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(54) **CURING LIGHT**

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(60) Provisional application No. 60/304,324, filed on Jul. 10, 2001.

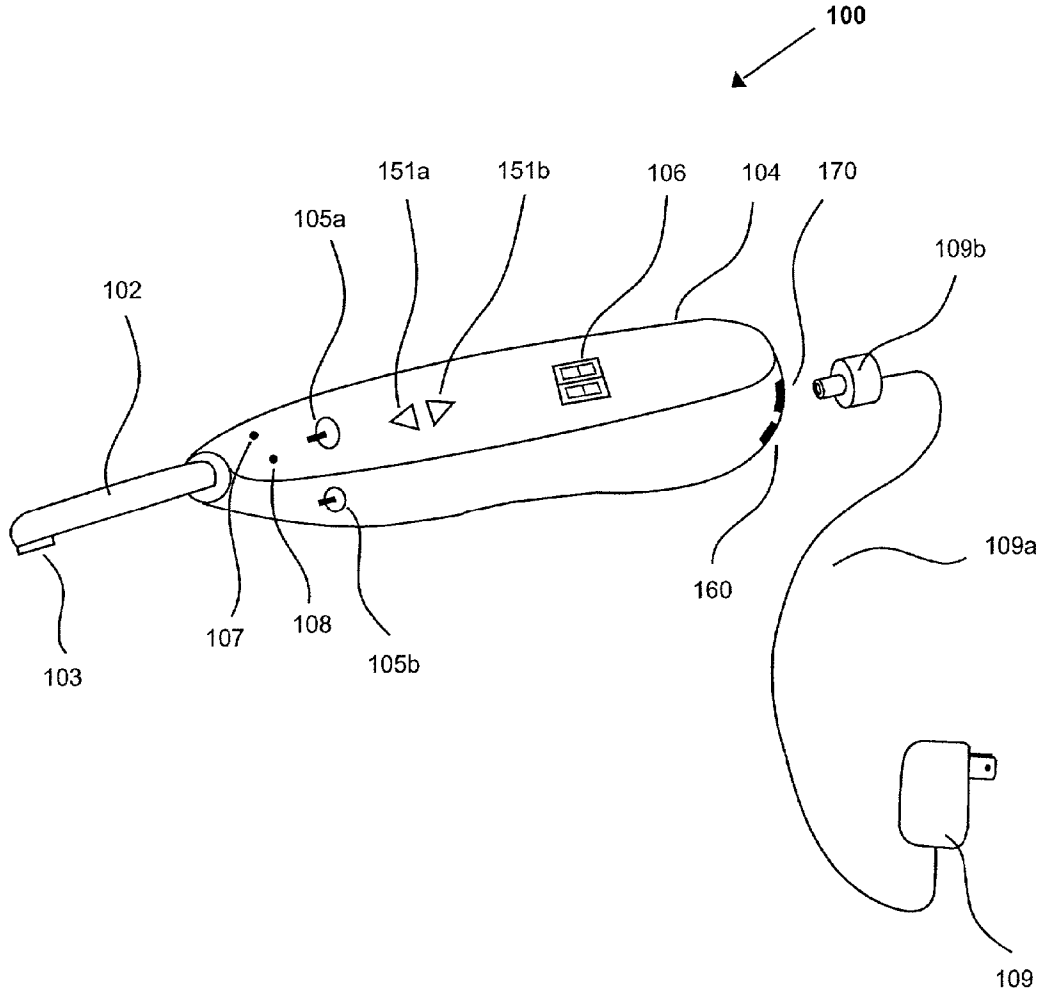
Publication Classification

(51) **Int. Cl.**[7] **H05B 37/02**

(52) **U.S. Cl.** **315/291**; 315/76

(57) **ABSTRACT**

A curing light system useful for curing light activated composite materials is disclosed. Various configurations of light emitting semiconductor chips and heat sinks are disclosed, as well as various structures and methods for driving, controlling and using them.



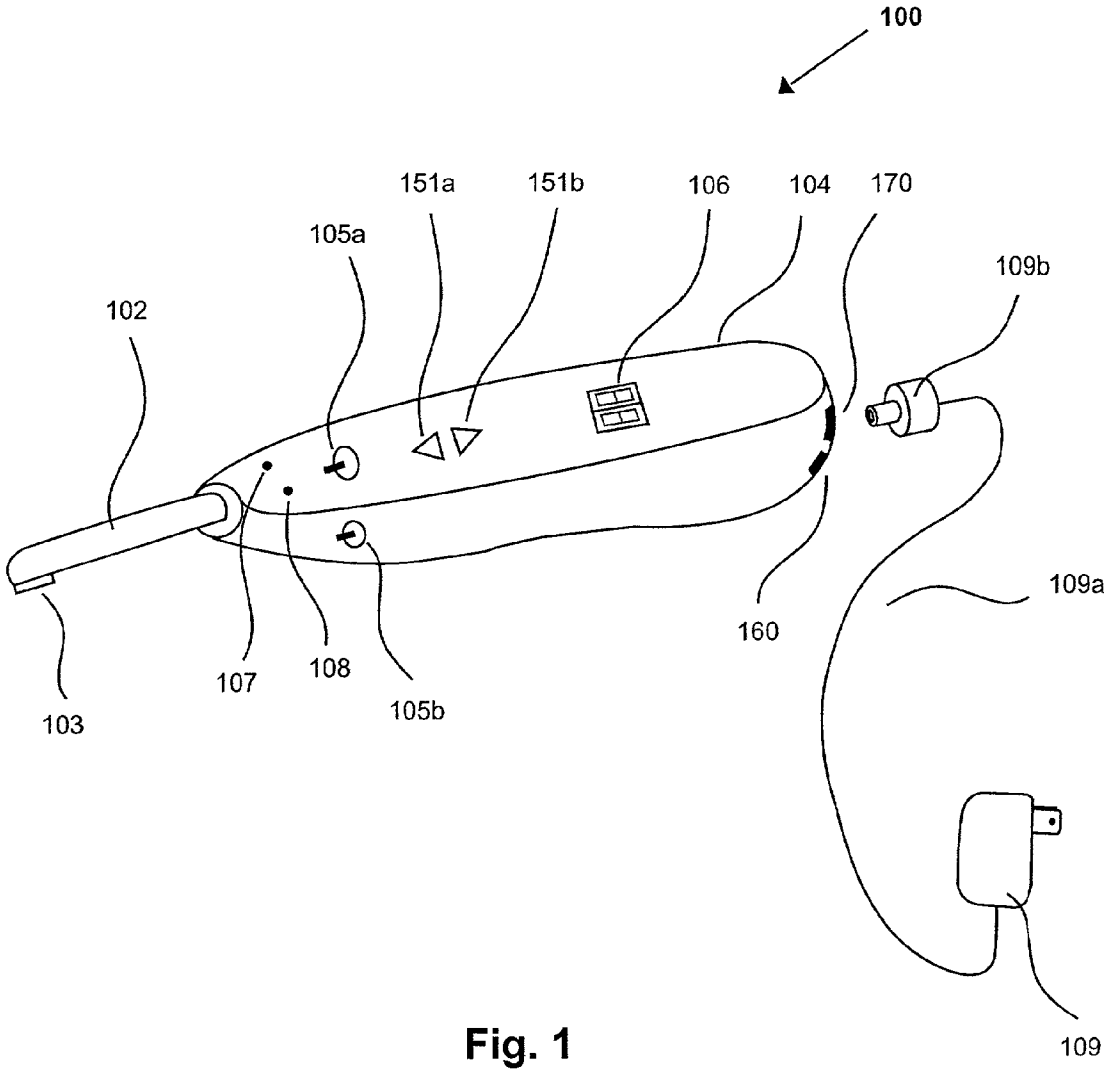

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Fig. 1

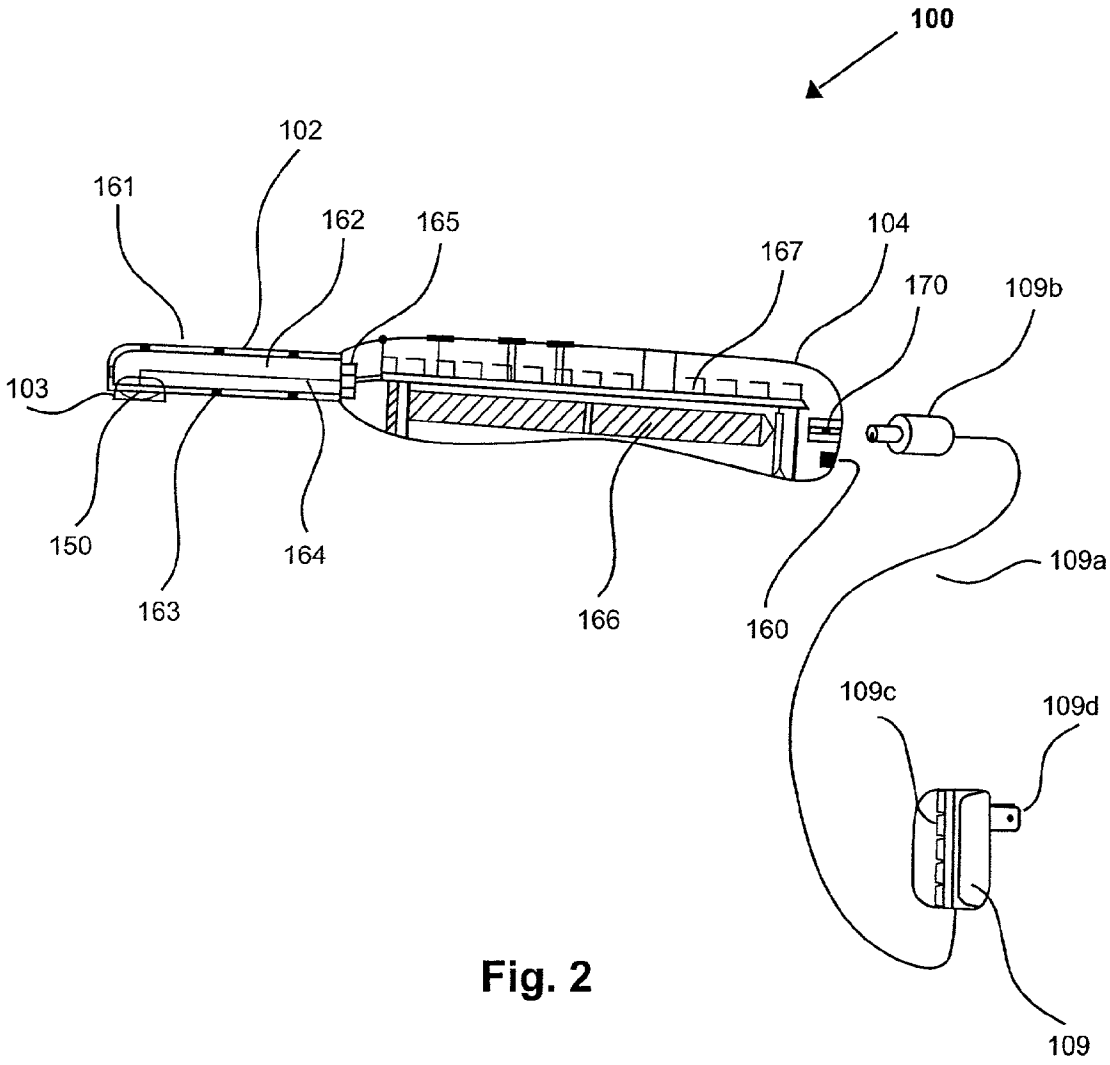

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Fig. 2

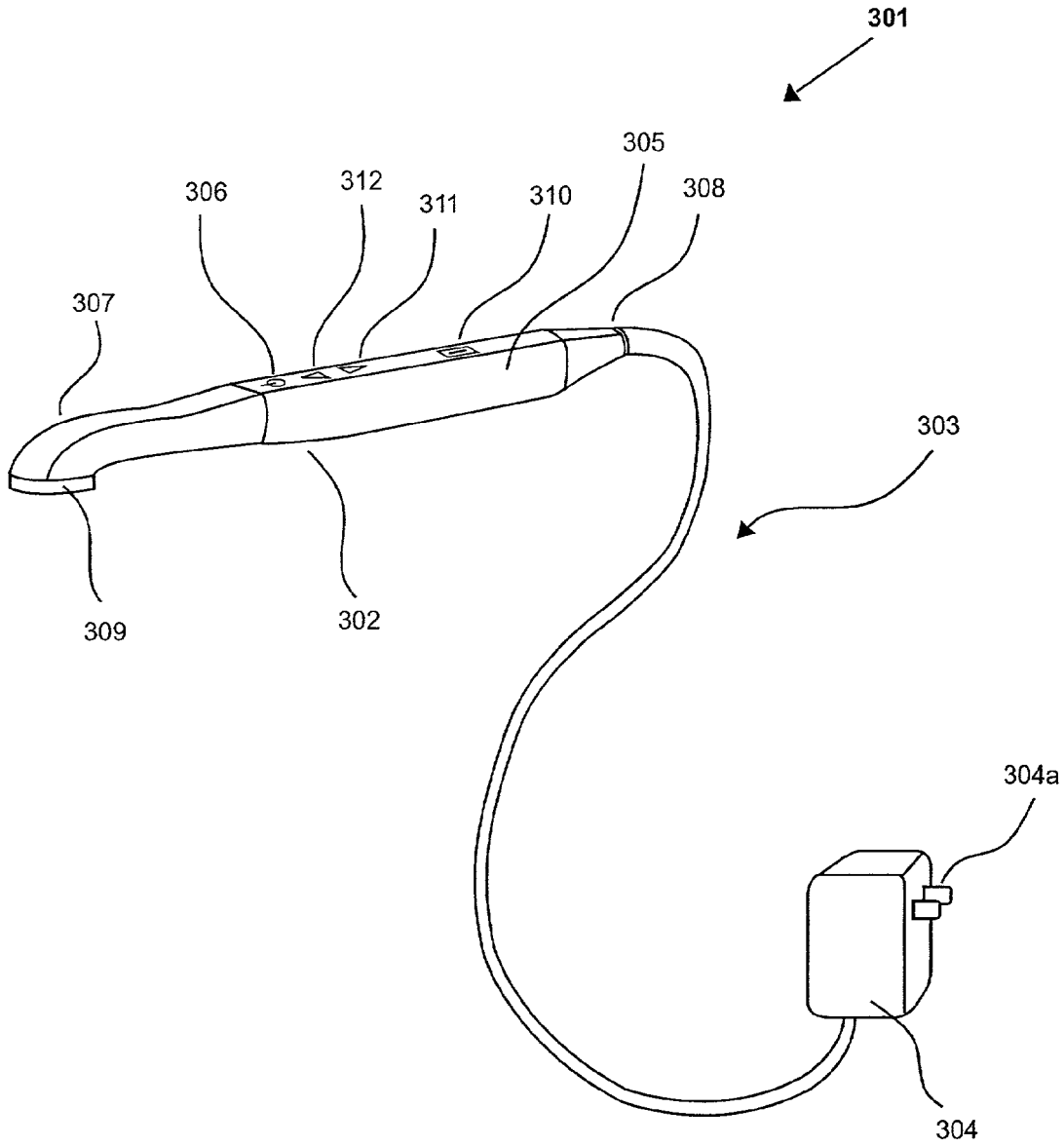


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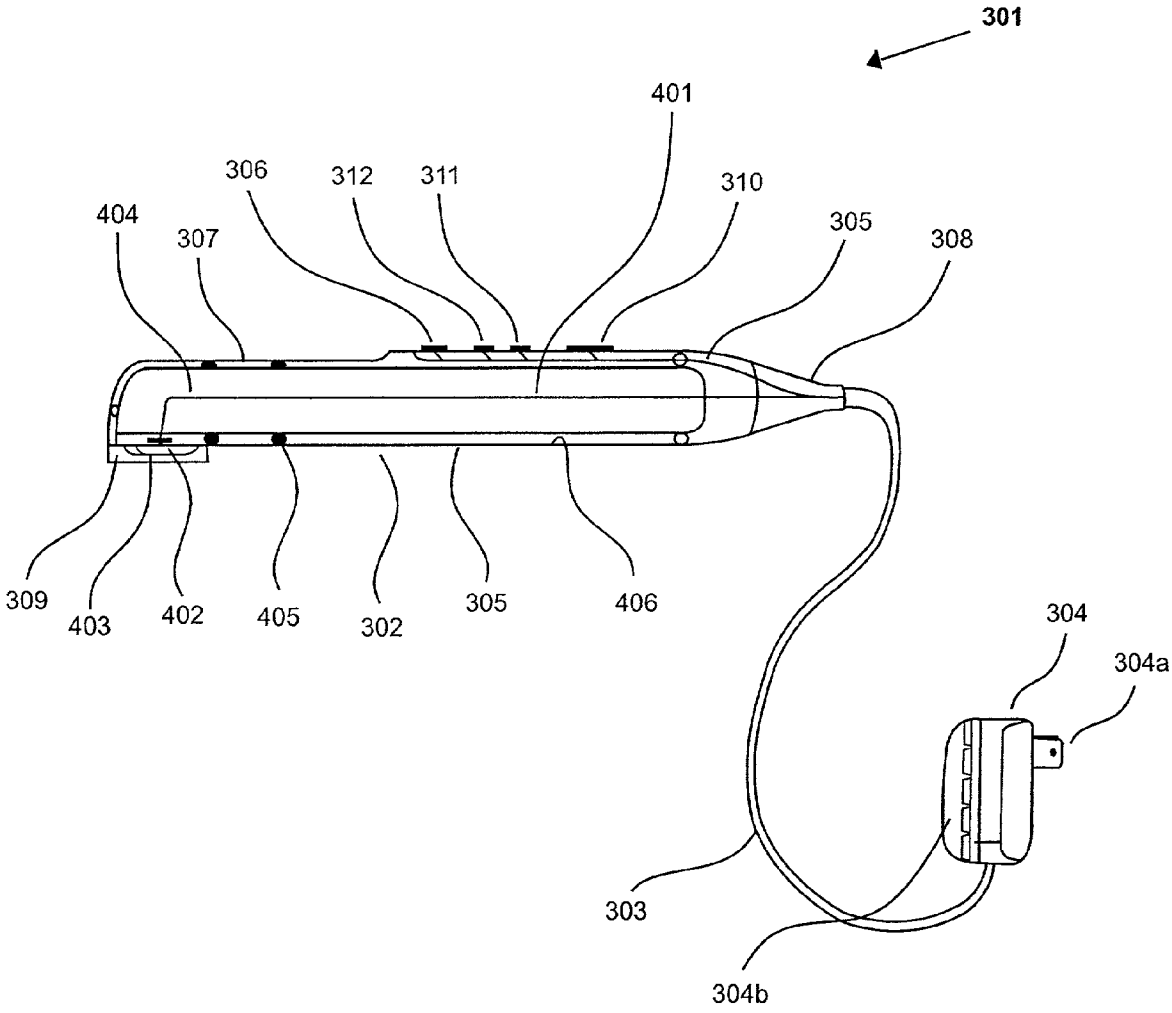

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Fig. 4

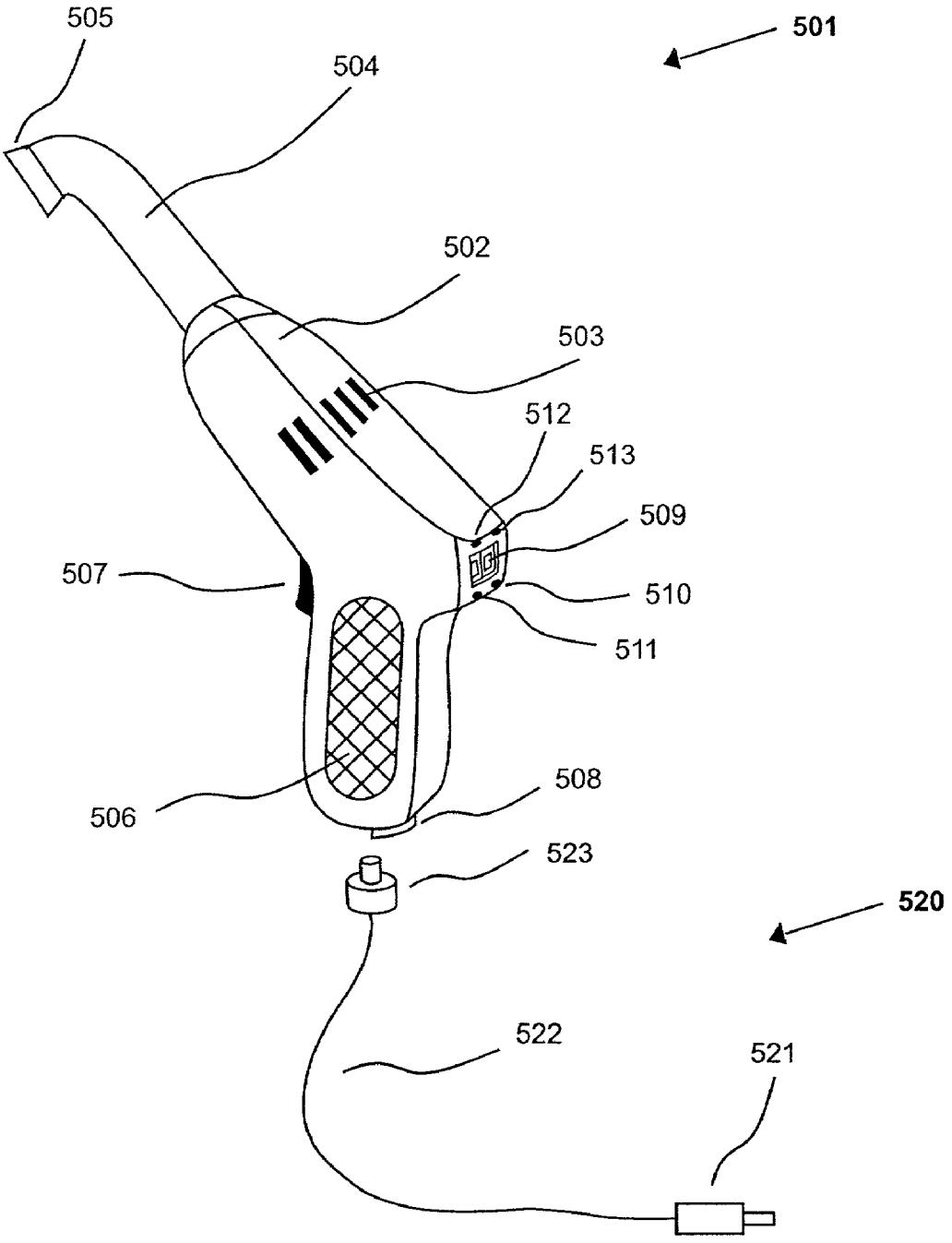

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Fig. 5

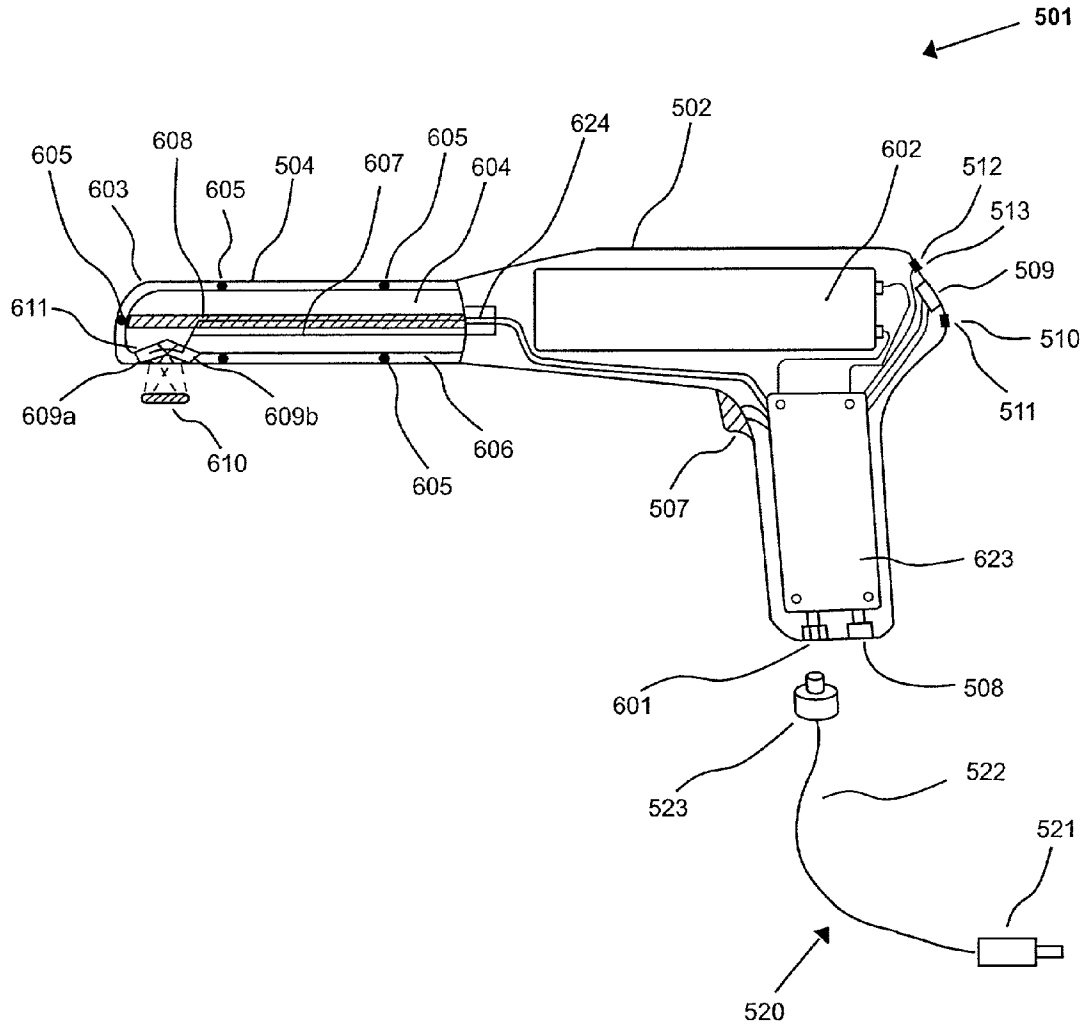

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Fig. 6

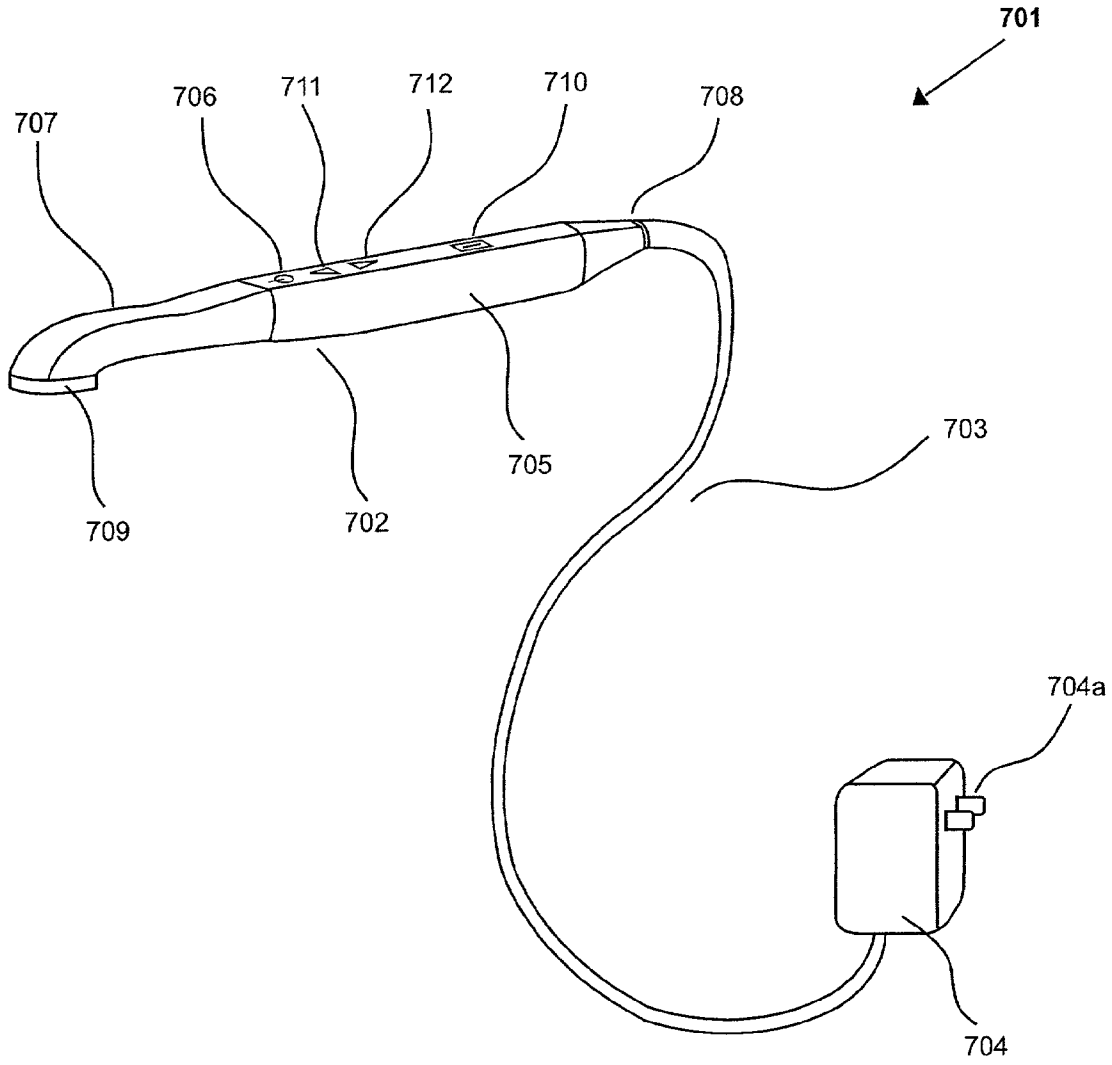


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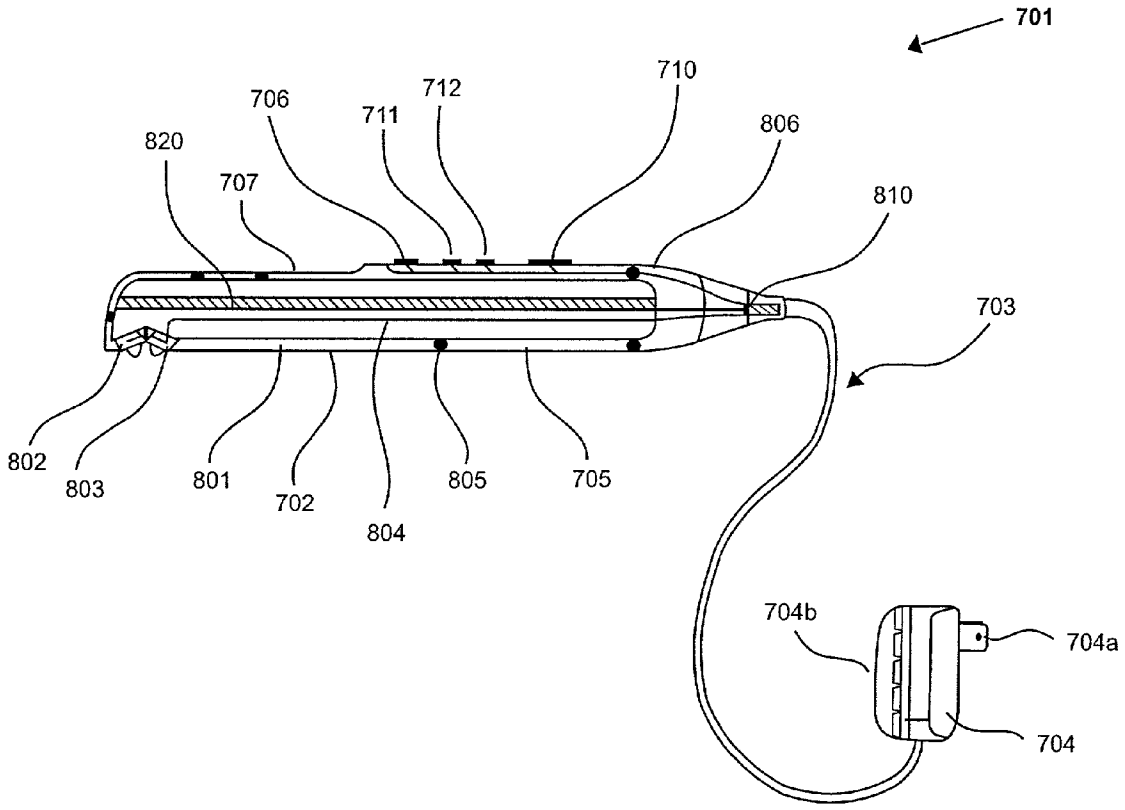

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Fig. 8

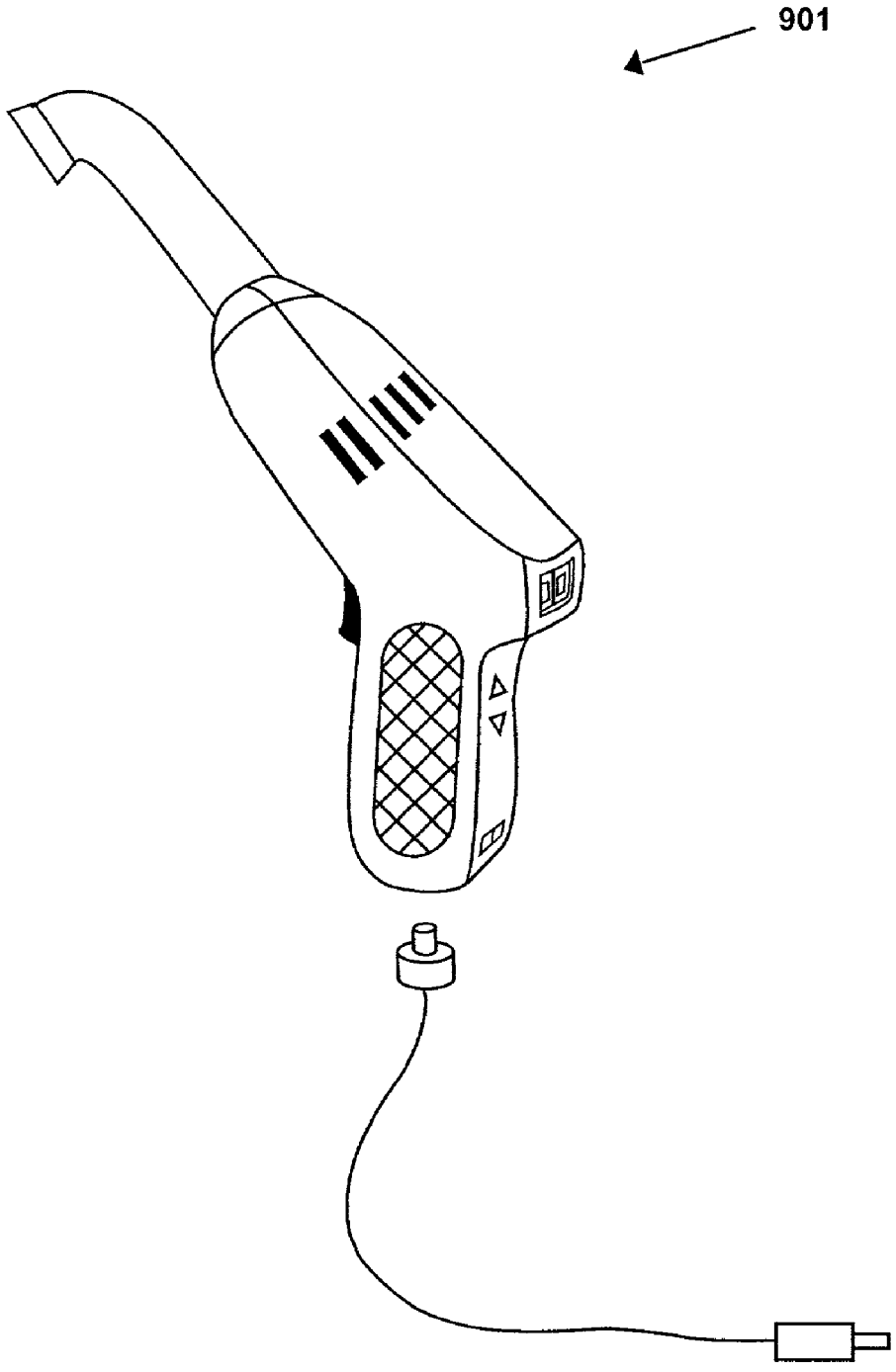


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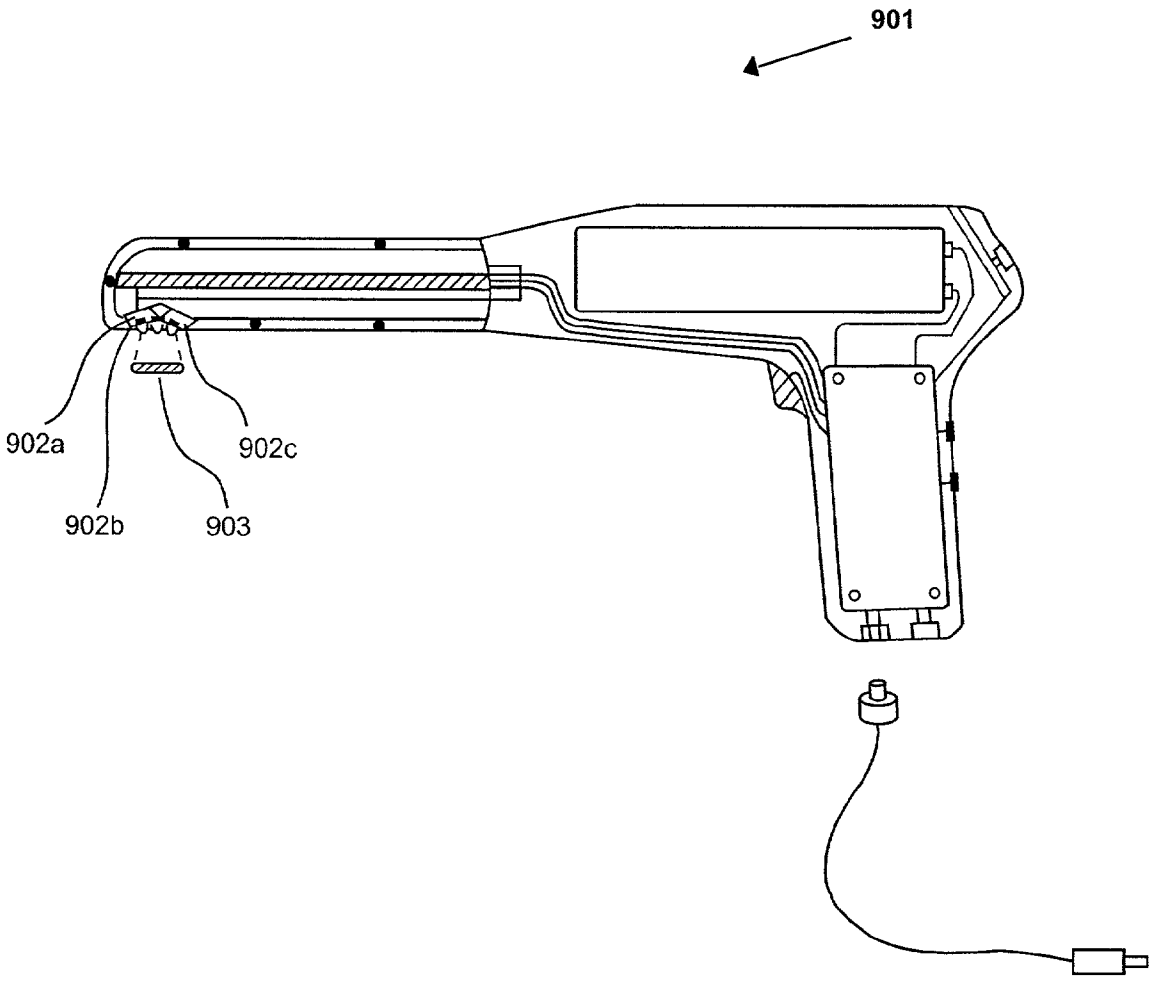


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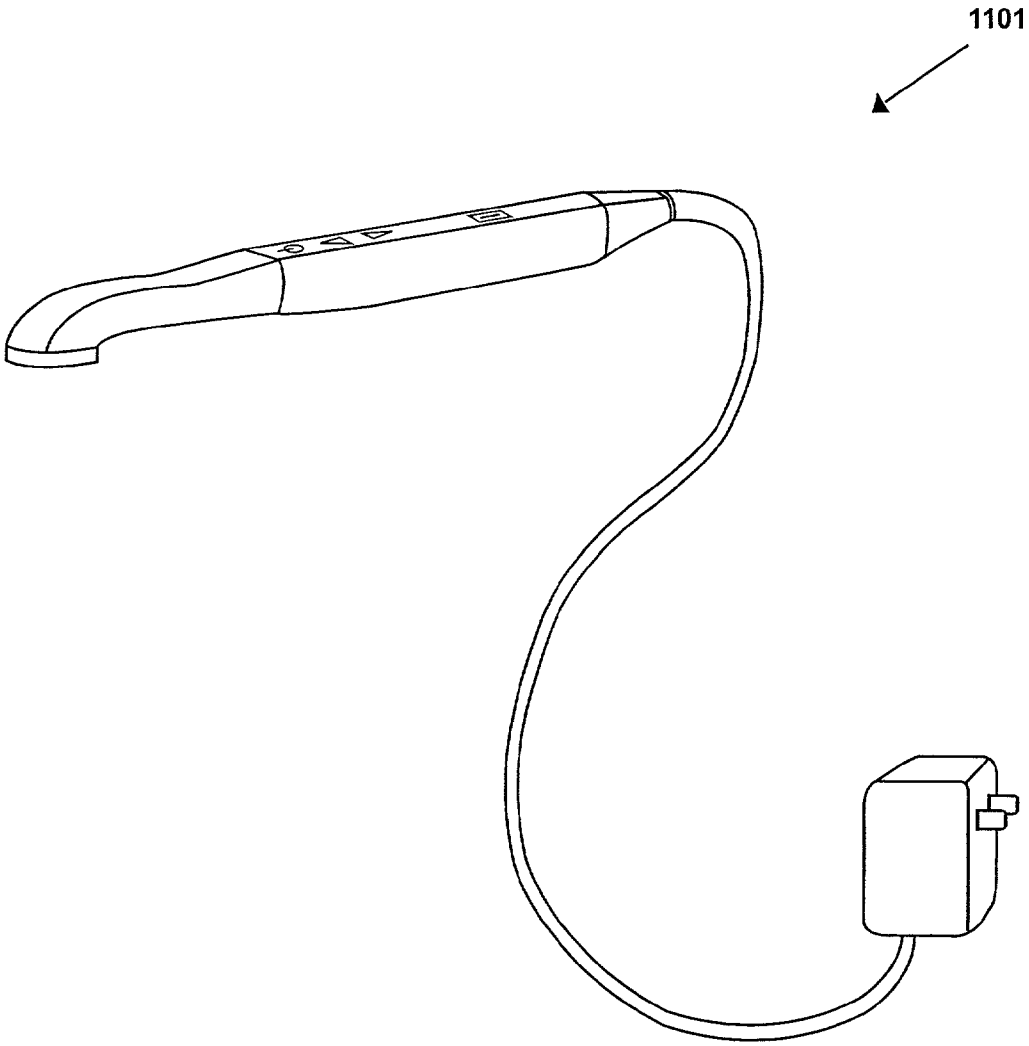


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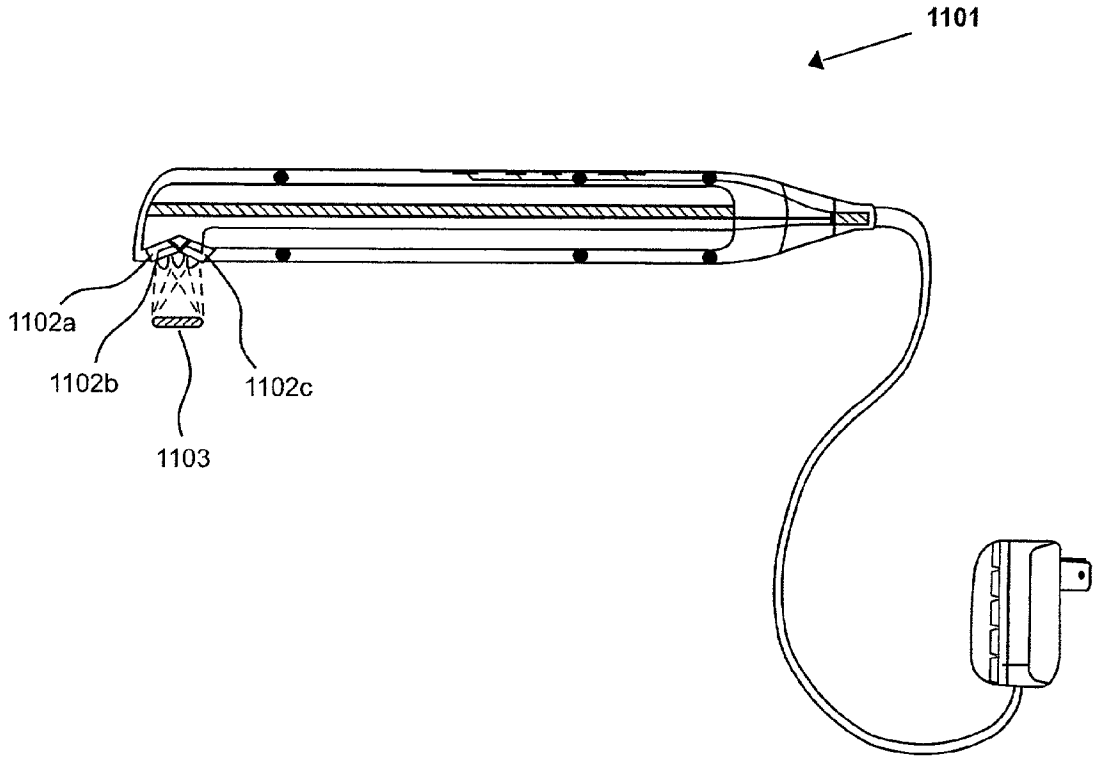


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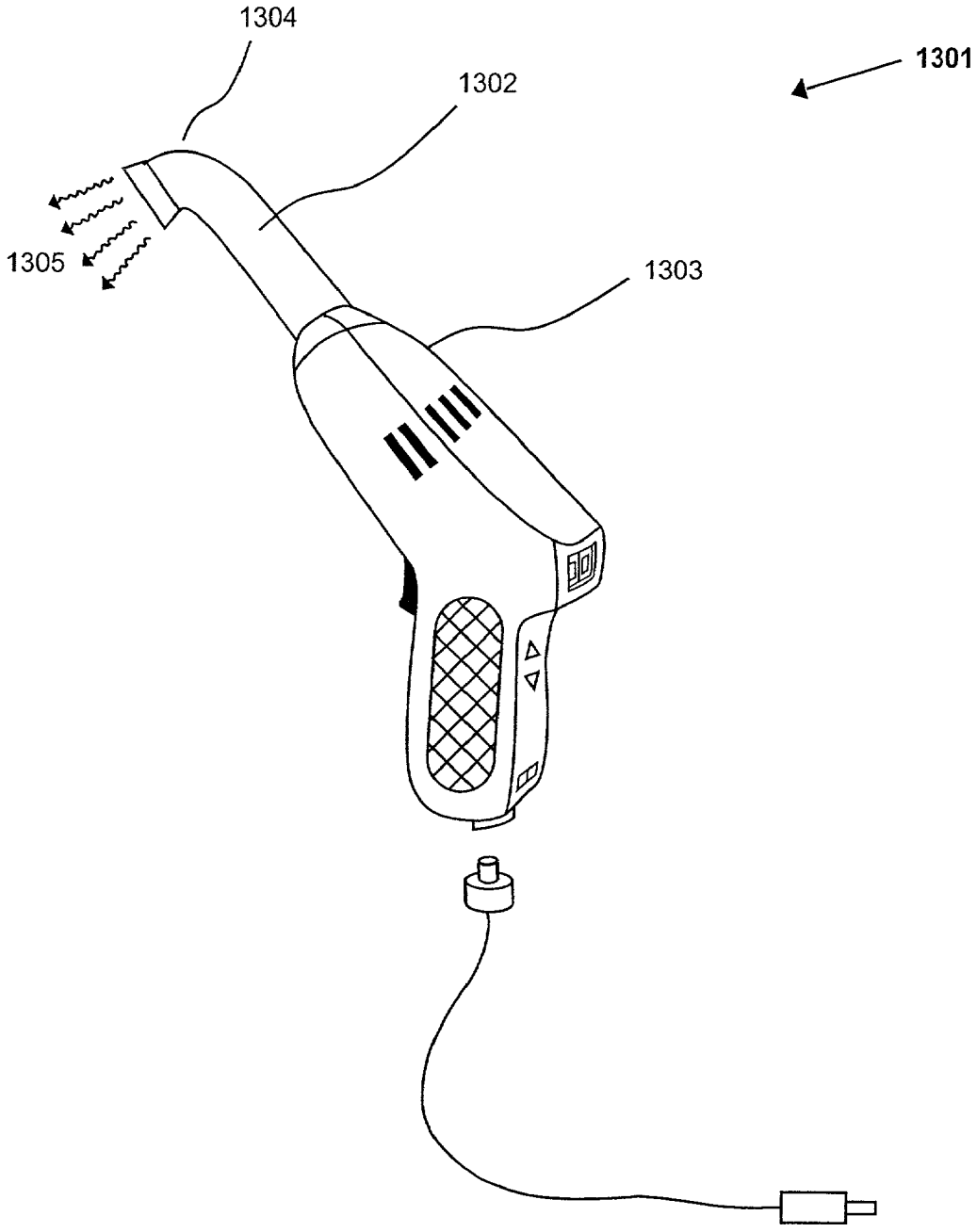


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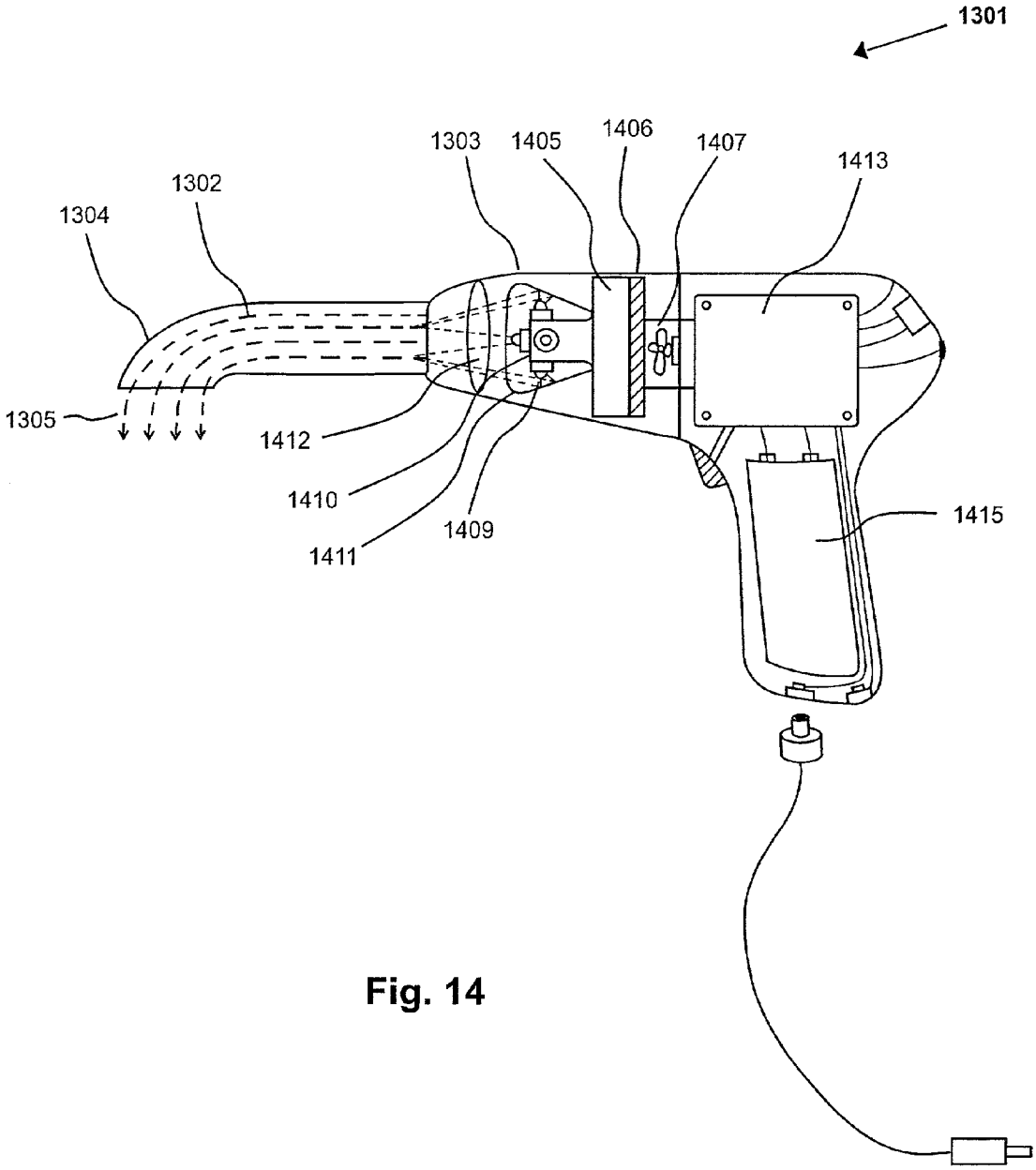

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Fig. 14

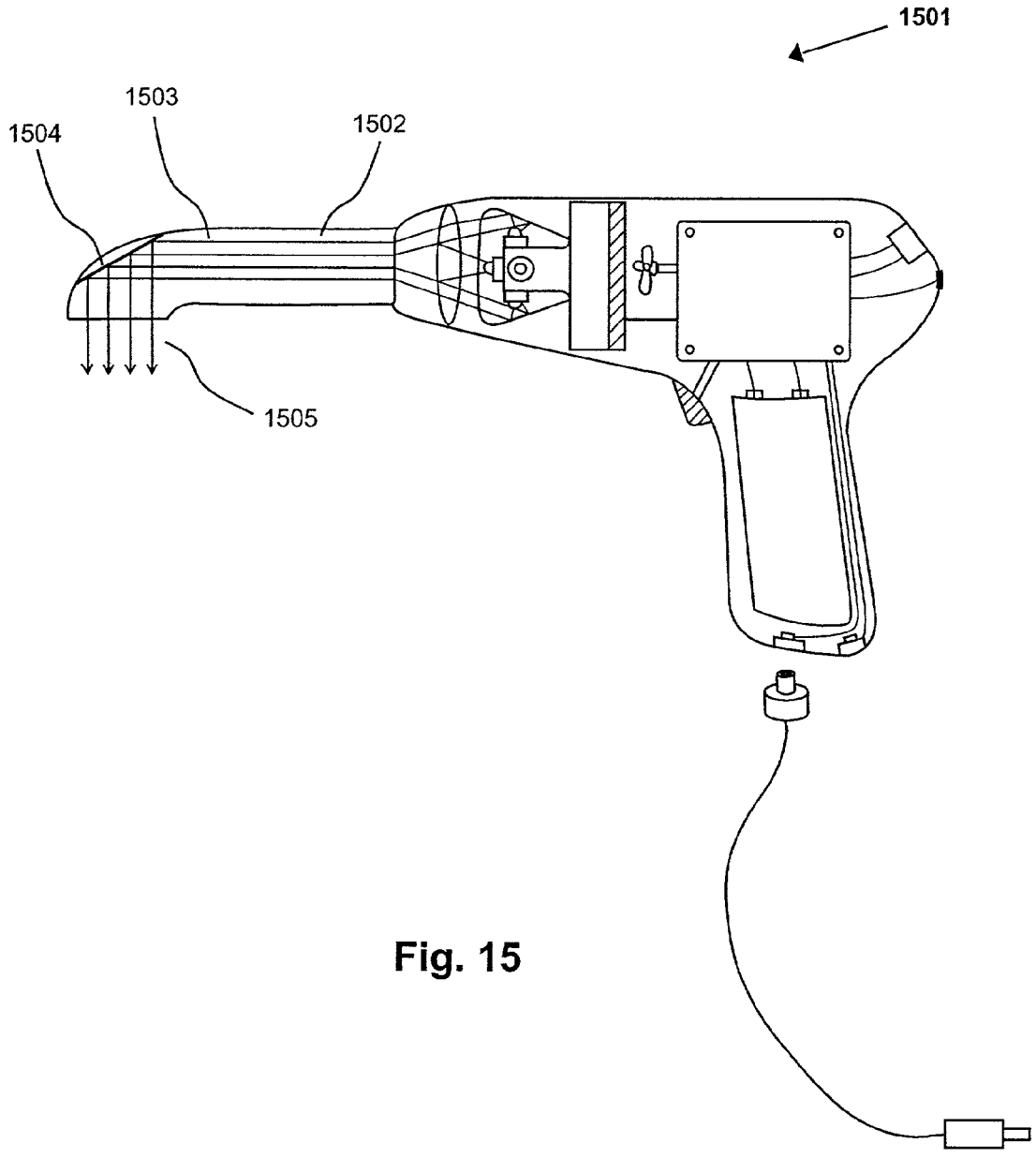


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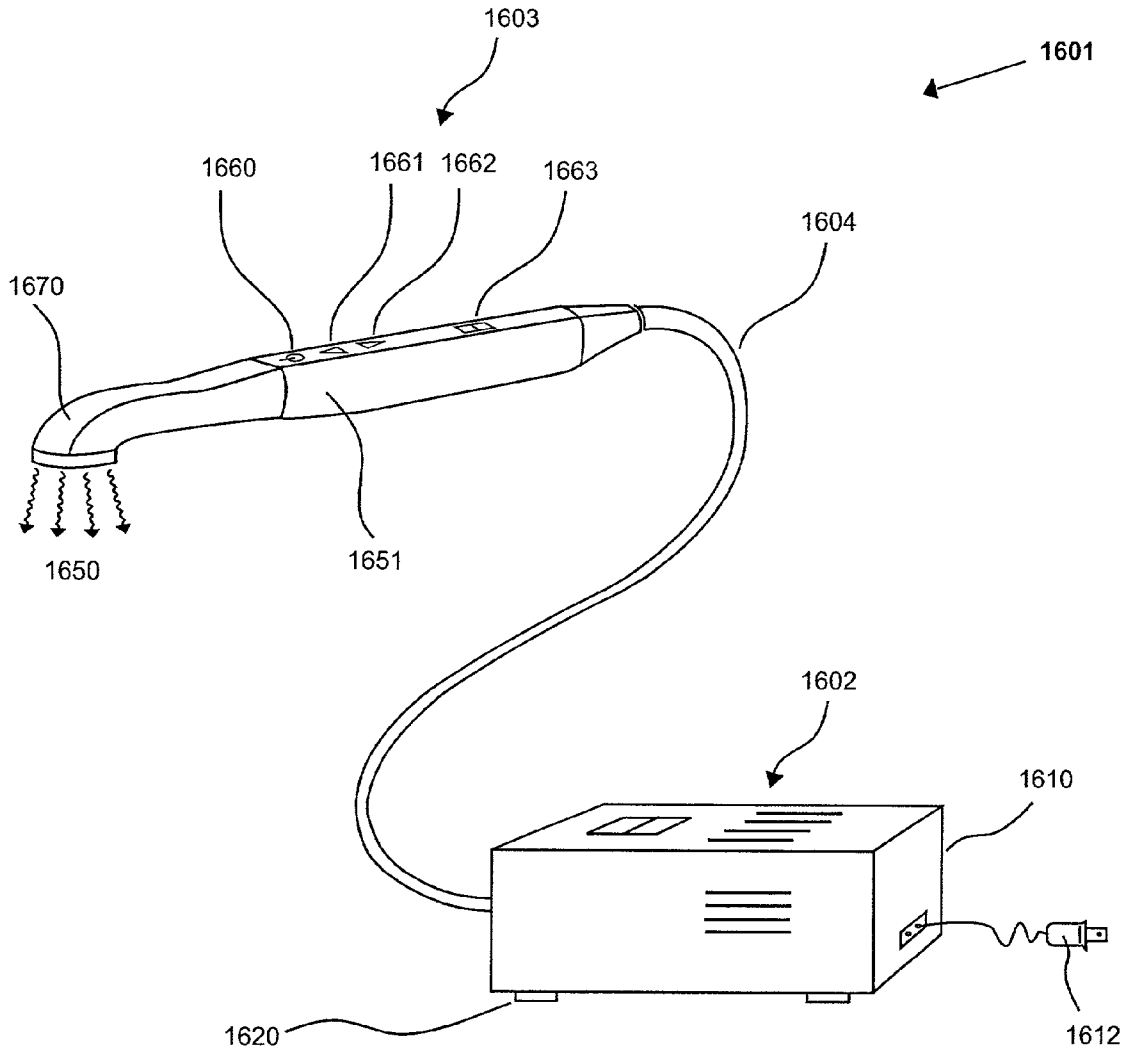

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Fig. 16a

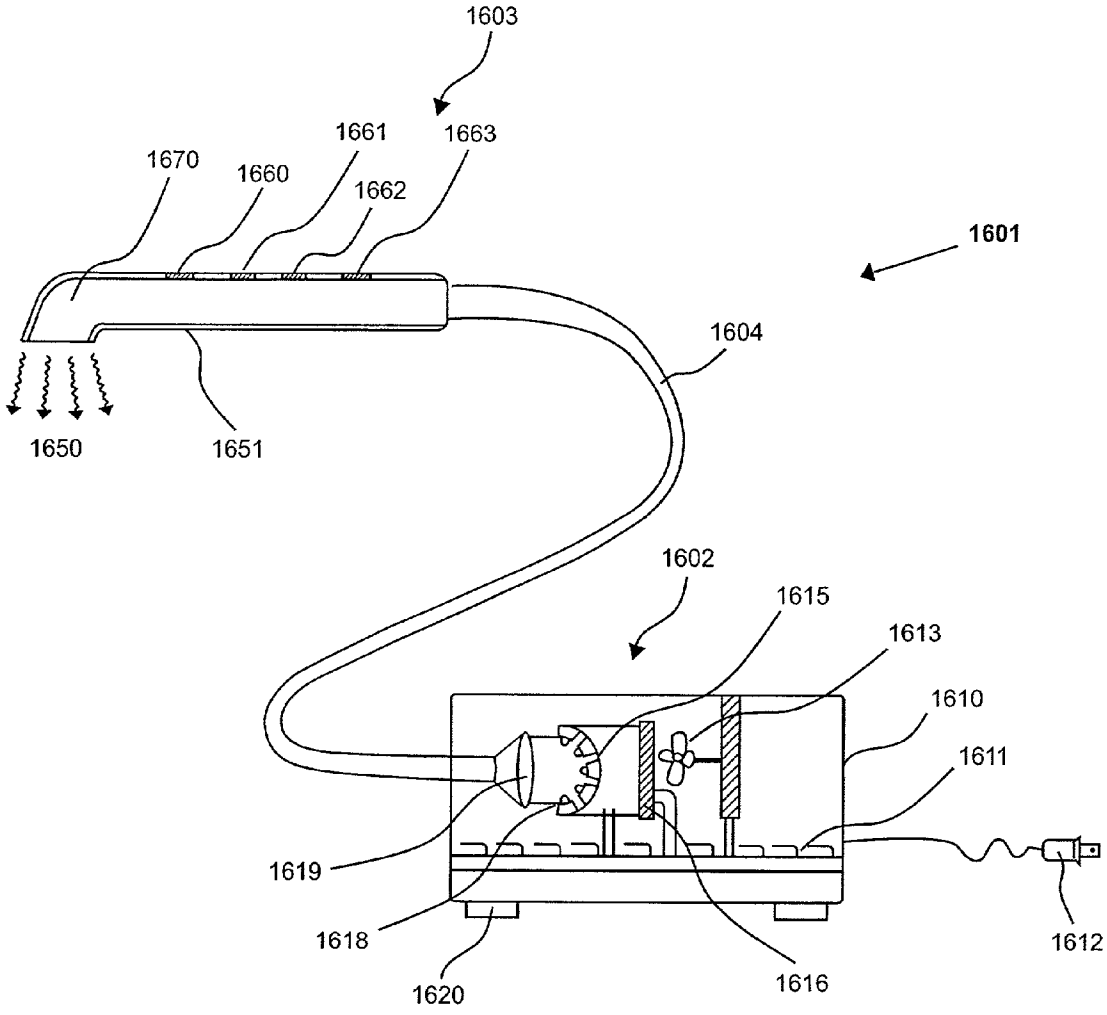

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Fig. 16b

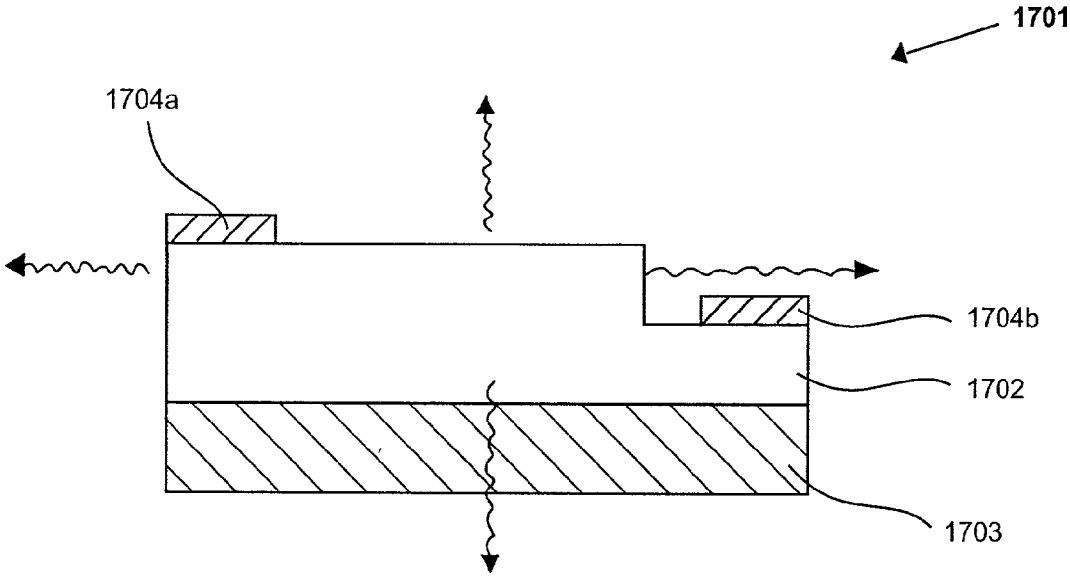


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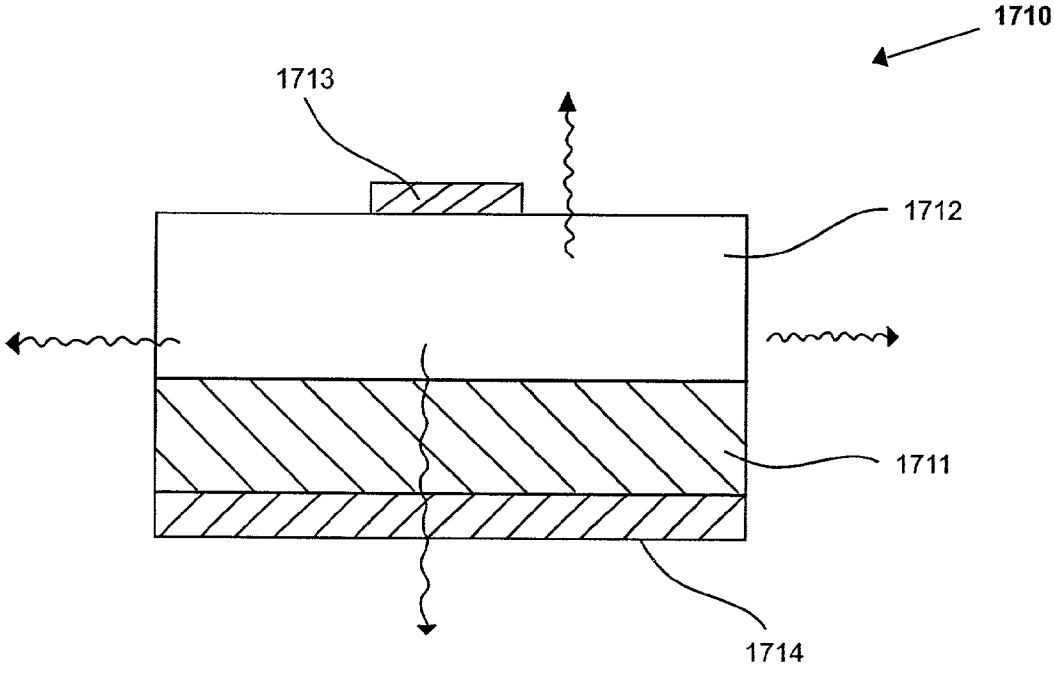


Fig. 17b

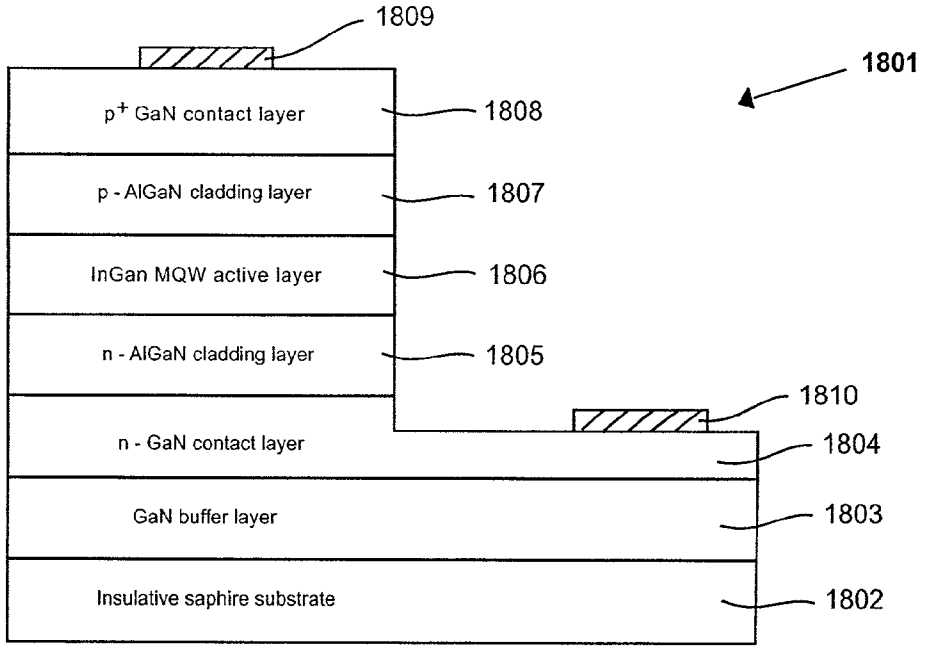


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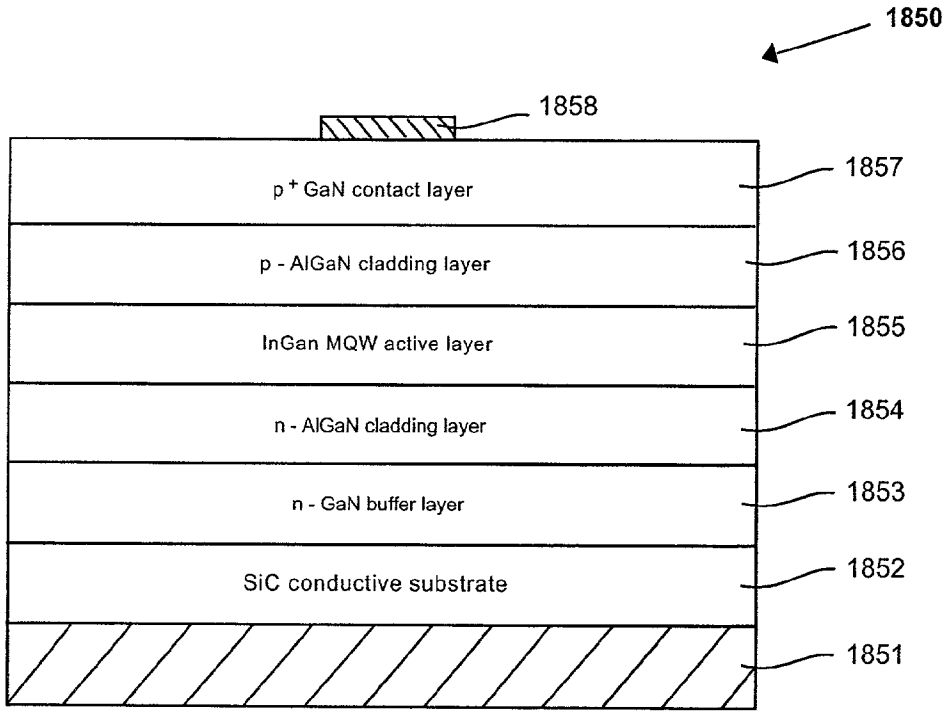


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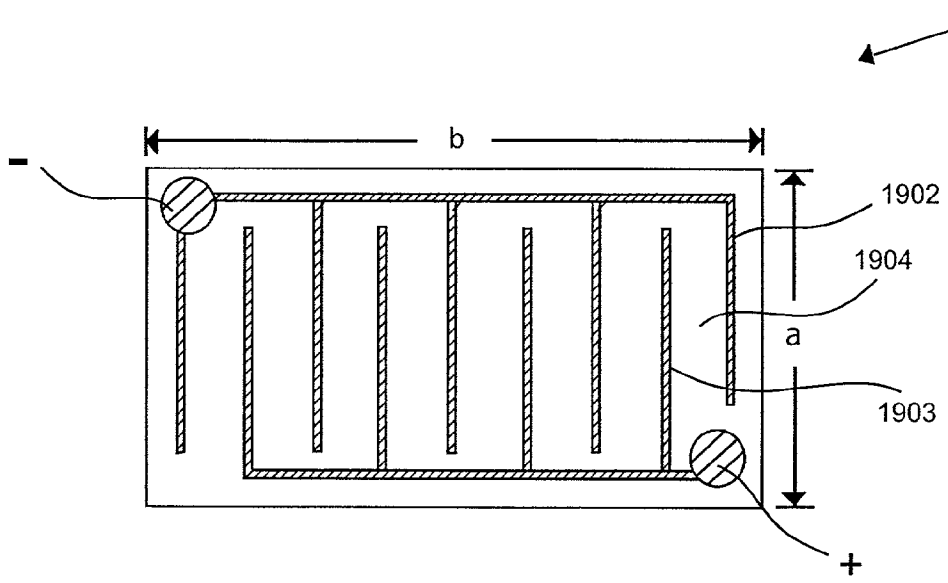


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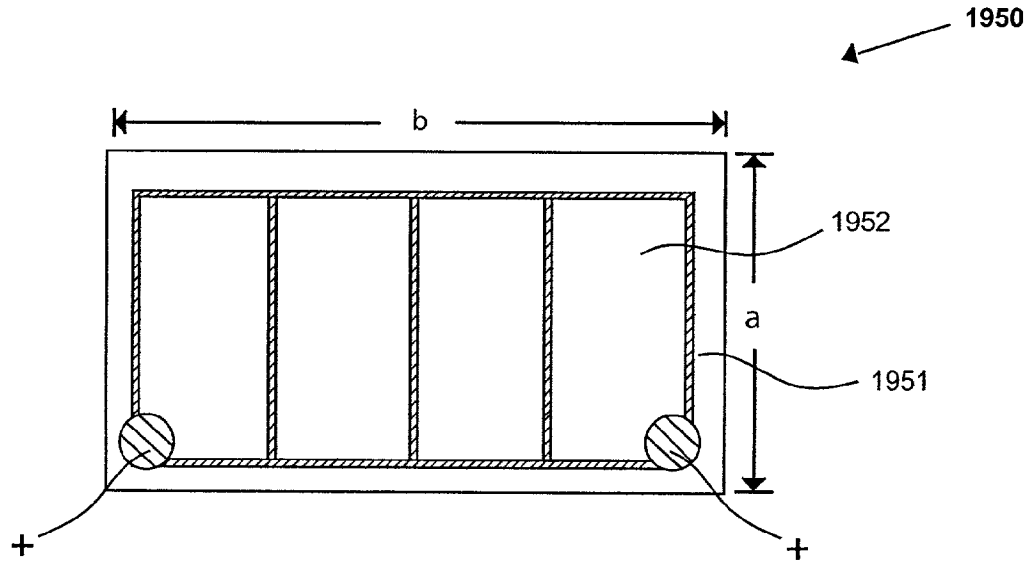


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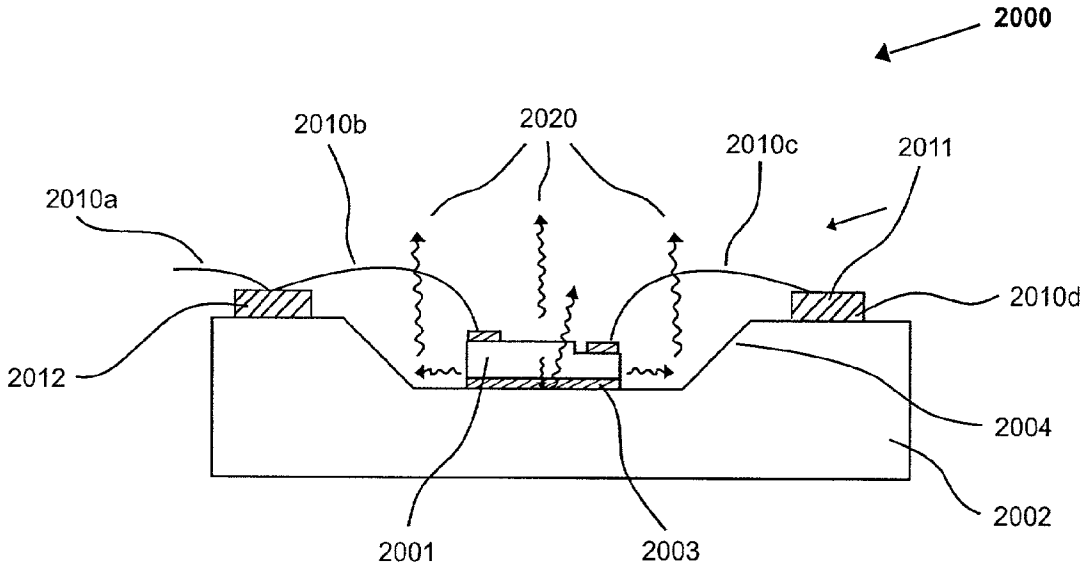


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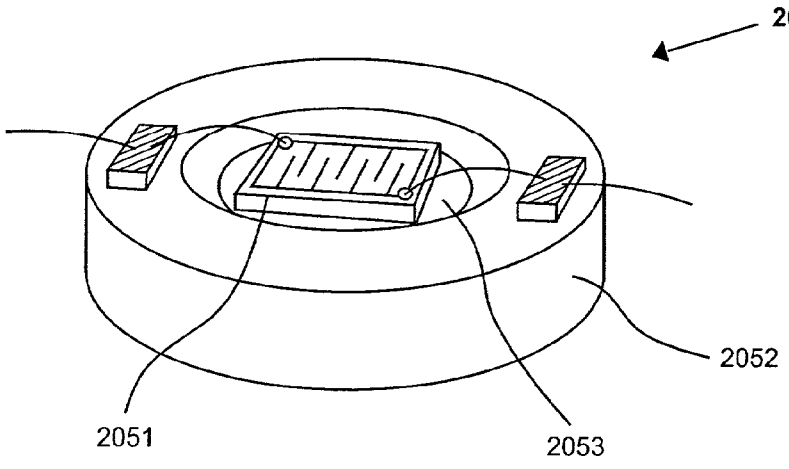


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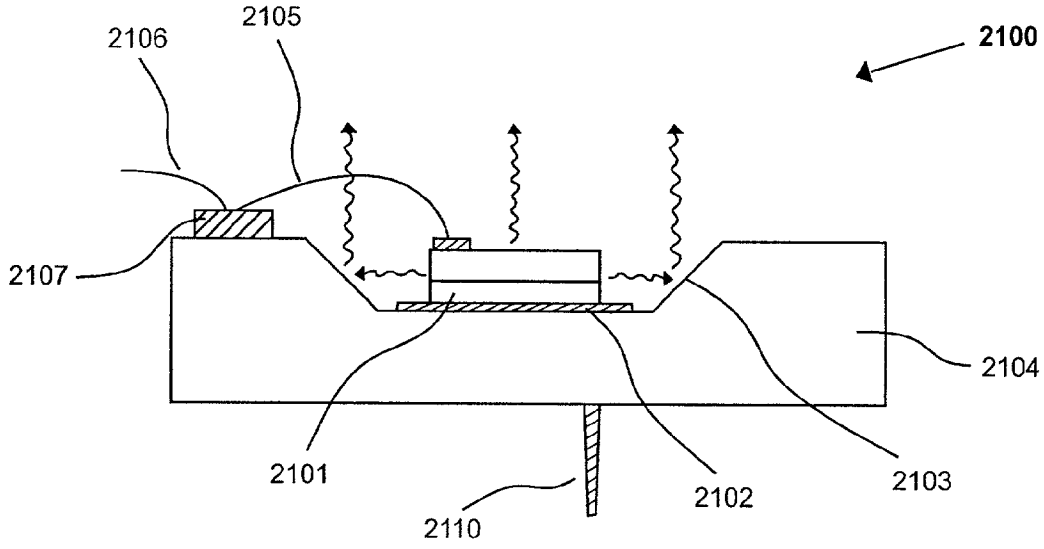


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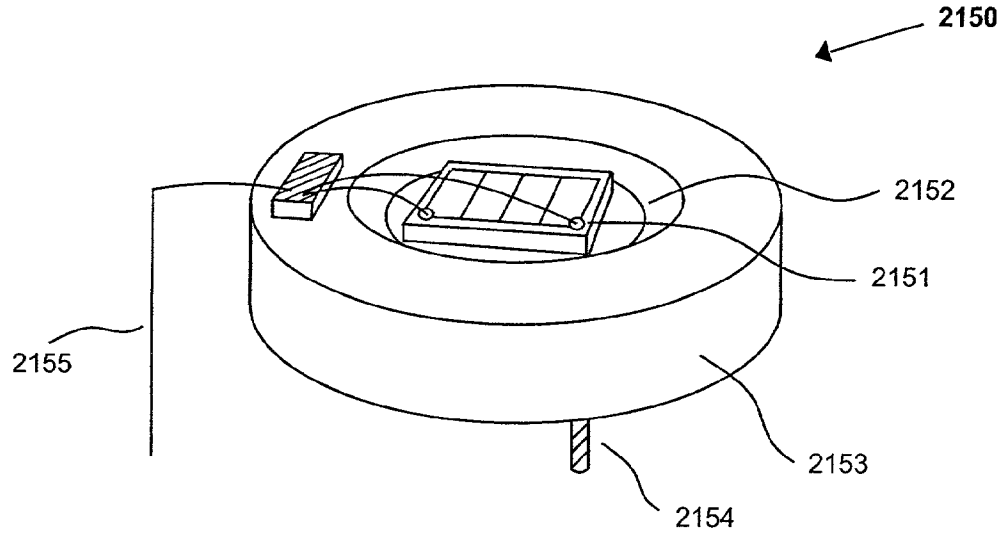


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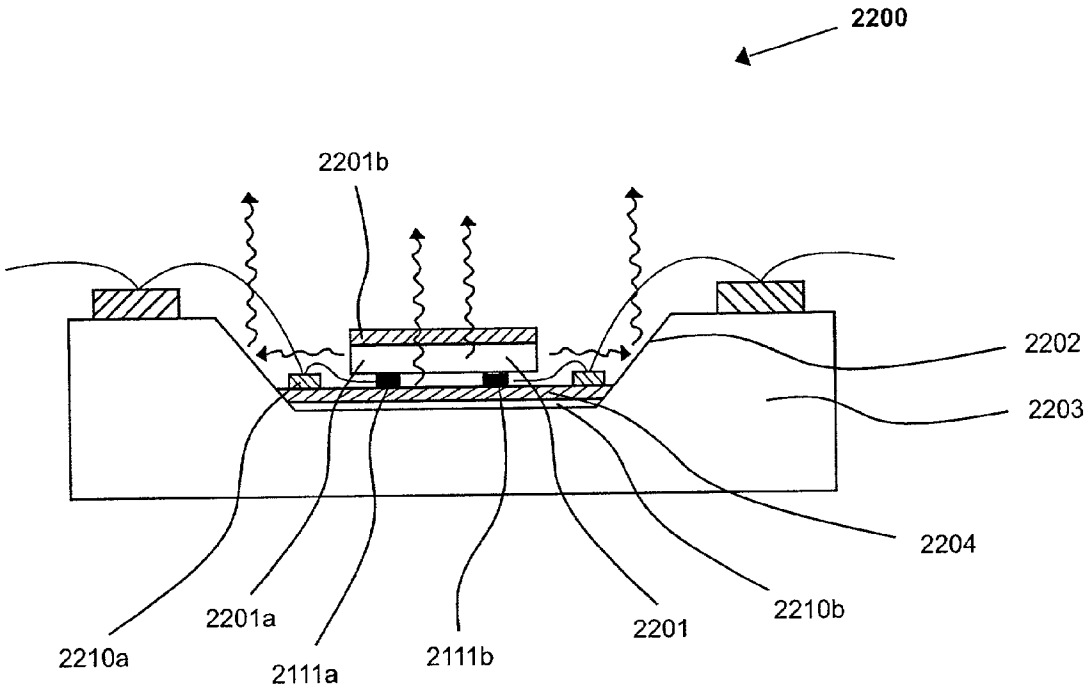

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Fig. 22a

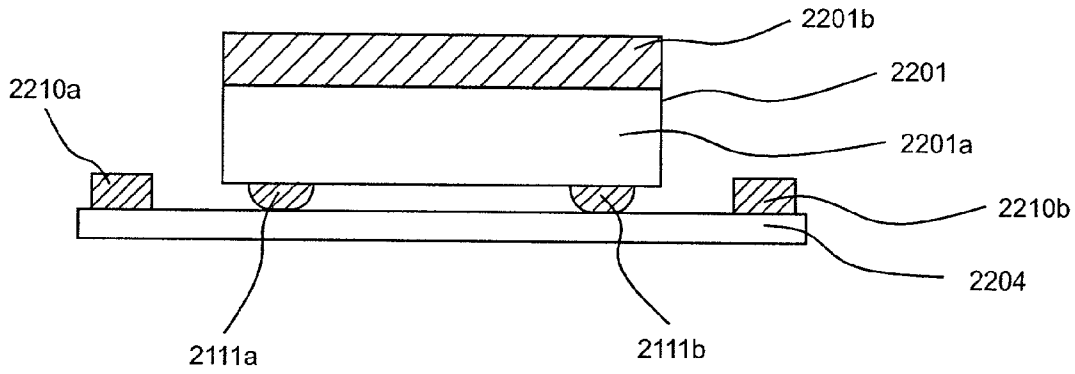


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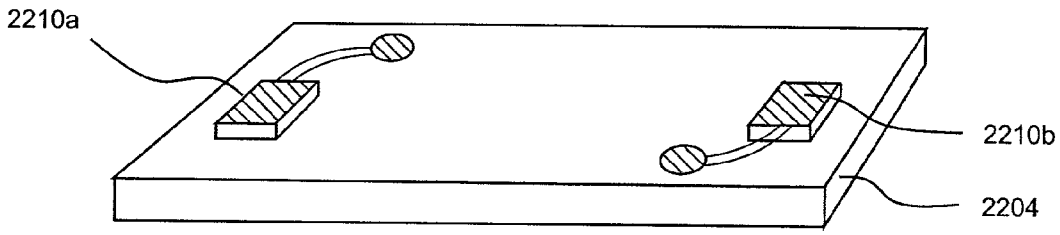


Fig. 22c

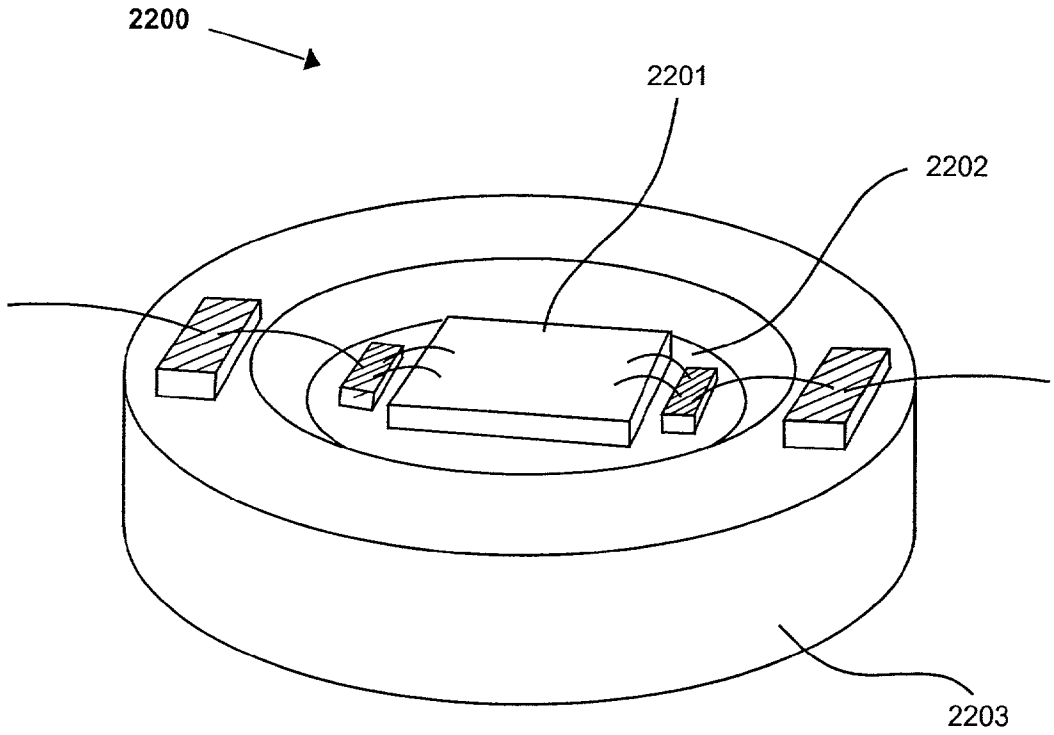


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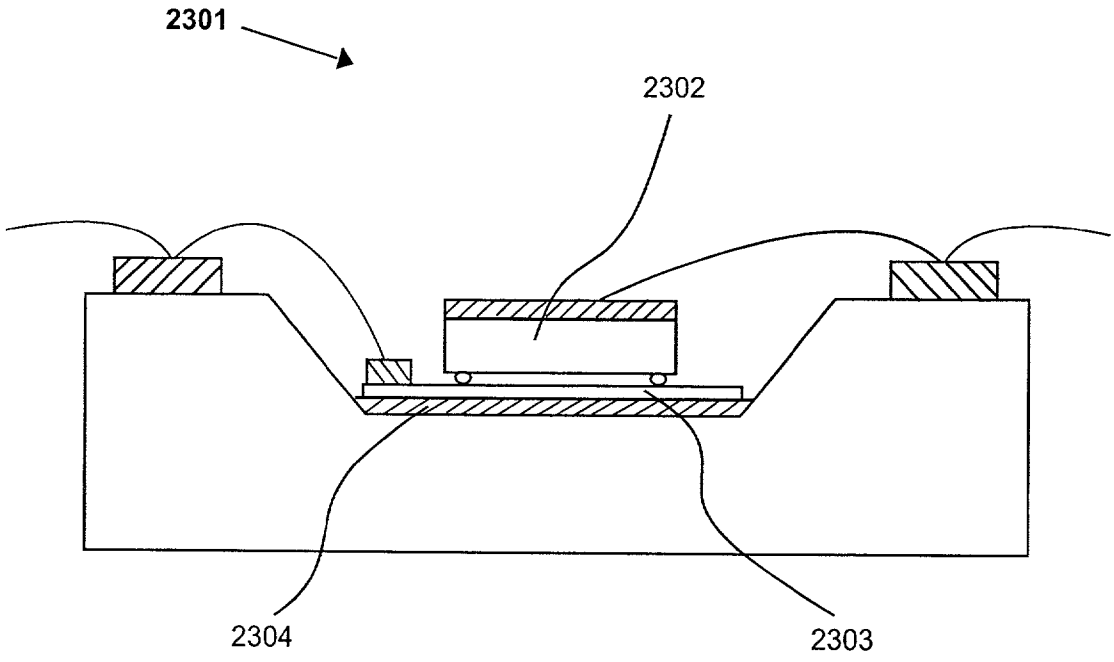


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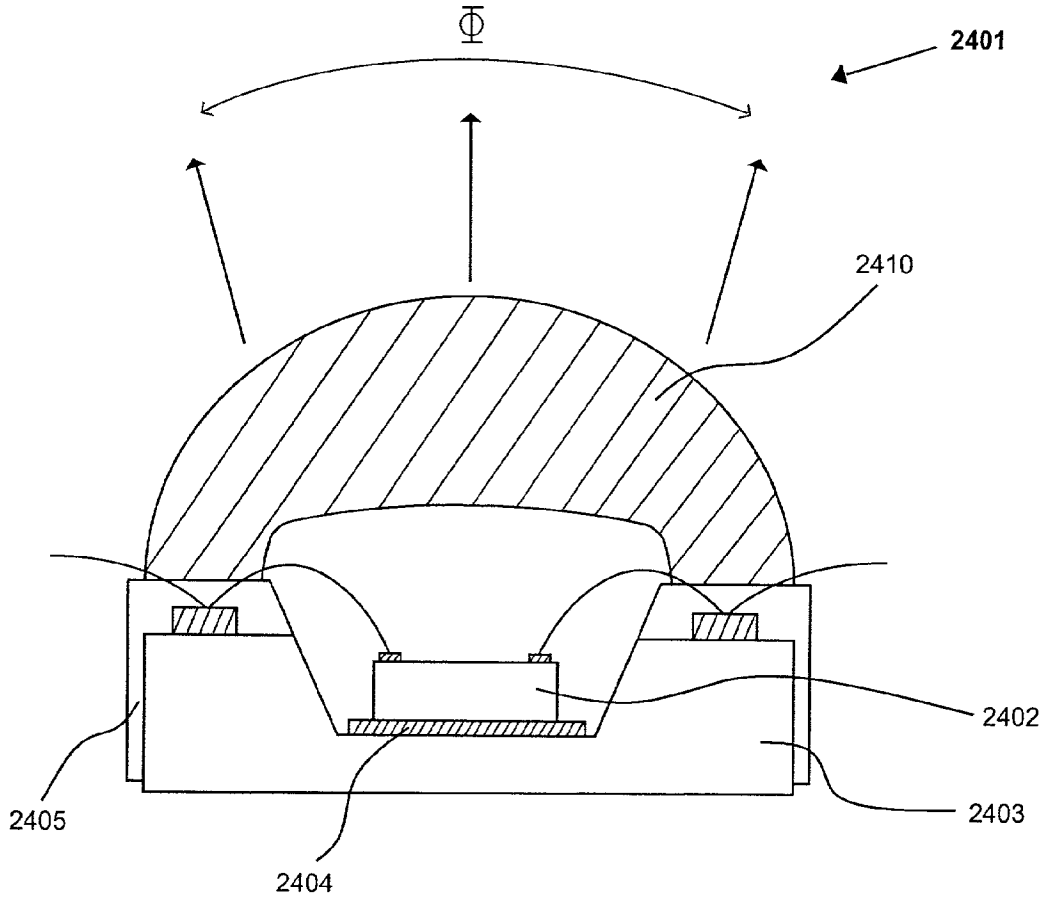


Fig. 24a

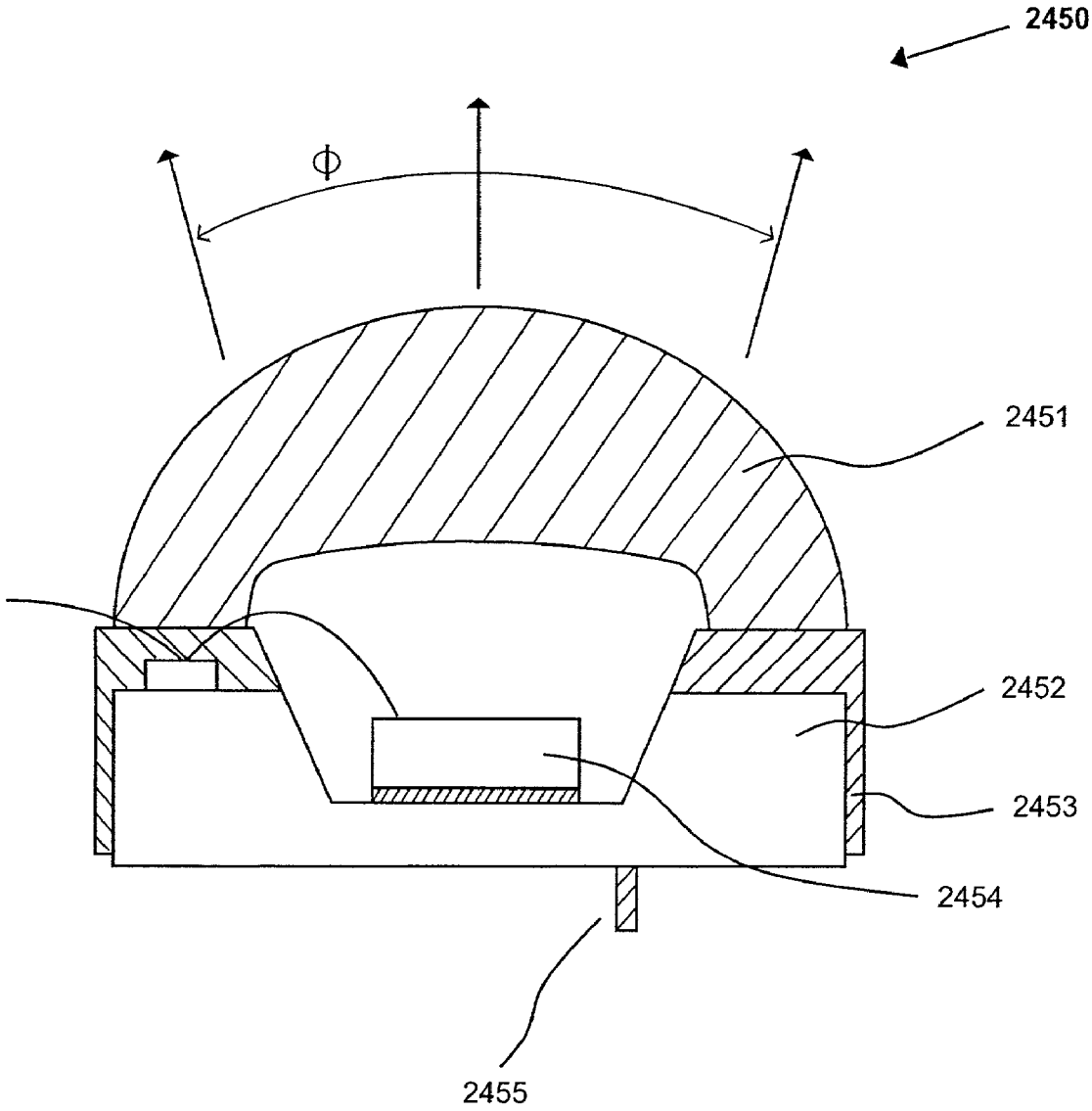


Fig. 24b

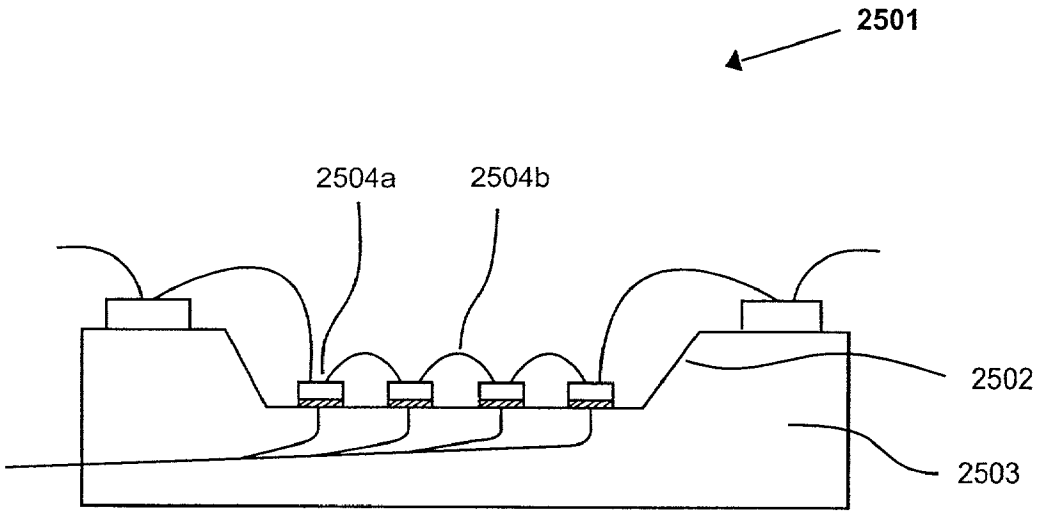


Fig. 25a

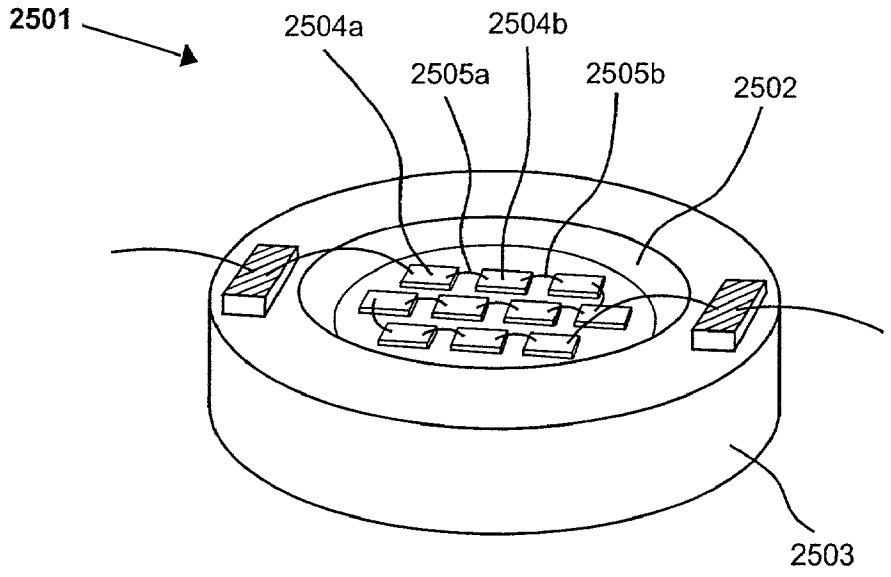


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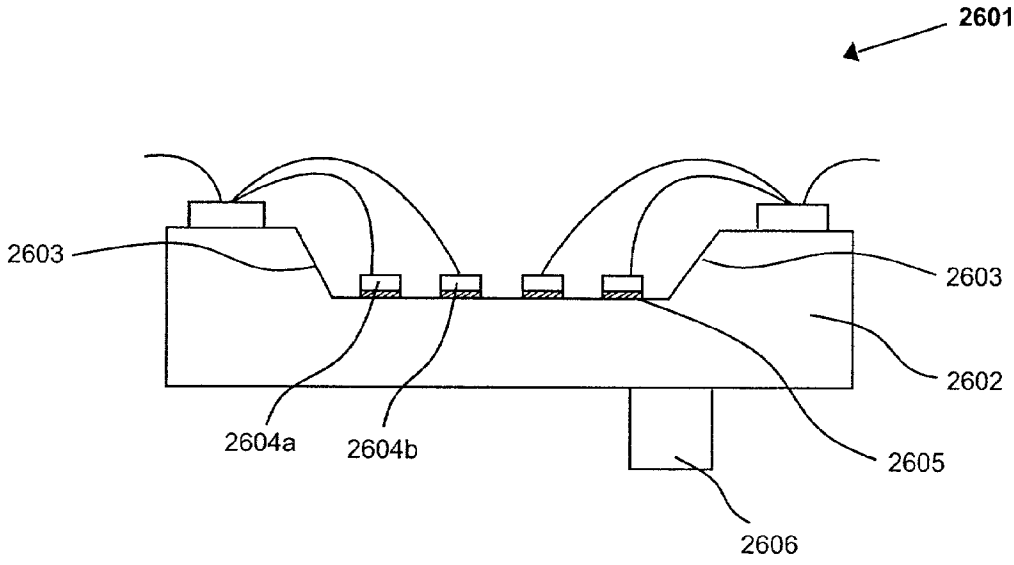


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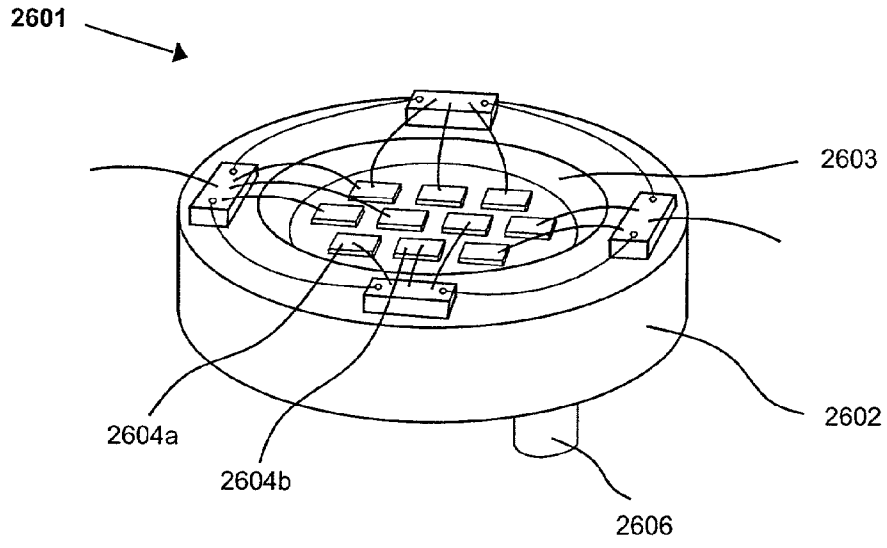


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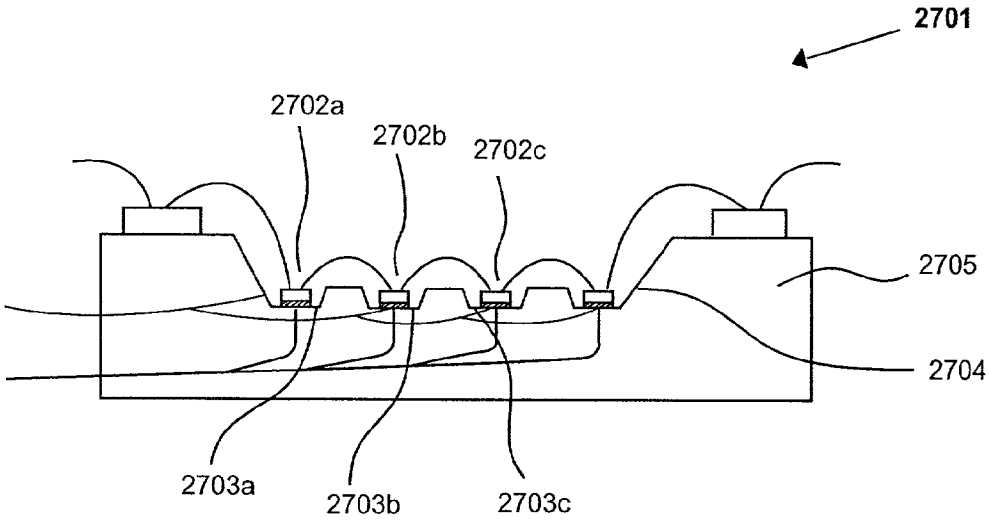


Fig. 27a

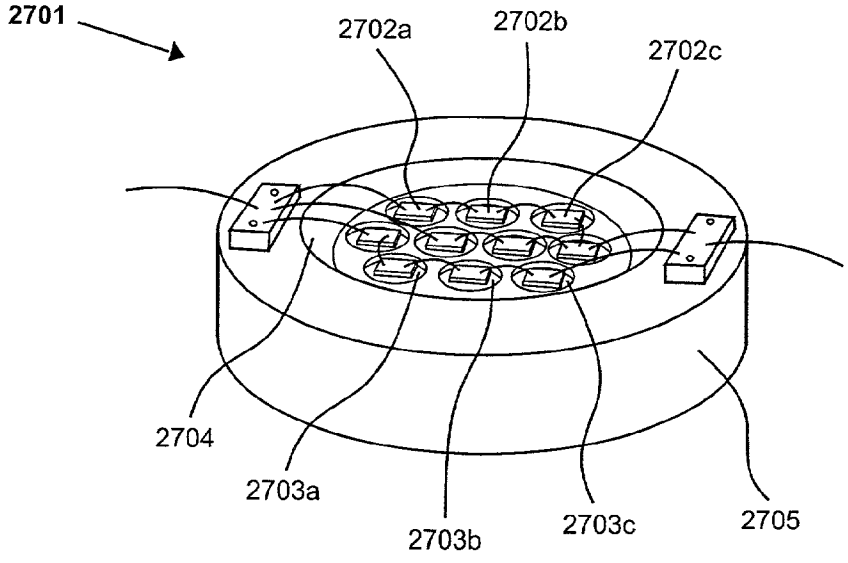


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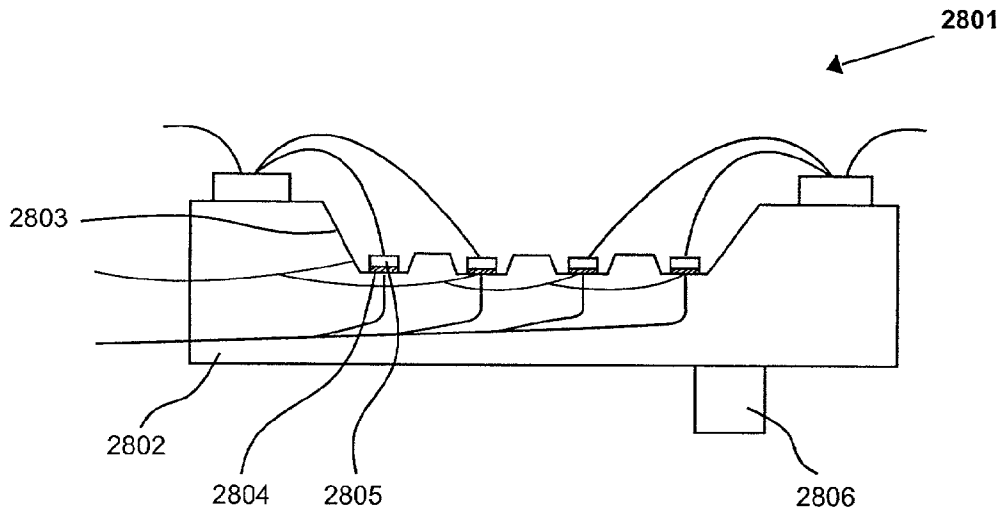


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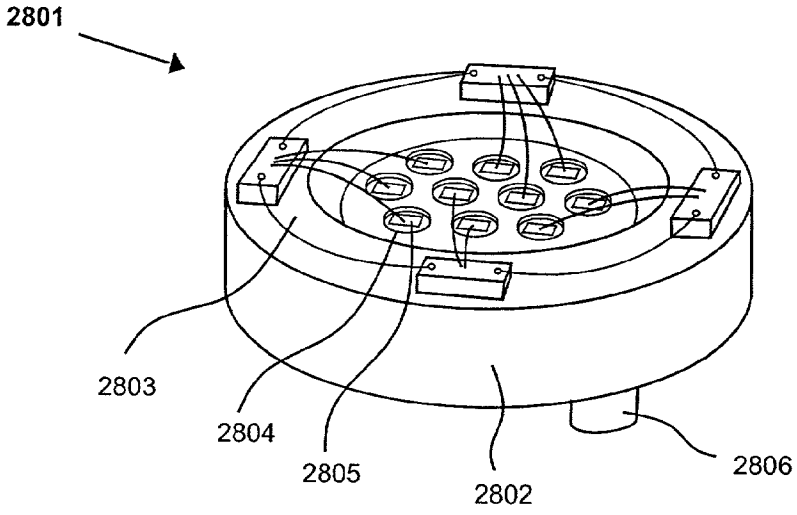


Fig. 28b

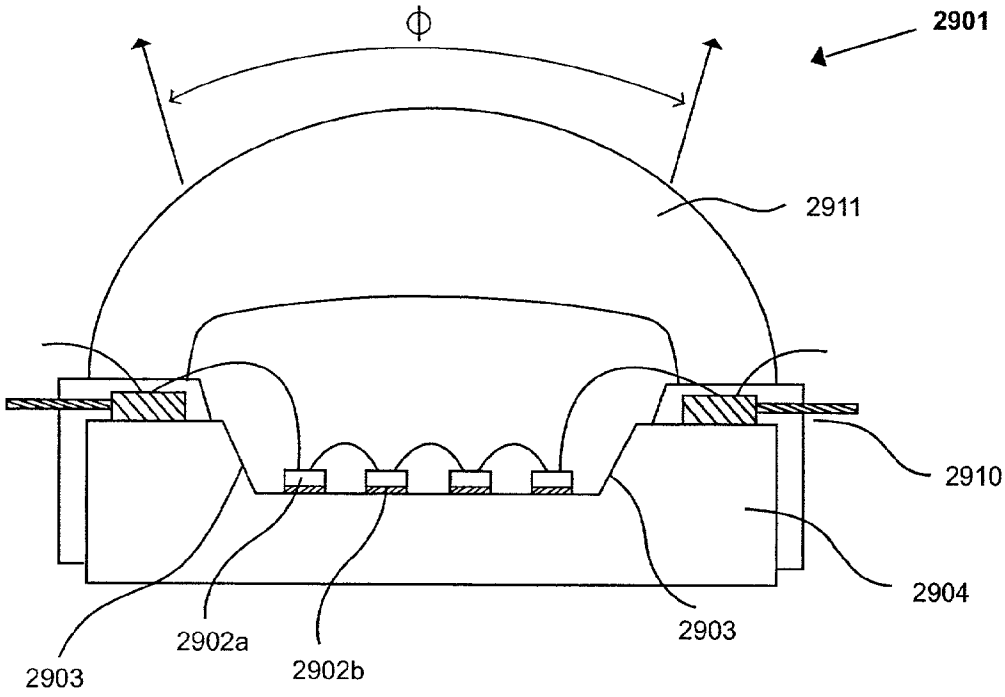


Fig. 29a

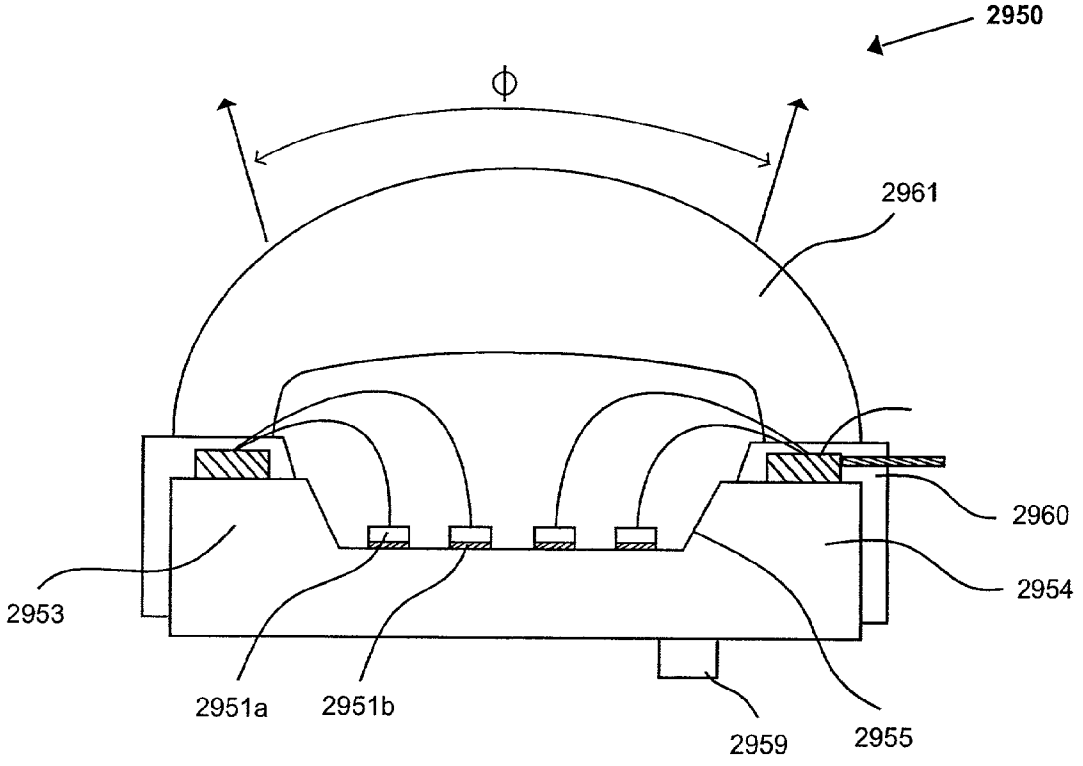


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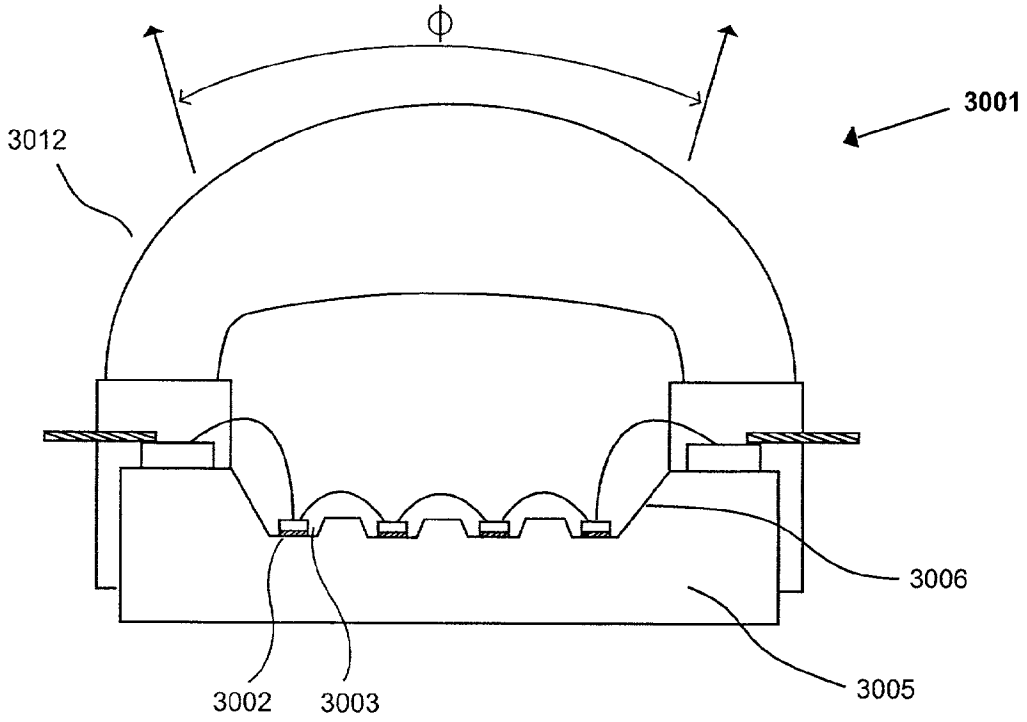


Fig. 30a

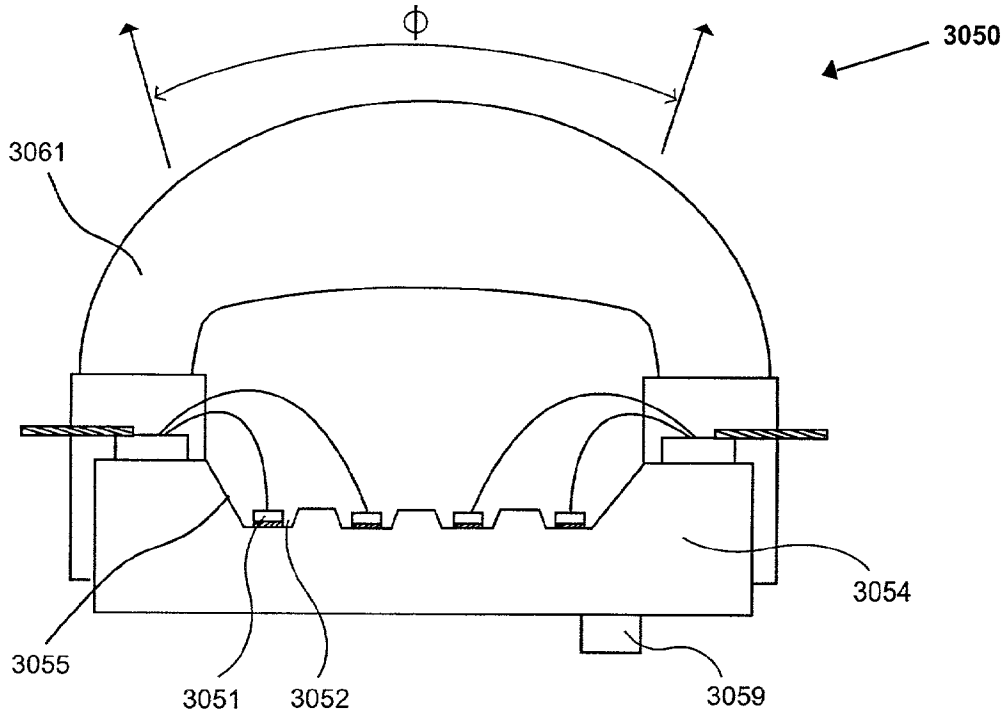


Fig. 30b

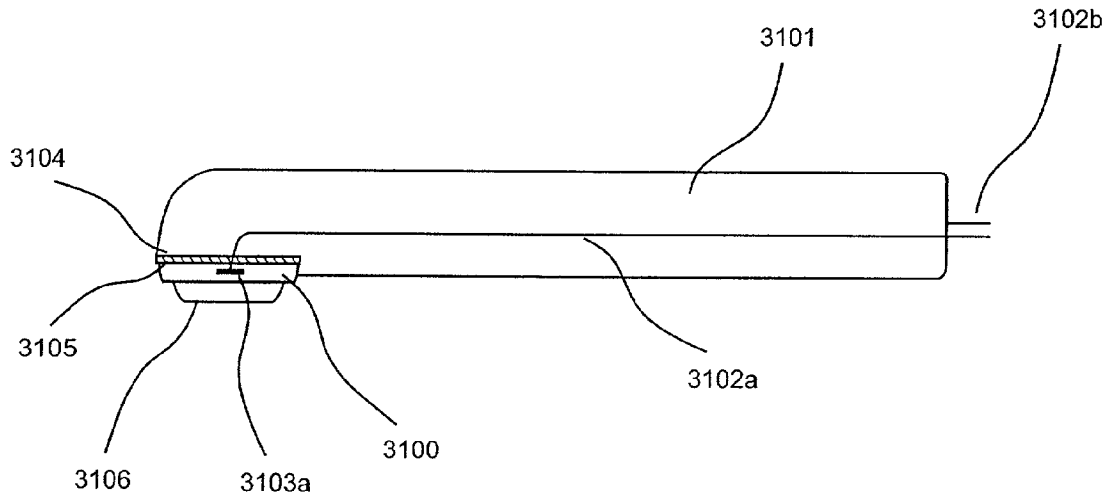


Fig. 31a

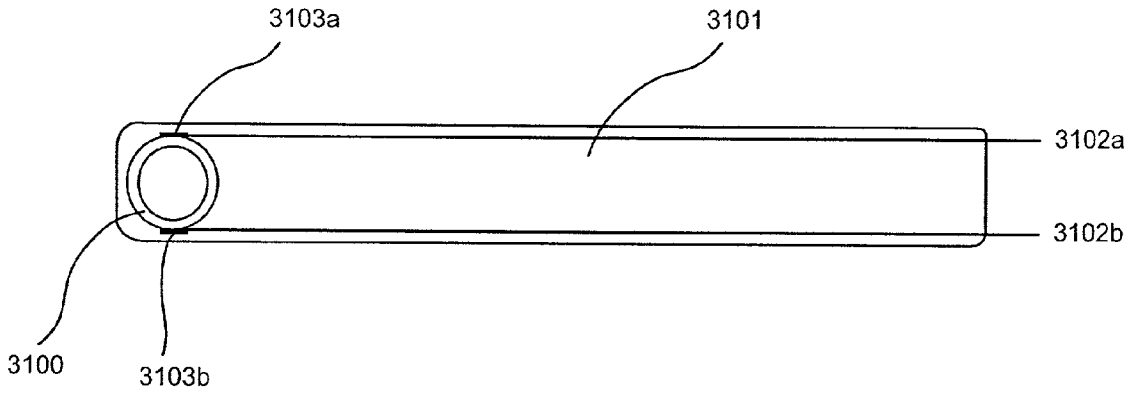


Fig. 31b

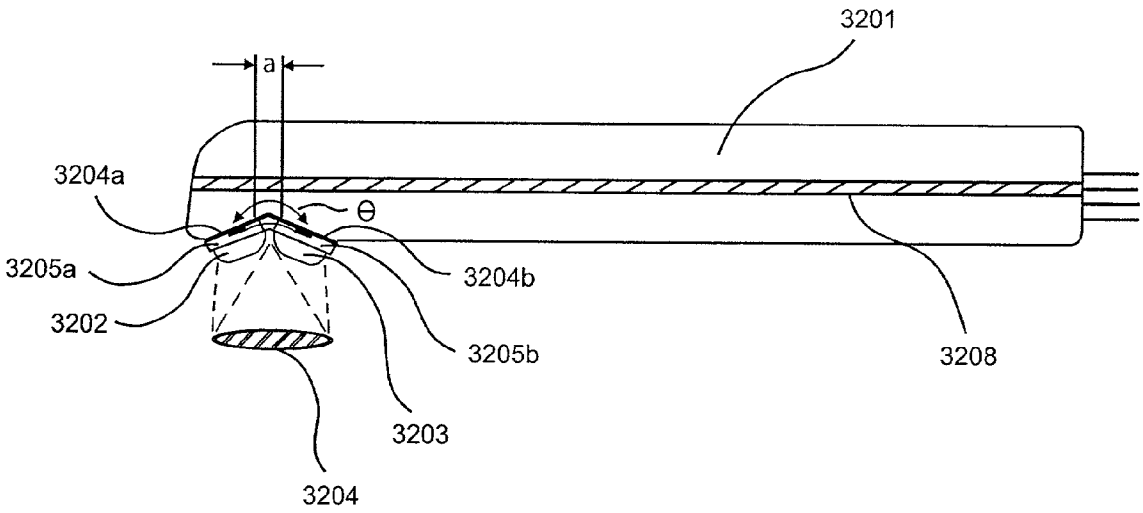


Fig. 32a

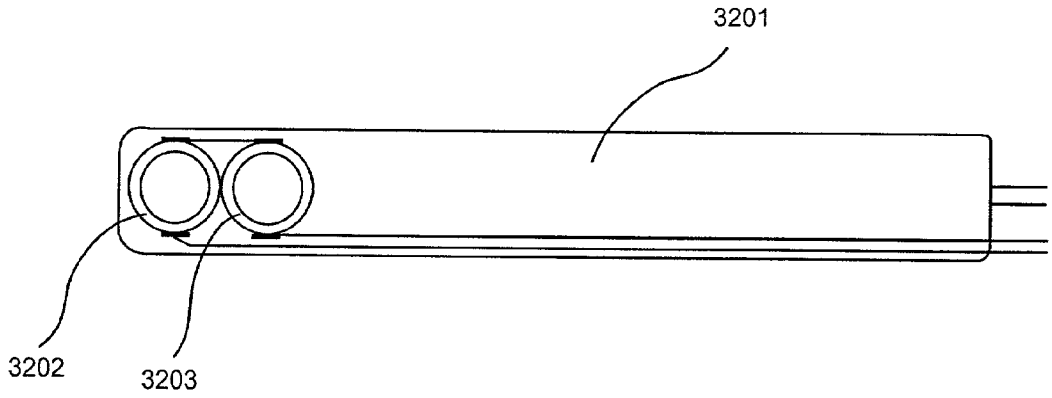


Fig. 32b

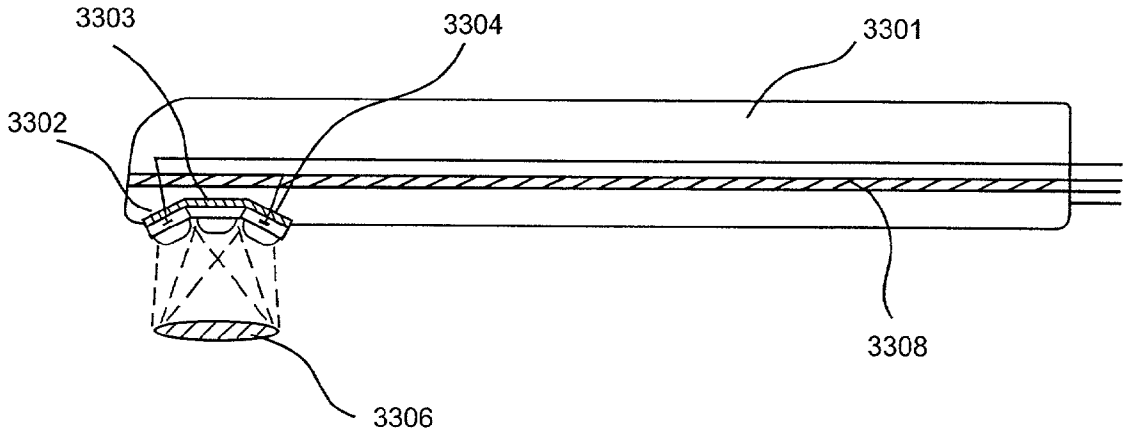


Fig. 33a

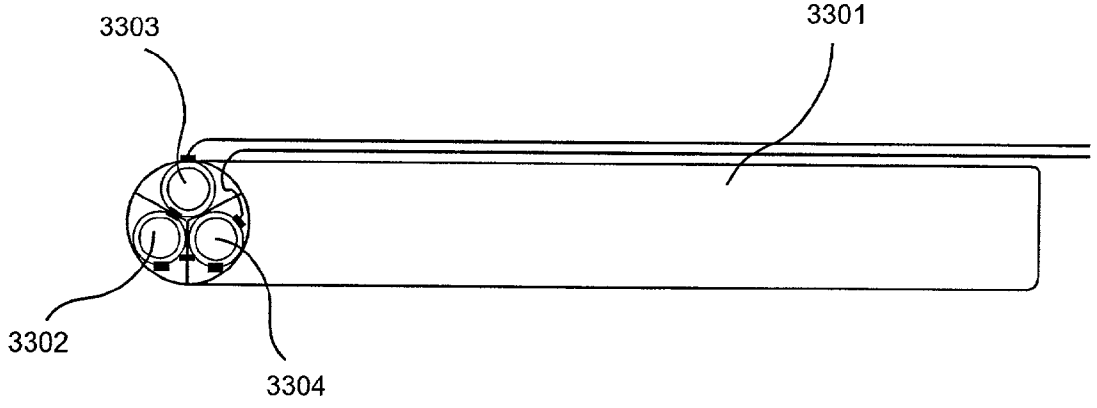


Fig. 33b

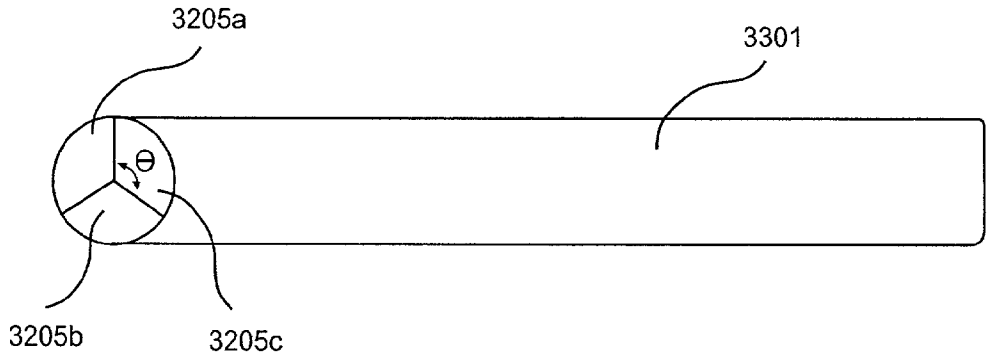


Fig. 33c

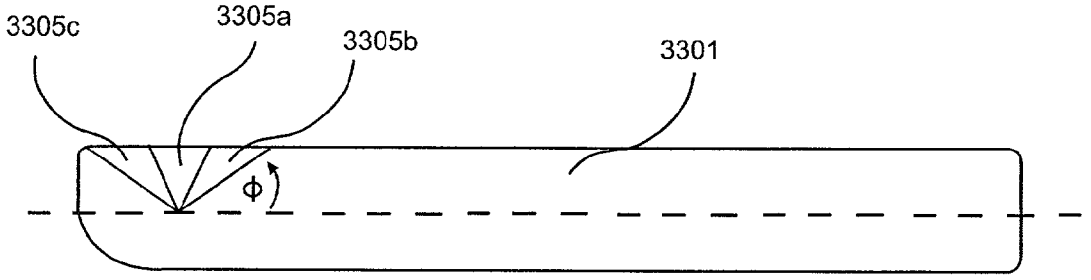


Fig. 33d

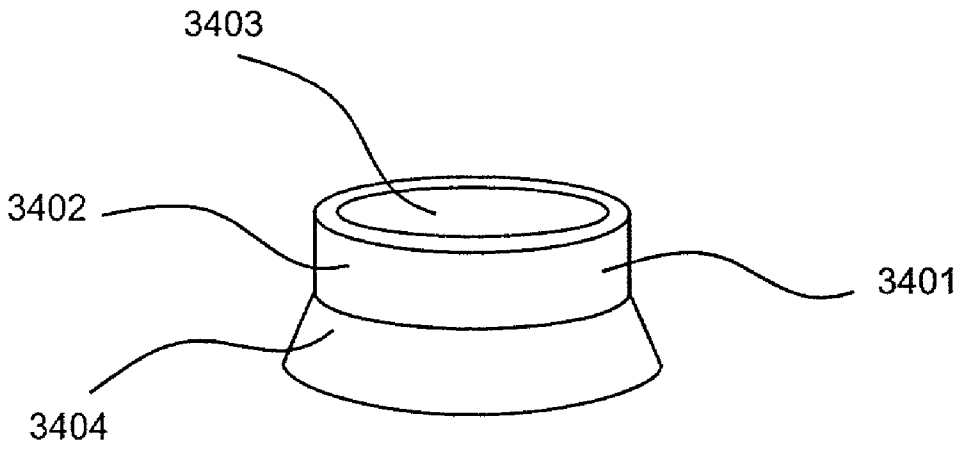


Fig. 34a

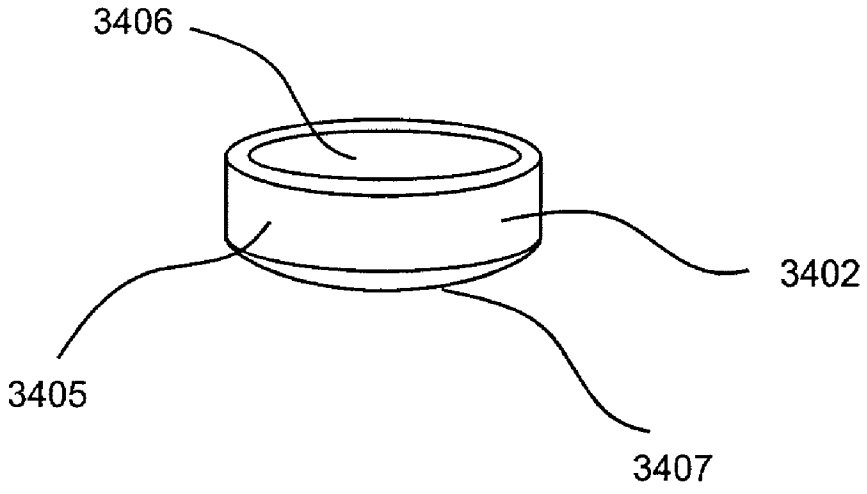


Fig. 34b

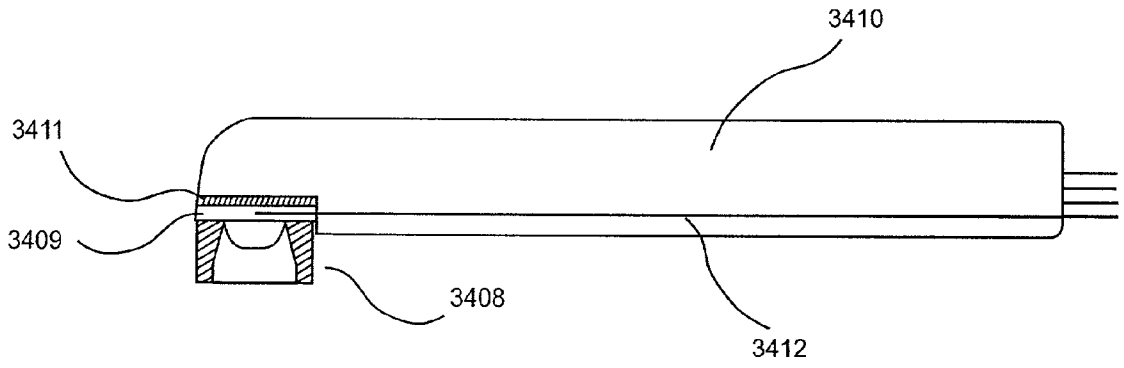


Fig. 34c

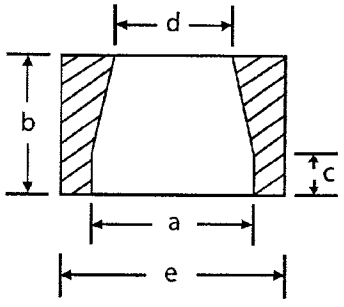


Fig. 34d

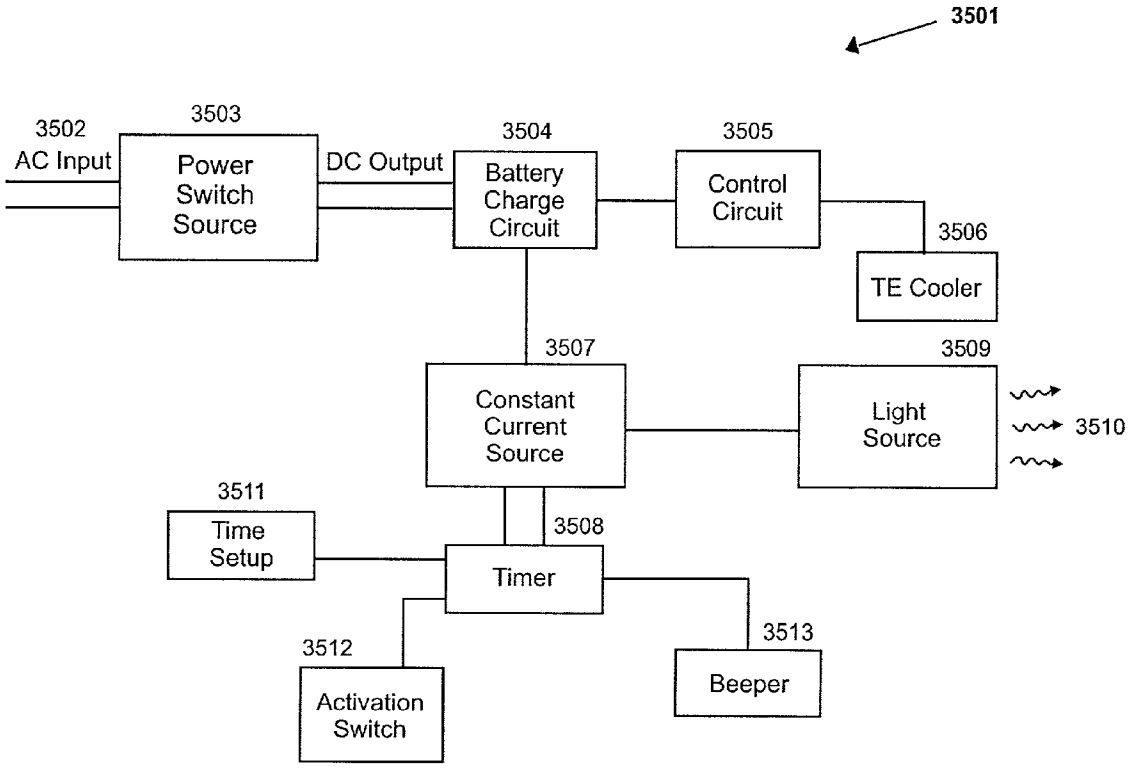

3501
3502
AC Input
3503
Power Switch Source
DC Output
3504
Battery Charge Circuit
3505
Control Circuit
3506
TE Cooler
3507
Constant Current Source
3509
Light Source
3510
3511
Time Setup
3508
Timer
3512
Activation Switch
3513
Beeper

Fig. 35

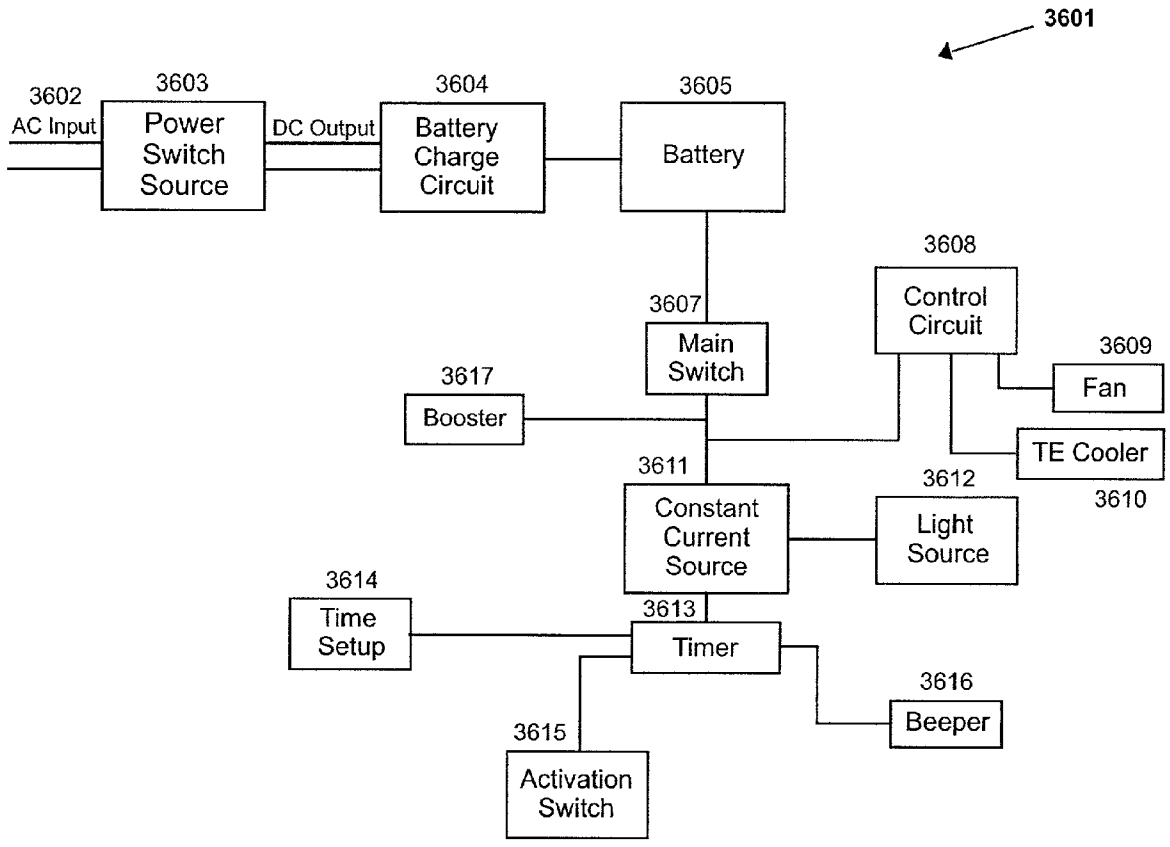

3601
3602
AC Input
3603
Power Switch Source
DC Output
3604
Battery Charge Circuit
3605
Battery
3607
Main Switch
3608
Control Circuit
3609
Fan
3617
Booster
TE Cooler
3610
3611
Constant Current Source
3612
Light Source
3614
Time Setup
3613
Timer
3616
Beeper
3615
Activation Switch

Fig. 36

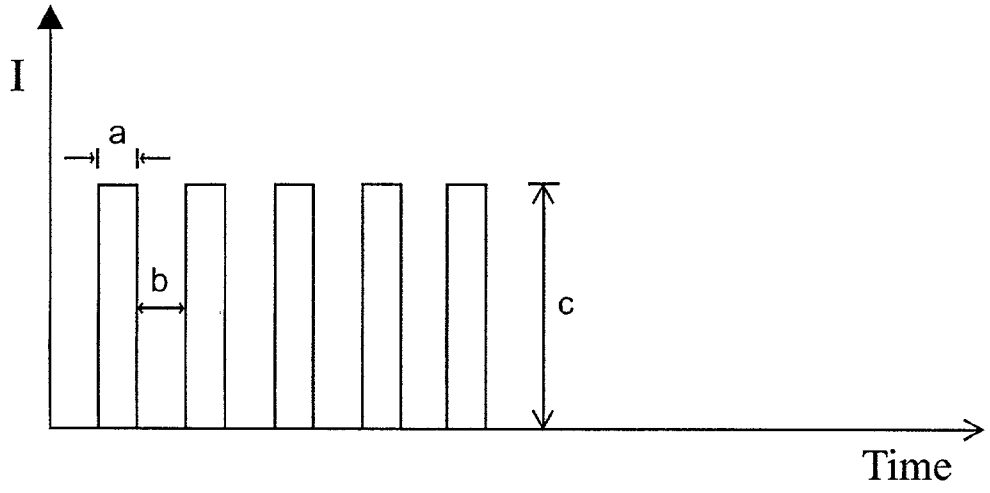


Fig. 37

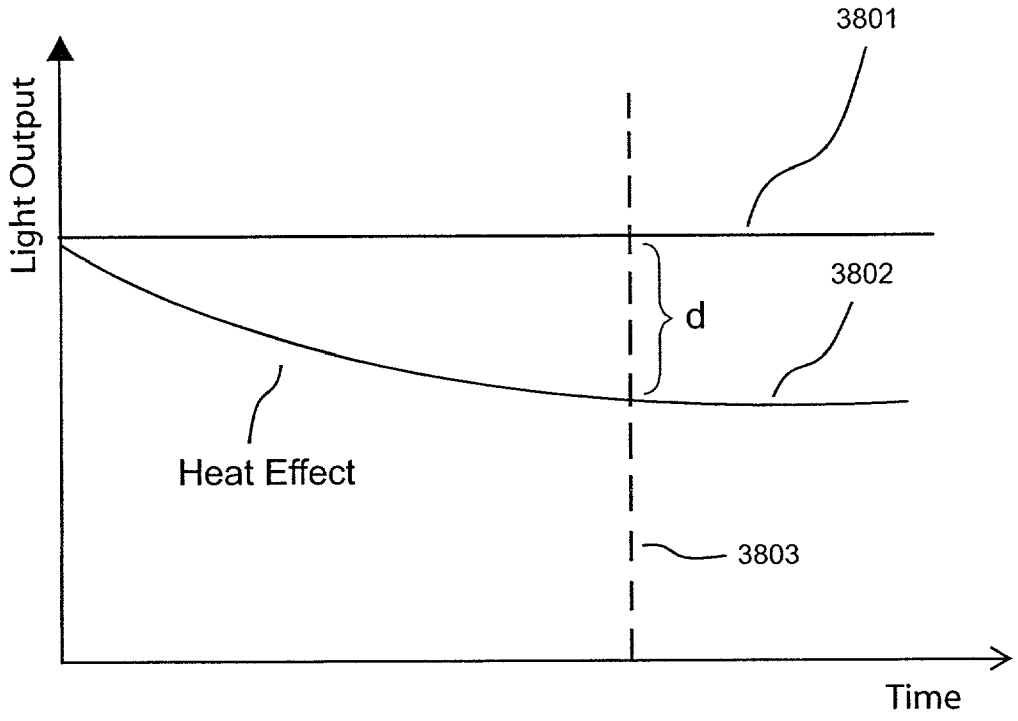


Fig. 38

CURING LIGHT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application is a continuation-in-part of Ser. Nos. 10/016,992; 10/017,272; 10/017,454; and 10/017,455; each of which was filed on Dec. 13, 2001, and each of which is a continuation-in-part of U.S. patent application Ser. No. 09/405,373 filed on Sep. 24, 1999, now U.S. Pat. No. 6,331,111, and priority is claimed thereto. Priority is also claimed to U.S. Provisional Patent Application Serial No. 60/304,324 filed on Jul. 10, 2001.

BACKGROUND OF THE INVENTION

[0002] The inventions relate to the field of curing lights that may be used to cure light activated composite materials. More particularly, the inventions relate to curing lights of various configurations that use semiconductor light sources to provide light of a wavelength and power level desired to effect curing. In many fields, composite materials, such as monomers and an initiator, are cured into durable polymers by use of a light source of appropriate wavelength to excite the initiator into initiating polymerization, and sufficient power to carry polymerization through to adequate completion.

[0003] In the prior art, various light sources have been used for the purpose of curing composite materials. Halogen bulbs, fluorescent bulbs, xenon bulbs, and plasma-arc lights have been used. More recently, there have been some efforts to produce an effective curing light using light emitting diodes (LED's), but those efforts have not met with widespread acceptance in the marketplace.

[0004] The prior art described above suffers from several disadvantages. First, many of those prior art lights generate a wide spectrum of light rather than light just of the desired wavelength for composite curing. Consequently, those prior art lights generate unnecessary heat. Second, many of those prior art lights require light transfer systems such as a light guide or fiber, which many embodiments of the present invention omit, providing a smaller and more efficient unit. Third, many of the prior art systems require an elaborate cooling system to handle heat, creating a large, heavy and expensive curing light. Many embodiments of the invention use a unique heat sink structure that avoids the need for complicated, noisy and expensive cooling systems. Many embodiments of the invention use a semiconductor light source and package which provides high power light for use in curing composite materials. Additional points of difference between the inventions and the prior art will become apparent upon reading the text below in conjunction with the appended drawings.

SUMMARY OF INVENTION

[0005] It is an object of some embodiments of the invention to provide a curing light system that uses a semiconductor light source to produce light capable of curing composite materials. Curing composite materials will involve polymerizing monomers into durable polymers. Various physical, electrical and semiconductor structures, materials and methods are provided to achieve this object. Additional objects, features and advantages of the invention will become apparent to those skilled in the art upon reading the specification and reviewing the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] **FIG. 1** depicts a battery-powered Curing light that uses a single light emitting diode chip as a light source.

[0007] **FIG. 2** depicts a cross-section of the light of **FIG. 1**.

[0008] **FIG. 3** depicts an AC-powered Curing light that uses a single light emitting diode chip as a light source.

[0009] **FIG. 4** depicts a cross section of the light of **FIG. 3**.

[0010] **FIG. 5** depicts a battery-powered curing light that uses two light emitting diode chips as a light source.

[0011] **FIG. 6** depicts a cross-section of the light of **FIG. 5**.

[0012] **FIG. 7** depicts an AC-powered curing light that uses two light emitting diode chips as a light source.

[0013] **FIG. 8** depicts a cross-section of the light of **FIG. 7**.

[0014] **FIG. 9** depicts a battery-powered curing light that uses three light emitting diode chips as a light source.

[0015] **FIG. 10** depicts a cross-section of the light of **FIG. 9**.

[0016] **FIG. 11** depicts an AC-powered curing light that uses three light emitting diode chips as a light source.

[0017] **FIG. 12** depicts a cross section of the light of **FIG. 11**.

[0018] **FIG. 13** depicts a battery-powered curing light that uses three or more semiconductor chip modules mounted on a heat sink in a manner that the light they emit is collected by a reflector apparatus and focused by a lens means onto a light transport mechanism, such as a light guide, plastic stack or fiber.

[0019] **FIG. 14** depicts a cross-section of the light of **FIG. 13**.

[0020] **FIG. 15** depicts an alternative embodiment of the light of **FIG. 13**, in the light transport mechanism is replace by a distally-located mirror which reflects generally coherent light emitted from the light source in a desired direction for use.

[0021] **FIG. 16*a*** depicts a light which uses a plurality of light emitting semiconductor modules mounted on a heat sink as a light source, a focusing means to produce a generally coherent beam of light, and a light transport means such as optically conductive cable for transporting light to a location remote from the light source for use.

[0022] **FIG. 16*b*** depicts a cross section of the light of **FIG. 16*a***.

[0023] **FIG. 17*a*** depicts a gross cross section of a light emitting diode chip that uses an insulative substrate.

[0024] **FIG. 17*b*** depicts a gross cross section of a light emitting diode chip that uses a conductive substrate.

[0025] **FIG. 18***a* depicts epitaxial layers of a light emitting diode chip that uses an insulative substrate.

[0026] **FIG. 18***b* depicts epitaxial layers of a light emitting diode chip that uses a conductive substrate.

[0027] **FIG. 19***a* depicts a top view of a light emitting diode chip array (single chip) with an insulative substrate.

[0028] **FIG. 19***b* depicts a top view of a top view of a light emitting diode chip array (single chip) with a conductive substrate.

[0029] **FIG. 20***a* depicts a side view of a chip package for a light emitting chip that shows a light emitting diode chip with an insulative substrate mounted in a well of a heat sink, with electrical connections and light emission shown.

[0030] **FIG. 20***b* depicts a perspective view of a chip package for a light emitting chip with an insulative substrate that shows a chip array mounted in a well of a heat sink.

[0031] **FIG. 21***a* depicts a side view of a chip package for a light emitting chip that shows a light emitting diode chip with a conductive substrate mounted in a well of a heat sink, with electrical connections and light emission shown.

[0032] **FIG. 21***b* depicts a perspective view of a chip package for a light emitting chip with a conductive substrate that shows a chip array mounted in a well of a heat sink.

[0033] **FIG. 22***a* depicts a side view of a chip package for a light emitting chip mounted in a well of a heat sink according to the so-called 'flip chip' design, the chip having an insulative substrate.

[0034] **FIG. 22***b* depicts a side view of a flip chip mounted on a flip chip pad.

[0035] **FIG. 22***c* depicts a perspective view of a flip chip pad.

[0036] **FIG. 22***d* depicts a perspective view of the chip package of **FIG. 22***a*.

[0037] **FIG. 23** depicts a side view of a flip chip package with a conductive susbtrate.

[0038] **FIG. 24***a* depicts a side view of a light emitting diode chip package including the chip (insulative substrate) and heat sink surface mount arrangement with a protective dome, lens or cover.

[0039] **FIG. 24***b* depicts a side view of a light emitting diode chip package including the chip (conductive substrate) and heat sink surface mount arrangement with a protective dome, lens or cover.

[0040] **FIG. 25***a* depicts an array of light emitting chips with insulative substrates in surface mount arrangement in a single well of a heat sink.

[0041] **FIG. 25***b* depicts a perspective view of the array of surface-mounted chips of **FIG. 25***a*.

[0042] **FIG. 26***a* depicts an array of light emitting chips with conductive substrates in surface mount arrangement in a single well of a heat sink.

[0043] **FIG. 26***b* depicts a perspective view of the array of surface-mounted chips of **FIG. 26***a*.

[0044] **FIG. 27***a* depicts an array of light emitting chips with insulative substrates in surface mount arrangement in individual sub-wells of a well of a heat sink.

[0045] **FIG. 27***b* depicts a perspective view of the array of surface-mounted chips of **FIG. 27***a*.

[0046] **FIG. 28***a* depicts an array of light emitting chips with conductive substrates in surface mount arrangement in individual sub-wells of a well of a heat sink.

[0047] **FIG. 28***b* depicts a perspective view of the array of surface-mounted chips of **FIG. 28***a*.

[0048] **FIG. 29***a* depicts a light emitting surface mount chip package including array of chips, heat sink and protective dome, lens or cover according to the chip and surface mount configuration of **FIG. 25***a* above.

[0049] **FIG. 29***b* depicts a light emitting surface mount chip package including array of chips, heat sink and protective dome, lens or cover according to the chip and surface mount configuration of **FIG. 26***a* above.

[0050] **FIG. 30***a* depicts a light emitting surface mount chip package including array of chips in sub-wells, heat sink and protective dome, lens or cover according to the chip and surface mount configuration of **FIG. 27***a* above.

[0051] **FIG. 30***b* depicts a light emitting surface mount chip package including array of chips in sub-wells, heat sink and protective dome, lens or cover according to the chip and surface mount configuration of **FIG. 28***a* above.

[0052] **FIG. 31***a* depicts a side view of a single surface mount light emitting diode chip mounted to an elongate heat sink in a manner such that light from the chip is emitted at generally a 90 degree angle to the longitudinal axis of the elongate heat sink.

[0053] **FIG. 31***b* depicts a bottom view of the device of **FIG. 31***a*.

[0054] **FIG. 32***a* depicts a cross-sectional side view of an elongate heat sink having two light emitting semiconductor chips in surface mount configuration in an angled orientation in order to present overlapping light beams for an enhanced density light footprint.

[0055] **FIG. 32***b* depicts a bottom view of the device of **FIG. 32***a*.

[0056] **FIG. 33***a* depicts a cross-sectional side view of an elongate heat sink having three light emitting semiconductor chips mounted on it in an angled orientation in order to present overlapping light beams for an enhanced density light footprint.

[0057] **FIG. 33***b* depicts a bottom view of the device of **FIG. 33***a*.

[0058] **FIG. 33***c* depicts a bottom view of the heat sink of **FIGS. 33***a* and **33***b* to permit the reader to understand the angular orientation of the light emitting semiconductor chips.

[0059] **FIG. 33***d* depicts a side view of the heat sink for 3 surface mounted LED's.

[0060] **FIG. 34***a* depicts a light shield which may be used in conjunction with curing lights of the invention to shield human eyes from light emitting by the curing light.

[0061] **FIG. 34***b* depicts a focus lens which may be used to focus light emitted by curing lights of the invention in order to present a denser light footprint.

[0062] **FIG. 34***c* depicts a light module with reflective cone installed.

[0063] **FIG. 34***d* depicts a reflective cone.

[0064] **FIG. 35** depicts a block diagram of control circuitry that may be used with the embodiments of the inventions that utilize AC power.

[0065] **FIG. 36** depicts by a block diagram of control circuitry that may be used with the embodiments of the inventions that utilize battery power.

[0066] **FIG. 37** depicts a graph of electrical current input **1** to the light emitting semiconductor chip(s) of the curing light versus time in a pulsed power input scheme in order to enhance light power output from the chip(s) and in order to avoid light intensity dimunition due to the heat effect.

[0067] **FIG. 38** depicts a graph of total light intensity output versus time in order to permit the reader to compare light intensity output when a current input pulsing scheme such as that of **FIG. 37** is used to a traditional continuous wave current input approach which generates a heat effect is used.

DETAILED DESCRIPTION

[0068] The inventions include various embodiments of curing light systems useful for curing light activated composite materials, principally by polymerizing monomers into durable polymers. The invented curing light systems have application in a variety of fields, including but not limited to medicine and dentistry where composite materials with a photoinitiator are used. The photoinitiator absorbs light of a particular wavelength and causes polymerization of the monomers into polymers.

[0069] Composite materials are applied to a surface and later cured by a variety of methods. One method includes use of a photoinitiator or multiple photoinitiators in the composite material. After the composite material has been placed in a desired location, light of a wavelength that activates the photoinitiator is applied to the composite. The light activates the photoinitiator and initiates curing of the composite material. In order to effect complete curing, the light must be of a wavelength to which the photoinitiator is sensitive, the light must be of a power level that will cause curing, and the light must be applied to the composite material for a sufficient duration of time. Although the light used to activate the photoinitiator must be of a wavelength to which a photoinitiator is sensitive, the light can come from a variety of sources, including gas lasers solid state lasers, laser diodes, light emitting diodes, plasma-arc lights, xenon-arc lights, and conventional lamps. In the present inventions, light is produced from a variety of different semiconductor chips arranged in numerous configurations.

[0070] **FIG. 1** depicts a battery-powered curing light **100** that uses a single light emitting diode chip as a light source. **FIG. 2** depicts a cross-section of the light **100** of **FIG. 1**. The portable curing light system **100** includes a light source module **102** which generates light of a desired wavelength or multiple wavelengths for activating a photoinitiator or multiple photoinitiators and initiating curing of a light activated composite material. The light source module **102** has a light shield **103** for blocking light generated by the light emitting semiconductor chip(s) **150** from reaching human eyes and skin. The apparatus **103** could also be configured as a lens or focusing cone for modifying the footprint of light emitted by the curing light. The light emitting semiconductor chip(s) **150** are located at the distal end of the curing light, and at the distal end of the light source module **102**. The chip(s) **150** are oriented to emit light at generally a right angle with the longitudinal axis of the light source module or the longitudinal axis of the curing light handpiece, although chips could be mounted to emit light at from about a 45 degree angle to about a 135 degree angle with the longitudinal axis of the light source module, heat sink, or handpiece as desired. The curing light system **100** includes a housing **104** for containing and protecting electronic circuits and a DC battery pack. In some embodiments, the light emitting semiconductor chip(s) may be powered by from less than about 25 milliamps to more than about 2 amps. Many embodiments of the inventions will have chip(s) powered from about 350 milliamps to about 1.2 amps of current. Higher power embodiments of the inventions will often use more than about 100 milliamps of current.

[0071] A switch **105***a* is provided on the top of the housing **104** facing a direction opposite from the direction that light would be emitted from the light source module **103**. A second switch **105***b* is provided on the side of the housing. The switches **105***a* and **105***b* are devices such as a button or trigger for turning the light emission of the curing light on and off. A timer **106** is provided to control the duration of time that the curing light emits a beam of light. Control buttons to set and adjust the timer are depicted as **151***a* and **151***b*.

[0072] An audible indicator or beeper may be provided in some embodiments of the invention to indicate when light emission from the curing light begins and ends. A first light emitting diode indicator lamp **107** is located on the housing in a visible location in order to indicate to the user low battery power. A second light emitting diode indicator lamp **108** is located on the housing in a visible location in order to indicate to the user that the battery is being charged. A main on/off switch to the curing light **160** is provided at the rear or proximal end of the housing. A wavelength selector may be provided in some embodiments of the invention so that the user may select the wavelength of light that he wishes to emit from the curing light, depending on the wavelength sensitivity of the photoinitiator in the composite material that he is using. The user may also select a combination of two or more wavelengths of light to be emitted together in some embodiments of the invention.

[0073] A separate battery charger module **109** is included in order to receive AC power from a traditional wall socket and provide DC power to the curing light system for both charging the batteries and powering the light source and control circuitry when the batteries if desired. The battery charger module **109** has a cable **109***a* and a plug **109***b* for plugging into a receptacle or connector **170** on the proximal end of the curing light housing **104**. The battery charger module **109** includes circuitry **109***c* for controlling battery charging of batteries **166**.

[0074] The light module **102** has a casing **161** that encases an elongate heat sink **162**. The casing **161** is separated from

the heat sink **162** by a buffer layer **163** such as insulation tape and an air space may be provided therebetween for heat dissipation. Electrically conductive wires **164** to power the light-emitting semiconductor chip(s) **150**. Internally, we can see that the heat sink **162** is an elongate and curved structure which positions a semiconductor chip at its end in a convenient place for use without a light guide. At the distal end of the heat sink **162**, there may be a smaller primary heat sink or semiconductor chip module which includes a smaller primary heat sink. A semiconductor module may be covered by a protective cover or dome or a focus lens. The heat sink **162** may be an elongate structure or other shape as desired. Use of an elongate heat sink **162** rapidly transfer heat away from the chip(s) **150** for heat dissipation. If heat transfer and dissipation are not handled adequately, damage to the chip(s) **150** may result, or light output of the chip(2) **150** may be diminished.

[**0075**] The light source module **102** is removable from the housing **104** and interfaces therewith and mounts thereto by a connection plug **165**. One or more batteries **166** are provided to power the curing light during use. The curing light may have control circuitry **167** located in the housing **102**. Battery charger **109***c* is located in the power supply **109** for controlling battery recharging and direct powering of the curing light from wall outlet power when the batteries are low. The power supply **109** has an AC plug **109***d*.

[**0076**] A unique advantage of the curing light system depicted in several embodiments of the invention is that all components, including the light source, batteries, control circuitry and user interface are conveniently located in or on a handpiece. This results in a very portable, yet compact and easy to use curing light system. Only when the batteries are being charged would the user need to have a cord attached to the curing light system or even be in the vicinity of AC power. However, the light system can be operated using power from a battery charger when the battery pack is being charged or when no batteries are being used.

[**0077**] **FIG. 3** depicts an AC-powered curing light that uses a single light emitting diode chip as a light source. **FIG. 4** depicts a cross section of the light of **FIG. 3**. Referring to these figures, one embodiment of a curing light system **301** of the invention is depicted. The curing light system **301** includes a handpiece or wand **302**, cabling **303**, and a power supply **304** with an AC plug **304***a*. Curing light control circuitry **304***b* may be located within the power supply **304** and is remote from the wand **302** in order to keep the wand compact and light weight. The handpiece or wand **302** has minimum size, weight and componentry for convenience of use. The handpiece **302** includes a housing **305**, an on/off switch or light output control **306**, an integral light source module **307**, and a device **309** which may be a light shield, light reflective cone or focus lens. The handpiece **302** receives electrical power from cabling **303**. A cable strain relief device **308** may be provided. A timer **310** may be provided with timer adjustment buttons **311** and **312** in order to control timed duration of light output from the curing light. All control circuitry **304***b* is located in a module remote from the handpiece **302**.

[**0078**] Referring to the cross section of **FIG. 4**, it can be seen that the heat sink **401** may be configured as an elongate device with a planar mounting platform on its distal end for mounting chips or chip modules thereto. The heat sink has a longitudinal axis, and the light emitting semiconductor chip(s) may be oriented at an angle with the longitudinal axis of the heat sink from about 45 to about 135 degrees. In some embodiments of the invention, the chips will be oriented to emit light at an angle with the heat sink longitudinal axis of 70 to 110 degrees, 80 to 100 degrees, or about 90 degrees. The heat sink distal end may be curved as desired to position a light emitting semiconductor device **401** thereon to be positioned in a location for convenient use. The semiconductor device **402** may be covered with a protective window, dome or focus lens **403**. The heat sink may occupy less than 50% of the length of the wand, more than 50% of the length of the wand, 60% of the length of the wand, 70% of the length of the wand, 80% of the length of the wand, 90% of the length of the wand, or up to 100% of the length of the wand. Electrical wire **404** provides power to the light emitting semiconductor device **402**. Insulation means **405** such as rubber insulators or insulation tape separate the heat sink **401** from the casing **305** and provide for airspace **406** therebetween for ventilation and heat dissipation.

[**0079**] **FIG. 5** depicts a battery-powered curing light **501** that uses two light emitting diode chips as a light source. **FIG. 6** depicts a cross-section of the light **501** of **FIG. 5**. The curing light **501** includes a housing or casing **502** for containing and protecting the curing light components. A series of vents **503** are provided in the housing **502** to permit heat to escape therefrom and to permit air circulation therein. At the distal end of the housing **502**, a light module **504** is provided. The light module **504** may include an angled tip and may be removable and replaceable with other light modules of differing characteristics as desired. A light shield, light reflective cone or focus lens **505** is provided at the distal end of the light module **504**. At the proximal end of the curing light **501**, a handle **506** is provided for grasping the curing light. An on-off switch or trigger **507** is provided on the distal side of the curing light handle **506** for effecting light emission. On the proximal side of the curing light handle **506**, a main switch **507** for powering up the curing light **501** is located. A timer **509** with timer adjustment buttons **510** and **511** is provided to time the duration of light output. Indicator lights **512** and **513** are provided to indicate low battery and battery charging. A battery charger module **520** is provided with a power supply **521**, cable **522** and plug **523**. The plug fits into receptacle **601** for charging the battery **602** of the curing light **501**.

[**0080**] Referring to **FIG. 6**, Light module **504** includes a casing **603** that contains an elongate heat sink **604** that is separated from the casing **603** by insulators **605** to form a ventilating and heat-dissipating air space **606** therebetween. Heat sink **604** may include a thermoelectric cooler material **608** thereon for enhanced heat dissipation. Electrical wires **607** power a pair of light emitting semiconductor devices or modules **609***a* and **609***b*. The semiconductor devices **609***a* and **609***b* are mounted on the heat sink **604** at a mounting receptacle **611** that has two adjacent angled planes oriented to cause the light output beams from the semiconductor devices **609***a* and **609***b* to overlap to provide an overlapped and enhanced intensity light footprint **610**. The mounting planes are oriented at an angle of from about 10 to about 180 degrees with respect to each other. The curing light **501** also includes a timer **509** with timer control buttons **621** and **622**, and electronic control circuitry **623**. A battery pack **602** is located inside casing **502** to provide operating power. The light module **504** is connected to housing **502** using an

electrical plug **624**. The light module **504** can therefore be unplugged and replaced with another light module of different power characteristics or which emits a different wavelength of light for different usage applications.

[**0081**] **FIG. 7** depicts an AC-powered curing light **701** that uses two light emitting diode chips as a light source. **FIG. 8** depicts a cross-section of the light **701** of **FIG. 7**. The curing light system **701** includes a handpiece or wand **702**, cabling **703**, and a power supply **704** with an AC plug **704***a*. Control circuitry **704***b* is located within the power supply **704** and is remote from the wand **702** in order to keep the wand compact and light weight. The handpiece or wand **702** has minimum size, weight and componentry for convenience of use. The handpiece **702** includes a housing **705**, an on/off switch or light output control **706**, an integral light source module **707**, and a light shield **709**. The handpiece **702** receives electrical power from cabling **703**. A cable strain relief device **708** may be provided. A timer **710** may be provided with timer adjustment buttons **711** and **712** in order to control timed duration of light output from the curing light. All control circuitry **704***b* is located in a module remote from the handpiece **702**. Referring to the cross section of **FIG. 8**, it can be seen that the heat sink **801** may be configured as an elongate device with a longitudinal axis shared with the longitudinal axis of the wand. The light emitting semiconductor chip **802** and **803** are mounted to the heat sink **801** at an acute angle to each other in order to produce an overlapping and enhanced intensity light footprint. The heat sink distal end may be curved as desired to position the light emitting semiconductor devices thereon for convenient use. The semiconductor devices **803** and **803** may be covered by a protective window, dome or focus lens. The heat sink may occupy less than 50% of the length of the wand, more than 50% of the length of the wand, 60% of the length of the wand, 70% of the length of the wand, 80% of the length of the wand, 90% of the length of the wand, or up to 100% of the length of the wand. Electrical wire **804** provides power to the light emitting semiconductor devices **802** and **803**. Insulation means **805** such as rubber insulators or insulation tape separate the heat sink **801** from the casing **705** and provide for airspace **806** therebetween for ventilation and heat dissipation. A connection plug **810** is provided for connecting the power module to the curing light. Thermoelectric cooler material **820** is optionally provided on the heat sink for enhanced cooling.

[**0082**] **FIG. 9** depicts a battery-powered curing light **901** that uses three light emitting diode chips or modules as a light source. **FIG. 10** depicts a cross-section of the light **901** of **FIG. 9**. The componentry of this curing light is as generally described previously except for its three light emitting diode light source structure. It uses three light emitting diode chips or chip modules **902***a*, **902***b* and **902***c* arranged in complementary angled configuration so that the light beams emitted by each overlap at a desired distance from the light source to form an overlapped and enhanced intensity light footprint **903**. The arrangement of 3 LED's is described elsewhere in this document.

[**0083**] **FIG. 11** depicts an AC-powered curing light **1101** that uses three light emitting diode chips or modules as a light source. **FIG. 12** depicts a cross-section of the light **1101** of **FIG. 11**. The componentry of this curing light is as generally described previously except for its three light emitting diode light source structure. It uses three light emitting diode chips or chip modules **1102***a*, **1102***b* and **1102***c* arranged in complementary angled configuration so that the light beams emitted by each overlap at a desired distance from the light source to form an overlapped and enhanced intensity light footprint **1103**.

[**0084**] **FIG. 13** depicts a battery-powered curing **1301** light that uses a plurality of semiconductor chip modules mounted on a heat sink in a manner that the light they emit is collected by a reflector apparatus and focused by a lens means onto a light transport mechanism, such as a light guide, plastic stack or fiber **1302**. **FIG. 14** depicts a cross-section of the light **1301** of **FIG. 13**. Many of the components of this light are as discussed previously for other curing light embodiments, and that discussion is not repeated here. However, the light source and light transport means are very different from embodiments discussed above. The curing light **1301** includes a housing **1303** which has a light transport means **1302** such as a light guide, plastic stack or fiber attached to it. The light transport means **1302** transports light from a light module to a remote location for use. The light transport means **1302** depicted has a curved distal portion **1304** to cause light **1305** to be emitted in a desired direction, such as at a right angle to the longitudinal axis of the curing light or the light transport means. The light transport means may be removable and replaceable with light guides of different lengths and configurations. A gross or secondary heat sink **1405** is provided for heat removal from the system. The secondary heat sink **1405** has a proximal side on which a thermoelectric material layer **1406** may be placed to enhance heat removal ability. Optionally, a fan **1407** may be provided to improve heat removal efficiency, and vents may be provided in the housing to encourage air circulation. The secondary heat sink **1405** may have mounted directly or indirectly to it a plurality of semiconductor light emitting chips or chip modules **1409**. Those chips **1409** may be mounted to a primary heat sink such as **1410**. Light emitted by the chips **1409** will be reflected by a reflector device **1411** such as a mirrored parabolic reflector to an optional lens or focusing device **1412** which focuses a generally coherent light beam onto the light transport means **1302**. The reflector may be of a desired shape for directing light, such as frusto-conical, parabolic or otherwise. If the light emitting devices are oriented so that the light which they emit is substantially directed toward the distal end of the curing light, the reflector may be omitted. A battery pack **1415** and control circuitry **1413** are provided.

[**0085**] **FIG. 15** depicts an alternative embodiment of the light of **FIG. 13**. The curing light **1501** has no light transport mechanism and instead has a light exit tube **1502** that has a distal end with a mirror or reflector **1504** which can reflect a generally coherent light beam **1503** to a light exit **1505** in a desired direction for use, such as at a generally right angle to the longitudinal axis of the light module or the curing light.

[**0086**] **FIG. 16***a* depicts a curing light curing light **1601** that has a light source and control module **1602** remotely located from a handpiece **1603** connected by a connection means **1604** that includes an optically conductive cable and electrical wires for electrical connection. **FIG. 16***b* depicts a cross section of the light of **FIG. 16***a*. The light source and control module **1602** includes a housing **1610** with optional air vents thereon, electronic control circuitry **1611**, an electrical cord with power plug **1612**, a cooling fan **1613** for air

circulation and heat dissipation, a heat sink **1615** which may be appropriately shaped to accept light emitting semiconductor devices on its distal side, such as having a concave hemispherical or parabolic portion, and having a thermoelectric cooler **1616** on its proximal side for enhanced heat dissipation. A plurality of light emitting semiconductor devices such as LED chip modules **1618** are mounted to the heat sink distal side so that they emit light into an optical system such as a focus lens **1619** which places a generally coherent light beam onto the optically conductive cable where it is transported to a distant handpiece **1603** that includes a housing **1651**, light exit **1650** for permitting light to be delivered to a composite material to be cured, and various controls such as light on/off control **1660**, timer display **1663**, and timer adjustment buttons **1661** and **1662**. The distal end of the handpiece housing **1670** may be angled from the longitudinal axis of the handpiece in for convenience of light application to a composite material.

[**0087**] As desired in various embodiments of the inventions, the light source may be a single LED chip, single LED chip array, an array of LED chips, a single diode laser chip, an array of diode laser chips, a VCSEL chip or array, or one or more LED or diode laser modules. The wavelength of light emitted from the semiconductor light source can be any desired wavelength or combination of different wavelength, depending on the sensitivity of the photoinitiator(s) in the composite material to be cured. Any of the semiconductor and heat sink arrangements described herein may be used to construct desired curing lights.

[**0088**] Referring to **FIG. 17***a*, a light emitting diode ("LED") chip **1701** is depicted in which the LED structure **1702** has been grown on top of or on one side of an insulative substrate **1703**. Electrodes **1704***a* and **1704***b* are provided to power the LED. In such a structure, all electrodes will be located on the top surface of the LED. Light is emitted from all sides of the LED as depicted.

[**0089**] A similar LED chip **1710** with a conductive substrate **1711** and accompanying LED structure **1712** and electrodes **1713** and **1714** is depicted in **FIG. 17***b*.

[**0090**] **FIG. 18***a* depicts an example of epitaxial layer configuration **1801** for an LED with an insulative substrate used in the invention. The LED includes an electrically insulative substrate such as sapphire **1802**. The substrate serves as a carrier, pad or platform on which to grow the chip's epitaxial layers. The first layer placed on the substrate **1802** is a buffer layer **1803**, in this case a GaN buffer layer. Use of a buffer layer reduces defects in the chip which would otherwise arise due to differences in material properties between the epitaxial layers and the substrate. Then a contact layer **1804**, such as n-GaN, is provided. A cladding layer **1805** such as n-AlGaN Sub is then provided. Then an active layer **1806** is provided, such as InGaN multiple quantum wells. The active layer is where electrons jump from a conduction band to valance and emit energy which converts to light. On the active layer **1806**, another cladding layer **1807**, such as p-AlGaN is provided that also serves to confine electrons. A contact layer **1808** such as p+GaN is provided that is doped for Ohmic contact. The contact layer **1808** has a positive electrode **1809** mounted on it. The contact layer **1804** has a negative electrode **1810**.

[**0091**] **FIG. 18***b* depicts epitaxial layer configuration **1850** for an LED with a conductive substrate. The LED includes an electrically conductive substrate such as SiC **1852** that has an electrode **1851** on it. The substrate serves as a carrier, pad or platform on which to grow the chip's epitaxial layers, and as a negative electrode in the chip. The first layer placed on the substrate **1852** is a buffer layer **1853**, such as n-GaN. A cladding layer **1854** such as n-AlGaN is provided followed by an active layer **1855** such as InGaN with multiple quantum wells. That is followed by a cladding layer **1856** such as p-AlGaN and finally a contact layer **1857** such as p+GaN that has an electrode **1858** mounted on it.

[**0092**] **FIG. 19***a* depicts a top view of an LED array on a single chip **1901** with a size a×b on an insulating substrate. The size of a and b are each greater than 300 micrometers. Semiconductor materials **1904** are located on an electrically insulative substrate (not shown). Positive and negative electrode pads are provided, each in electrical connection with its respective metal electrode strip **1902** and **1903** arranged in a row and column formation (8 columns shown) to create the array and power the chip. This structure enables the LED to emit light of greater power than that which is possible in a non-array traditional chip.

[**0093**] **FIG. 19***b* depicts a top view of an LED array on a single chip **1950** with a size a×b on a conductive substrate. Each of sizes a and b is greater than 300 micrometers. Semiconductor materials **1952** are located on an electrically conductive substrate (not shown). Positive electrode pads are provided in electrical connection with a metal strip **1951** arranged in an array formation to power the chip. The substrate serves as the negative electrode in the embodiment depicted.

[**0094**] Referring to **FIG. 20***a*, a side view of a surface mount LED chip package **2000** including the LED chip **2001** on a heat sink **2002** is provided. The LED chip depicted has an insulating substrate and is mounted in a well **2004** of the heat sink **2002** by the use of heat conductive and light reflective adhesive **2003**. Light is emitted by the chip in all directions, and light which is emitted toward the adhesive **2003** or the well walls is reflected outward in a useful direction **2020**. The chip is electrically connected via wires **2010***a*, **2010***b*, **2010***c* and **2010***d* using intermediary islands **2011** and **2012**. The LED chip is located in a circular well **2004** of the heat sink **2002**. The circular well is formed with sides or walls at about a 45 degree angle or other desired angle (such as from about 170 to about 10 degrees) so that light emitted from the side of the chip will be reflected from the walls of the well in a desired direction as indicated by arrows in the figure. This allows the highest possible light intensity to be obtained using a chip of given size. The well walls may have a light reflective coating to increase efficiency.

[**0095**] Referring to **FIG. 20***b*, a perspective view of a LED chip array (single chip) chip package **2050** including the chip array **2051** on an insulative substrate in a well **2052** of a heat sink **2053** is depicted.

[**0096**] Referring to **FIG. 21***a*, a side view of an LED chip module **2100** is provided. An LED chip **2101** with a conductive substrate is mounted in a circular well **2103** of a heat sink **2104** by use of heat conductive light reflective adhesive **2102**. A negative electrode **2110** is provided on the heat sink. Positive electrical connection is provided by wires **2105** and **2106**, and island **2107**.

[**0097**] Referring to **FIG. 21***b*, a chip array package **2150** that includes an LED chip array **2151** with a conductive

substrate mounted in a well **2152** of a heat sink **2153** with an electrode **2154** and wire connection **2155** is depicted.

[**0098**] **FIG. 22***a* depicts a side view of a chip package **2200** for a light emitting diode chip array **2201** mounted in a well **2202** of a heat sink **2203** according to the so-called 'flip chip' design, the chip having an insulative substrate. **FIG. 22***b* depicts a side view of a flip chip **2201** mounted on a flip chip pad **2204**. **FIG. 22***c* depicts a perspective view of a flip chip pad **2204**. **FIG. 22***d* depicts a perspective view of the chip package **2200** of **FIG. 22***a*. Intermediate islands or electrode pads **2201***a* and **2210***b* are provided on the flip chip pad to ease of electrical connection with the chip. Electrode bumps **2111***a* and **2111***b* are provided between the chip and the pad for electrical connection. The chip has an electrode **2201***b* on top and its epitaxial layers **2201***a* facing down toward the pad **2204** and the bottom of the well **2202**. The pad **2204** upper surface is light reflective so that light is reflected from the pad in a useful direction. The pad **2204** may be coated with a light reflective film, such as Au, Al or Ag. In such a package, all of the light emitted from the chip can be reflected back in the light exit direction for highest light output.

[**0099**] **FIG. 23** depicts a flip chip package **2301** in which a chip **2302** with a conductive substrate is mounted upside down (electrode up) on a flip chip pad **2303** with light reflective and heat conductive adhesive **2304** in the well of a heat sink. Electrical connection takes advantage of the exposed electrode of the chip **2302**.

[**0100**] Referring to **FIG. 24***a*, a high power LED package **2401** is depicted using a chip **2402** with an insulative substrate mounted in the well of a heat sink **2403** using heat conductive and light reflective adhesive **2404**. The heat sink is surrounded by a known insulating material **2405** that serves the purpose of protecting electrode and dome connections. The walls and bottom of the well may be polished to be light reflective, or may be covered, plated, painted or bonded with a light-reflective coating such as Al, Au, Ag, Zn, Cu, Pt, chrome, other metals, plating, plastic and others to reflect light and thereby improve light source efficiency. Electrodes and/or connection blocks are provided for electrical connection of the chip. An optical dome or cover **2410** may optionally be provided for the purpose of protecting the chip and its assemblies, and for the purpose of focusing light emitted by the chip. The dome may be made of any of the following materials: plastic, polycarbonate, epoxy, glass and other suitable materials. The configuration of the well and the dome provide for light emission along an arc of a circle defined by ϕ. **FIG. 24***b* depicts a similar arrangement for a chip package **2450** in which the chip **2454** has a conductive substrate and thus when mounted to the heat sink **2452** can use an electrode **2455** on the heat sink itself for electrical connection. Protective dome **2451** and insulating covering **2453** are provided.

[**0101**] Referring to **FIGS. 25***a* and **25***b*, a chip package **2501** is provided with an array of light emitting semiconductor chips **2504***a*, **2504***b*, etc. having electrically insulative substrates located in a single well **2502** of a heat sink **2503**. The chips are mounted by an electrically conductive and heat conductive adhesive **2605**. The chips are electrically connected to each other by wires **2505***a*, **2505***b*, etc.

[**0102**] Referring to **FIGS. 26***a* and **26***b*, a chip package **2601** is provided that has a heat sink **2602** with a single well **2603** and an array of LED chips **2604***a*, **2604***b*, etc. in the well **2603**. The chips have electrically conductive substrates and an electrode **2606** is provided on the heat sink.

[**0103**] Referring to **FIG. 27***a*, a chip package **2701** is depicted with an array of LED chips **2702***a*, **2702***b*, **2702***c*, etc. is depicted, with each chip located in its own individual sub-well **2703***a*, **2703***b*, **2703***c* in a gross well **2704** of a heat sink **2705**. The chips have electrically insulative substrates.

[**0104**] Referring to **FIG. 27***b*, a chip package **2750** is depicted that has an array of LED chips **2763***a*, **2763***b*, **2763***c* with electrically conductive substrates. Each LED chip is mounted in its own individual sub-well, all located within a gross well **2761** of a heat sink **2762**.

[**0105**] **FIGS. 28***a* and **28***b* depict a chip package **2801** that has a heat sink **2802** with a gross well **2803** and a plurality of sub-wells **2804** therein, each sub-well having a light emitting chip **2805** with a conductive substrate within it. The heat sink **2803** has a negative electrode **2806** for electrical connection.

[**0106**] Referring to **FIG. 29***a*, an LED chip module **2901** is depicted that has an array of LED chips **2902***a*, **2902***b*, etc located in a well **2903** of a heat sink **2904**. Insulative covering **2910** as well as a cover or dome **2911** are provided respectively. The chips of **FIG. 29***a* have insulative substrates.

[**0107**] Referring to **FIG. 29***b*, an LED chip module **2950** is depicted that has an array of LED chips **2951***a*, **2951***b*, etc. located in a well **2955** of a heat sink **2954**. Insulative covering **2960** as well as a cover or dome **2961** are provided respectively. The chips of **FIG. 29***b* have conductive substrates and an electrode **2959** is provided on the heat sink.

[**0108**] Referring to **FIG. 30***a*, an LED chip module **3001** is depicted that has an array of LED chips **3002**, with each chip in a sub-well **3003** of a gross well **3006** of a heat sink **3005** and the entire module covered by a protective or focus dome **3012**. The chips have electrically insulative substrates.

[**0109**] Referring to **FIG. 30***b*, an LED chip module **3050** is depicted that has an array of LED chips **3051**, with each chip in a sub-well **3052** of a gross well **3055** of a heat sink **3054** and the entire module covered by a protective or focus dome **3061**. The chips have electrically conductive substrates and there is an electrode **3056** on the heat sink.

[**0110**] Referring to **FIGS. 31***a* and **31***b*, side and bottom views of a surface mount chip configuration are depicted for mounting a single LED **3100** or LED module (as described previously) to an elongate heat sink **3101**. Electrically conductive wires **3102***a* and **3102***b* and electrodes **3103***a* and **3103***b* are provided for powering the LED. The LED is mounted on a platform **3104** formed on the heat sink distal end. Mounting is achieved by use of light reflective and heat conductive adhesive **3105**. A cover or focus dome **3106** is provided over the LED. The heat sink has a longitudinal axis, and the LED is mounted so that the average beam of light that it emits is generally at a 45 to 135 degree angle with that axis, and in some instances at a right angle to it.

[**0111**] **FIGS. 32***a* and **32***b* depict side and bottom views of an elongate heat sink **3201** having two light emitting semiconductor chips or modules **3202** and **3203** mounted on mounting platforms **3204***a* and **3204***b* using adhesive **3205***a* and **3505***b* (such as heat conductive or light reflective

adhesive). The chips are mounted on the heat sink in an angled orientation with respect to each other in order to present overlapping light beams for an enhanced density light footprint **3204**. The angle of orientation of the chips is depicted as θ which can be from zero to 180 degrees, or from 30 to 150 degrees, or from 45 to 135 degrees, or from 70 to 110 degrees, or from 80 to 100 degrees or about 90 degrees, as desired. The chips are offset from each other by a desired distance 'a', which can range from zero to any desired distance. Wires and electrodes are provided to power the LED's. An optional thermoelectric cooler **3208** may be provided to enhance heat removal.

[0112] **FIG. 33***a* depicts a cross-sectional side view of a light module that uses three light emitting chips or chip modules. **FIG. 33***b* depicts a bottom view of the same. **FIG. 33***c* depicts a bottom view of the heat sink and mounting platform arrangement. **FIG. 33***d* depicts a side view of the heat sink and mounting platform arrangement. An elongate heat sink **3301** is provided having three light emitting semiconductor chips or modules **3302**, **3303**, and **3304** mounted on mounting platforms in an angled orientation with respect to each other in order to present overlapping light beams for an enhanced density light footprint **3306**. The mounting platforms depicted are generally planar and are arranged to present the densest useful light footprint. The modules may each include their own primary heat sink. The modules or chips may be mounted to the elongate heat sink using a heat conductive or light reflective adhesive as desired. Electrical wires and electrodes are used to power the chips or modules. An optional thermoelectric cooler **3308** may be provided. The mounting platforms **3305***a*, **3305***b* and **3305***c* can be seen more clearly in **FIGS. 33***c* and **33***d*. The mounting platforms depicted are arranged in circular fashion at an angular offset θ with respect to each other, which in this case is 120 degrees. More mounting platforms could be used, and any desired arrangement of the mounting platforms could be accommodated. In **FIG. 33***d* it can be seen that the mounting platforms **3305***a*, **3305***b* and **3305***c* are arranged at an angle ϕ with the longitudinal axis of the heat sink **3301**. The angle ϕ can be from 0 to 90 degrees, from 10 to 80 degrees, from 20 to 70 degrees, from 30 to 60 degrees, from 40 to 50 degrees, or about 45 degrees as desired to generate the densest usable light footprint.

[0113] **FIG. 34***a* depicts a light shield **3401** which may be used in conjunction with curing lights of the invention to shield human eyes from light emitting by the curing light. The light shield includes an orifice **3403** through which light from a curing light may pass, the receptacle **3403** being formed by the light shield body **3402**. A flare **3404** of the shield performs most of the protective function.

[0114] **FIG. 34***b* depicts a focus lens **3402** which may be used to focus light emitted by curing lights of the invention in order to present a denser light footprint. The focus lens has an outer periphery **3405**, a light entrance side **3506** and a light exit **3507**. The focus lens may be designed according to known optical principles to focus light output from chips which may not be in an optimal pattern for use in curing.

[0115] **FIG. 34***c* depicts a reflection cone **3408** in conjunction with LED module **3409**, which is mounted on a heat sink **3910** by using heat conductive adhesive **3411**. One or more connection wires **3412** may be provided to power the LED module **3409**. The purpose of the light reflective cone is to re-shape the light beam from the LED module to create a light footprint of desired size and density. The inner wall of the cone **3408** may be coated with a highly reflective material, such as the reflective materials mentioned elsewhere in this document. The light beam from the LED module will change its path and configuration due to being reflected by the cone **3408**.

[0116] A detailed depiction of the light reflective cone **3408** is provided in **FIG. 34***d*, which illustrates a cross-sectional view of the cone. An opening with an appropriate diameter "a" is provided at the proximal side of the cone for fitting to a light module of a curing light. The diameter "a" is chosen as an appropriate size for permitting light to enter therein. The cone has a total length "b". Adjacent light entrance at "a", a cylindrical portion of the cone is provided having a longitudinal length "c". Following cylindrical portion "c", there is a frusto-conical section of the cone interior having a length "b" minus "c". A light exit is provided at the end of the cone opposite the light inlet. The light exit has a diameter "d", where in many embodiments of the invention, "d" will be smaller than "a". The exterior diameter of the cone at its point of attachment to a light module is "e", where "e" is greater than "a". As desired, the various dimensions of the cone as well as its basic geometry (such as conical, frusto-conical, cylindrical, parabolic, etc.) are selected to achieve a desired light footprint size and density. Preferably, at least some portion of the interior surfaces of the reflective cone will have the ability to reflect light to aid in increasing the density of a light footprint. Appropriate reflective surfaces are mentioned elsewhere herein. Example dimensions of the various portions of the reflective cone in one embodiment of the invention are as follow: a=from about 5 mm to about 8 mm; b=from about 5 mm to about 8 mm; c=from about 2 mm to about 3 mm; d=from about 4 mm to about 6 mm; e=from about 8 mm to about 10 mm. Actual structure and dimensions of a reflective cone or reflective attachment or light exit for a curing light may vary depending on product type and application and design choice.

[0117] **FIG. 35** depicts a logic diagram **3501** of circuitry that may be used by AC-powered versions of the invented curing lights. AC power input **3502** is provided to a power switch source **3503** which outputs DC power to a main switch **3504**. Main switch **3504** powers the control circuit **3505** and the optional TE cooler **3506** if so equipped. Main switch **3504** also provides a constant current source **3507** for the timer **3508**, timer setup **3511**, timer activation switch **3572** and optional light output beeper **3513**. Constant current source **3507** also powers the light source **3509** to accomplish light output **3510**.

[0118] Referring to **FIG. 36, a** logic diagram **3601** of circuitry that may be used by battery-powered versions of the invented curing lights is depicted. AC power input **3602** is provided to a power switch source **3603** which outputs DC power to a battery charge unit **3604** that charges battery **3605**. The battery **3605** powers main switch **3507**. Main switch **3607** powers the control circuit **3608** that controls the optional TE cooler **3610** and the fan **3609**. Main switch **3607** also provides a constant current source **3611** for the timer **3613**, timer setup **3614**, timer activation switch **3615** and optional light output beeper **3616**. Constant current source **3611** also powers the light source **3612** to accomplish light output. An electrical voltage booster **3617** may be provided

to increase the voltage from the battery to meet electrical requirements of the light source.

[0119] Referring to **FIG. 37, a** graph of electrical current input **1** to the light emitting semiconductor chip(s) of the curing light versus time in a pulsed power input scheme is depicted. **FIG. 38** depicts a graph of total light intensity output versus time in order to permit the reader to compare light intensity output when a current input pulsing scheme such as that of **FIG. 37** is used to a traditional continuous wave current input approach which generates a heat effect is used. A pulsed current input scheme is used in order to enhance light power output from the chip(s) and in order to avoid light intensity reduction due to the heat effect. It has been found that when operated in continuous wave mode, the heat effect or heat buildup in the light emitting semiconductor chips will cause a decrease in light output intensity over time, until a stabilized light output yield is reached **3802** at point in time **3803**. In contrast, when current input to the semiconductor light source is pulsed, a greater even level of light power output with greater intensity is achieved **3801**. Laboratory experiments have shown this increased to be more than 20% in some embodiments, providing significantly increased light yield and stable light intensity output in exchange for a simple control modification. Each of the square waves in **FIG. 37** is a pulse of current input to the semiconductor light source, measured by "a=duration", "b=rest period", and "c=current input level (amps.)".

[0120] Examples of some heat sink materials which may be used in the invention include copper, aluminum, silicon carbide, boron nitride natural diamond, monocrystalline diamond, polycrystalline diamond, polycrystalline diamond compacts, diamond deposited through chemical vapor deposition and diamond deposited through physical vapor deposition. Any materials with adequate heat conductance can be used.

[0121] Examples of heat conductive adhesives which may be used are silver based epoxy, other epoxies, and other adhesives with a heat conductive quality. In order to perform a heat conductive function, it is important that the adhesive possess the following characteristics: (i) strong bonding between the materials being bonded, (ii) adequate heat conductance, (iii) electrically insulative or electrically conductive as desired (or both), and (iv) light reflective as desired, or any combination of the above. Examples of light reflective adhesives which may be used include silver and aluminum based epoxy.

[0122] Examples of substrates on which the semiconductors used in the invention may be grown include Si, GaAs, GaN, InP, sapphire, SiC, GaSb, InAs and others. These may be used for both electrically insulative and electrically conductive substrates.

[0123] Materials which may be used to used as a thermoelectric cooler in the invention include known semiconductor junction devices.

[0124] The semiconductor light source of the invention should emit light of a wavelength suitable to activate photoinitiators in the composite material to be cured.

[0125] Heat sinks used in this invention can be of a variety of shapes and dimensions, such as those depicted in the drawings or any others which are useful for the structure of the particular light source being constructed. It should be noted that particular advantage has been found when attaching the semiconductor light source to a small primary heat sink, and then the small primary heat sink is attached to an elongate secondary heat sink to draw heat away from the semiconductor and away from the patient's mouth.

[0126] While the present invention has been described and illustrated in conjunction with a number of specific embodiments, those skilled in the art will appreciate that variations and modifications may be made without departing from the principles of the invention as herein illustrated, described, and claimed.

[0127] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects as only illustrative, and not restrictive. The scope of the invention is, therefore, indicated by the appended claims, rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

1. A curing light comprising:

a wand adapted to be grasped by a human hand for use in positioning and manipulating the curing light,

an elongate heat sink with a proximal end and a distal end, said proximal end being proximate said wand, said elongate heat sink having a longitudinal axis,

a mounting platform located at said elongate heat sink distal end, said mounting platform being adapted to have a LED chip module,

an LED chip module mounted on said mounting platform, said LED chip module including

a primary heat sink, said primary heat sink having a smaller mass than said elongate heat sink,

a well on said primary heat sink for mounting an LED chip,

an LED chip mounted in said well,

a cover that provides protective covering for said LED chip and which permits light emitted by said LED chip to pass through it to provide usable light exiting from said light module, and

a thermoelectric cooler located on said elongate heat sink, said thermoelectric cooler serving to assist in heat dissipation.

2. A curing light as recited in claim 1 wherein light emitted by said LED chip module is emitted at an angle of from about 30 degrees to about 150 degrees to said elongate heat sink longitudinal axis.

3. A curing light as recited in claim 1 wherein light emitted by said LED chip module is emitted at an angle of about 90 degrees to said elongate heat sink longitudinal axis.

4. A curing light as recited in claim 1 further comprising at least one air vent on said wand.

5. A curing light as recited in claim 1 further comprising a plurality of insulators to insulate said elongate heat sink from said wand.

6. A curing light as recited in claim 1 wherein said wand has a housing and said elongate heat sink is located at least partially within said housing.

7. A curing light as recited in claim 6 further comprising an air space between said elongate heat sink and said wand.

8. A curing light comprising:

a wand adapted to be grasped by a human hand for use in positioning and manipulating the curing light,

an elongate heat sink with a proximal end and a distal end, said proximal end being proximate said wand, said elongate heat sink having a longitudinal axis,

a primary heat sink,

said primary heat sink having a smaller mass than said elongate heat sink,

said primary heat sink being attached to said elongate heat sink,

at least one semiconductor device capable of emitting light useful in curing composite materials directly mounted to said primary heat sink,

a cover that provides protective covering for said chip and which permits light emitted by said chip to pass through it to provide usable light exiting from the cover, and

a thermoelectric cooler located on said elongate heat sink, said thermoelectric cooler serving to assist in heat dissipation.

9. A curing light as recited in claim 8 wherein light emitted by said chip is emitted at an angle of from about 30 degrees to about 150 degrees to said elongate heat sink longitudinal axis.

10. A curing light as recited in claim 8 wherein light emitted by said LED chip module is emitted at an angle of about 90 degrees to said elongate heat sink longitudinal axis.

11. A curing light as recited in claim 8 further comprising a plurality of insulators to insulate said elongate heat sink from said wand.

11. A curing light as recited in claim 8 wherein said wand has a housing and said elongate heat sink is located at least partially within said housing.

12. A curing light as recited in claim 11 further comprising an air space between said elongate heat sink and said wand.

13. A curing light as recited in claim 12 further comprising at least one air vent on said wand.

14. A curing light as recited in claim 8 wherein said chip is selected from the group consisting of light emitting diode chips, laser chips, light emitting diode chip array, diode laser chips, diode laser chip array, surface emitting laser chips, edge emitting laser chips, and VCSEL chips.

15. A curing light as recited in claim 8 wherein said cover is selected from the group consisting of windows and focus lenses.

16. A curing light comprising:

a wand adapted to be grasped by a human hand for use in positioning and manipulating the curing light,

a wand housing that forms at least a portion of the outer surface of said wand,

controls located on said wand housing for controlling initiation and termination of light emission from the curing light,

a heat sink, said heat sink serving to assist in heat dissipation, and said heat sink located in said wand housing,

a plurality of insulators useful for insulating said heat sink from said housing,

air space between said heat sink and said housing,

at least one vent located on said housing,

at least one semiconductor device capable of emitting light useful in curing composite materials, and

a thermoelectric cooler in physical contact with said heat sink, said thermoelectric cooler serving to assist in heat dissipation;

wherein light emitted by said chip is emitted at an angle of from about 30 degrees to about 150 degrees to said elongate heat sink longitudinal axis; and

wherein said chip is selected from the group consisting of light emitting diode chips, laser chips, light emitting diode chip array, diode laser chips, diode laser chip array, surface emitting laser chips, edge emitting laser chips, and VCSEL chips.

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