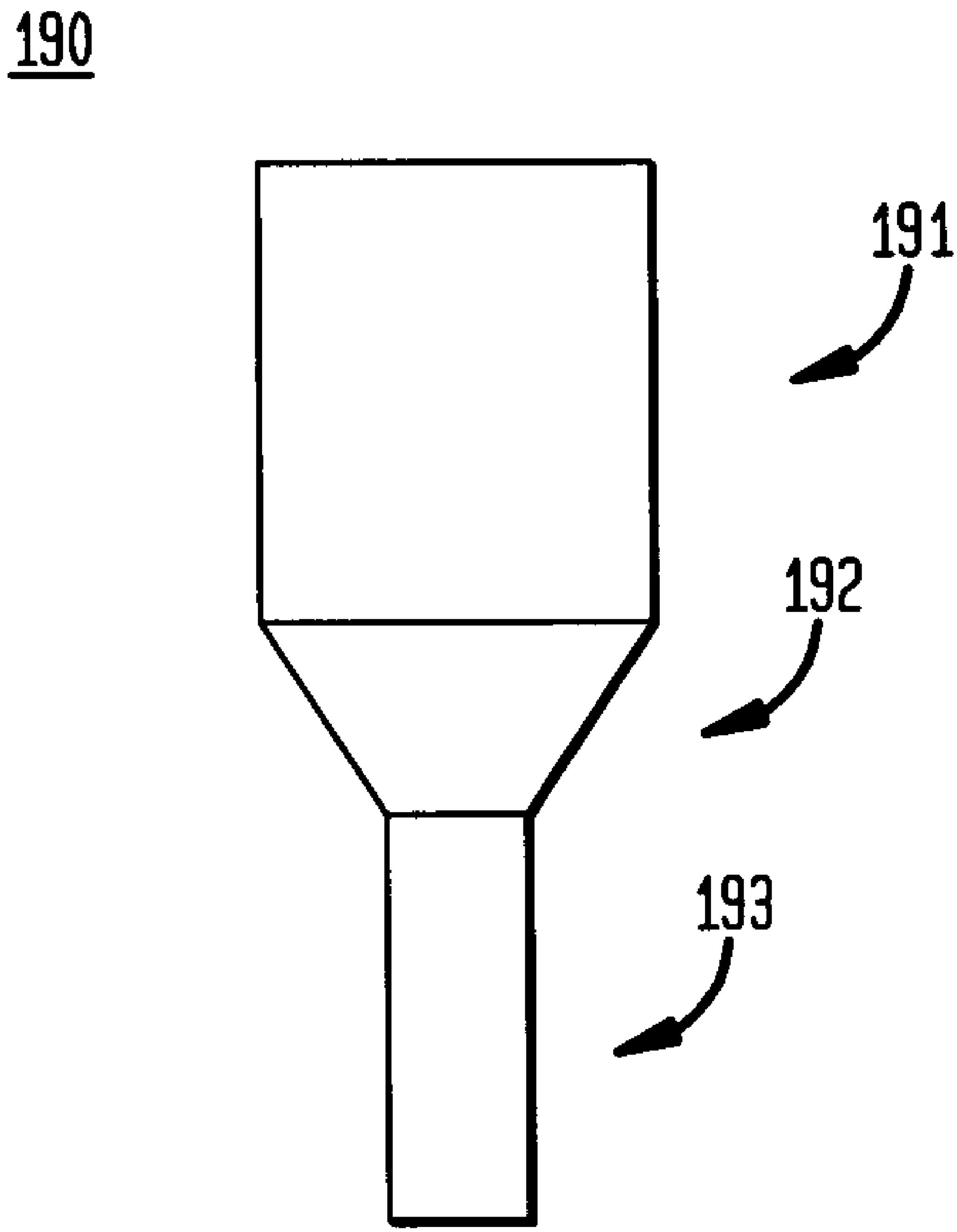


FIG. 19



LIGHT EMITTING DIODES PACKAGED FOR HIGH TEMPERATURE OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Ser. No. 60/467,857, "Light Emitting Diodes Packaged for High Temperature Operation", filed May 5, 2003. The 60/467,857 application is incorporated by reference herein.

FIELD OF THE INVENTION

This invention relates to light emitting diodes and, in particular, to light emitting diodes packaged for high temperature operation.

BACKGROUND OF THE INVENTION

Light emitting diodes (LEDs) are being used as light sources in an increasing variety of applications extending from communications and instrumentation to household, automotive and visual display. Many of these applications require higher levels of power or subject the LEDs to higher temperature operating environments. In response, LED manufacturers have improved the purity of the semiconductor materials in order to keep the LED output intensity high as temperature increases. As a result, desired applications of LEDs are now constrained by the thermal limits of their packaging.

The currently prevalent plastic LED packages have an operational temperature limit of about 80° C. Some LED die, however, will operate at 120° C., and industry preference is for an operational temperature of about 200° C. Accordingly there is a need for an improved light emitting diode packaged for high temperature operation.

SUMMARY OF THE INVENTION

In accordance with the invention, an LED packaged for high temperature operation comprises a metal base including an underlying thermal connection pad and a pair of electrical connection pads, an overlying ceramic layer, and a LED die mounted overlying the metal base. The LED is thermally coupled through the metal base to the thermal connection pad, and the electrodes are electrically connected to the underlying electrical connection pads. A low thermal resistance insulating layer can electrically insulate other areas of die from the base while permitting heat passage. Heat flow can be enhanced by thermal vias to the thermal connector pad. Ceramic layers formed overlying the base can add circuitry and assist in distributing emitted light. The packaged diode can be made by the low temperature co-fired ceramic on metal technique (LTCC-M). The LTCC-M packaged diode can operate at temperatures as high as 250° C.

BRIEF DESCRIPTION OF THE DRAWINGS

The advantages, nature and various additional features of the invention will appear more fully upon consideration of the illustrative embodiments now to be described in detail in connection with the accompanying drawings. In the drawings:

FIG. **1** is a schematic cross section of a first embodiment of an LED packaged for high temperature operation;

FIG. **2** illustrates how circuit components can be added to the overlying ceramic layer;

FIGS. **3**A and **3**B illustrate exemplary light dispersive cavities in the ceramic layer;

FIG. **4** is a schematic cross section of an alternative embodiment of an LED;

FIGS. **5**, **6** and **7** show alternative embodiments of the packaged LED;

FIG. **8** depicts an array of LEDs in accordance with the embodiment of FIG. **1**;

FIG. **9** illustrates, in schematic cross section an array that is particularly easy to fabricate;

FIGS. **10** and **11** are top views of advantageous arrays;

FIG. **12** shows the inventive LED array as a plug in card;

FIG. **13** shows the card of FIG. **12** mounted on an additional external heatsink;

FIGS. **14** and **15** are a top and side view of flip-chip die bonded to the traces of an LTCC-M package by solder or gold balls;

FIG. **16** shows conductive traces in an LTCC-M package;

FIG. **17** shows a single LED package having isolated base terminals and vias;

FIG. **18** shows the package of FIG. **17** adapted for a plurality of LED die; and

FIG. **19** shows a round punch tool for forming a tapered cavity.

It is to be understood that these drawings are for illustrating the concepts of the invention and are not to scale.

DETAILED DESCRIPTION

This description is divided into two parts. In Part I describes the structure and features of light emitting diodes (LEDs) packaged for high temperature operation in accordance with the invention and illustrate exemplary embodiments. In Part II we provide further details of the LTCC-M technology used in packaging the LEDs.

I. LEDs Packaged for High Temperature Operation

Referring to the drawings, FIG. **1** is a schematic cross section of an LED **10** packaged for high temperature operation. LED **10** is mounted overlying and thermally coupled to a metal base **11**. Advantageously the metal base **11** includes a patterned low thermal resistance, electrically insulating layer **12** to provide electrical insulation from the base **11** and a patterned conductive layer **13** to provide thermal coupling and electrical connection. The layers **12** and **13** can be patterned to provide insulation or electrical connection regions as desired. An LED **10** having an anode **10**A and a cathode **10**C can be mounted overlying the base **111** by solder bonding the electrodes **10**A and **10**C to conductive pad regions **13**A and **13**C of patterned conductive layer **13**.

Electrical connections may be made through the metal base **11** to underlying electrical connection pads **15**A and **15**B using electrically insulated vias **14** or the metal of the base **11**. Solderable electrical connection pads **15**A and **15**B may be deposited on the underside of metal base **11** to permit surface mounting of the base **11** on a printed circuit board (not shown). The remaining areas of the base **11** may be provided with one or more thermal connector pads **16** to carry heat from the LED package to the printed circuit board. Advantageously the base **11** makes contact with plated through holes (not shown) in a printed circuit board during solder assembly. Such through holes would transfer heat from the diode package into the PCB carrier (typically aluminum or copper).

Overlying the base **11**, one or more ceramic layers **17** can be added to the surface of the package. The ceramic layers on the base **11** form a cavity **18** around the LED **10**. The shape of the cavity walls, as will be discussed below, can affect the distribution of light from the LED **10**. The ceramic layer **17** can include circuitry for connecting multiple diodes in an array, electrostatic discharge protection circuitry, diode control and power supply connections and other surface mount components (not shown in FIG. **1**).

A transparent cover **19** can be provided by bonding a transparent clear cover or lens over the cavity **18** (as by epoxy). The seal can be made hermetic by addition of a bonding pad and brazed seal ring (not shown).

In an advantageous embodiment, the metal base **11** is copper/molybdenum/copper (CMC), the low thermal resistance electrical insulating layer **12** (about 2 micrometers) can be an oxidized layer of the metal base, deposited glass or another deposited insulator such as nickel oxide (about 2 micrometers), and the conductive layer **13** can be gold, silver or other suitable conductor. The LED electrodes **10**A, **10**C can be solder bonded to the gold bonding pads **13**A, **13**C by AuSn solder. The underlying pads **15** and **16** for electrical connection and heat sinking are preferably PdAg and Ag, respectively.

As shown in FIG. **2**, the ceramic layer **17** overlying base **11** can be composed of a plurality of ceramic layers **17**A, **17**B, **17**C and **17**D. Each ceramic layer can include circuit components for powering, controlling, protecting and interconnecting LEDs. While the circuitry will vary for different applications, FIG. **2** illustrates how to add surface mounted active devices **20**, buried capacitors **21**, connectors **22**, interconnecting vias **23**, and buried resistors **24**. The metal base **11** with overlying ceramic layer **17** incorporating circuitry can be fabricated using the low temperature co-fired ceramic on metal technique (LTCC-M) described, for example, in U.S. Pat. No. 6,455,930 issued Sep. 24, 2002 and incorporated herein by reference.

Since a good amount of light is emitted from the edges of LED die, the shape of the ceramic cavity is an important factor in the total light efficiency. The ceramic cavity walls can be formed in a variety of ways including embossing, coining, stamping, forming by lamination, or routing the ceramic in the "green" or unfired state.

FIGS. **3**A and **3**B illustrate exemplary light dispersive cavities for the LED of FIG. **1**. In FIG. **3**A the cavity **18** is provided with walls **30** having straight taper. In FIG. **3**B, the walls **31** have a parabolic taper. In general, each diode cavity **18** can be shaped to improve the light output and focus. White fired glass ceramic is reflective and disperses light to reduce the appearance of bright spots. The reflectivity of the cavity surface can be increased by polishing the surface or by applying a reflective coating such as silver, as by spraying, painting, sputtering or chemical vapor disposition. It is advantageous to smooth the side walls so that applied materials such as epoxy will shrink back and form a reflective gap.

FIG. **4** is a schematic cross section of an alternative embodiment of a single LED packaged for high temperature operation. In this embodiment a lens **40** overlying the LED **10** replaces the ceramic layer **17**, cavity **18** and lens cover **19**. The other features of the FIG. **4** device are substantially the same as described for the FIG. **1** device.

Other variations of the high temperature LED would include a LED die with a single electrode on the bottom of the package with the second electrode as a wire bondable pad on the top side. Or both electrodes could be on the top surface with wire bonding to each.

FIG. **5** is a schematic cross section of an alternative LED packaged for high temperature applications. The FIG. **5** device is similar to FIG. **1** device except that the metal base **51** is formed, as by coining, to include a concave light reflecting cavity **52** around the LED die **10**. FIG. **5** also illustrates that the LED die **10** can have one of its electrodes **53** on its top surface. The top electrode **53** can be connected, for example by a bonding wire **54** to a top bonding pad **55** on the ceramic **17** and through via **57** including insulated via section **56** to the bonding pad **15**A underlying the formed metal base **51**. The other LED electrode can be on the bottom surface connected to bonding pad **59** and further connected by way of the metal base and via **57** to the second underlying bonding pad **15**B. The formed metal base **51** can be provided with underlying ceramic supports **58**A, **58**B so that underlying bonding pads **15**A, **15**B are coplanar with thermal base connector **16**. This arrangement presents pads **15**A, **15**B and connector **16** in a single plane for surface mount connection onto a PC board.

The embodiment of FIG. **6** is similar to that of FIG. **5** except that the LED **10** is mounted on the ceramic layer **17** rather than on the formed metal base **51**. Here the ceramic layer **17**, conforming to the coined metal base, acts as a light reflector. The bottom electrode of the LED **10** can be connected to metal base **51** by way of a bonding pad **60** and conductive vias **61** through the ceramic to the base **51**. The vias **61** are numbered and dimensioned to conduct heat as well as electricity.

The FIG. **7** embodiment is similar to the FIG. **5** embodiment except that the cavity **18** in the ceramic layer **17** is enlarged so that the shaped region of formed metal base **51** is more widely exposed for acting as a layer area reflector.

The LED structure of FIG. **1** may easily be replicated to form an array of LEDs. FIG. **8** illustrates an exemplary array **80** of diodes **10**, with buried interconnection circuitry (not shown) added to the ceramic (**17** of FIG. **1**) connected to common electrodes **81**A, **81**C.

FIG. **9** is a schematic cross section of an array **90** of LTCC-M packaged LED diodes **10** that is particularly easy to fabricate. In essence array **90** comprises a plurality of diodes **10** disposed between a heat sink **91** and an apertured PC board **92**. The light emitting portion of each LED **10** is aligned with a corresponding window aperture **93** of PC board **92**. The PC board **92** advantageously contains the control and driver circuits (not shown) and electrical connections between the circuits and the LED's, e.g. connections **94**. The PC Board **92** can be conveniently secured to the heat sink (which can be a sheet of aluminum), as by screws **95**, to hold the diodes **10** in thermal contact with the heat sink. Advantageously thermal coupling between the diodes and the heat sink can be facilitated by thermal grease.

The array **90** is particularly easy to fabricate. After forming PC board **92** and providing a plurality of LTCC-M packaged diodes **10** as described herein, the diodes can be surface mounted on the PC board with the light emitting portions aligned with apertures, and LED contacts aligned with PC board contacts. After solder reflow connection, the PC board **92** can be secured to the heat sink **91** by screws **95**. The apertures and LEDs can be arranged across the surface of the board to achieve any desired configuration of a two-dimensional array of LEDs.

FIG. **10** is a top view illustrating a first advantageous configuration of LEDs **10** forming a closely packed hexagonal array. The PC board **92** includes common electrodes **81**A and **81**C.

FIG. **11** is a top view of a second advantageous configuration. The LEDs are distributed in a plurality of sets **111**A,

111B, and **111**C in respective sectors around the circumference of a circle and in a set **111**D in the center of the circle, all to emulate a concentrated light source.

FIG. **12** shows an embodiment of the invention suitable for use as a plug in card. A plurality of cavities **122** includes a plurality LED die **123**, **124**, and **125**. LED die **123**, **124**, and **125** can be identical die (for increased luminosity), or they can be individual colors and lit in various patterns for single, or mixed color displays. They can also be lit in various combinations to give variable intensity or to show patterns. Card contact fingers **126**, **127**, **128**, and **129** show an exemplary embodiment to control the displayed color. Here, finger **129** is an electrical common (common cathode or common anode), and fingers **126**, **127**, and **128** are each connected to a single color die in each well to cause the card to light red, green, or blue respectively. In the example, each LED die is wired to the respective LED die of the same color in each well and to the respective control finger for that color. In another version of this embodiment, decoding/driver electronics can be embedded directly in the layers of the card and can control individual LED die or groups of die.

FIG. **13** shows card advantageously mounted on heat sink **132** for additional cooling. Also the card is shown plugged into edge connector **133** showing how contact is made with contact fingers **126**, **127**, **128**.

Semiconductor die can also be directly connected as flip-chips to any of the described LED assemblies. In this embodiment, surfaces of the package can be bumped with a bondable material such as gold or solder. The bumps can be applied to correspond to the metal terminals of the semiconductor die. The die can then be attached to the package by applying heat and/or thermosonic agitation to create metallurgical connections between the bumped terminals on the package and the die terminals. This embodiment is shown in FIGS. **14** and **15**. FIG. **14** is a top view showing flip-chip die **143** in LTCC-M package **141**. FIG. **15** is a side view of the same assembly showing flip chip **143** connected to a wiring plane on surface **142** by bumps **144**. FIG. **16** shows a top view of a package before the die is installed. Wiring traces **161** can be seen residing on surface **142**.

In another embodiment of the invention, as shown in FIG. **17**, connections to the LED assembly can be made by isolated terminals **175** on base **174**. Openings in insulating layer **171** form wells for the LEDs as before. Insulating layer **171** can optionally include ground plane **172**. Metal vias **173** can facilitate electrical connections from isolated terminals **175** to the die via conductive traces (not shown). FIG. **18** shows a version of this embodiment designed to house a plurality of die **10**.

The invention may now be more clearly understood by consideration of the following specific example.

EXAMPLE

This part was built using a 13% copper, 74% molybdenum, 13% copper (CMC) metal laminate produced by H.C. Starck Corp. Thick film gold bonding pads are fired on the metal base to correspond to the location of each diode electrode. The pads are connected electrically and thermally to the CMC base. 4 layers of CMC-compatible ceramic tape are used to form the LED cavities, make the electrical connections, and form the array housing. The ceramic tape is composed of glasses and resins supplied by Ferro Corp. and others. The tape materials are ground, mixed, and cast into flat sheets. The sheets are then processed using common "green" tape processing including punching, printing, collating, and laminating.

The cavities are formed by routing (cutting away material with a rotary tool), pressing the shape using a rigid tool during lamination in the green state, or by punching the cavity in each ceramic layer (green-state punching) using a round punch tool **190** with punch shaft **191** and tapered shaft **192** (FIG. **19**). Round Punch **193** pushes out the ceramic tape chad, then the tapered shaft **192** presses a taper into the green tape. The surface is optionally coated with a silver or aluminum metal powder prior to each punch. During the punching operation the metal powder is transferred to the ceramic tape. When fired, the metal sinters into the ceramic. The surface of the taper can also be polished after firing using a rotary polishing tool. A polished surface can also result by using a ceramic powder with a finer grain size in the production of the ceramic tape. The finer grain size reduces the surface roughness of the finished part.

The CMC base is attached during lamination and joined to the tape layers during firing at ~900° C. Multiple arrays are processed on a single wafer, which is then singulated by dicing after firing. After the package is complete, individual diodes are connected to the gold pads in the bottom of each cavity by soldering using 80% Au/20% Sn solder, or using electrically conductive epoxy such as Ablebond 84LMI. The gold pads are connected to the metal base. Conductive vias connect an electrical terminal on the top ceramic layer to the metal base. The anode or cathode are commonly connected to the back side of the diode which is in-turn connected to the gold bonding pad The opposite side of the diode is electrically connected to the array using a wire bond. The bond is connected from the diode to a bonding pad on one of the ceramic layers. Thick film, conductive traces are deposited onto the surface of the ceramic layer containing the bonding pads. The traces are connected to an electrical terminal on the top ceramic layer through electrically conductive vias. A variety of diode connections are possible including series, parallel, and combined series-parallel. Voltage dropping and current limiting resistors, inductors, and capacitors may be added as components buried in between the ceramic layers, or as discrete components mounted on the top surface of the package. Additional control, ESD protection, and voltage regulation semiconductors may be added in die or packaged form. Finally, an index matching epoxy, such as Hysol 1600, may be added to each diode cavity to improve the light output of each device, followed by a cover or lens that may be attached using clear Hysol 1600.

II. LTCC-M Packaging

Multilayer ceramic circuit boards are made from layers of green ceramic tapes. A green tape is made from particular glass compositions and optional ceramic powders, which are mixed with organic binders and a solvent, cast and cut to form the tape. Wiring patterns can be screen printed onto the tape layers to carry out various functions. Vias are then punched in the tape and are filled with a conductor ink to connect the wiring on one green tape to wiring on another green tape. The tapes are then aligned, laminated, and fired to remove the organic materials, to sinter the metal patterns and to crystallize the glasses. This is generally carried out at temperatures below about 1000° C., and preferably from about 750–950° C. The composition of the glasses determines the coefficient of thermal expansion, the dielectric constant and the compatibility of the multilayer ceramic circuit boards to various electronic components. Exemplary crystallizing glasses with inorganic fillers that sinter in the temperature range 700 to 1000° C. are Magnesium Alumino-Silicate, Calcium Boro-Silicate, Lead Boro-Silicate, and Calcium Alumino-Boricate.

More recently, metal support substrates (metal boards) have been used to support the green tapes. The metal boards lend strength to the glass layers. Moreover since the green tape layers can be mounted on both sides of a metal board and can be adhered to a metal board with suitable bonding glasses, the metal boards permit increased complexity and density of circuits and devices. In addition, passive and active components, such as resistors, inductors, and capacitors can be incorporated into the circuit boards for additional functionality. Where optical components, such as LEDs are installed, the walls of the ceramic layers can be shaped and/or coated to enhance the reflective optical properties of the package. Thus this system, known as low temperature cofired ceramic-metal support boards, or LTCC-M, has proven to be a means for high integration of various devices and circuitry in a single package. The system can be tailored to be compatible with devices including silicon-based devices, indium phosphide-based devices and gallium arsenide-based devices, for example, by proper choice of the metal for the support board and of the glasses in the green tapes.

The ceramic layers of the LTCC-M structure must be matched to the thermal coefficient of expansion of the metal support board. Glass ceramic compositions are known that match the thermal expansion properties of various metal or metal matrix composites. The LTCC-M structure and materials are described in U.S. Pat. No. 6,455,930, "Integrated heat sinking packages using low temperature co-fired ceramic metal circuit board technology", issued Sep. 24, 2002 to Ponnuswamy, et al and assigned to Lamina Ceramics. U.S. Pat. No. 6,455,930 is incorporated by reference herein. The LTCC-M structure is further described in U.S. Pat. Nos. 5,581,876, 5,725,808, 5,953,203, and 6,518,502, all of which are assigned to Lamina Ceramics and also incorporated by reference herein.

The metal support boards used for LTCC-M technology do have a high thermal conductivity, but some metal boards have a high thermal coefficient of expansion, and thus a bare die cannot always be directly mounted to such metal support boards. However, some metal support boards are known that can be used for such purposes, such as metal composites of copper and molybdenum (including from 10–25% by weight of copper) or copper and tungsten (including 10–25% by weight of copper), made using powder metallurgical techniques. Copper clad Kovar®, a metal alloy of iron, nickel, cobalt and manganese, a trademark of Carpenter Technology, is a very useful support board. AlSiC is another material that can be used for direct attachment, as can aluminum or copper graphite composites.

Another instance wherein good cooling is required is for thermal management of flip chip packaging. FIGS. **14** and **15**, for example show the inventive LED system where the LTCC-M package house LED die. Densely packed microcircuitry, and devices such as decoder/drivers, amplifiers, oscillators and the like which generate large amounts of heat, can also use LTCC-M techniques advantageously. Metallization on the top layers of an integrated circuit bring input/output lines to the edge of the chip so as to be able to wire bond to the package or module that contains the chip. Thus the length of the wirebond wire becomes an issue; too long a wire leads to parasitics. The cost of very high integration chips may be determined by the arrangement of the bond pads, rather than by the area of silicon needed to create the circuitry. Flip chip packaging overcomes at least some of these problems by using solder bumps rather than wirebond pads to make connections. These solder bumps are smaller than wire bond pads and, when the chip is turned upside down, or flipped, solder reflow can be used to attach the chip to the package. Since the solder bumps are small, the chip can contain input/output connections within its interior if multilayer packaging is used. Thus the number of transistors in it, rather than the number and size of bond pads will determine the chip size.

However, increased density and integration of functions on a single chip leads to higher temperatures on the chip, which may prevent full utilization of optimal circuit density. The only heat sinks are the small solder bumps that connect the chip to the package. If this is insufficient, small active or passive heat sinks must be added on top of the flip chip. Such additional heat sinks increase assembly costs, increase the number of parts required, and increase the package costs. Particularly if the heat sinks have a small thermal mass, they have limited effectiveness as well.

In the simplest form of the present invention, LTCC-M technology is used to provide an integrated package for a semiconductor component and accompanying circuitry, wherein the conductive metal support board provides a heat sink for the component. A bare semiconductor die, for example, can be mounted directly onto a metal base of the LTCC-M system having high thermal conductivity to cool the semiconductor component. In such case, the electrical signals to operate the component must be connected to the component from the ceramic. In FIGS. **5**, **6**, and **7**, wire bond **54** serves this purpose. Indirect attachment to the metal support board can also be used. In this package, all of the required components are mounted on a metal support board, incorporating embedded passive components such as conductors and resistors into the multilayer ceramic portion, to connect the various components, i.e., semiconductor components, circuits, heat sink and the like, in an integrated package. The package can be hermetically sealed with a lid.

For a more complex structure having improved heat sinking, the integrated package of the invention combines a first and a second LTCC-M substrate. The first substrate can have mounted thereon a semiconductor device, and a multilayer ceramic circuit board with embedded circuitry for operating the component; the second substrate has a heat sink or conductive heat spreader mounted thereon. Thermoelectric (TEC) plates (Peltier devices) and temperature control circuitry are mounted between the first and second substrates to provide improved temperature control of semiconductor devices. A hermetic enclosure can be adhered to the metal support board.

The use of LTCC-M technology can also utilize the advantages of flip chip packaging together with integrated heat sinking. The packages of the invention can be made smaller, cheaper and more efficient than existing present-day packaging. The metal substrate serves as a heat spreader or heat sink. The flip chip can be mounted directly on the metal substrate, which is an integral part of the package, eliminating the need for additional heat sinking. A flexible circuit can be mounted over the bumps on the flip chip. The use of multilayer ceramic layers can also accomplish a fan-out and routing of traces to the periphery of the package, further improving heat sinking. High power integrated circuits and devices that have high thermal management needs can be used with this new LTCC-M technology.

It is understood that the above-described embodiments are illustrative of only a few of the many possible specific embodiments, which can represent applications of the invention. Numerous and varied other arrangements can be made by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A packaged LED for high temperature operation comprising:

a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;

a layer of ceramic overlying the metal base; and

an LED mounted on the ceramic layer, wherein the LED includes a pair of electrodes electrically connected to respective underlying electrical connection pads, and wherein the LED is thermally coupled to the metal base by one or more thermal vias, and thermally coupled through the metal base to the thermal connection pad.

2. The packaged LED of claim wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.

3. The packaged LED of claim **1** wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a bonding wire from the electrode to a bonding pad on the ceramic layer.

4. The packaged LED of claim **1** wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.

5. The packaged LED of claim **1** wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.

6. An array of LEDs comprising a plurality of LEDs according to claim **1** overlying a common metal base.

7. A packaged LED for high temperature operation comprising:

a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;

a layer of ceramic overlying the metal base; and

an LED having a pair of electrodes overlying the metal base, wherein the LED is thermally coupled through the metal base to the thermal connection pad and at least one electrode is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.

8. The packaged LED of claim **7**, wherein the layer of ceramic includes a cavity and the LED is mounted in the cavity.

9. The packaged LED of claim **8**, wherein the cavity has tapered sides to reflect light from the LED.

10. The packaged LED of claim **7**, wherein the metal base includes a concave region to reflect light and the LED is mounted overlying the concave region.

11. The packaged LED of claim **7**, wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.

12. The packaged LED of claim **7**, wherein the LED is mounted on the ceramic layer overlying the thermal connection pad and the LED is thermally coupled by one or more thermal vias to the metal base overlying the thermal connection pad.

13. The packaged LED of claim **7**, wherein at least one electrode of the LED is connected to one of the underlying

electrical connection pads by an electrical path including a bonding wire from the electrode to a bonding pad on the ceramic layer.

14. The packaged LED of claim **7**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.

15. An array of LEDs comprising a plurality of LEDs according to claim **7** overlying a common metal base.

16. A packaged LED for high temperature operation comprising:

a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;

a layer of electrically insulating material overlying the metal base; and

an LED mounted on the layer of electrically insulating material, wherein the LED includes a pair of electrodes electrically connected to respective underlying electrical connection pads, and wherein the LED is thermally coupled to the metal base by one or more thermal vias, and thermally coupled through the metal base to the thermal connection pad.

17. The packaged LED of claim **16**, wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.

18. The packaged LED of claim **16**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a bonding wire from the electrode to a banding pad on the layer of electrically insulating material.

19. The packaged LED of claim **16**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.

20. The packaged LED of claim **16**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.

21. An array of LEDs comprising a plurality of LEDs according to claim **16** overlying a common metal base.

22. A packaged LED for high temperature operation comprising:

a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;

a layer of electrically insulating material overlying the metal base; and

an LED having a pair of electrodes overlying the metal base, wherein the LED is thermally coupled through the metal base to the thermal connection pad and at least one electrode is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.

23. The packaged LED of claim **22**, wherein the layer of electrically insulating material includes a cavity and the LED is mounted in the cavity.

24. The packaged LED of claim **23**, wherein the cavity has tapered sides to reflect light from the LED.

25. The packaged LED of claim **22**, wherein the metal base includes a concave region to reflect light and the LED is mounted overlying the concave region.

26. The packaged LED of claim **22**, wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.

27. The packaged LED of claim **22**, wherein the LED is mounted on the layer of electrically insulating material overlying the thermal connection pad and the LED is thermally coupled by one or more thermal vias to the metal base overlying the thermal connection pad.

28. The packaged LBD of claim **22**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a

bonding wire from the electrode to a bonding pad on the layer of electrically insulating material.

29. The packaged LED of claim **22**, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.

30. An may of LEDs comprising a plurality of LEDs according to claim **22** overlying a common metal base.

* * * * *

Exhibit 10

U.S. Patent No. 7,095,053
("'053 Patent")

Accused Products

The General Electric ("GE") Infusion (M1000/830/W/N) (97186) ("GE Infusion") LED Module infringes at least Claims 7, 11, 13-14, 22, 26, 28-29 of the '053 Patent.

Claim 7	GE Infusion M1000/830/W/N LED Module
7[Pre]. A packaged LED for high temperature operation comprising:	The GE Infusion LED Module contains several packaged LEDs ("GE Infusion LED Package(s)"), as shown in the optical image below. At least one of the GE Infusion LED Packages meets all recited claim elements, as shown in further detail below. GE Infusion LED Package  Optical Image of GE Infusion LED Module

Claim 7	GE Infusion M1000/830/W/N LED Module
	The remainder of the preamble is not limiting. The GE Infusion LED Package analyzed in this claim chart is a packaged LED for high temperature operation because it meets the structural limitations recited in claim elements 7[a]-7[e], as shown in further detail below. One of the GE Infusion LED Packages, shown in the optical image below, was removed from the GE Infusion LED Module and was analyzed to demonstrate that the relevant limitations of claim 7 and its asserted dependent claims and claim 22 and its asserted dependent claims are met. REDACTED

Claim 7	GE Infusion M1000/830/W/N LED Module
7[a]. a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;	The GE Infusion LED Package contains a metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads, as shown in the optical and x-ray images of the GE Infusion LED Package below. ***"a metal base"*** The [redacted] metal at the bottom of the GE Infusion LED Package, shown in the images below, together constitute the "metal base." T[redacted] REDACTED

Claim 7	GE Infusion M1000/830/W/N LED Module
	REDACTED

Claim 7	GE Infusion M1000/830/W/N LED Module
	"the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads" The three pieces of metal at the bottom of the GE Infusion LED Package, which form the "metal base," include at their bottom-most surface, a thermal connection pad and a pair of electrical connection pads, as labeled and shown in the x-ray and optical images below. Each of these pads is "underlying" the metal base because each is at the bottom-most surface of the metal base. REDACTED REDACTED

Claim 7	GE Infusion M1000/830/W/N LED Module
7[b]. a layer of ceramic overlying the metal base; and	The GE Infusion LED Package contains a layer of ceramic overlying the metal base, as shown in the x-ray image of the product below. ***"a layer of ceramic"*** As shown in the x-ray of the GE Infusion LED Package below, the product contains a layer of ceramic. [redacted]. **REDACTED** ***"overlying the metal base"*** The ceramic layer identified in the x-ray above is overlying the metal base [redacted]

Claim 7	GE Infusion M1000/830/W/N LED Module
7[c]. an LED having a pair of electrodes overlying the metal base,	The LED in the GE Infusion LED Package includes a pair of electrodes overlying the metal base. ***"pair of electrodes"*** As shown in the x-ray of the GE Infusion LED Package below, the LED die includes two electrodes: [redacted] REDACTED ***"overlying the metal base"*** As shown in the x-ray of the GE Infusion LED Package above, the pair of electrodes are overlying the metal base [redacted]

Claim 7	GE Infusion M1000/830/W/N LED Module
7[d]. wherein the LED is thermally coupled through the metal base to the thermal connection pad	The LED in the GE Infusion LED Package is thermally coupled through the metal base to the thermal connection pad. As shown below in the x-ray of the GE Infusion LED Package, the LED die is thermally coupled through the metal base to the thermal connection surface [redacted]. [redacted] [redacted] the LED die is thermally coupled through the metal base to the thermal connection surface. REDACTED

Claim 7	GE Infusion M1000/830/W/N LED Module
7[e]. and at least one electrode is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.	In the GE Infusion LED Package, at least one electrode of the LED is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base. ***"at least one electrode is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via"*** As shown in the x-rays of the GE Infusion LED Package below, the electrical path that connects the electrode to the metal base includes an insulated conducting via. [redacted] **REDACTED** ***"through the metal base"*** As shown in the x-rays of the GE Infusion LED Package above, the electrical path (including insulated conducting vias) that connects the LED die to the electrical connection pad runs through the metal base. [redacted]

Claim 11	GE Infusion M1000/830/W/N LED Module
11. The packaged LED of claim 7, wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.	The underlying electrical connection pads and the underlying thermal connection pad in the GE Infusion LED Package are coplanar to permit surface mounting on corresponding pads of a PC board, as shown in the x-ray, optical image, and excerpted figure below. REDACTED REDACTED

Claim 13	GE Infusion M1000/830/W/N LED Module
13. The packaged LED of claim 7, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a bonding wire from the electrode to a bonding pad on the layer of electrically insulating material.	In the GE Infusion LED Package, at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a bonding wire from the electrode to the bonding pad on the ceramic layer. REDACTED

Claim 13	GE Infusion M1000/830/W/N LED Module
	REDACTED

Claim 14	GE Infusion M1000/830/W/N LED Module
14. The packaged LED of claim 7, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.	In the GE Infusion LED Package, at least one electrode of the LED is connected to one of the underlying connection pads by an electrical path including the metal base. [redacted] REDACTED

Claim 22	GE Infusion M1000/830/W/N LED Module
22[Pre] A packaged LED for high temperature operation comprising:	The GE Infusion LED Module contains one or more packaged LEDs as shown above under claim 1[pre]. The remainder of the preamble is not limiting. The GE Infusion LED Package analyzed in this claim is a packaged LED for high temperature operation because it meets the structural limitations recited in claim elements 22[a]-22[e], as shown in further detail below.
22[a] a metal base, the metal base including an underlying thermal connection pad and a pair of underlying electrical connection pads;	See evidence and analysis for claim limitation 7[a], above.
22[b] a layer of electrically insulating material overlying the metal base; and	See evidence and analysis for claim limitation 7[b], above. Claim limitation 7[b] shows that the GE Infusion LED Package contains a ceramic layer overlying the metal base. This ceramic material is electrically insulating. [redacted]
22[c] an LED having a pair of electrodes overlying the metal base,	See evidence and analysis for claim limitation 7[c], above.
22[d] wherein the LED is thermally coupled through the metal base to the thermal connection pad and	See evidence and analysis for claim limitation 7[d], above.

Claim 22	GE Infusion M1000/830/W/N LED Module
22[e] at least one electrode is electrically connected to at least one of the underlying electrical connection pads by an electrical path including an insulated conducting via through the metal base.	See evidence and analysis for claim limitation 7[e], above.

Claim 26	GE Infusion M1000/830/W/N LED Module
26. The packaged LED of claim 22, wherein the underlying electrical connection pads and the underlying thermal connection pad are coplanar to permit surface mounting on corresponding pads of a PC board.	See evidence and analysis for claim 11, above.

Claim 28	GE Infusion M1000/830/W/N LED Module
28. The packaged LED of claim 22, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including a bonding wire from the electrode to a bonding pad on the layer of electrically insulating material.	See evidence and analysis for claim 13, above.

Claim 29	GE Infusion M1000/830/W/N LED Module
29. The packaged LED of claim 22, wherein at least one electrode of the LED is connected to one of the underlying electrical connection pads by an electrical path including the metal base.	See evidence and analysis for claim 14, above.

Exhibit 11

U.S. Patent No. 7,528,421
("'421 Patent")

Accused Products

The GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857) ("GE Bright Stik™ LED Bulb") infringes at least Claims 1-2, 6 and 10 of the '421 Patent.

Claim 1	**GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)**
1[pre]. A LED assembly adapted for surface mounting and high temperature operation, the LED assembly comprising:	The GE Bright Stik™ LED Bulb is a luminaire that contains an LED assembly adapted for surface mounting and high temperature operation. An image of the GE Bright Stik™ LED Bulb (and its retail packaging) is shown below.  GE Bright Stik™ LED Bulb Packaging

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	The GE Bright Stik™ LED Bulb contains at least one LED assembly. As shown in the below image of the GE Bright Stik™ LED Bulb, [redacted] [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	One of the GE Bright Stik™ LED [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	The GE Bright Stik™ LED [redacted] is an LED assembly adapted for surface mounting, [redacted] [redacted] The remainder of the preamble is not limiting. [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[a]. a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar;	[redacted] includes a thermally conducting base, wherein at least a portion of the thermally conducting base is substantially planar. ***"a thermally conducting base"*** [redacted] includes a thermally conducting base, [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	"at least a portion of the thermally conducting base is substantially planar" [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[b]. one or more electrically insulating layers overlying at least a portion of the planar portion of the thermally conducting base and defining a surface cavity,	***"one or more electrically insulating layers"*** [redacted] includes one or more electrically insulating layers, as shown below in the images of the product. [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	[redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	[redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	"overlying at least a portion of the planar portion of the thermally conducting base" The electrically insulating layer [redacted] overlies at least a portion of the planar portion of the thermally conductive base, as shown in the images below. [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	"one or more electrically insulating layers . . . defining a surface cavity" The electrically insulating layer defines a surface cavity, as shown below. [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	[redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[c]. wherein the electrically insulating layers include one or more terminals;	The electrically insulating layer [redacted] identified above under claim limitation 1[b] includes one or more terminals. The electrically insulating layer includes a terminal, [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[d]. one or more LED die disposed at least partially within the surface cavity,	[redacted] includes one or more LED die disposed at least partially within the surface cavity [redacted] [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[e]. wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base, and electrically connected to the one or more terminals of the one or more insulating layers,	***"wherein the one or more LED die are in thermal contact with the planar portion of the thermally conducting base"*** [redacted] includes one or more LED die that are in thermal contact with the planar portion of the thermally conducting base. As shown in the below images of the product, [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	"wherein the one or more LED die are . . . electrically connected to the one or more terminals of the one or more insulating layers" [redacted] includes one or more LED die that are electrically connected to one or more terminals of the insulating layer. As shown in the images below, [redacted] [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[f]. wherein a bottom surface of the LED assembly includes a thermally conductive region in solderable thermal contact with the thermally conducting base, for spreading heat transmitted to the base from the one or more LED die; and	***"wherein a bottom surface of the LED assembly includes a thermally conductive region in solderable thermal contact with the thermally conducting base"*** [redacted] contains a bottom surface that includes a thermally conductive region in solderable thermal contact with the thermally conducting base. As shown in the images below, [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	"for spreading heat transmitted to the base from the one or more LED die" [redacted] for spreading heat transmitted to the base from the LED die. For example, [redacted]

Claim 1	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
1[g]. further comprising an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad.	[redacted] further includes an LED assembly mount selected from the group consisting of an electrically insulated fastener and a solderable bonding pad. In particular, [redacted] [redacted]

Claim 2	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
2. The LED assembly of claim 1, wherein the thermally conductive region is an integral part of the thermally conducting base.	[redacted] includes a thermally conductive region that is an integral part of the thermally conducting base. As shown below, [redacted]

Claim 2	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
	[redacted]

Claim 6	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
6. The LED assembly of claim 1, wherein the thermally conducting base includes a metal base.	[redacted] includes a thermally conducting base that includes a metal base, as shown below. [redacted]

Claim 10	GE Bright Stik™ 15W (100W Replacement) Non-Dimmable LED Light Bulb (Soft White) (63857)
10. The LED assembly of claim 1, wherein the one or more LED die are at least partially encapsulated within the cavity.	[redacted] includes one or more LED die that are at least partially encapsulated within the cavity. For example, as shown in the images below, [redacted]

Exhibit 12

U.S. Patent No. 8,506,118
("'118 Patent")

Accused Products

The GE Tetra® MAX LED Lighting System (GEMX2471-W1)[1] ("Tetra Stick") infringes at least claim 15 of the '118 Patent.

Claim 15	GE Tetra® MAX LED Lighting System (GEMX2471-W1)
15. A light fixture comprising:	The preamble is not a limitation. To the extent the preamble is construed as a limitation, the Tetra Stick is a light fixture. [redacted]

[redacted]

Claim 15	GE Tetra® MAX LED Lighting System (GEMX2471-W1)
15[a] a housing comprising a base and a top; and	The Tetra Stick is a light fixture containing a housing with a base and a top. The housing of the Tetra Stick is identified in the image below [redacted] The top and base of the housing within the Tetra Stick is shown in the image below: [redacted]

Claim 15	GE Tetra® MAX LED Lighting System (GEMX2471-W1)
15[b] a light emitting diode (LED) light emission module disposed within the housing, the light emission module comprising:	The Tetra Stick includes a light emitting diode (LED) emission module disposed within the housing. An image showing the light emission module of the Tetra Stick is provided below. [redacted]
15[c] a plurality of LEDs;	The LED emission modules of the Tetra Stick include a plurality of LEDs. For example, [redacted]

Claim 15	GE Tetra® MAX LED Lighting System (GEMX2471-W1)
15[d] a platform having a first side oriented towards the plurality of LEDs, and a second side oriented away from the plurality of LEDs; and	The LED light emission module of the Tetra Stick includes a platform having a first side oriented towards the plurality of LEDs, and a second side oriented away from the plurality of LEDs. [redacted]

Claim 15	GE Tetra® MAX LED Lighting System (GEMX2471-W1)
15[e] a plurality of convex lenses disposed on the second side, wherein each of the plurality of convex lenses is associated with one of the plurality of LEDs.	A plurality of convex lenses are disposed on the second side of the platforms of the light emission modules of the Tetra Stick. [redacted] [redacted]

Exhibit 13

U.S. Patent No. 8,674,608
("'608 Patent")

Accused Products

One or more luminaires containing a Daintree Wireless embedded sensor in conjunction with the Daintree EZ Connect App for mobile devices (e.g., Android and iOS) (collectively the "Daintree EZ Connect System")[1] infringes at least claims 20-21, 24, 28, and 37 of the '608 Patent.

Claim 20	Daintree EZ Connect System
20. A system for controlling a luminaire comprising:	The preamble is not a limitation. To the extent the preamble is construed as a limitation, the Daintree EZ Connect System is a system for controlling luminaires. [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
20[a] a controller including a processor and memory to analyze data and to control a light source to emit light;	The Daintree EZ Connect System includes a controller including a processor and memory to analyze data and to control a light source to emit light. The Daintree EZ Connect System uses a controller [redacted] [redacted] [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
20[b] an interface that is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface;	The Daintree EZ Connect System includes an interface that is manipulable to cause a signal to be sent to the controller, wherein the signal relates to a state of the interface. Specifically, [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
	[redacted]

[redacted]

Claim 20	Daintree EZ Connect System
20[c] sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis;	The Daintree EZ Connect System includes sensors in communication with the controller to detect a condition in the environment and generate the data relating to the condition, the data being transmittable to the controller for analysis. The Daintree EZ Connect System [redacted] [redacted] [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
	[redacted] ***"sensors in communication with the controller . . . the data being transmittable to the controller for analysis"*** The sensors, [redacted] are in communication with the controller and transmit the [redacted] data generated to the controller for analysis. [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
20[d] rules definable to affect operation of the light source, the rules being stored in the memory to be comparable with the data, the rules being definable using the interface;	The Daintree EZ Connect System uses rules definable to affect operation of light sources, the rules being stored in memory to be comparable with the data [redacted] ***"rules definable to affect operation of the light source . . . the rules being definable using the interface"*** Rules in the Daintree EZ Connect System are definable to affect the operation of the light source using at least [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
	[redacted]

[redacted]

Claim 20	Daintree EZ Connect System
	"the rules being stored in the memory to be comparable with the data" The rules in the Daintree EZ Connect System are stored in the memory to be comparable with the data. The rules are stored in the memory of [redacted] [redacted]

[redacted]

Claim 20	Daintree EZ Connect System
20[e] wherein the light source is operable in a plurality of modes defined by the rules, at least one of the plurality of modes being selectable and definable using the interface.	The Daintree EZ Connect System includes light sources operable in a plurality of modes defined by the rules, at least one of the plurality of modes being selected and definable using the interface. For example, the Daintree EZ Connect System includes [redacted] [redacted] At least one of the plurality of modes is selectable and definable using the interface. For example, [redacted]

[redacted]

Claim 21	Daintree EZ Connect System
21. A system according to claim 20 wherein the sensors include a motion detector in communication with the controller to detect motion in the environment as the condition, wherein the motion detector transmits the data to the controller relating to the motion that is detected.	The Daintree EZ Connect System includes a motion detector in communication with the controller to detect motion in the environment as the condition, wherein the motion detector transmits the data to the controller relating to the motion that is detected. The sensors [redacted]

[redacted]

Claim 21	Daintree EZ Connect System
	"wherein the motion detector transmits the data to the controller relating to the motion that is detected" The motion detector is [redacted] [redacted]

[redacted]

Claim 24	Daintree EZ Connect System
24. A system according to claim 20 further comprising a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller.	The Daintree EZ Connect System includes a timer in communication with the controller, wherein the timer transmits data to the controller relating to an amount of time elapsed relating to an event definable by the rules, the timer being includable in the controller. For example, [redacted]

[redacted]

Claim 28	Daintree EZ Connect System
28. A system according to claim 20 wherein the light source is a light emitting semiconductor device.	The Daintree EZ Connect System includes a light source that is a light emitting semiconductor device. A [redacted]

[redacted]

Claim 28	Daintree EZ Connect System
	[redacted]

[redacted]

Claim 28	Daintree EZ Connect System
	[redacted]

[redacted]

Claim 37	Daintree EZ Connect System
37. A system according to claim 20 wherein the light source is operable by dimming the light source or moving the light source between an on position and an off position.	The Daintree EZ Connect System allows the light source to be operable by dimming the light or moving the light source between an on position and an off position. For example, [redacted] [redacted]

[redacted]