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(12) United States Patent
Cao

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(54) **DENTAL CURING LIGHT USING PRIMARY AND SECONDARY HEAT SINK COMBINATION**

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(73) Assignee: **Cao Group, Inc.**, Sandy, UT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 27 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/017,272**

(22) Filed: **Dec. 13, 2001**

(65) **Prior Publication Data**

US 2002/0197582 A1 Dec. 26, 2002

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/405,373, filed on Sep. 24, 1999, now Pat. No. 6,331,111.

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

(51) **Int. Cl.**[7] **A61C 3/00**

(52) **U.S. Cl.** **433/29**; 362/800

(58) **Field of Search** 433/29, 215; 606/1, 606/13, 16; 607/88; 362/119, 800, 804

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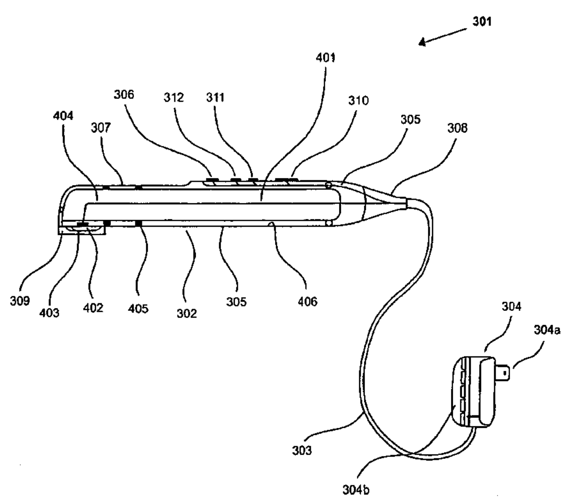
(57) **ABSTRACT**

A curing light system useful for curing light activated composite materials is disclosed. The system includes a light emitting semiconductor device, a primary heat sink and a secondary heat sink. 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.

20 Claims, 45 Drawing Sheets



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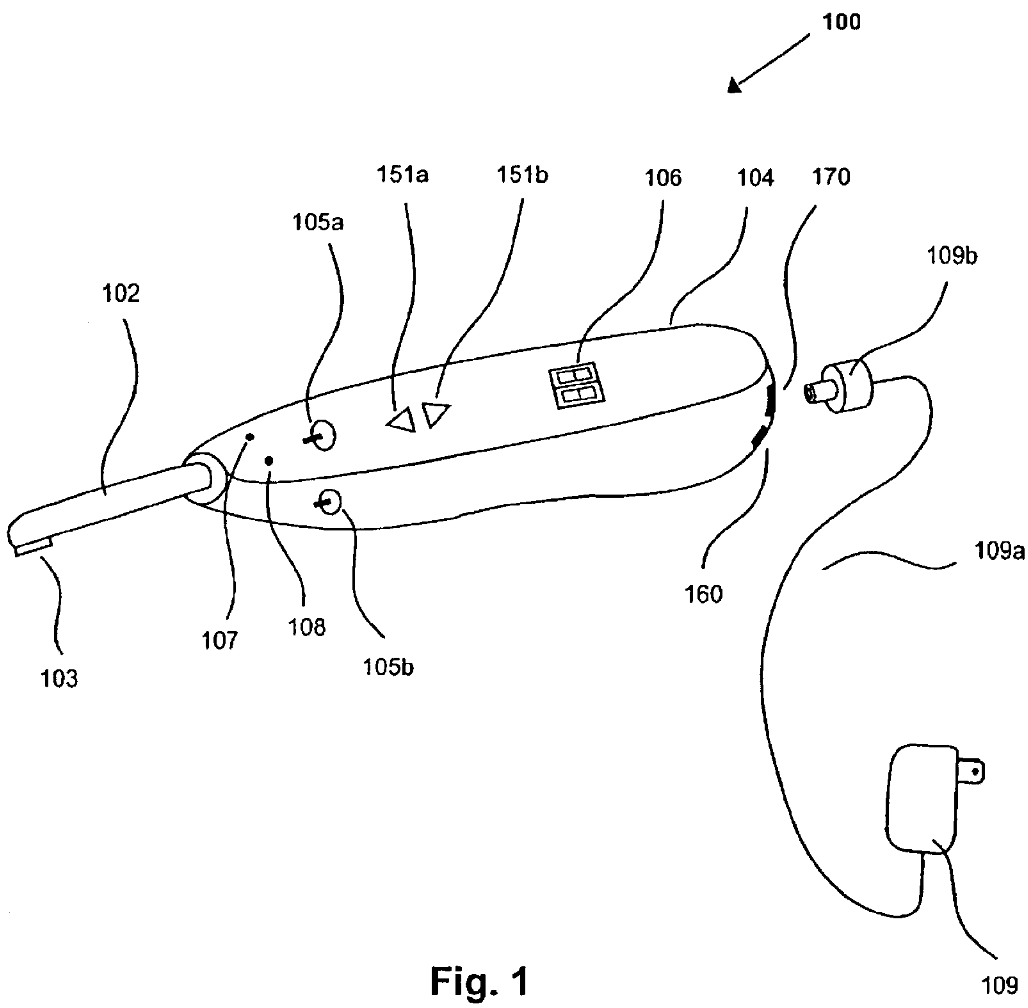
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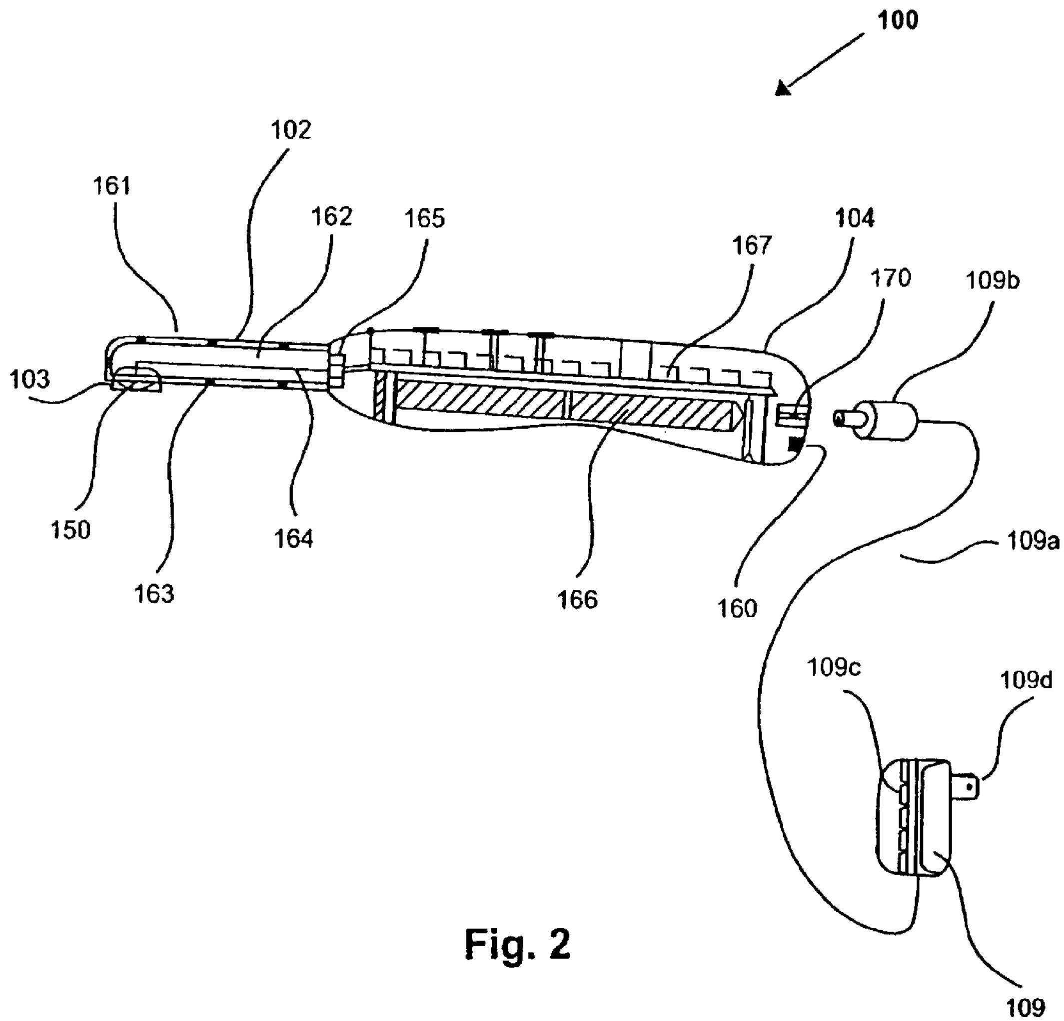
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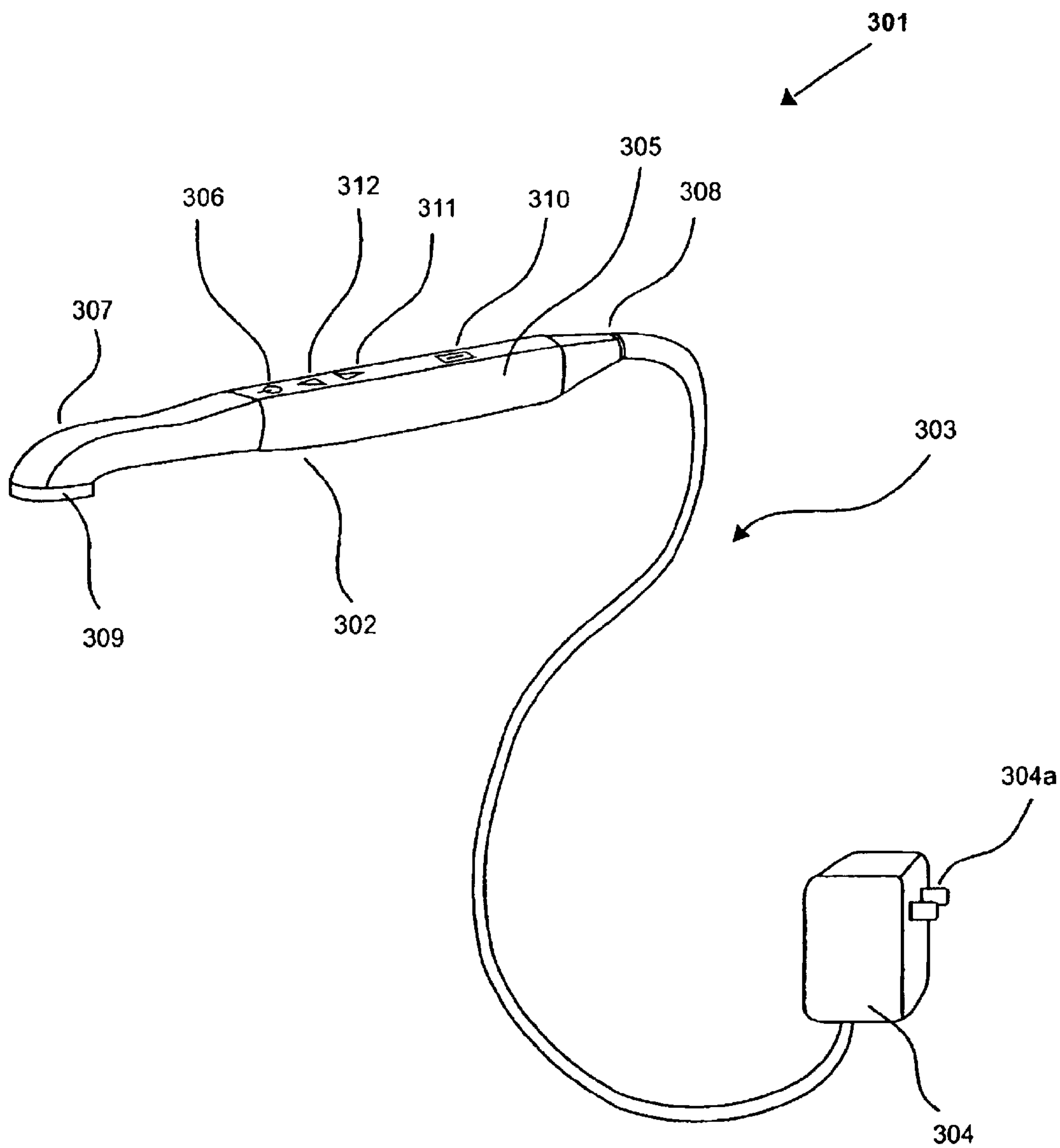

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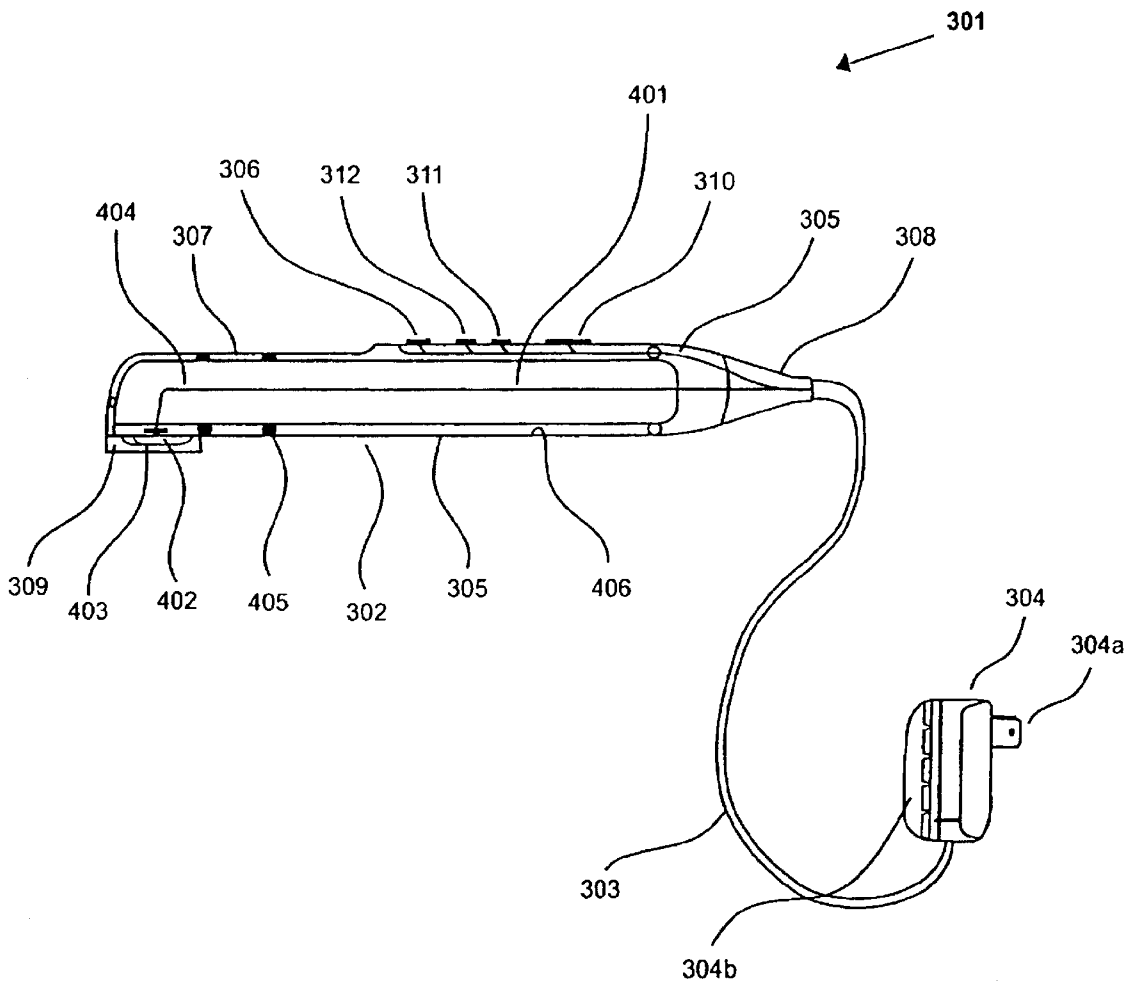
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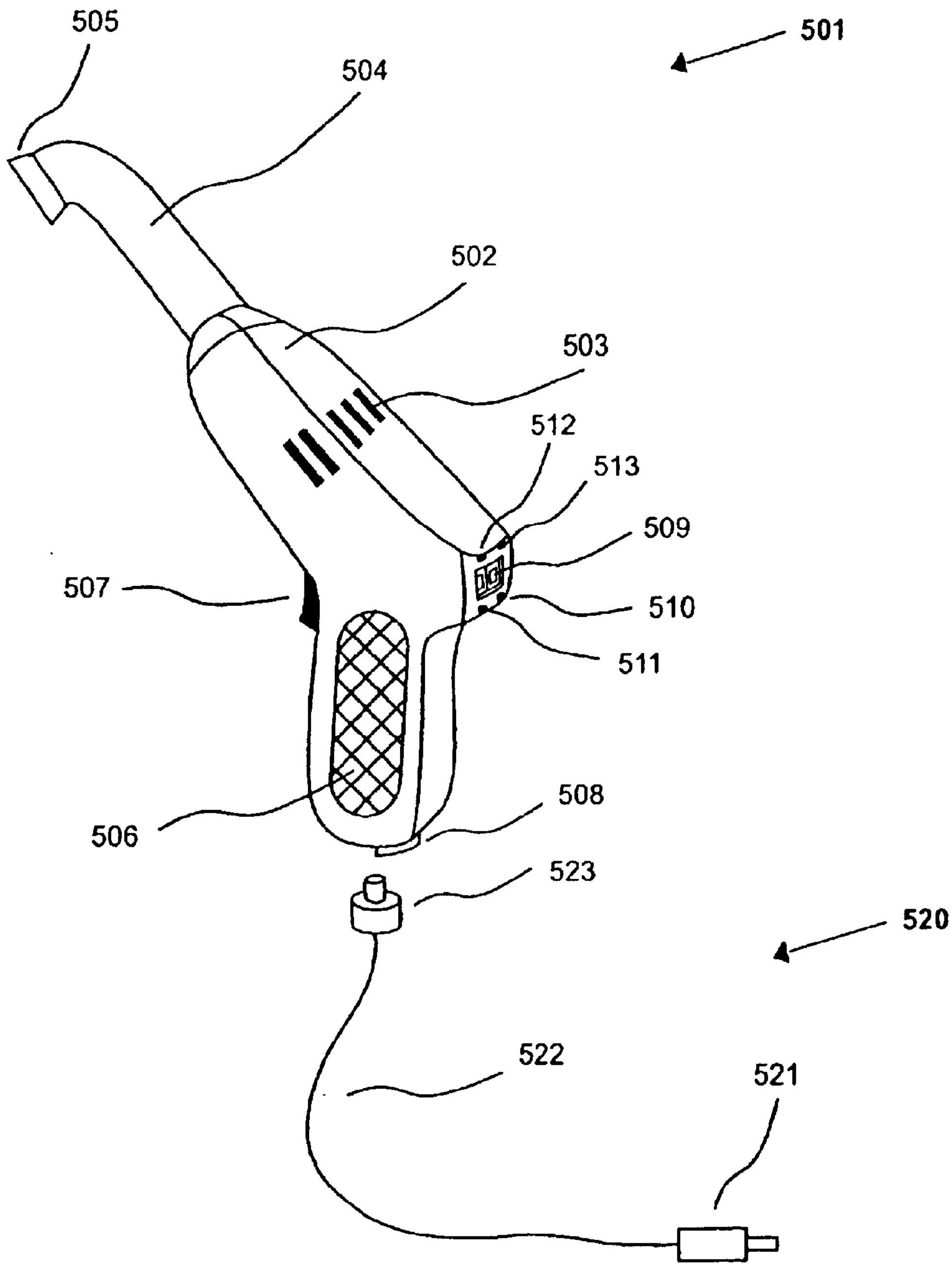
Fig. 4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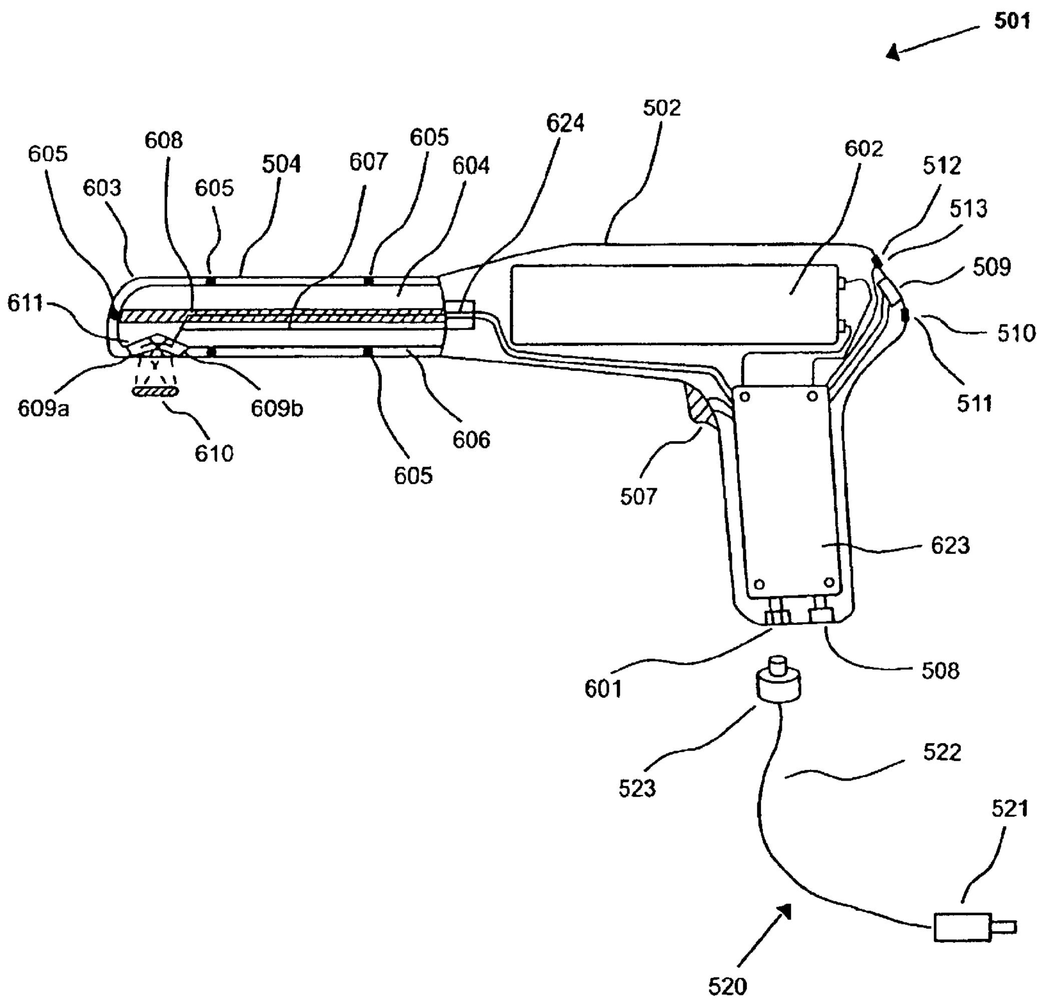
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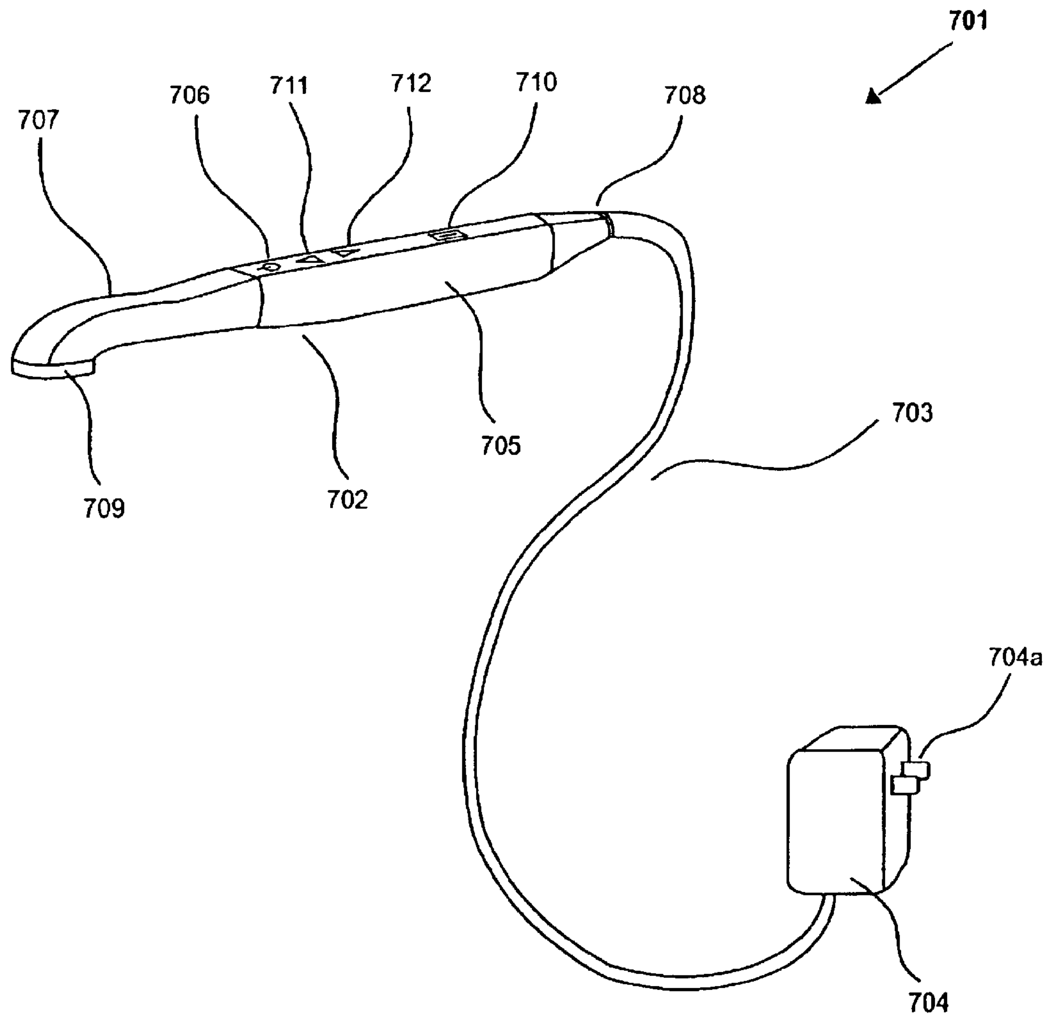
Fig. 6



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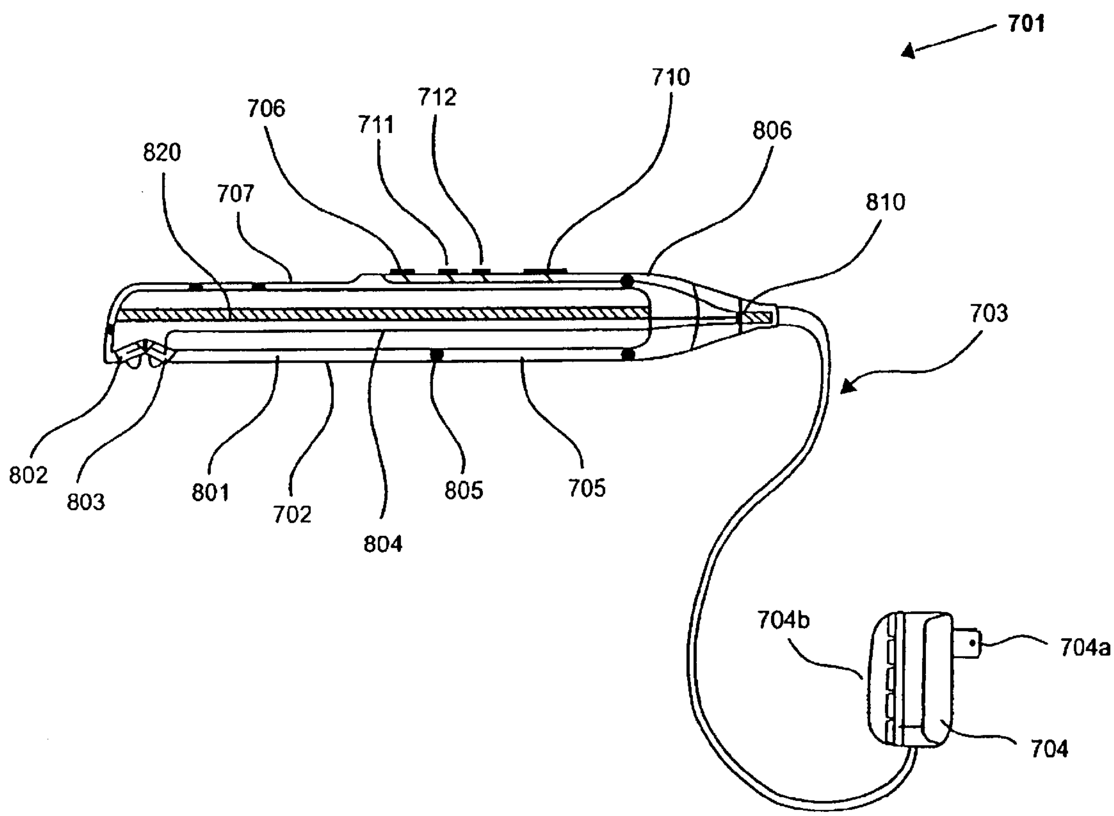
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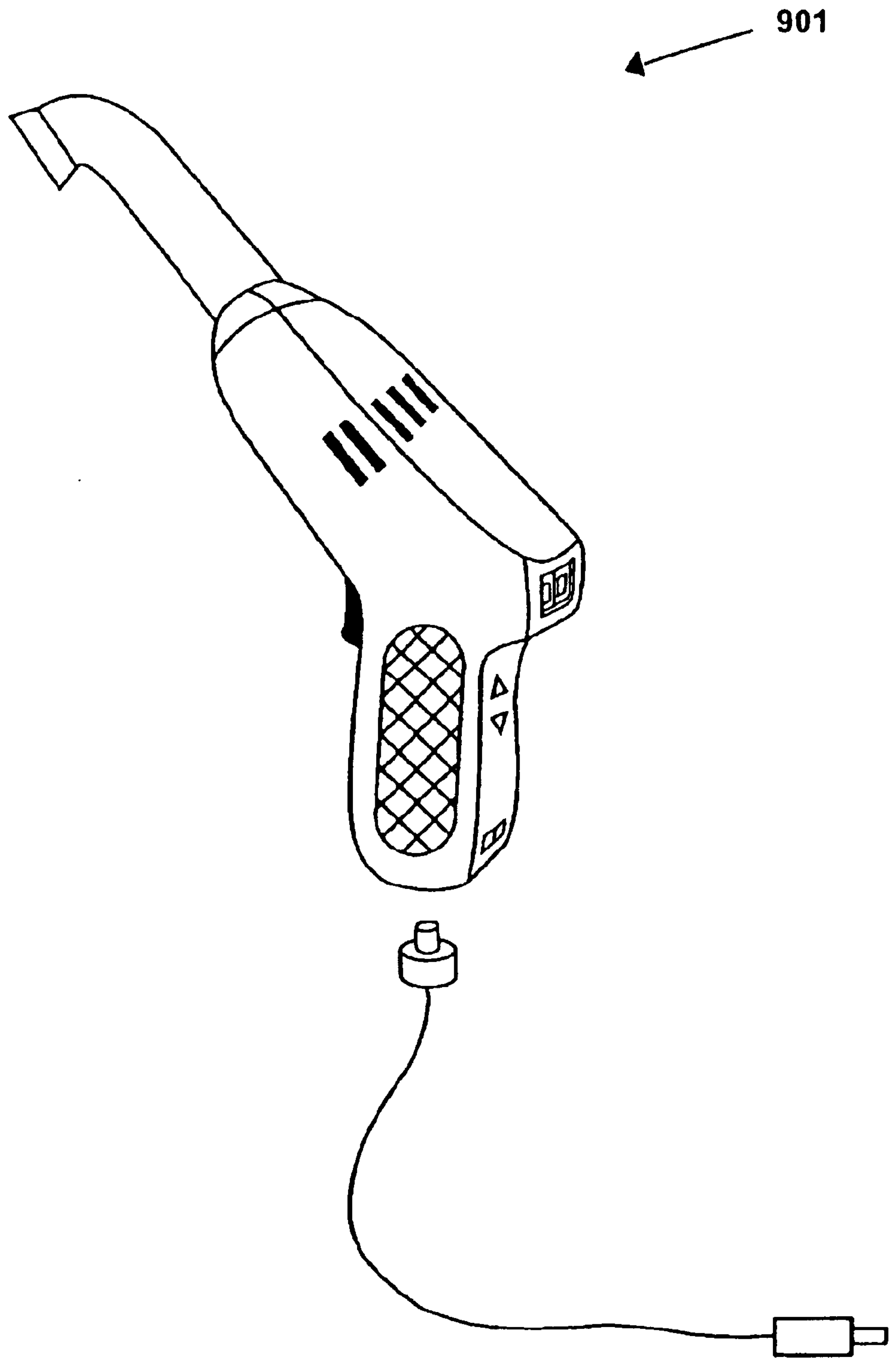

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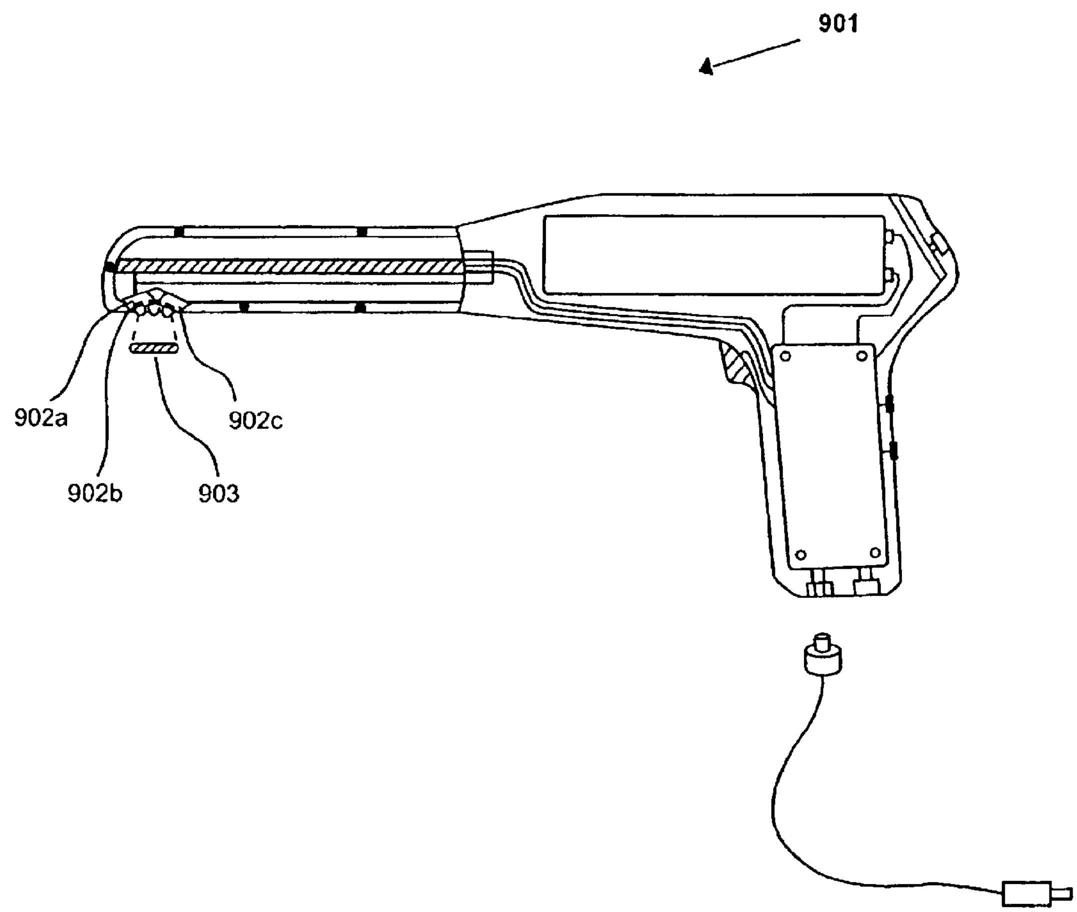

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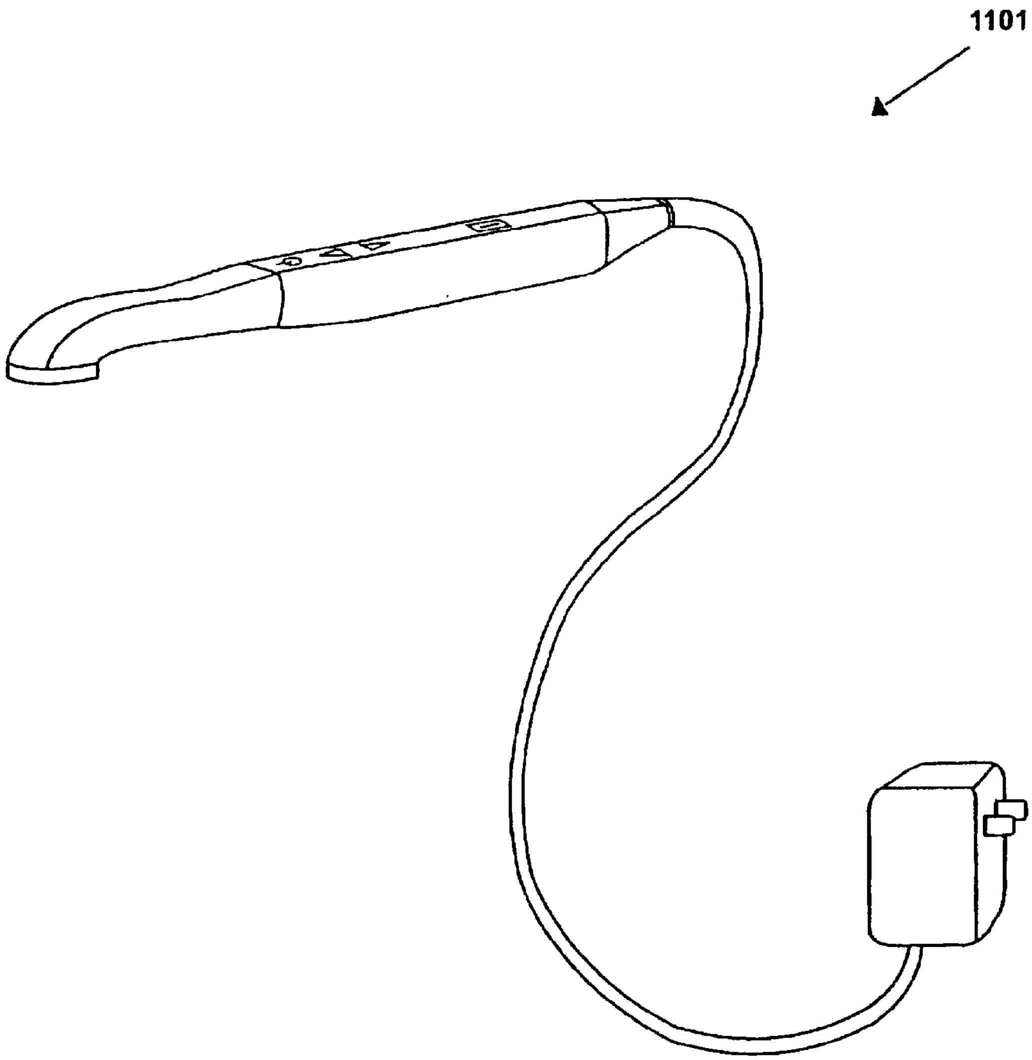

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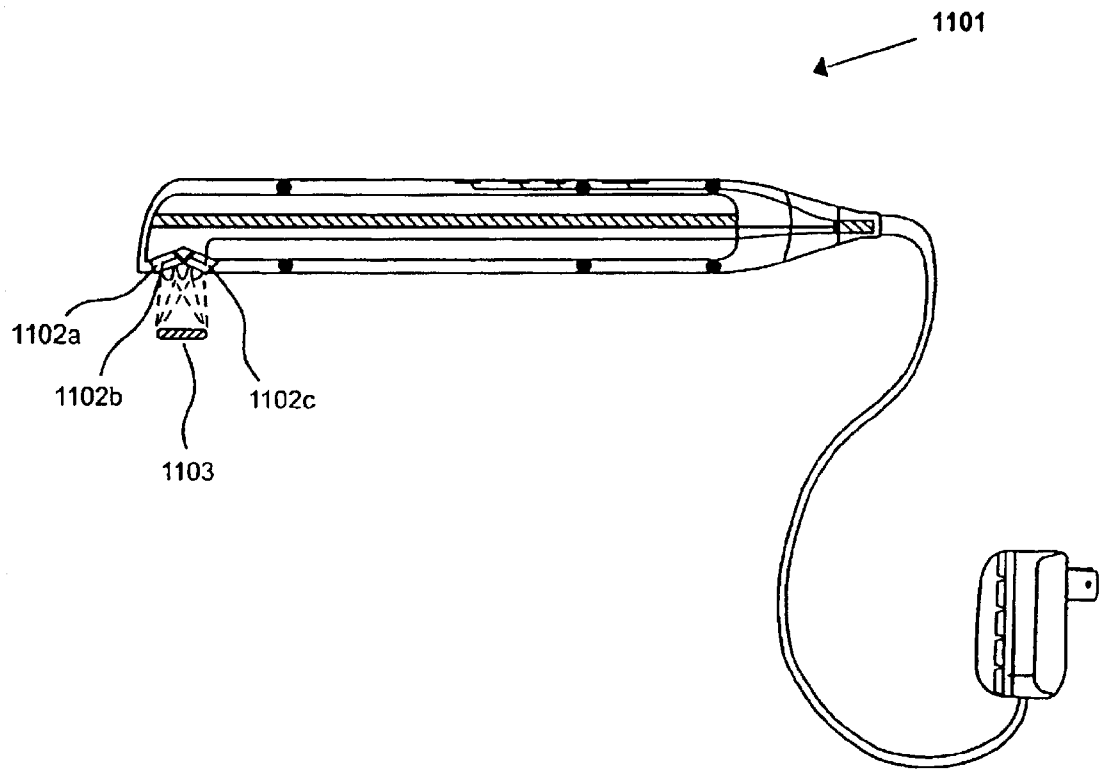

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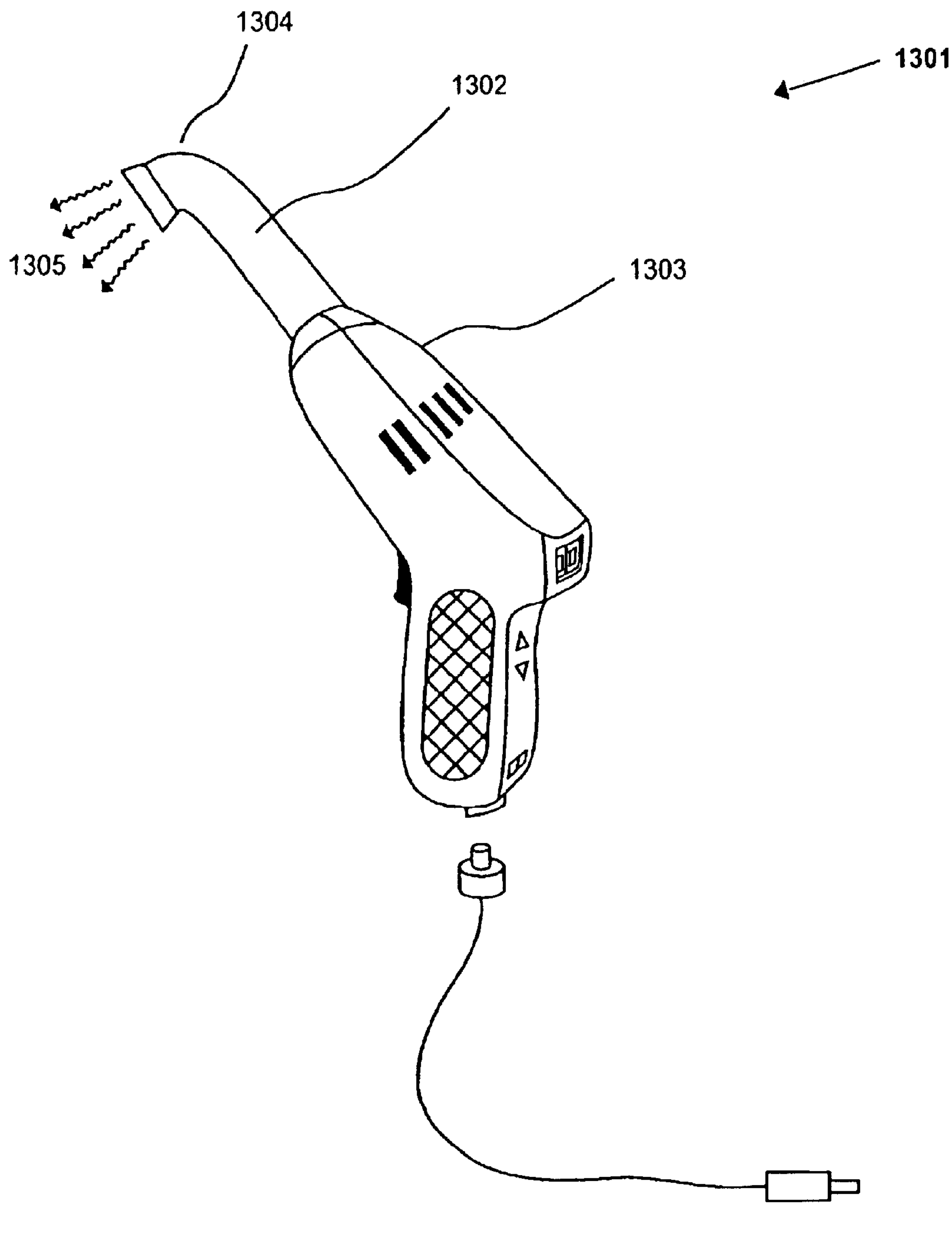

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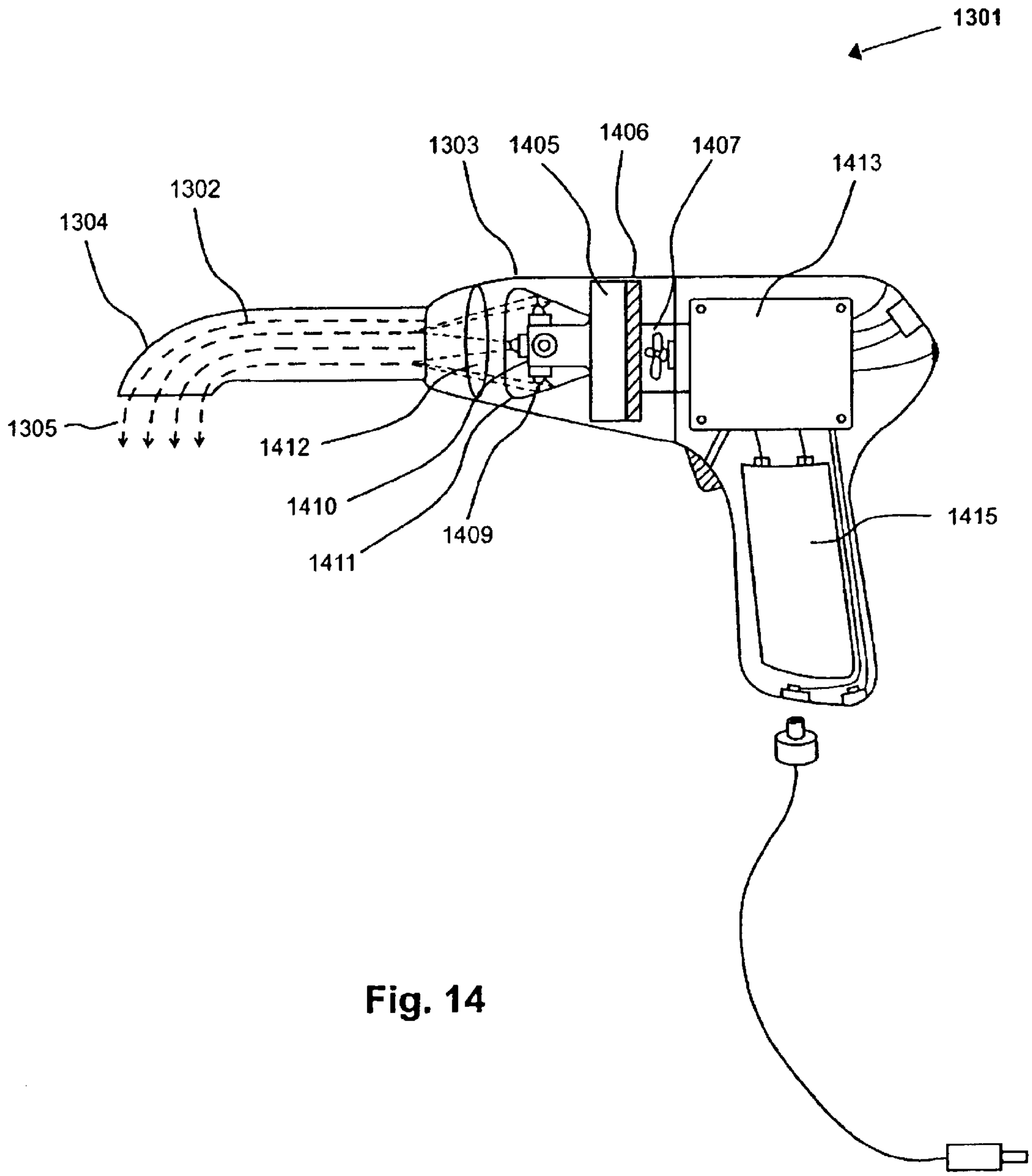
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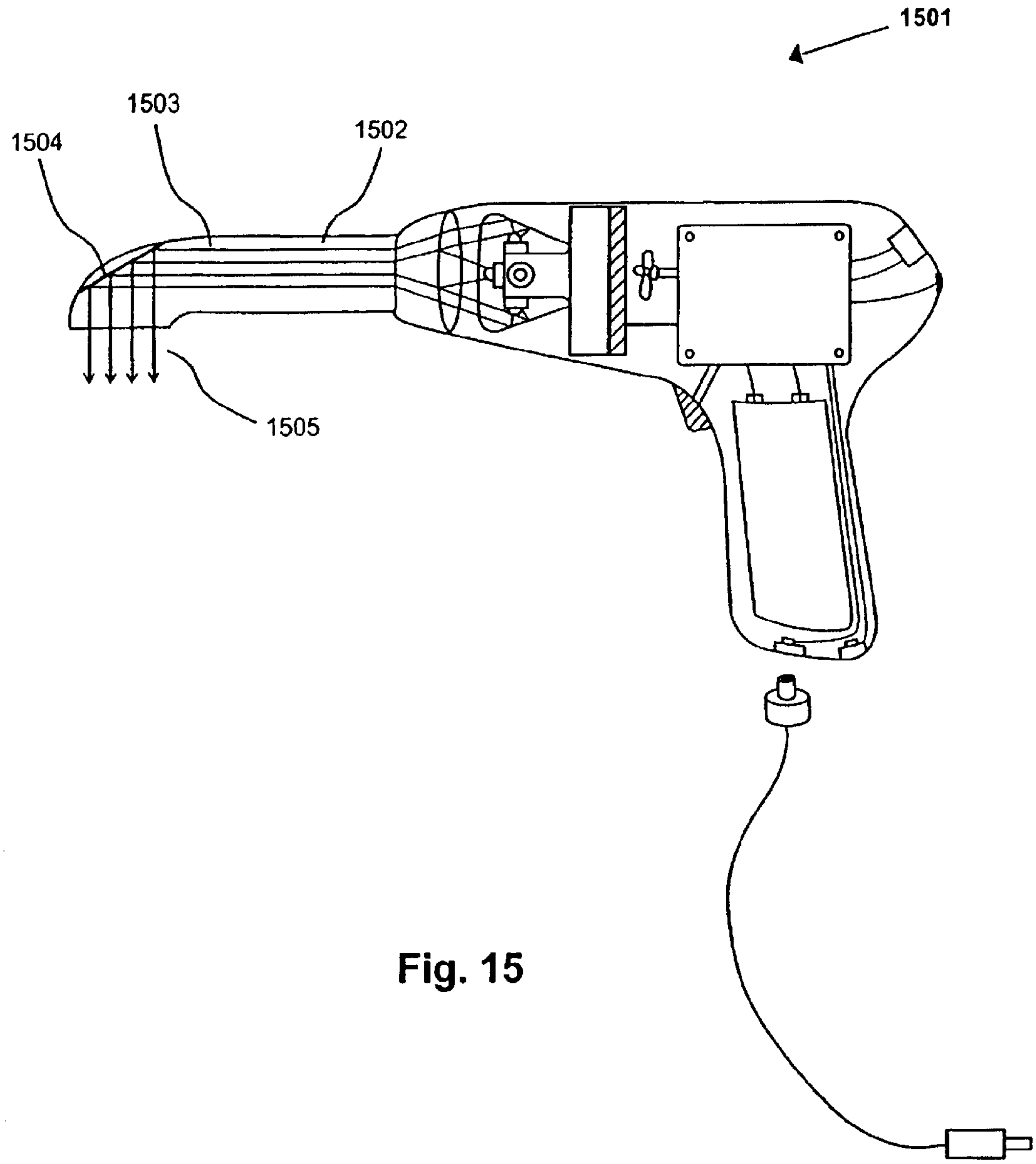

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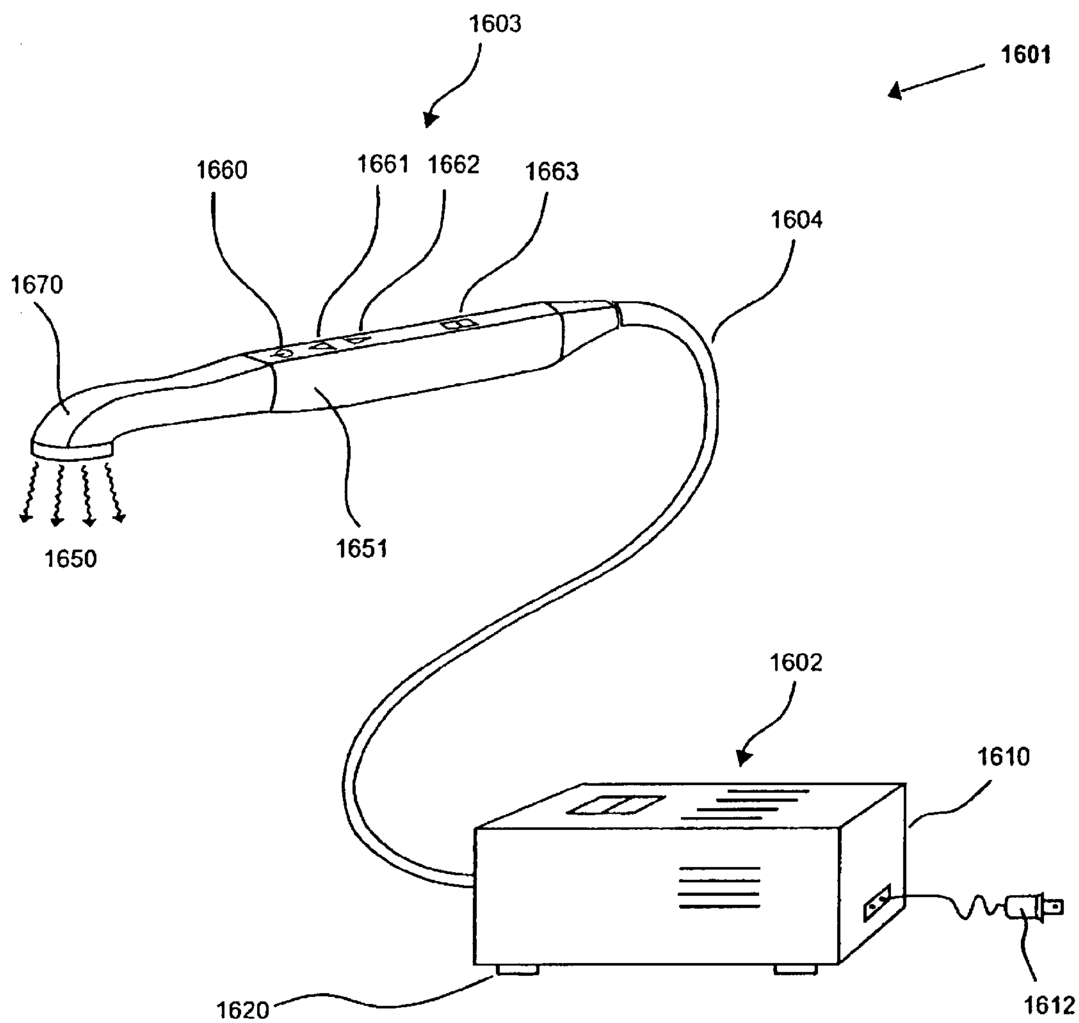
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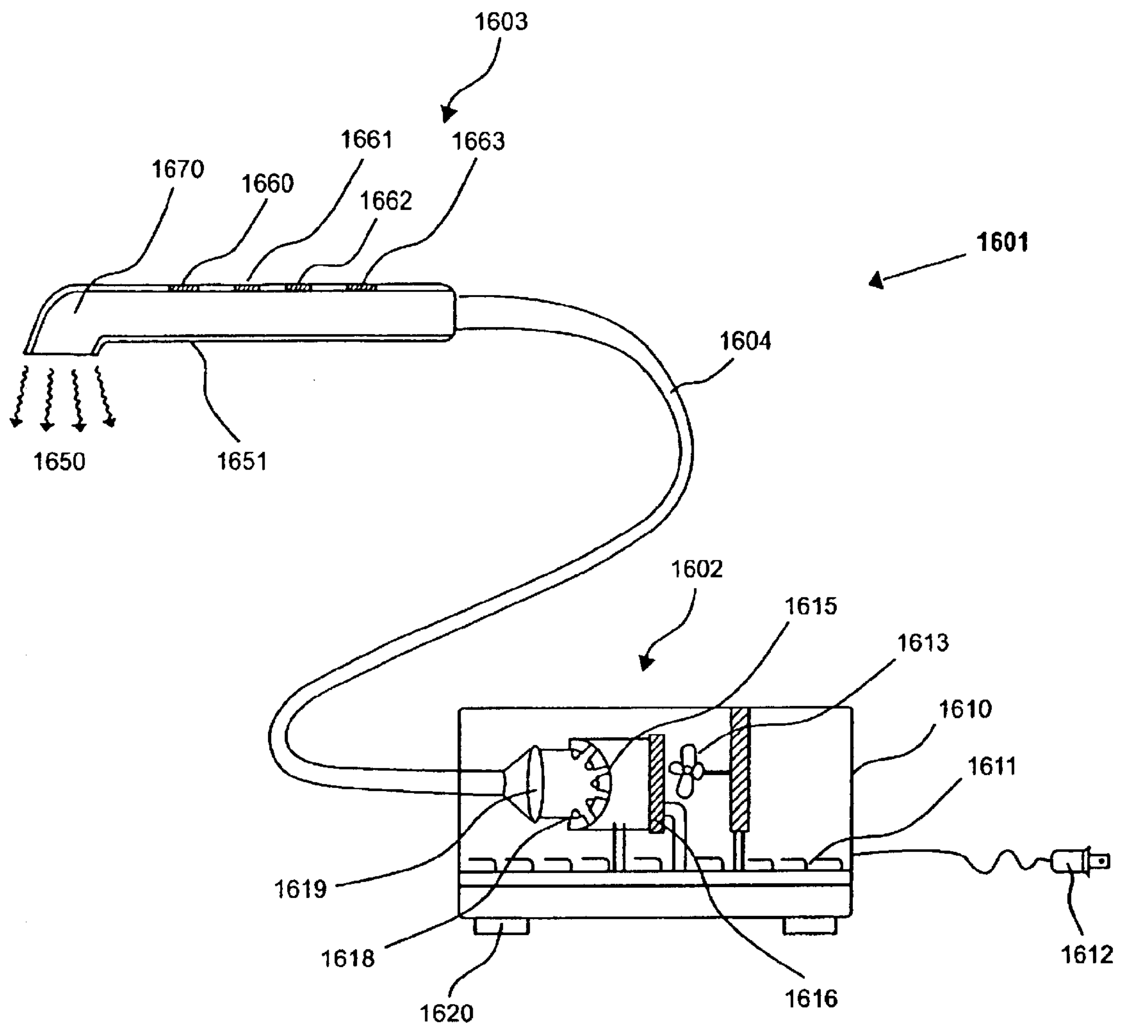
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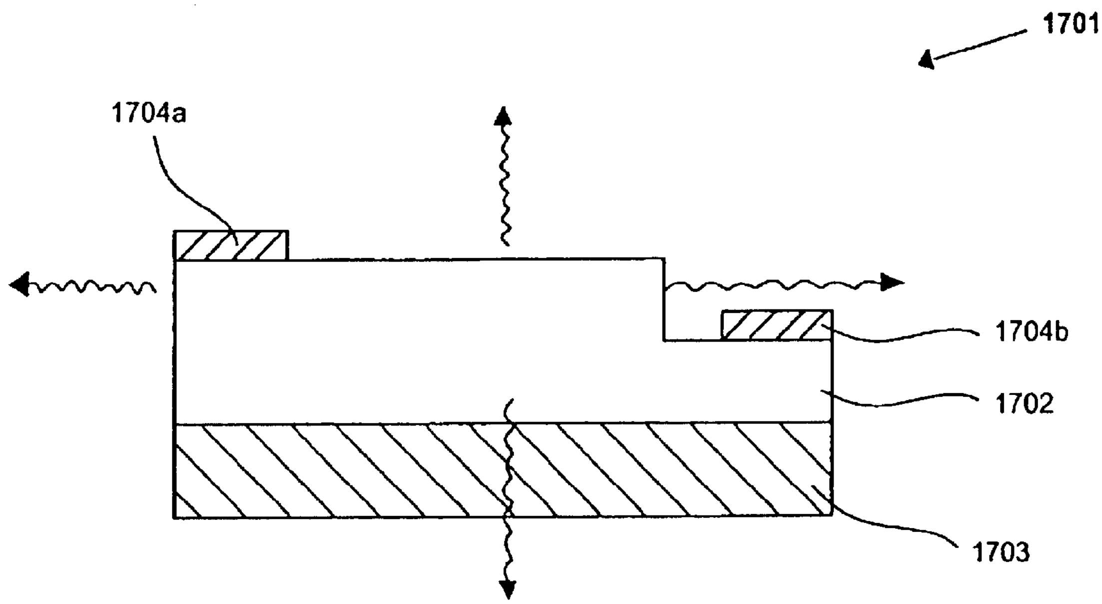
Fig. 16b



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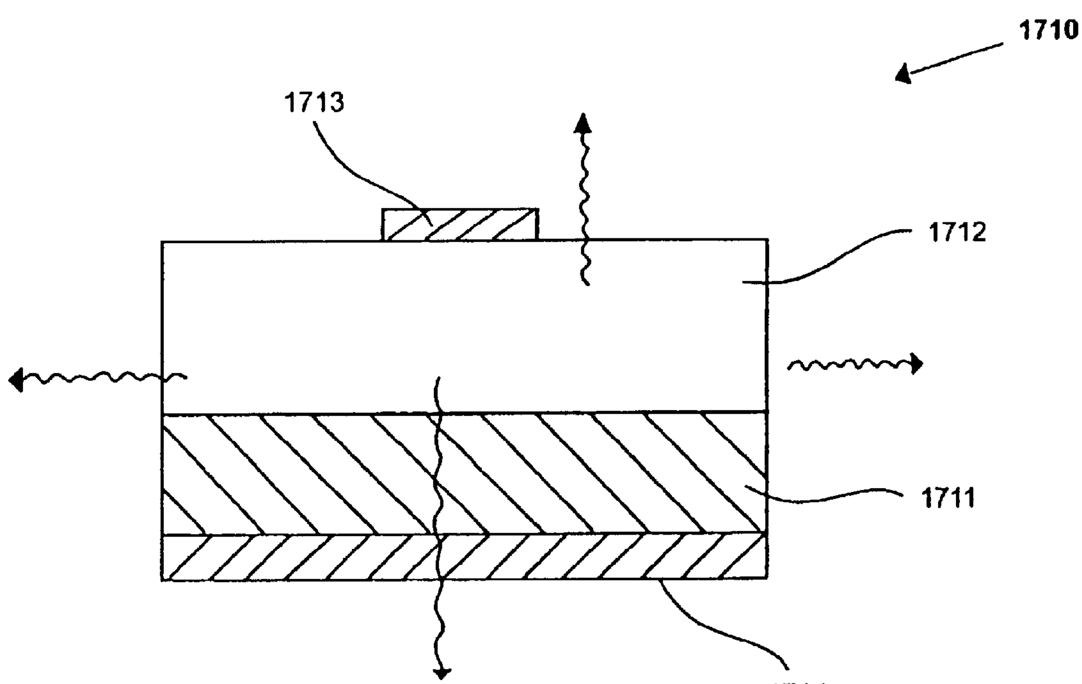

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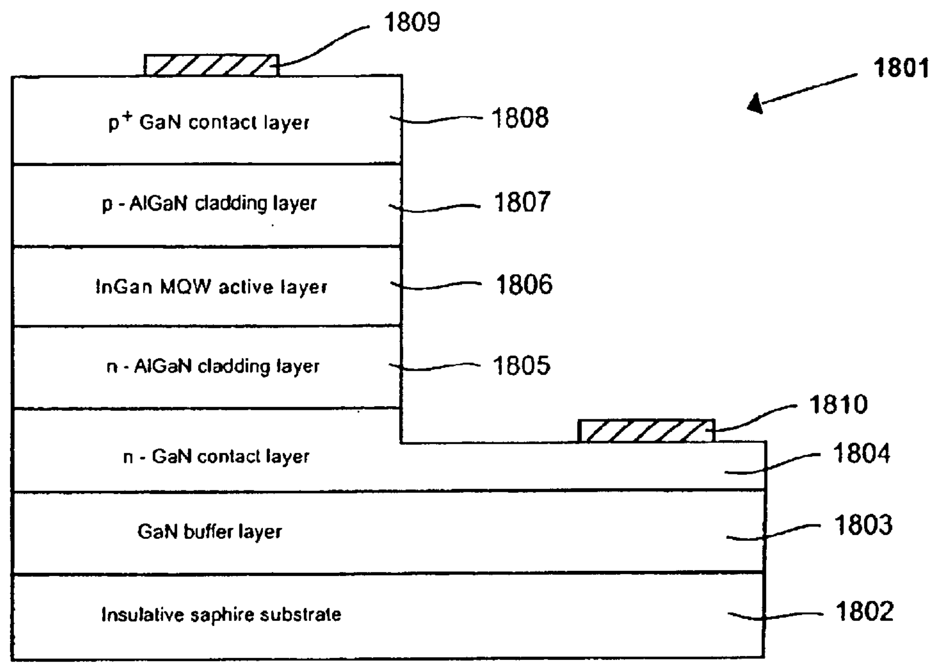

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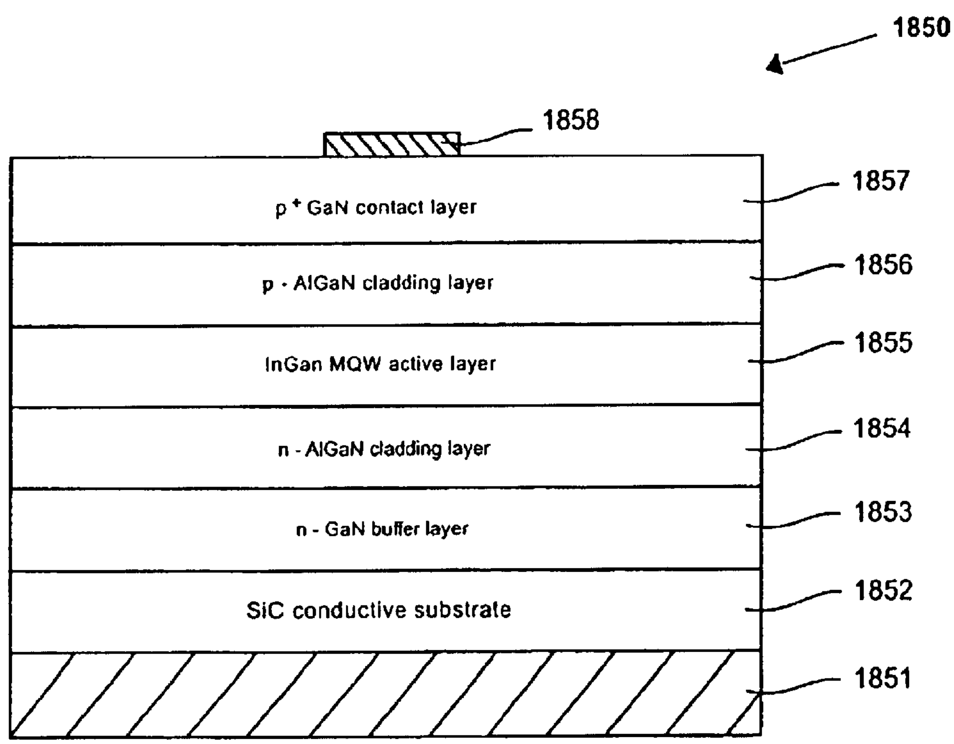

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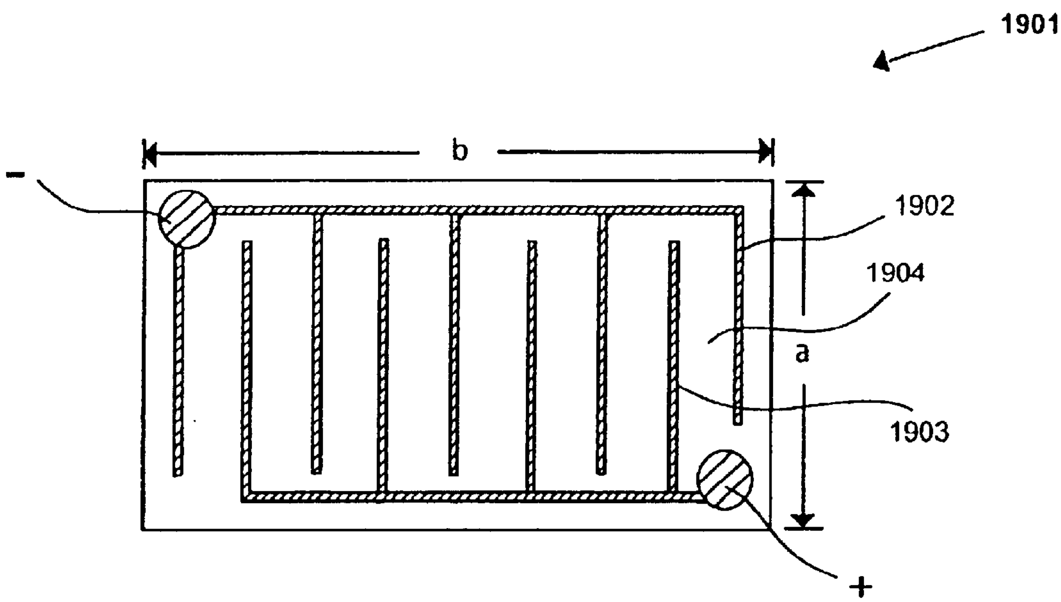

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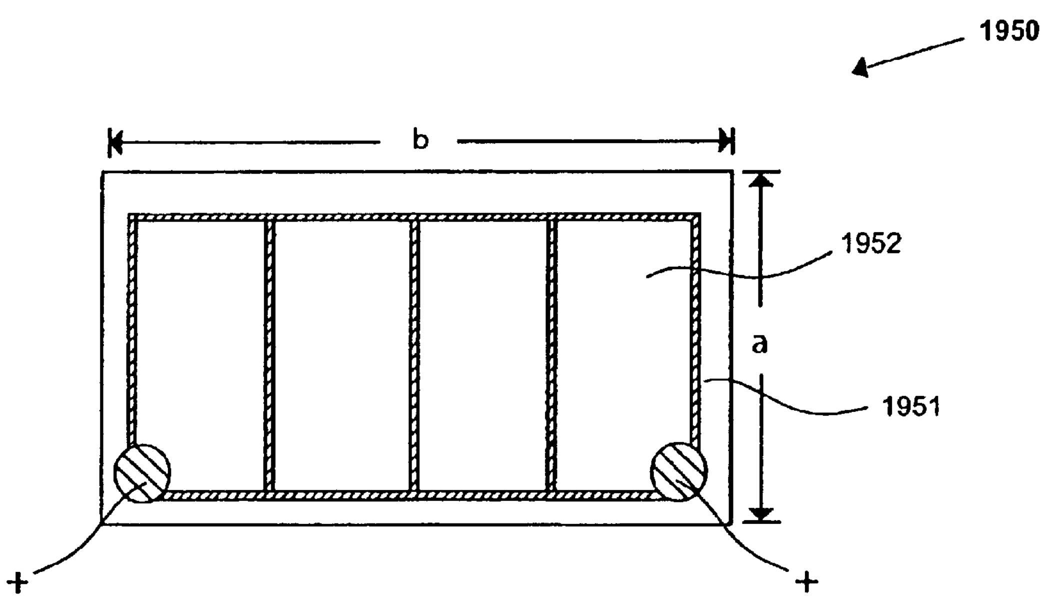

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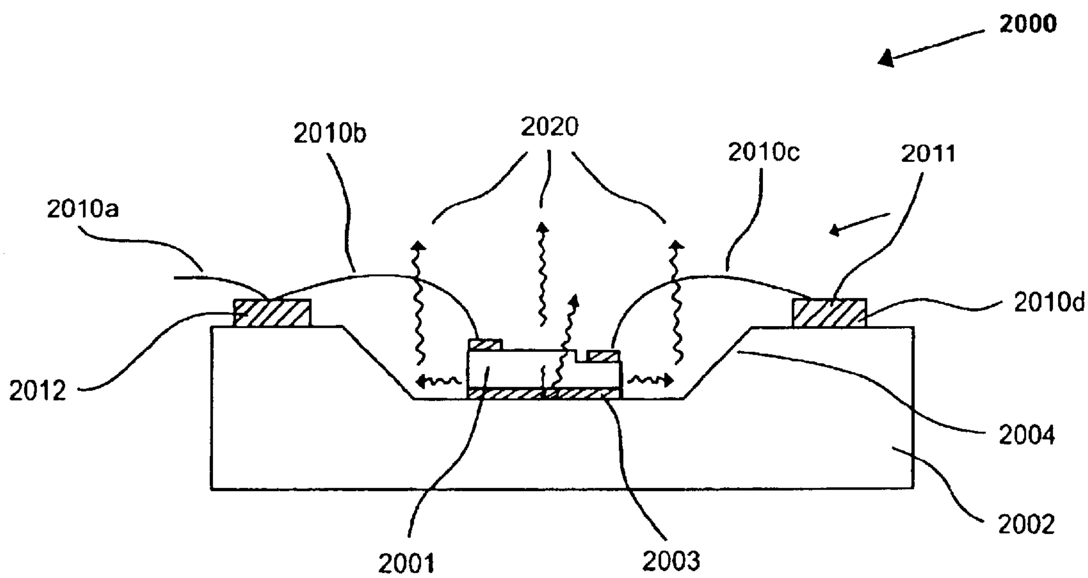

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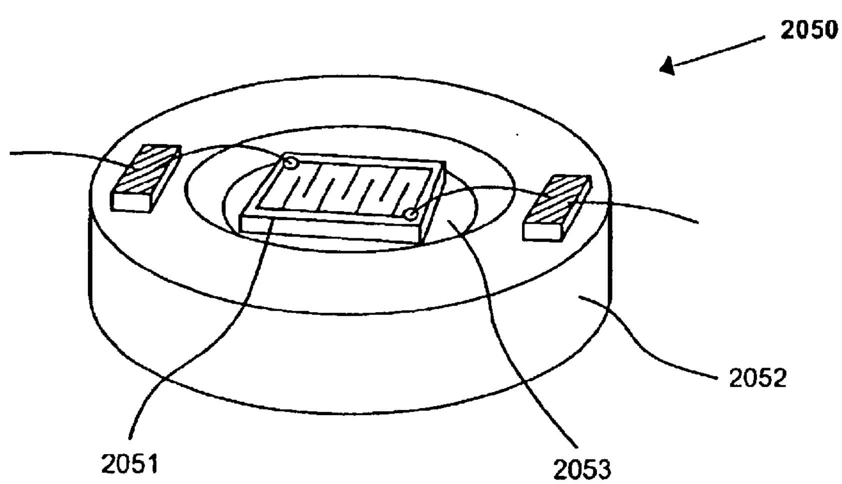

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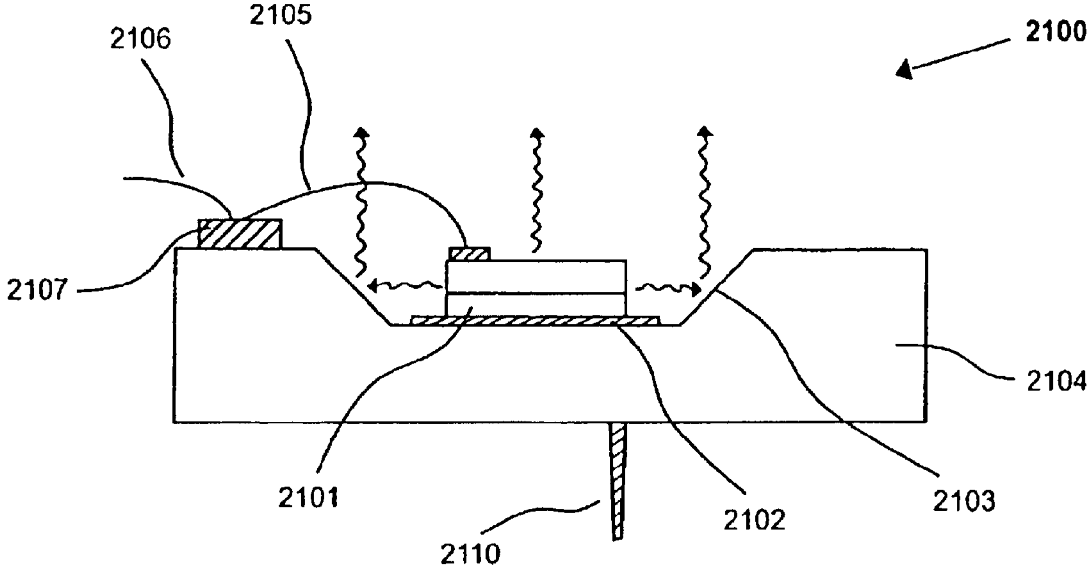

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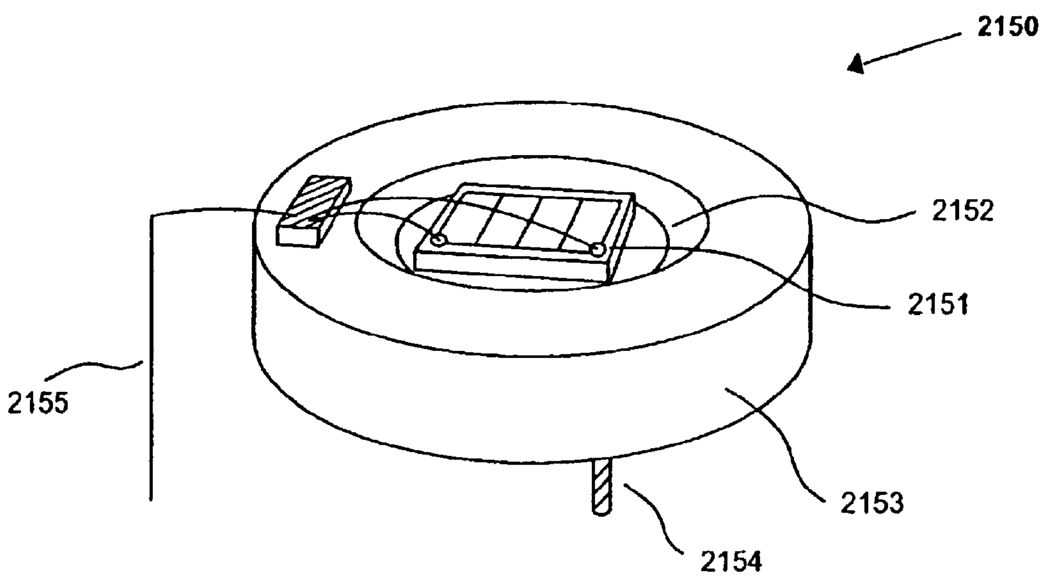

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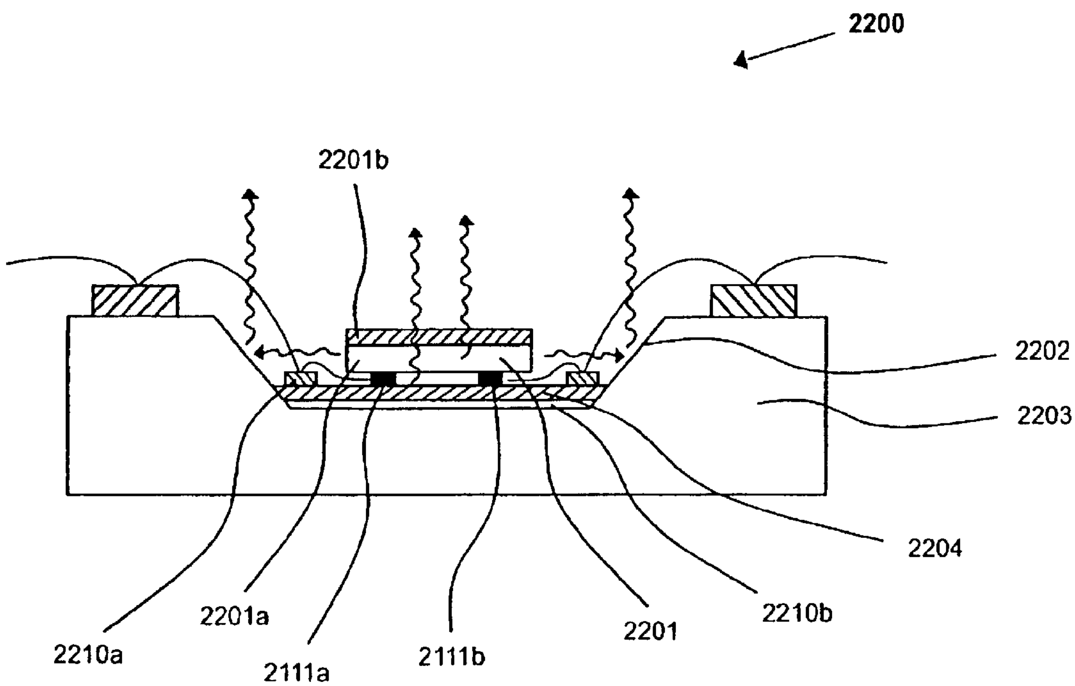
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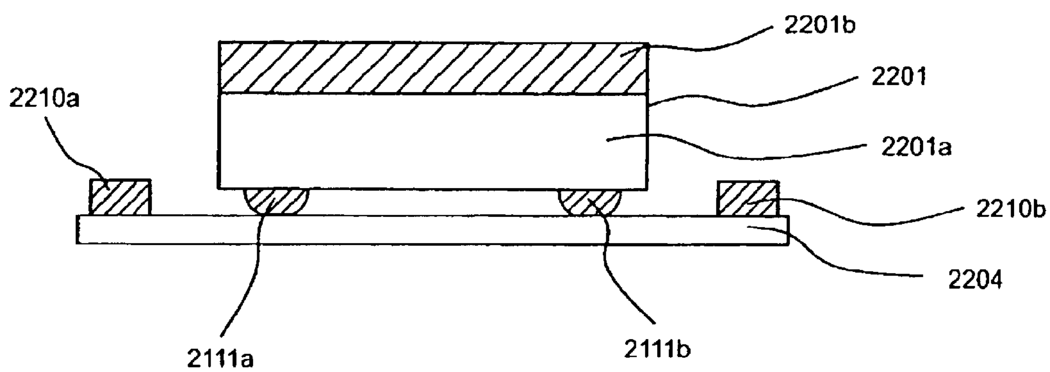
Fig. 22a



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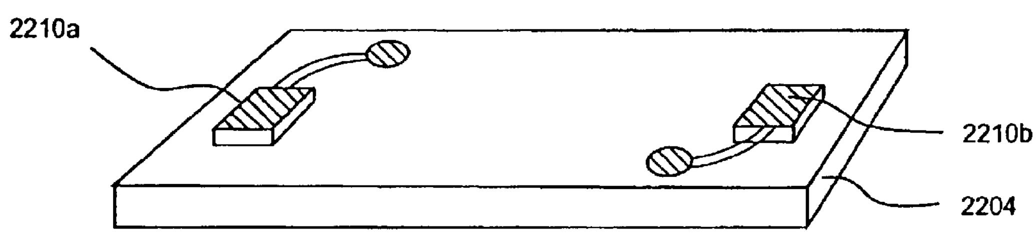

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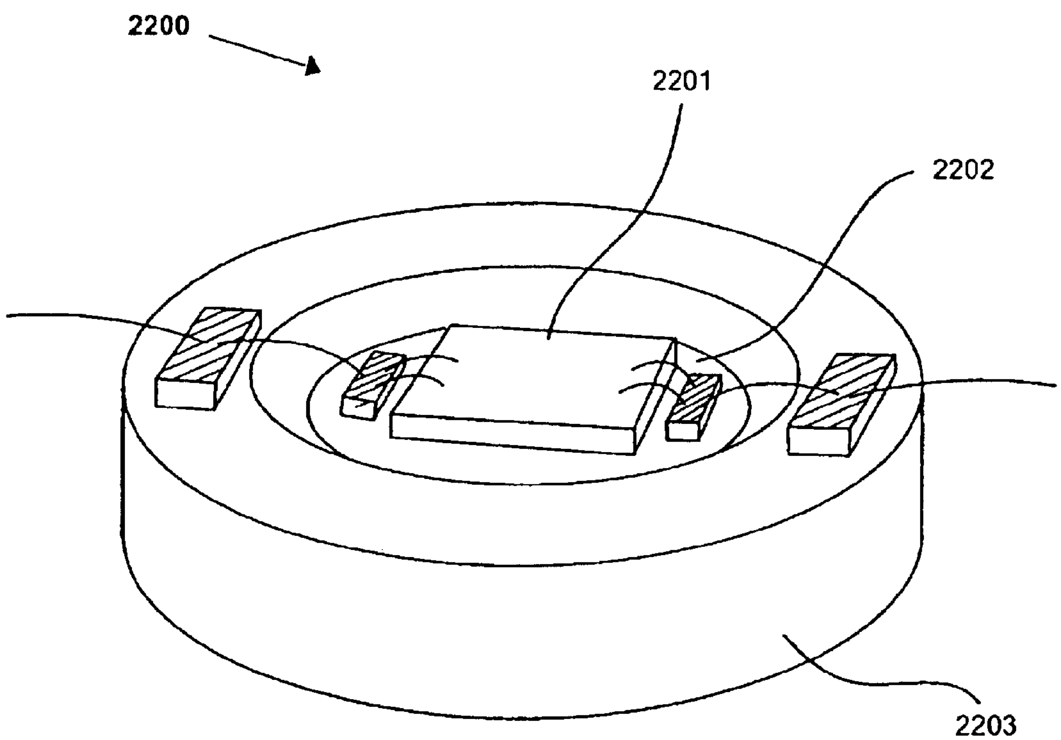

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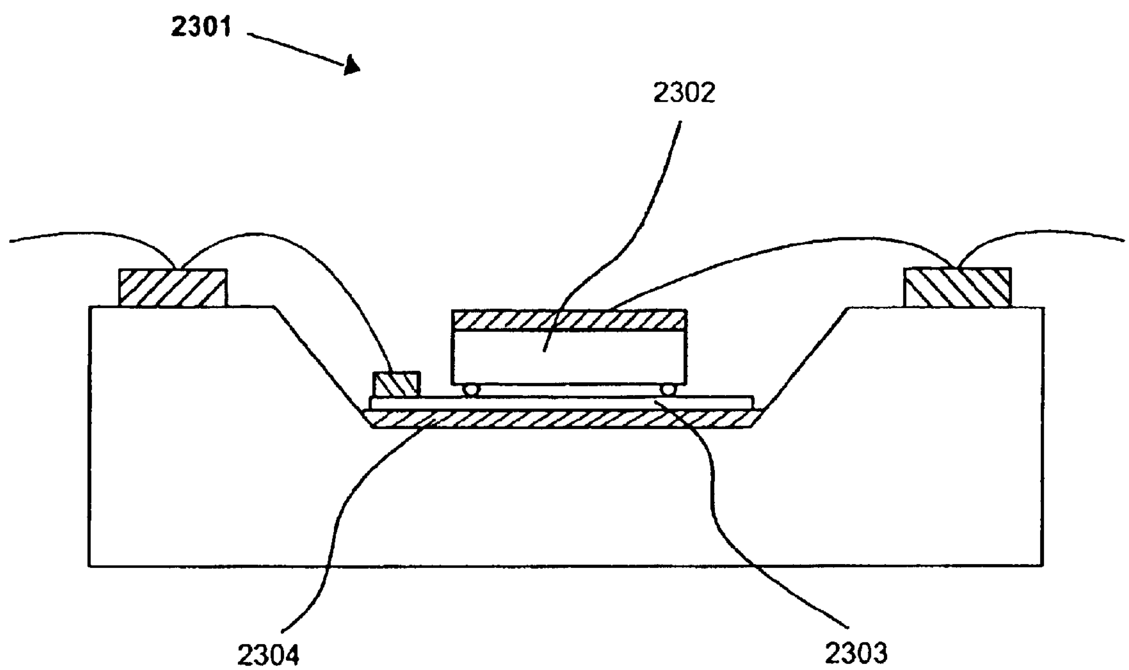

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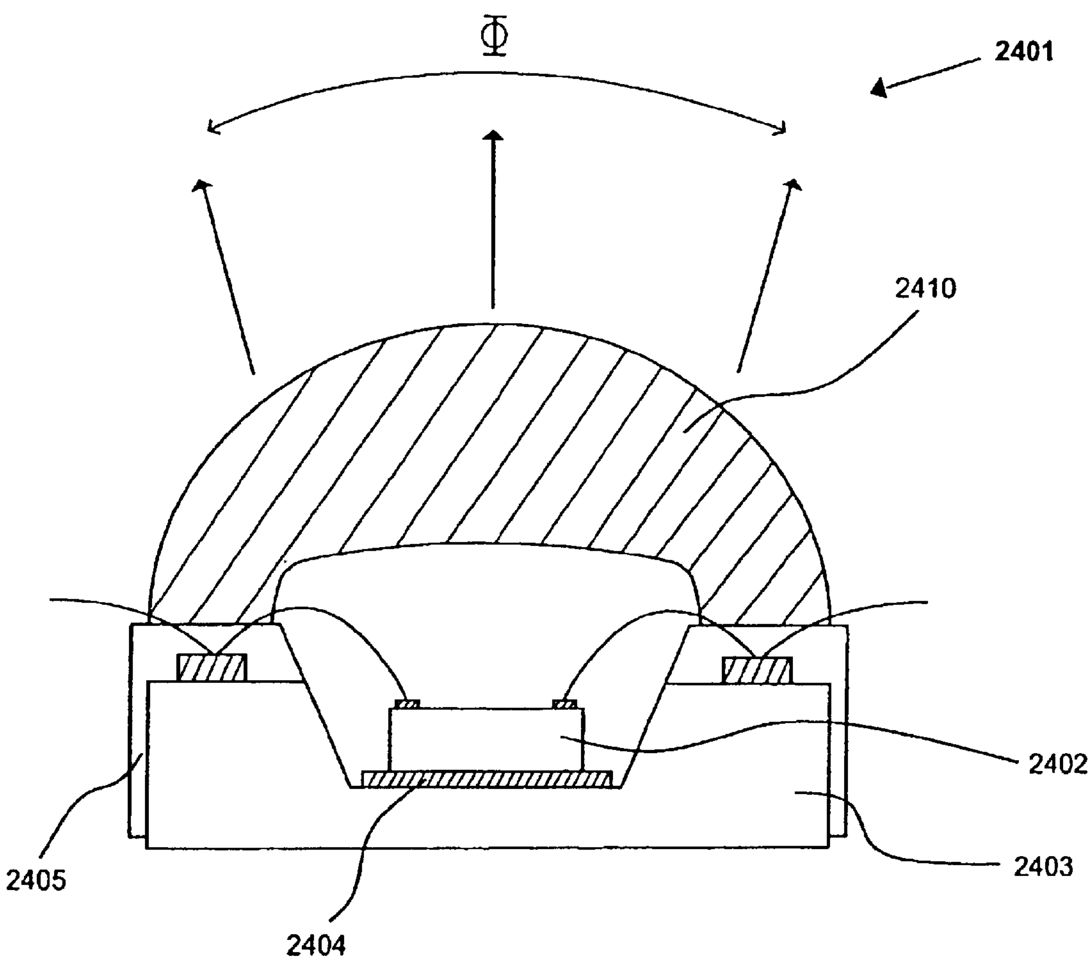

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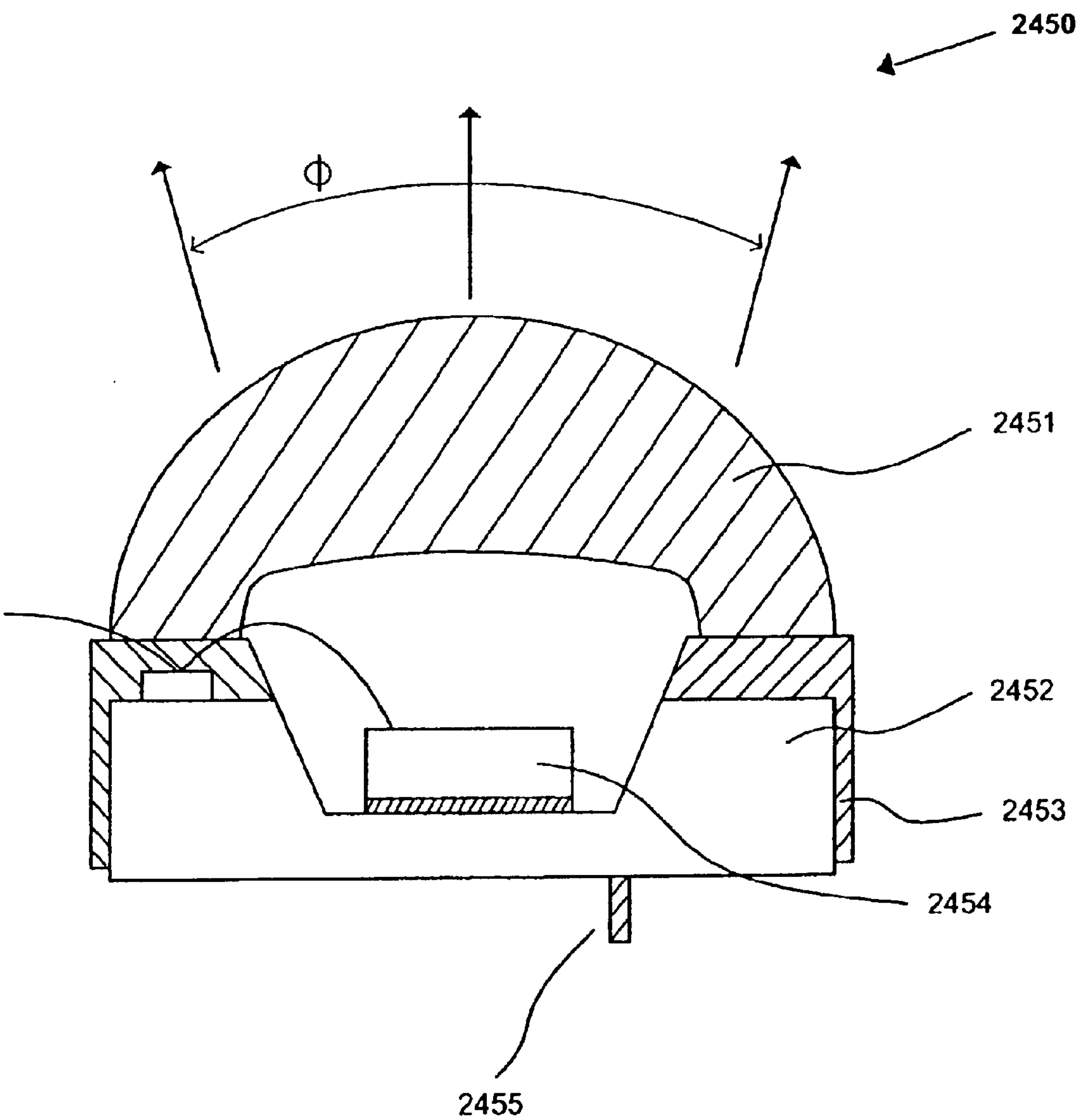

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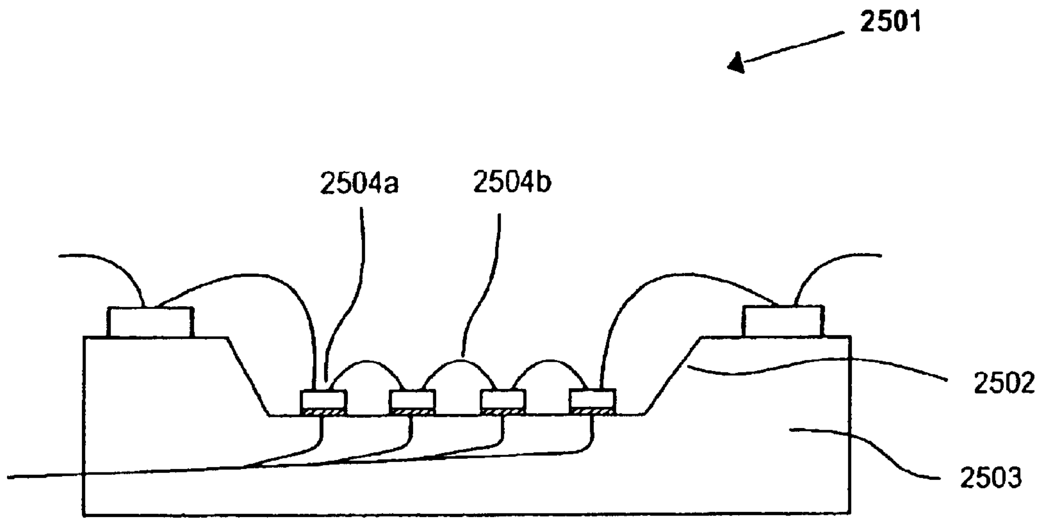

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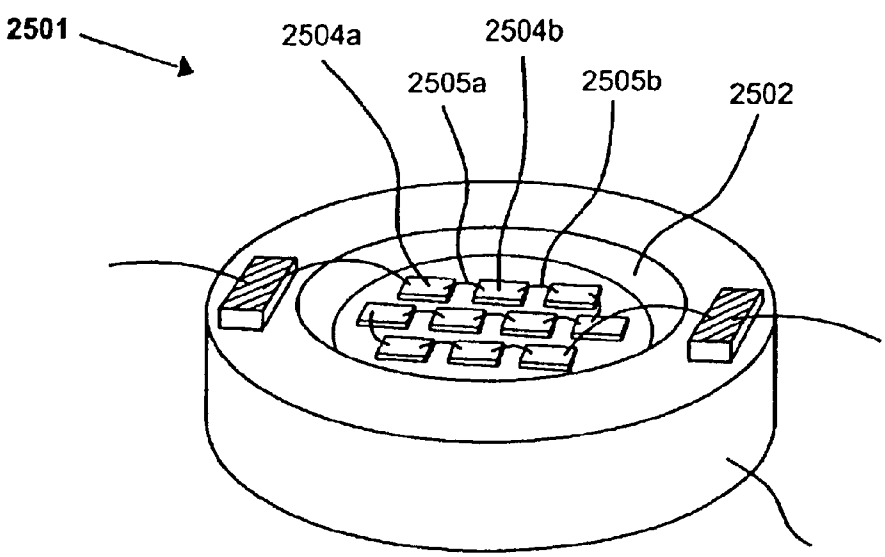

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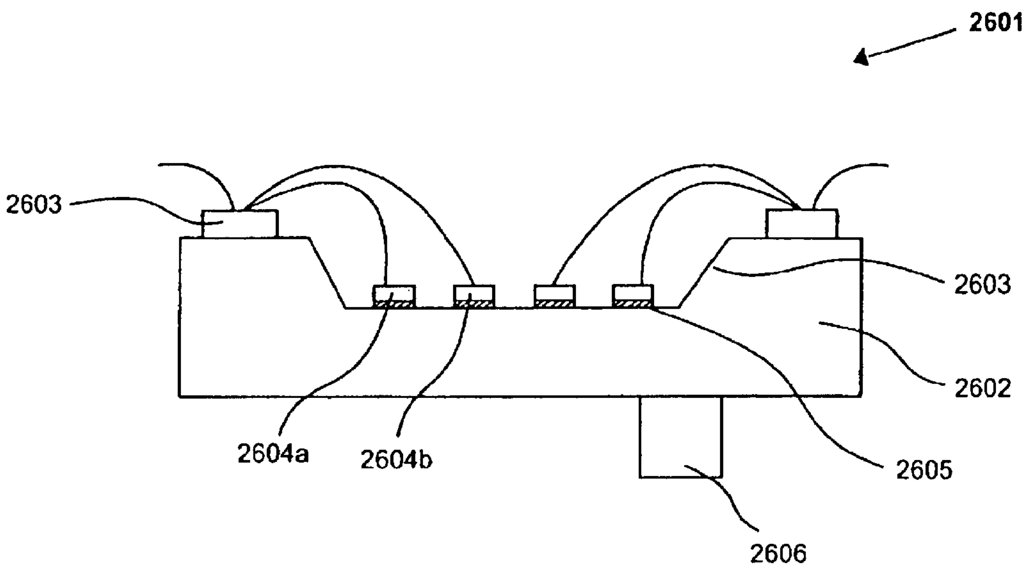

Fig. 26a

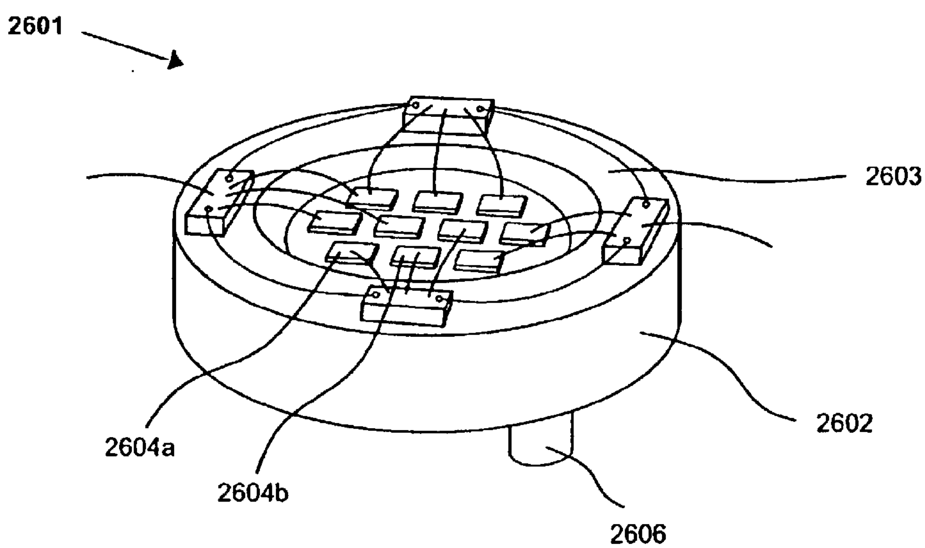

Fig. 26b

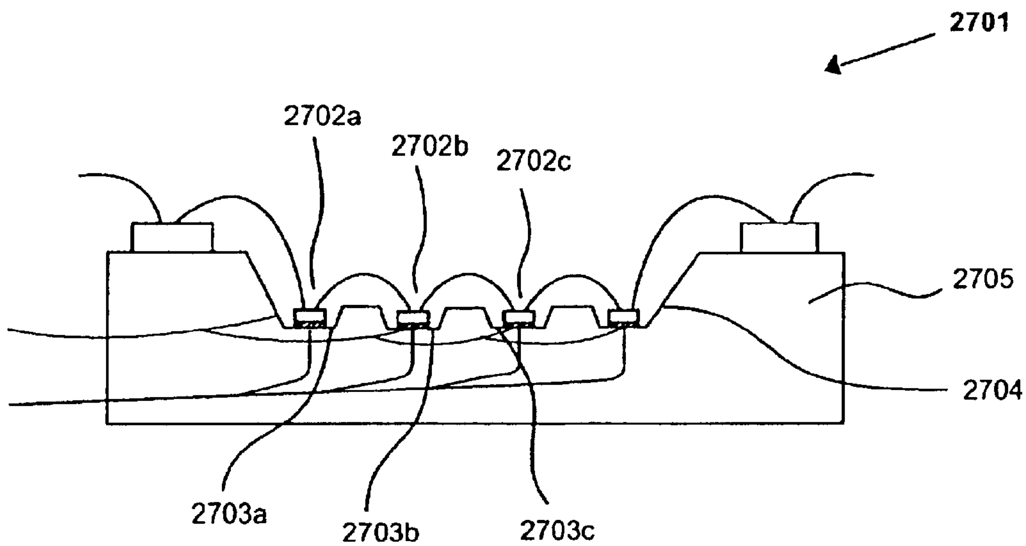

Fig. 27a

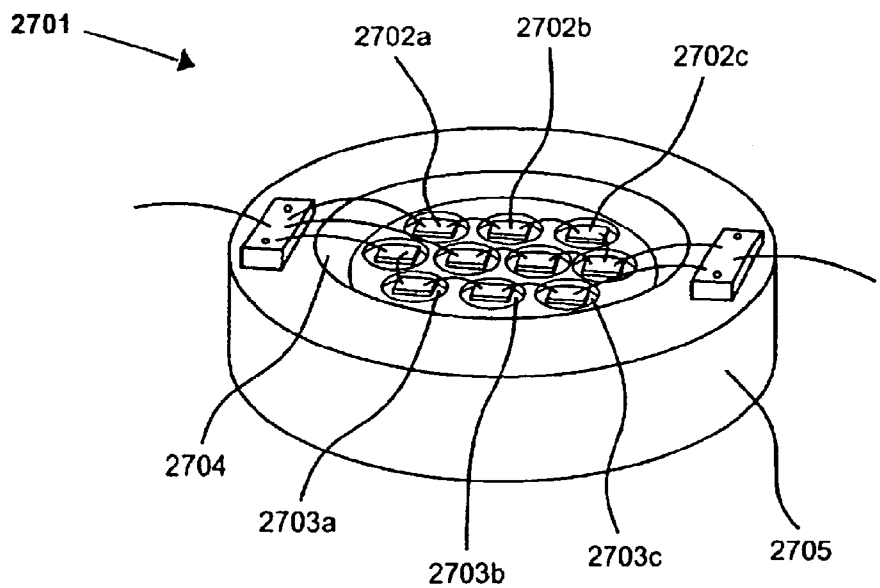

Fig. 27b

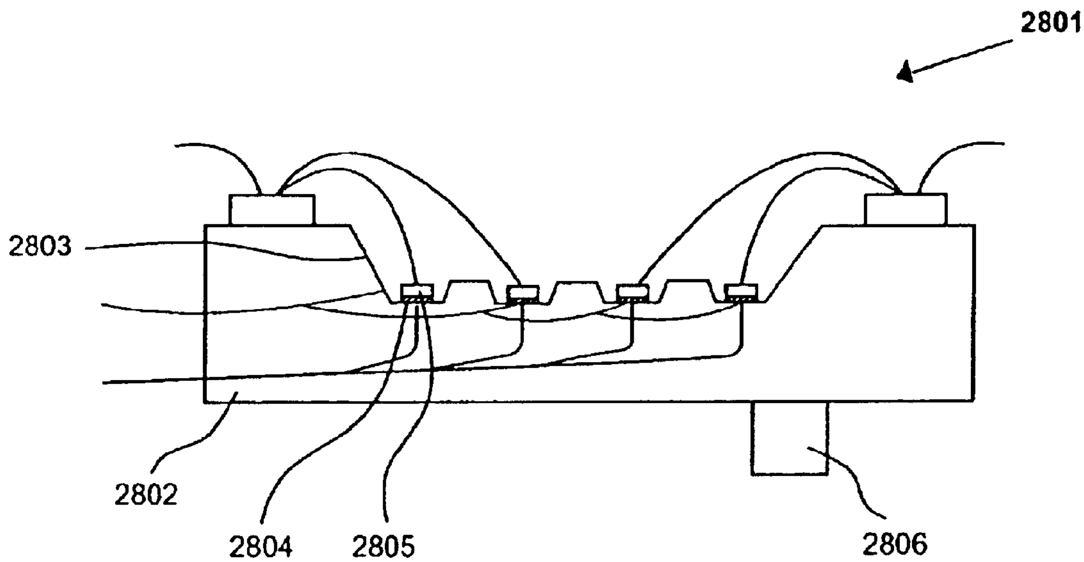

Fig. 28a

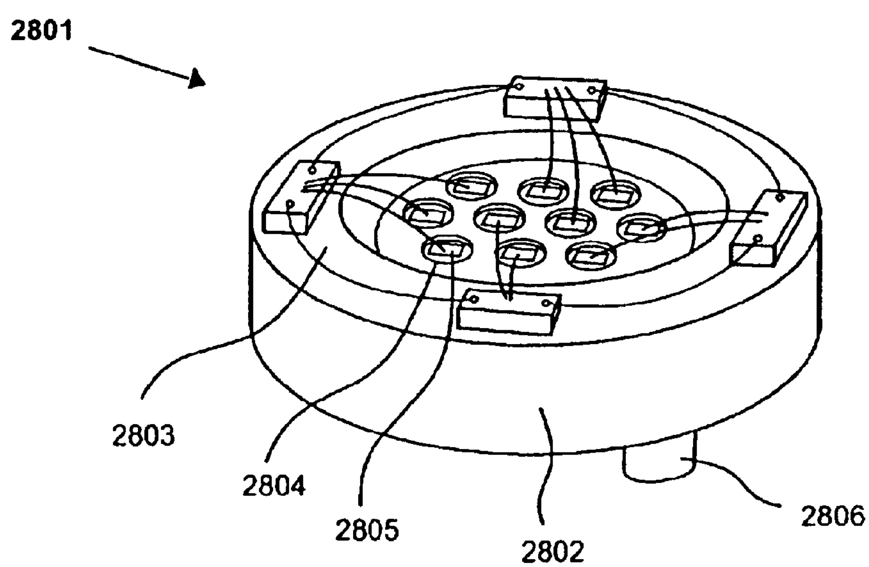

Fig. 28b

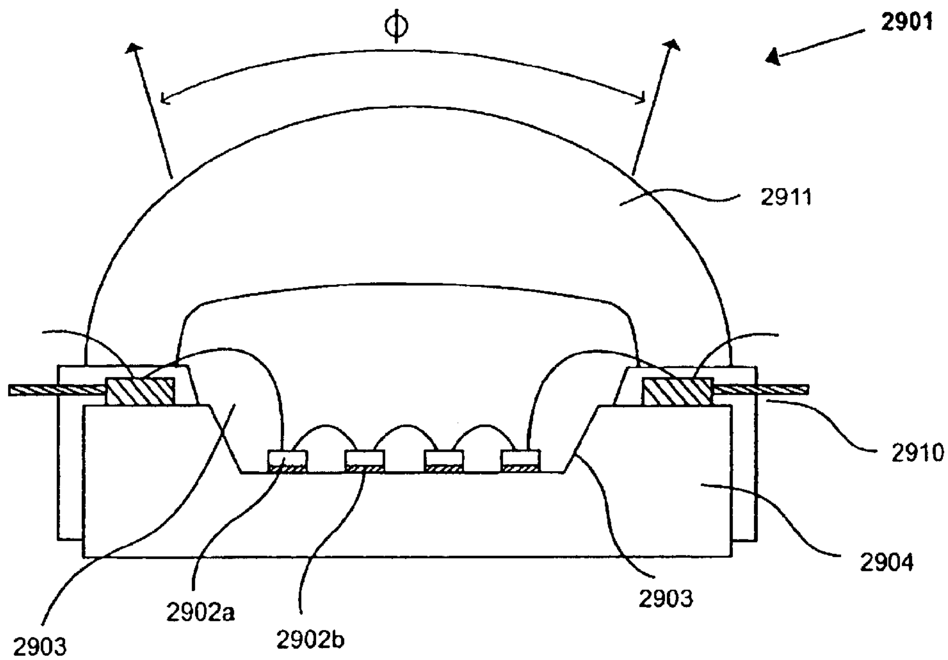

Fig. 29a

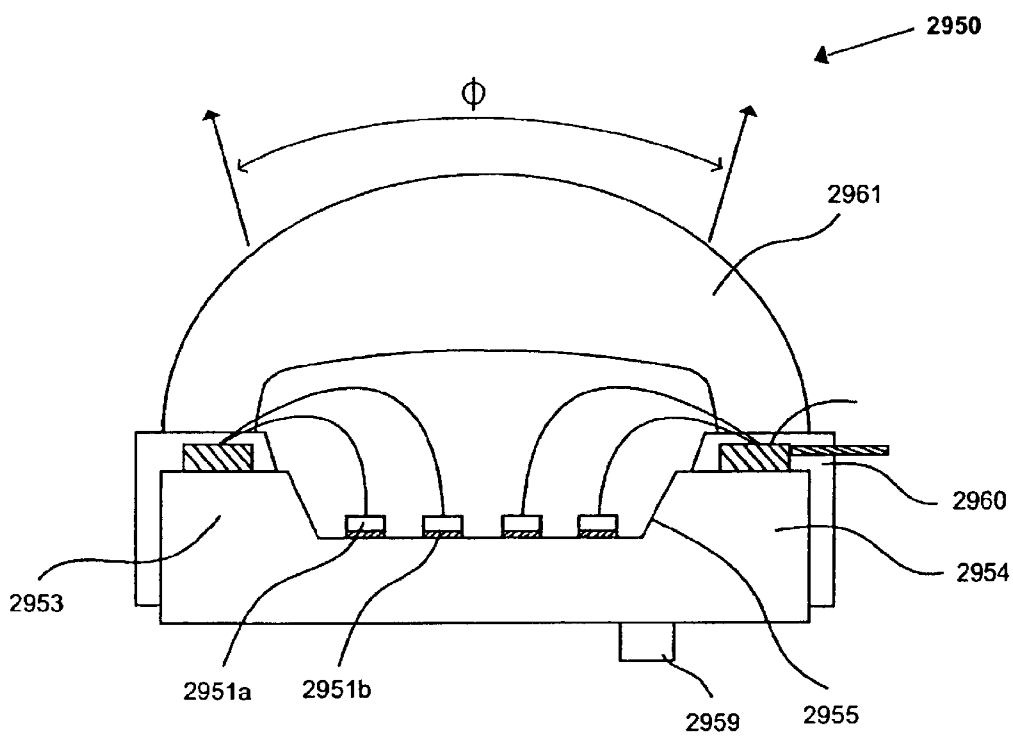

Fig. 29b

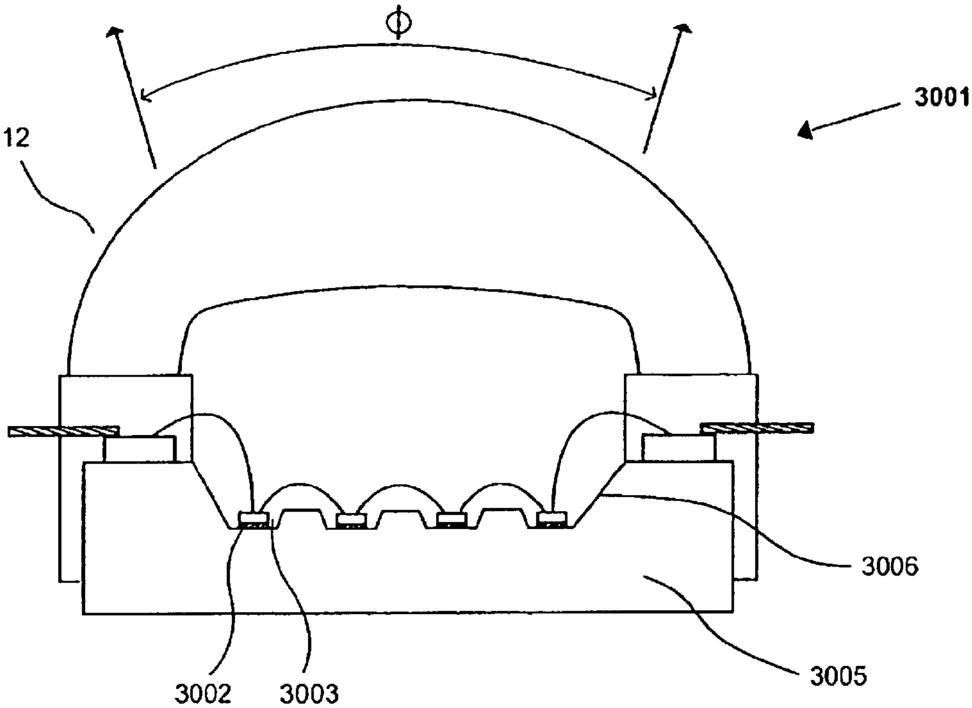

Fig. 30a

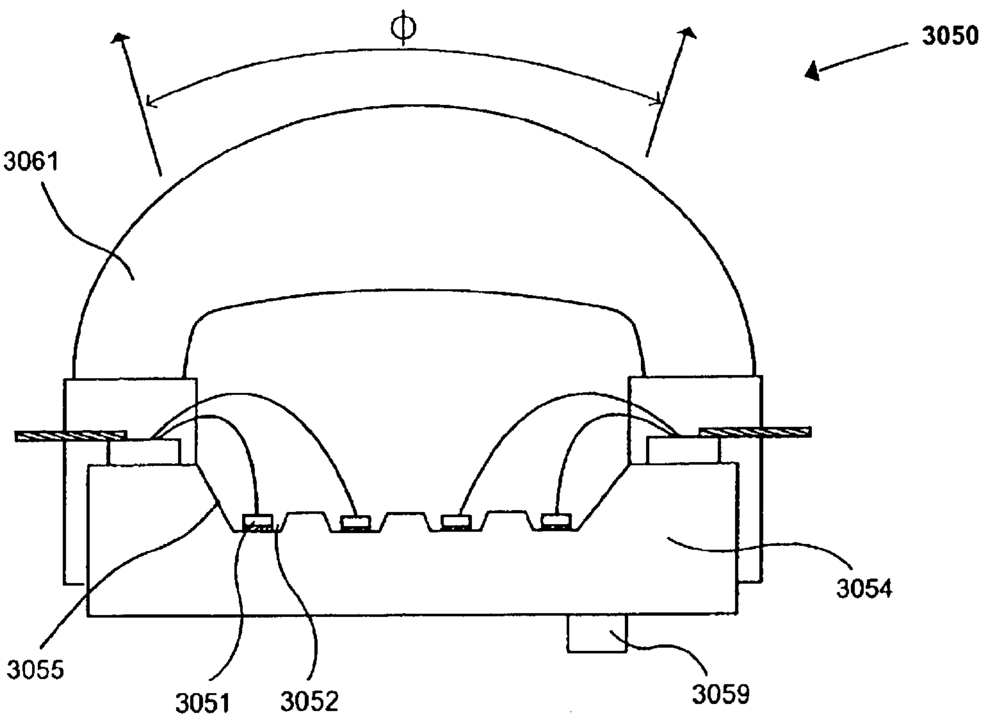

Fig. 30b

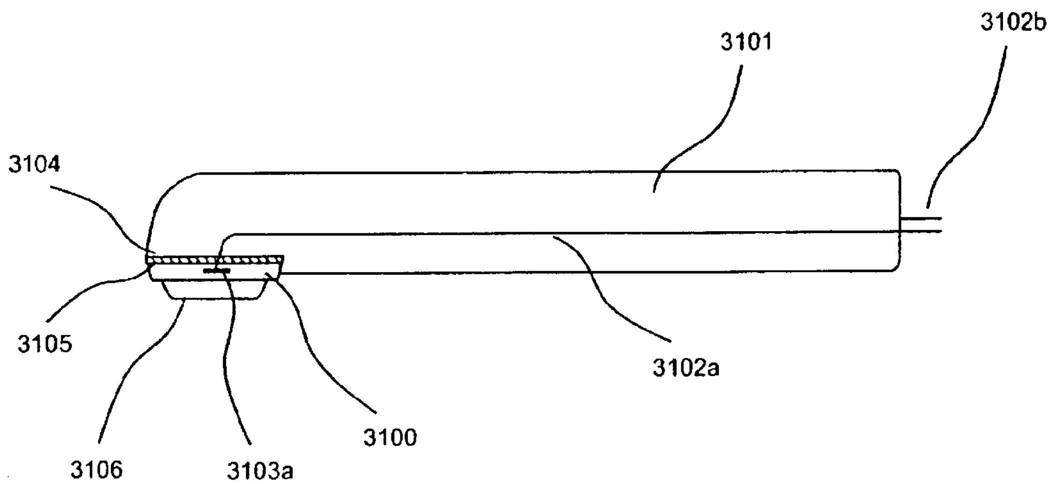

Fig. 31a

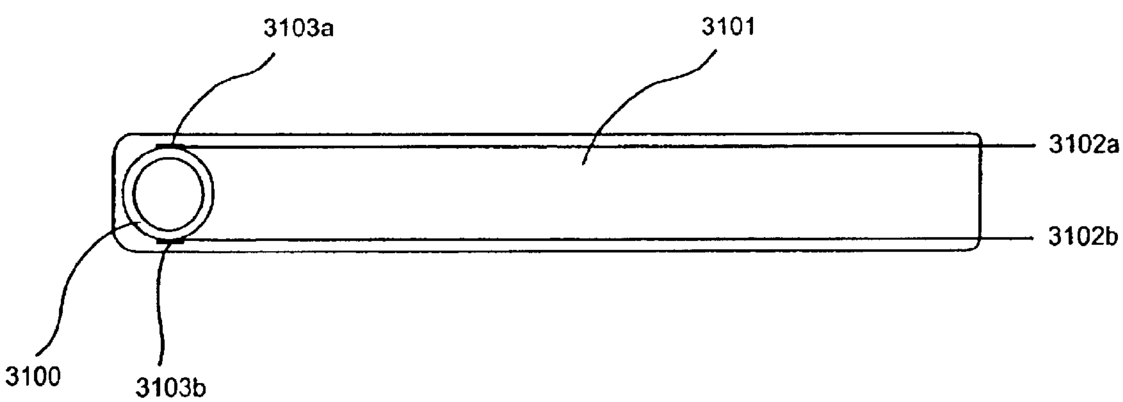

Fig. 31b

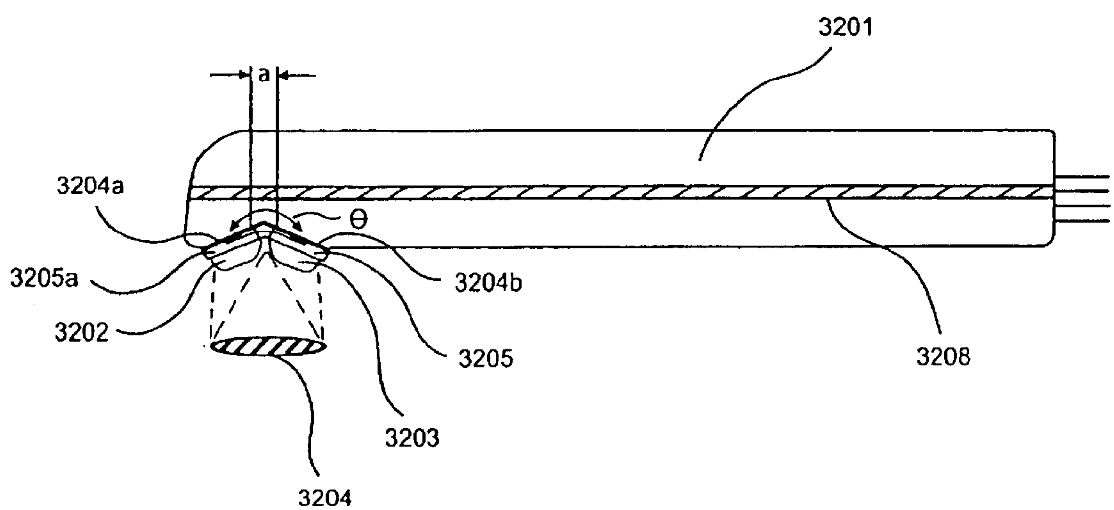

Fig. 32a

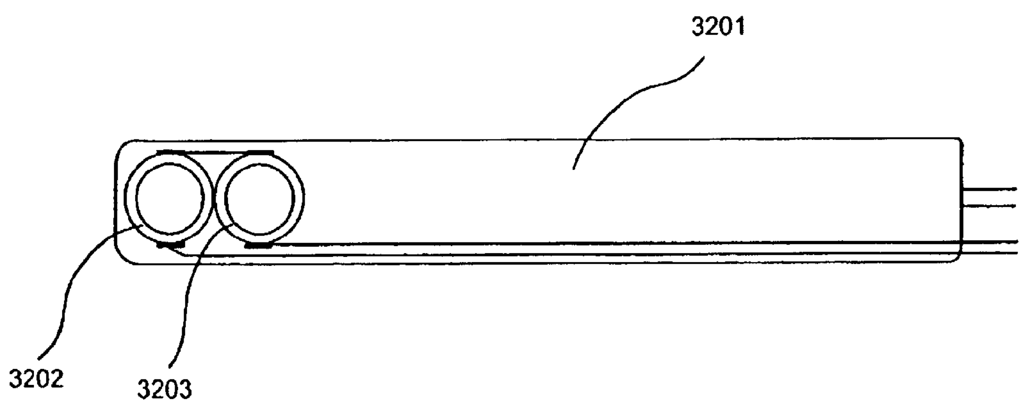

Fig. 32b

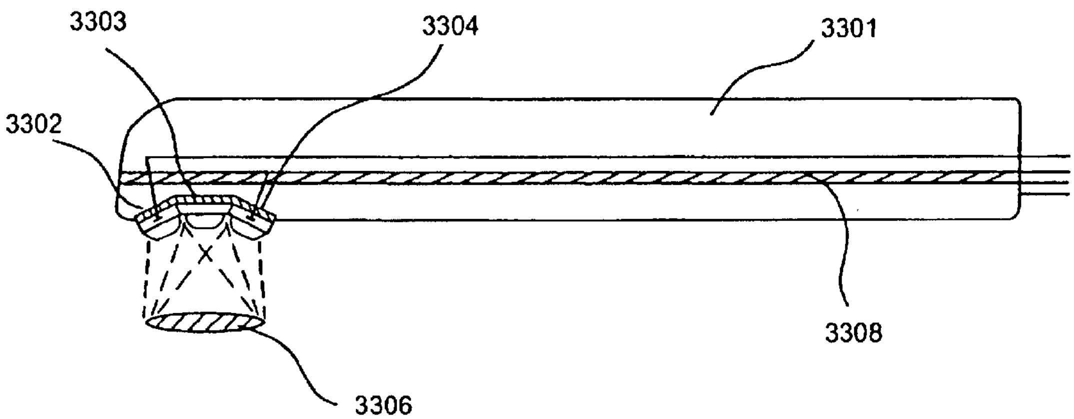

Fig. 33a

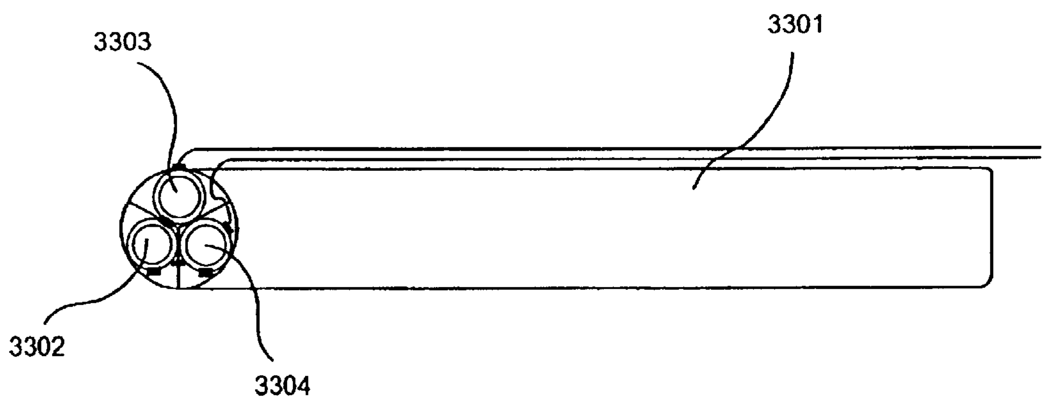

Fig. 33b

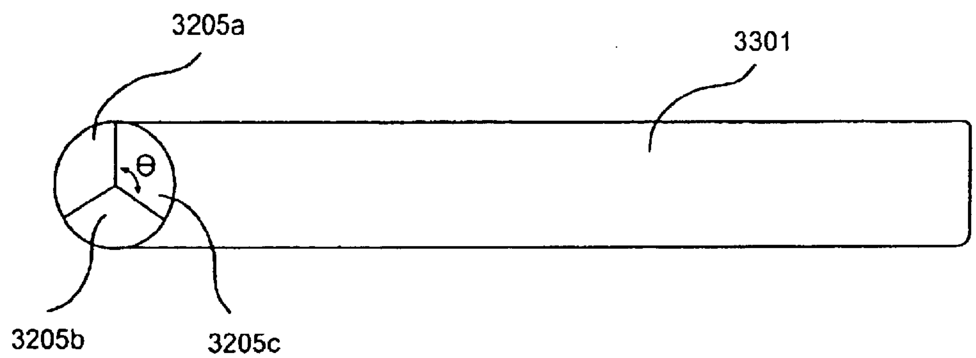

Fig. 33c

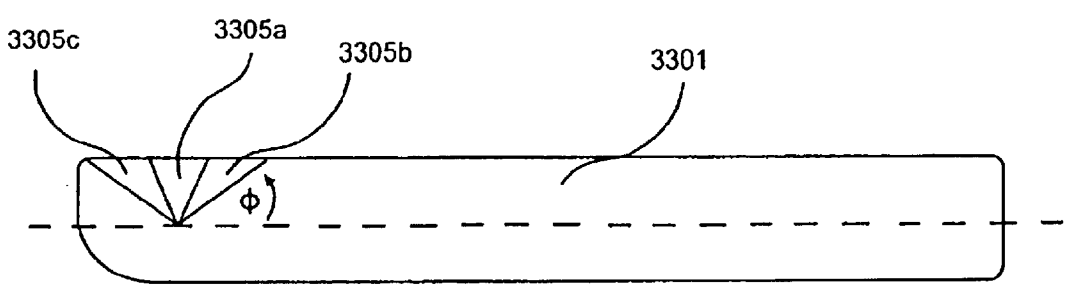

Fig. 33d

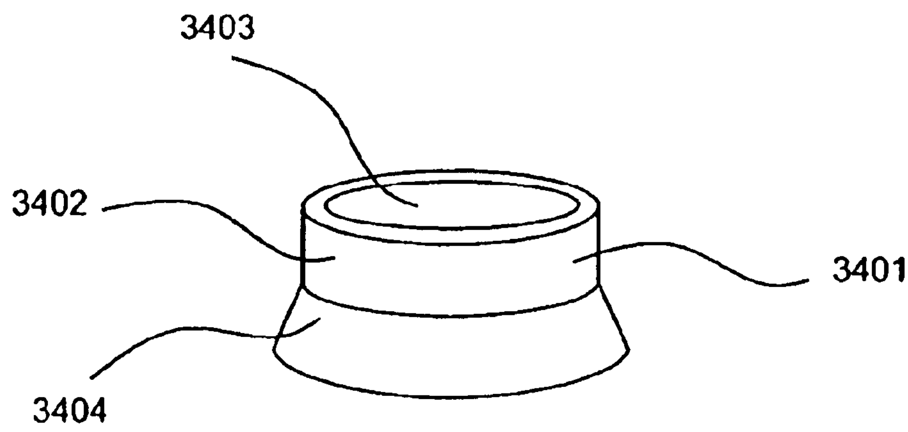

Fig. 34a

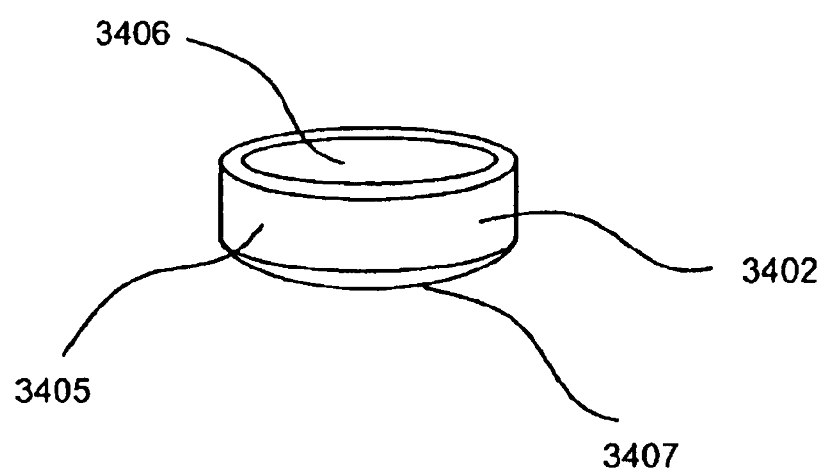

Fig. 34b

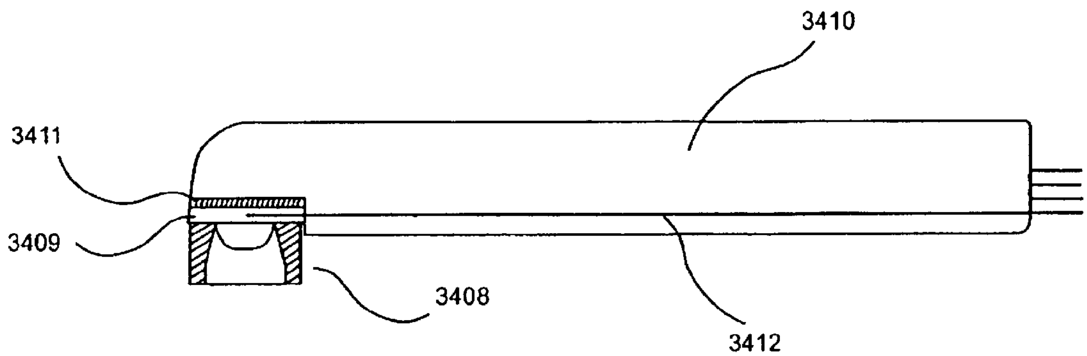

Fig. 34c

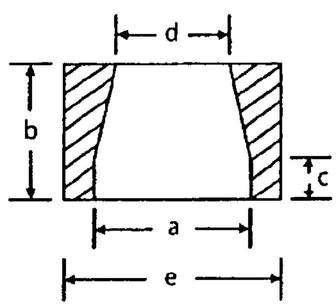

Fig. 34d

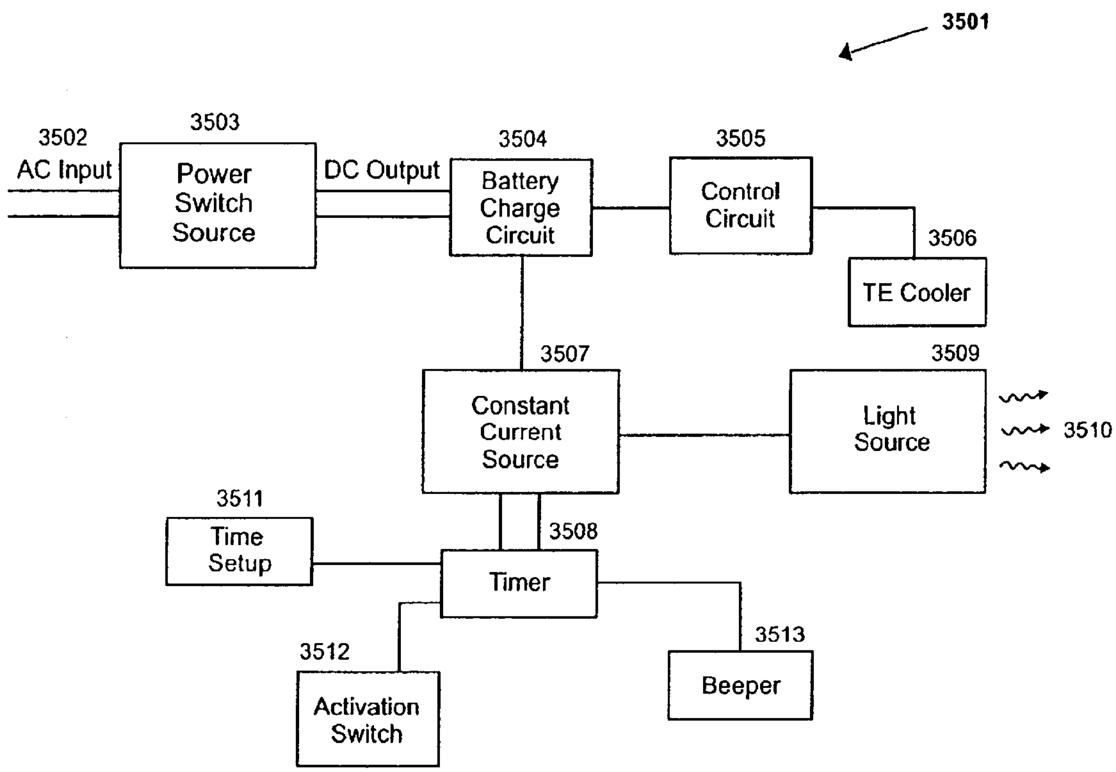
3501
3502
AC Input
3503
Power
Switch
Source
DC Output
3504
Battery
Charge
Circuit
3505
Control
Circuit
3506
TE Cooler
3507
Constant
Current
Source
3509
Light
Source
3510
3511
Time
Setup
3508
Timer
3512
Activation
Switch
3513
Beeper

Fig. 35

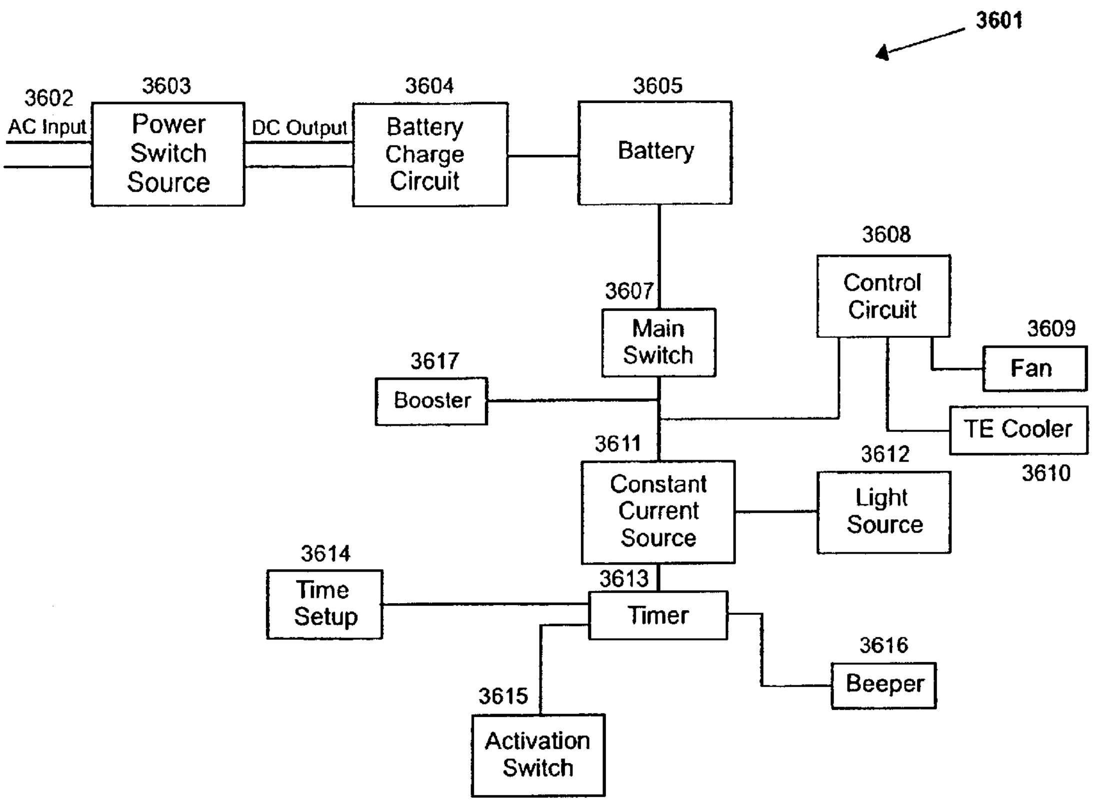
3601
3602
AC Input
3603
Power Switch Source
DC Output
3604
Battery Charge Circuit
3605
Battery
3608
Control Circuit
3607
Main Switch
3609
Fan
3617
Booster
TE Cooler
3610
3611
Constant Current Source
3612
Light Source
3614
Time Setup
3613
Timer
3616
Beeper
3615
Activation Switch

Fig. 36

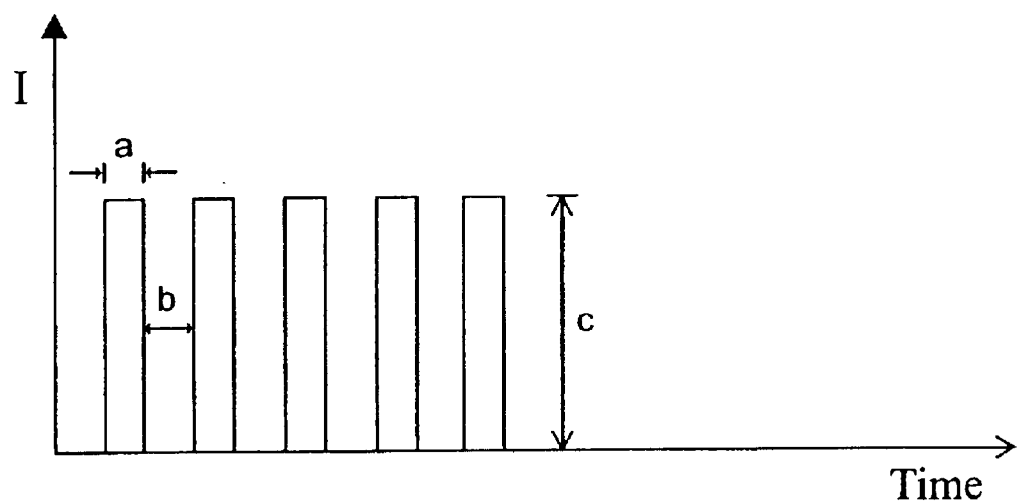

Fig. 37

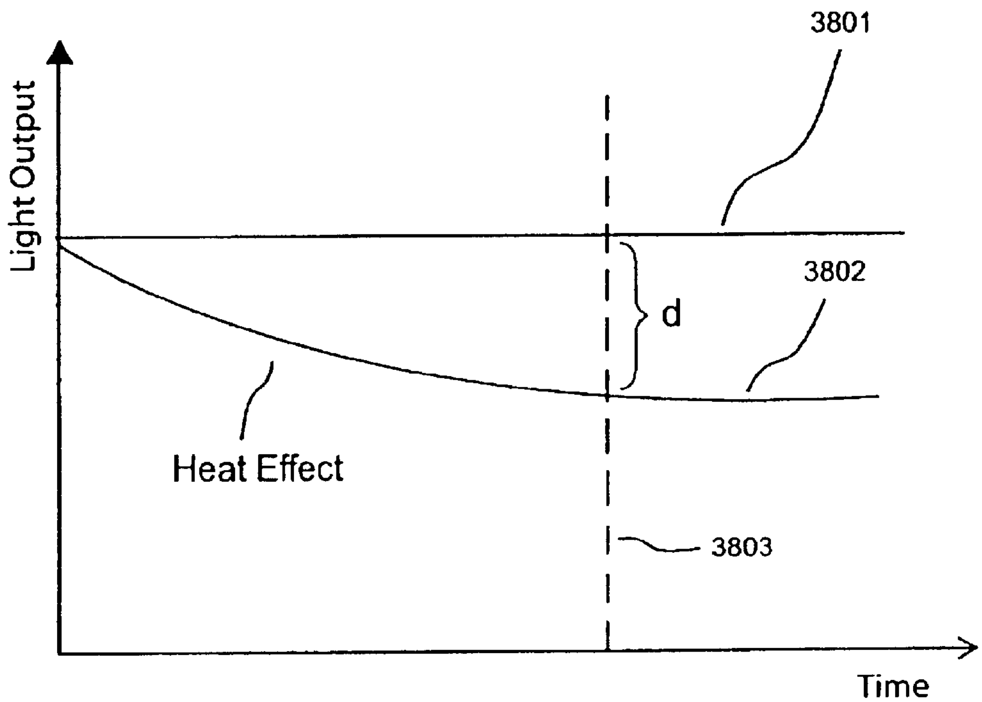

Fig. 38

DENTAL CURING LIGHT USING PRIMARY AND SECONDARY HEAT SINK COMBINATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application 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

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 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.

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. 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

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

FIG. **1** depicts a battery-powered dental curing light that uses a single light emitting diode chip as a light source.

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

FIG. **3** depicts an AC-powered dental 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**.

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

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

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

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

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

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

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

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

FIG. **13** depicts a battery-powered curing light that uses five 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.

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

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.

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.

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

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

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

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

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

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

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

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.

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.

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.

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.

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.

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

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

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

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

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.

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.

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.

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

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.

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

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.

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

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.

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

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.

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.

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.

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.

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.

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

FIG. **32***a* depicts a cross-sectional side view of an elongate heat sink having two light emitting semiconductor chips mounted on it in an angled orientation in order to present overlapping light beams for an enhanced density light footprint.

FIG. **32***b* depicts a top view of the device of FIG. **32***a*.

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.

FIG. **33***b* depicts a top view of the device of FIG. **33***a*.

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

FIG. **33***d* depicts a side view of the heat sink.

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.

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.

FIG. **34***c* depicts a side view of a dental curing light having a light shield and focus lens.

FIG. **34***d* depicts a cross-sectional view of a light shield.

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

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

FIG. **37** depicts a graph of electrical current input I 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.

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

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.

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.

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 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.

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*.

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.

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**.

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.

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**. Control circuitry **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*.

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.

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 light shield **309**. 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**.

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.

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 **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**. 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 **620** with timer control buttons **621** and **622**, and electronic control circuitry **623**.

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.

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**.

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**.

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.

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.

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.

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.

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.

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*.

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-AIGaN 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-AIGaN 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**.

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-AIGaN 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-AIGaN and finally a contact layer **1857** such as p+GaN that has an electrode **1858** mounted on it.

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 chip.

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.

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.

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.

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 wire **2105** and island **2107**.

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.

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.

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**.

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 covered with a light-reflective coating such as Al, Au and others to 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.

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.

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.

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.

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**.

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.

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.

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.

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.

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.

Referring to FIGS. **31***a* and **31***b*, side and top views of a surface mount chip configuration are depicted for mounting a single LED **3100** or LED module 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.

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*. 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 20 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.

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. FIG. **33***d* depicts a side view of the heat sink. 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.

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.

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 dental curing.

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**.

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.

Referring to FIG. **37**, a graph of electrical current input I 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 dimunition 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 increase d 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.)".

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.

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, and (iv) light reflective as desired. Examples of light reflective adhesives which may be used include silver and aluminum based epoxy.

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.

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

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

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.

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.

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.

What is claimed is:

1. A dental curing light comprising:

a light module,

an elongate heat sink located in said light module, said elongate heat sink having a proximal end, a distal end and a longitudinal axis therebetween, said elongate heat sink being part of said light module,

a mounting platform located at said elongate heat sink distal end,

a primary heat sink mounted to said mounting platform, said primary heat sink being smaller in overall volume than said elongate heat sink,

a well located on said primary heat sink, and

a light emitting semiconductor device mounted in said well of said primary heat sink; and

wherein said mounting platform is oriented so that light emitted from said light emitting semiconductor device is emitted at generally a 30 to 150 degree angle to said elongate heat sink longitudinal axis.

2. A dental curing light as recited in claim **1** wherein said light emitting semiconductor device is mounted in said well by use of an adhesive selected from the group consisting of light reflective adhesive and heat conductive adhesive.

3. A dental curing light as recited in claim **1** wherein said light emitting semiconductor device 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.

4. A dental curing light as recited in claim **1** wherein said light emitting semiconductor device utilizes a driving current of not more than about 350 millliamps.

5. A dental curing light as recited in claim **1** wherein said mounting platform is oriented so that light emitted from said light emitting semiconductor device is emitted generally orthogonal to said elongate heat sink longitudinal axis.

6. A dental curing light as recited in claim **1** wherein said mounting platform is oriented so that light emitted from said light emitting semiconductor device is emitted at generally a 45 to 135 degree angle to said elongate heat sink longitudinal axis.

7. A dental curing light as recited in claim **1** wherein at least one of said primary heat sink and said elongate heat sink include material selected from the group consisting of copper, aluminum, silicon carbide, boron nitride, natural diamond, monocrystalline diamond, polycrystalline diamond, polycrystalline diamond compact, diamond deposited through chemical vapor deposition, and diamond deposited through physical vapor deposition.

8. A dental curing light as recited in claim **1** wherein said light emitting semiconductor device includes a substrate and epitaxial layers grown thereon.

9. A dental curing light as recited in claim **8** wherein said substrate is selected from the group consisting of Si, GaAs, GaN, InP, sapphire, SiC, GaSb and InAs.

10. A dental curing light as recited in claim **8** wherein said epitaxial layers include at least one active layer, at least one cladding layer, at least one buffer layer, and at least one contact layer.

11. A dental curing light as recited in claim **8** wherein at least one of said epitaxial layers includes a GaN.

12. A dental curing light as recited in claim **1** further comprising a cover over said light emitting semiconductor device.

13. A dental curing light as recited in claim **12** wherein said cover is transparent.

14. A dental curing light as recited in claim **12** wherein said cover is a focus lens.

15. A dental curing light as recited in claim **1** wherein said well includes a light reflective coating on its interior.

16. A dental curing light as recited in claim **1** further comprising electronic circuitry for controlling operation of the dental curing light.

17. A dental curing light as recited in claim **16** wherein said electronic circuitry is capable of providing pulsed current input to said light emitting semiconductor device.

18. A dental curing light as recited in claim **1** further comprising a thermoelectric cooler on said elongate heat sink, said thermoelectric cooler assisting in heat dissipation.

19. A dental curing light comprising:

a light module,

an elongate heat sink located in said light module, said elongate heat sink having a proximal end, a distal end and a longitudinal axis therebetween, said elongate heat sink being part of said light module,

a mounting location located at said elongate heat sink distal end,

a primary heat sink mounted to said mounting location, said primary heat sink being smaller in overall volume than said elongate heat sink,

a light emitting semiconductor device mounted to said primary heat sink at said mounting location; and

wherein said mounting location is oriented so that light emitted from said light emitting semiconductor device is emitted at generally a 30 to 150 degree angle to said elongate heat sink longitudinal axis.

20. A dental curing light comprising:

an elongate heat sink, said elongate heat sink having a proximal end, a distal end and a longitudinal axis therebetween,

a light emitting semiconductor device mounted in a fixed position with respect to said primary elongate heat sink;

wherein said light emitting semiconductor device emits at least some light that travels in a direction that is in the range of a 30 to 150 degree angle to said elongate heat sink longitudinal axis.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,783,362 B2
APPLICATION NO. : 10/017272
DATED : August 31, 2004
INVENTOR(S) : Densen Cao

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

Column 16
Line 61, replace the phrase “said primary elongate heat sink” with “said elongate heat sink”

Signed and Sealed this

Twenty-second Day of December, 2009

David J. Kappos
Director of the United States Patent and Trademark Office