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(74) Agents: BERGMAN, Michael et al.; BERGMAN KUTA LLP, P.O. BOX 400167, Cambridge, MA 02140 (US).

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(71) Applicant (for all designated States except US): DISCUS DENTAL IMPRESSIONS, INC. [US/US]; 8550 Higuera Street, Culver City, California 90232 (US).

(72) Inventors; and

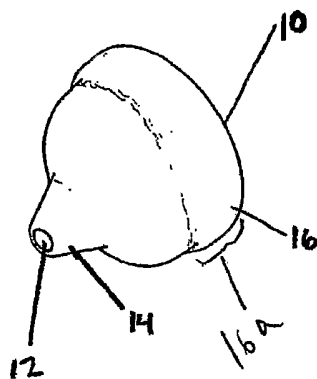
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(75) Inventors/Applicants (for US only): WONG, Joseph [US/US]; c/o DISCUS DENTAL IMPRESSIONS, INC., 8550 Higuera Street, Culver City, California 90232 (US). HAYMAN, Robert [US/US]; c/o DISCUS DENTAL IMPRESSIONS, INC., 8550 Higuera Street, Culver City, California 90232 (US).

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(54) Title: CURING LIGHT HAVING A DETACHABLE TIP



(57) Abstract: The present invention relates to a curing light having a detachable tip for spot curing of light sensitive composites. A series of tips having varying apertures is also envisioned. The present invention also relates to a curing light having a detachable tip for effecting partial curing of light sensitive composites. The advantage of the tip of the present invention, as compared to prior art tips, is that it is adapted to be fitted over the end of a curing light device without the need to remove any protective cover, focusing lens or similar structure that may be mislaid or lost. It also offers the added advantage of a simplified design without the necessity for having built-in complex optical properties normally served by the protective cover while, at the same time, the tip retains the advantages offered by prior art tips.

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## CURING LIGHT HAVING A DETACHABLE TIP

Field of the Invention

[0001] This invention relates to curing light devices for use in dentistry. Specifically, this invention relates to curing light devices for activating the curing composites and/or adhesives in dentistry.

Background of the Invention

[0004] In the field of dentistry, tooth restoration and repaired, dental cavities are often filled and/or sealed with compounds that are photosensitive, either to visible and/or ultraviolet light. These compounds, commonly known as light-curable compounds, are placed within dental cavity preparations or onto dental surfaces and are cured when exposed to light from a dental curing light device. Many light-curing devices are configured to be handheld devices. Some are equipped with a light guide.

[0005] Some techniques employed by dental professionals include an initial partial curing followed by a complete cure. Some curing lights can be equipped with a removable tip for this partial cure. The size of the curing light spot can also be changed by attaching removable tips with different-sized translucent portions for performing the partial cure. Some of these tips are also made to be disposable so that the tip can be disposed of if it is contaminated with curable material during a curing process, as is disclosed in U.S. Patent No. 6,709,128, incorporated herein by reference.

[0006] In some dental procedures, the curing light can be equipped with an attachment, to manipulate the curable

compound before and during irradiation of the compound with radiant energy suitable for curing the compound, to compress the compound within the treated tooth to get rid of air pockets before the compound is completely cured and to obtain the desired restoration effect, as described in U.S. Patent No. 6,702,576. This contact is useful because it generally enables the practitioner to ensure that the dental compound is properly applied within the dental restoration. A transparent attachment for such manipulation may be detachably connected with the curing light device. The transparent attachment has at least a transparent tip through which light passes during the light-curing procedure. The transparent attachment may be color tinted or treated for creating a desired effect, such as, for filtering undesirable wavelengths of light. The transparent attachment may also include optical focusing, collimating, or dispersing attributes for directing the light to the desired application site in a desired manner.

[0007] However, the tip in the art is constructed so that if a lens cover or protector is used without the tacking tip, the lens cover will have to be removed prior to attaching the tacking tip.

[0008] In another manner, as disclosed in U.S. Patent no. 6,835,064, a curing light has 2 sets of LEDs: one set emitting light at a wavelength spectrum having partial overlap with the absorption spectrum of the composite activator or sensitizer, and another set emitting light at a wavelength spectrum that substantially overlaps with the absorption spectrum of the composite sensitizer.

#### Summary of the Invention

[0009] The present invention relates to a curing light having a detachable tip for spot curing of light sensitive

composites.

[0010] The present invention also relates to a curing light having a detachable tip for effecting partial curing of light sensitive composites.

[0011] One advantage of the tip of the present invention as compared to prior art tips is that it is adapted to be securely fitted over the end of a curing light device until actively removed, without the need to remove any protective cover, focusing lens, reflector, light guide, clear cover, dome or similar structure that may be mislaid or lost. The tip of the present invention also offers the added advantage of a simplified design without the necessity of having built-in complex optical properties normally served by the protective cover. At the same time, the presently disclosed tip retains the advantages offered by prior art tips. In one embodiment, the portion of the tip that envelopes the portion of the lens cap may be made of the same material. In another embodiment, the portion of the tip that envelopes the portion of the lens cap may be made of different materials having similar coefficients of thermal expansion.

[0012] The curing light includes a light module housing having a substantially hollow interior, a proximal end and a distal end. Portions of the light module housing serve as a handle. A light module is housed in a desired position within the interior of the module housing. The light module includes at least one light source and at least one heat sink. The heat sink serves to divert heat away from the light source.

[0013] The light module housing further includes a lens cap (which may be open or closed), which may be a reflector, a focusing lens, a dome, a lens cover, a light guide or similar

structure, or combinations thereof. The lens cap is located near the proximal end of the housing. A detachable tip, adapted to envelope at least a portion of the lens cap, includes a conical-shaped body having an open aperture at the apex of the conical-shaped body. The tip may be opaque, either colored or white, and, except for the aperture, substantially blocks all light.

[0014] The present invention also relates to a curing light device suitable for curing of light curable dental composite material. The curing light device includes a distal end and a proximal end, with the proximal end of the housing being the light emitting end. The curing light includes a molded reflector, a lens cap and a tip adapted to securely envelope the cap until actively removed. The lens cap may be a lens cover, a dome, a light guide, a focusing lens or a similar structure, or combinations thereof. The molded reflector and at least a portion of the housing to which the reflector is attached may be made of similar materials or materials having similar coefficients of thermal expansion.

[0015] The present invention further relates to a tip adapted to securely envelope at least a portion of the lens cap until actively removed, the tip including a conical-shaped body having an exterior, an interior, and an aperture at the apex of the conical-shaped body. The tip may be opaque, for example, white or colored, and except for the aperture, substantially blocks all light. The tip also includes at least one protrusion on the interior of the body for repeatably positioning of the tip onto the lens cap.

[0016] The present invention still further relates to a series of tips having apertures of varying diameters for effecting spot curing of composites with varying sizes.

[0017] In one embodiment, the reflector may be of a substantially cylindrical shape having a hollow interior, a proximal end, a distal end, an inside and an outside surface. The reflector may be an integral part of the proximal end of the housing, at the extension of the housing. The interior surface of the reflector has a reflective surface, for example, the reflective surface includes a thin coating of metal.

[0018] In another embodiment, the reflective surface is concave and is adapted for directing and/or focusing the light from the light source to a desired location, such as the detachable tip.

[0019] In yet another embodiment of the invention, the tip, the lens cap, the reflector and the portion of the housing on which the tip is mounted may be formed of the same material or different materials having similar coefficients of thermal expansion. This minimizes stress to the assembled curing light device that may otherwise result due to thermal effects during use.

[0020] In a further embodiment of the invention, the lens cap and the tip may be attached as a unit and the entire unit is detachable. The attachment may be permanent or removable. In some embodiments, the tip enveloping the lens cap and the lens cap may also be integrally molded together.

[0021] In one aspect, the tip includes a circular ring section having a side-wall adapted to envelope the lens cap securely in a friction fit. In one embodiment, the inner diameter of the side-wall of the circular ring section is substantially uniform throughout for fitting over a lens cap having a substantially uniform diameter side wall.

[0022] In another aspect, the lens cap includes ridges for mating with a corresponding groove, channel, depression or enlarged diameter portion on the inside side-wall of the circular ring section of the tip such that the tip envelopes at least a portion of the lens cap.

[0023] In a further aspect, at least a portion of the interior surface of the tip may be reflective for reflecting any light towards the aperture.

[0024] In yet a further aspect, the curing light housing includes a polymer, and a polymeric molded reflector having a reflective coating on its inside surface. A polymeric lens cap fits over the proximal end of the housing and a polymeric detachable tip fits over the lens cap. The reflective coating may be a metal coating, formed by any coating method including vacuum deposition.

[0025] In still yet another aspect, the reflector and at least the portion of the housing close to the reflector are integrally molded together.

[0026] In still yet a further aspect, the reflector is attached to the housing. The attachment may be effected by an adhesive, and/or grooves or threads present in either one or both mating surfaces. The attachment can be permanent or temporary (i.e., removable and replaceable).

#### Brief Description of the Figures

[0027] FIG. 1 shows a cross-section of an embodiment of a curing light.

[0028] FIG. 1a shows a cross-section of an embodiment of a detachable tip of the present invention.

[0029] FIG. 1b shows a rear side perspective view of an embodiment of a detachable tip of the present invention.

[0030] FIG. 1c shows a front perspective view of an embodiment of a detachable tip of the present invention.

[0031] FIG. 2 shows a front side perspective view of a lens cap of the present invention.

[0032] FIG. 2a shows a rear side perspective view of a lens cap of the present invention.

[0033] FIG. 3 shows a cross-sectional view of an embodiment of the proximal end of the light module housing fitted with a tip of the present invention.

[0034] FIG. 4 shows a sectional view of an embodiment of the reflector of the invention.

[0035] FIG. 5 shows a cross sectional side-view of an embodiment of the reflector with a light source of the invention.

[0036] FIG. 6 shows a posterior perspective view of an embodiment of the reflector of the invention.

[0037] FIG. 7 shows an exploded perspective view of the proximal portion of the housing of the curing light of the invention.

[0038] FIG. 8 shows a cross-sectional view of the proximal end of a housing of a curing light of the invention.

[0039] FIG. 9 shows an embodiment of a charger base or cradle.

#### Detailed Description of the Invention

[0040] The detailed description set forth below is intended as a description of the presently preferred device provided in accordance with aspects of the present invention and is not intended to represent the only forms in which the present invention may be practiced or utilized. It is to be understood, however, that the same or equivalent functions and components may be accomplished by different embodiments that are also intended to be encompassed within the spirit and scope of the invention.

[0041] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs. Although any methods, devices and materials similar or equivalent to those described herein can be used in the practice or testing of the invention, the preferred methods, devices and materials are now described.

[0042] A curing light device useful for curing or activating light-activated materials is disclosed. The present invention has applications in a variety of fields, including but not limited to medicine and dentistry, where light-activated materials comprising a photoinitiator or photoinitiators are used. As an example, a photoinitiator absorbs light of a particular wavelength and initiates the polymerization of monomers into polymers.

[0043] FIG. 1 shows a cross-sectional view of a curing light 100 having a light module housing 101 which includes a

handle 102 having a distal end 111, a proximal end 112 and a neck and head portion 103 on its proximal end at an angle to the handle portion 102. The light module housing 101 has a substantially cylindrical shape having a substantially hollow interior 101a with at least one heat sink 120 located in the light module housing 101. The heat sink 120 includes at least one mounting platform (not labeled) for mounting a light source 130, for example, a lamp, an arc lamp such as a halogen light source, semiconductor light emitting devices, light-emitting chips such as an LED, a solid state LED, an LED array, a fluorescent bulb, and so on or combinations thereof.

[0044] In an exemplary embodiment, at least one reflector 46 to focus and direct the light from the light source 130, may be located towards the head and neck portion 103 of the proximal end 112 of the housing 101, as shown in FIG. 5 and 7.

[0045] FIG. 1 also shows a lens cap 20 present towards the head and neck portion 103 of the light module housing 101. The lens cap 20 may be detachably mounted towards the head and neck portion 103, or it may be integrally formed on the head and neck portion 103, and will be discussed in detail below.

[0046] FIG. 1a shows a cross-sectional view of a detachable tip 10, adapted for securely enveloping the lens cap 20, as shown in FIG. 1. The lens cap includes a proximal end 20a and a distal end 20b, as shown in FIG. 2. As noted, the lens cap may be a reflector, a lens cover, a focusing dome, a light guide and the like, or combinations thereof.

[0047] As noted before, the tip has the advantage of being configured to be fitted over the end of a curing light device without the need to remove any protective cover, reflector or focusing lens so that parts may not be mislaid or lost. It

also has the added advantage of a simplified design without the necessity of having built-in complex optical properties normally served by the protective cover, lens cover, a focusing lens, a dome, a light guide, a reflector or similar structure. At the same time, the tip retains all the advantages offered by prior art tips, such as, to be used in tacking or shaping the composite, to partially cure the composite, to spot cure the composite or the like.

[0048] In one embodiment, the portion of the tip 10 adapted for enveloping the portion of the lens cap 20 may be made of the same material. In another embodiment, the portion of the tip 10 adapted for enveloping the portion of the lens cap 20 may be made of different materials having similar coefficients of thermal expansion. In a further embodiment, the portion of the tip 10 adapted for enveloping the portion of the lens cap 20, and the portion of the housing attached to the lens cap may be made of the same material different materials having similar coefficients of thermal expansion. Therefore, the choice of material may aid in minimizing thermal stress during operation or cool down of the curing light device.

[0049] In one embodiment, the lens cap 20 includes a rim, a bump, a ridge, a protrusion or similar raised structure 22 about its distal end 20b for mating with a corresponding groove, channel, depression, or enlarged diameter portion 13 of the tip 10, as shown in FIG. 3, to be discussed in more detail below.

[0050] The tip 10 has a substantially hollow interior 19, as shown in FIG. 1c (a front perspective view of tip 10), with a proximal portion 16 and a distal portion 14, as shown in FIGs. 1b (a rear side perspective view of tip 10), and 1c.

[0051] The proximal portion 16 of the tip 10 may include a circular ring section 16a, as exemplified in FIGs. 1b and 1c. The circular ring portion 16a may include a flat side wall having substantially the same diameter throughout, as exemplified in FIGs. 1b and 1c. In one embodiment, the proximal portion 16 may also include an enlarged region 16b for facilitating ease of grip during attaching and removal of the tip 10 to and from the lens cap 20, as shown in FIGs. 1c and 3. In one aspect, the inner diameter of 16b may be substantially the same as the rest of the proximal portion 16. In another aspect, the outer diameter of portions of the enlarged portion 16b may be larger than the diameter of the rest of the proximal portion 16. In a further aspect, portions of the inner diameter 13 of this enlarge portion 16b may be larger than the rest of the proximal portion 16 for easy mating with the rim portion 22 of the lens cap 20, as exemplified in FIGs. 2 and 3.

[0052] An aperture 12 is disposed towards the distal end 14, near the apex of the tip 10. In one embodiment, apart from the aperture 12, the tip is substantially opaque to light emitted by the curing light 100. Thus, the diameter or footprint of the beam exiting the curing light device of the present invention corresponds to the diameter or size of the aperture 12 of the tip 10. In another embodiment, a series of tips with varying aperture size is envisioned for use depending on the size of spot curing desired to add versatility to the system. All the tips in a series may be sized to fit securely over a lens cap and for the same curing light, only the size of the aperture is varied.

[0053] FIG. 1c shows the interior cavity 19 of the tip 10 from its proximal end 16. In one embodiment, at least portions of this interior cavity 19 may be reflective, for reflecting,

directing or focusing light entering the tip 10 from the curing light towards the aperture 12. In another embodiment, the interior may be opaque, adapted to absorb light except that passing through the aperture 12.

[0054] The aperture 12 is substantially smaller than the diameter of the interior cavity 19, serving to reduce the footprint of the light exiting the tip 10 in relation to the light entering it, effecting spot curing even if the diameter of light exiting the lens cap 20 is relatively large.

[0055] The tip 10 also has an elongated portion towards the distal end 14 and aperture 12 that may also allow for spot manipulation of the curing compound, if desired.

[0056] FIG. 1c also exemplifies at least one internal protrusion 18. The protrusion 18 may serve to prevent the lens 20 from being pushed too deeply into the tip 10 or vice versa. It may also help to position the tip 10 over the lens cap 20 in a more repeatable fashion so that the distance between the lens cap 20 and the aperture 12 may be predetermined or preset, as shown in FIG. 3, according to the position of protrusion. Thus, the protrusion does not only provide a repeatable positioning of the tip 10, it may also be adapted to vary the pre-determined position of the tip 10. In addition, the protrusion may be of any structure, including a bump, a ridge or similar.

[0057] Alternately, as shown in FIG. 3, a zoomed in cross-sectional view of tip 10 disposed onto lens cap 20 of curing light device 100 is exemplified, with the locking interaction between the ridge or rim 22 on lens cap 20 and the corresponding groove, channel, depression or enlarged inner diameter portion 13 of tip 10. The mating of ridge or rim 22 of the lens cap 20 with the enlarged inner diameter portion,

depression, channel or groove 13 of the enlarged portion 16b may also serve to position the tip 10 onto the lens cap 20 in a repeatable fashion. Similarly, the position of the channel, depression or enlarged inner diameter portion 13 may also serve to vary the pre-determined position of the tip 10.

[0058] In another embodiment, not shown, the bump, ridge, rim, protrusion or similar raised structure may be included on the tip 10 with a corresponding groove, channel, depression or similar feature included on the lens cap 20 so as to provide a substantially similar positioning feature as discussed above.

[0059] The lens cap 20 and the tip 10 may be made of the same or different material from the housing 101 of the curing light device. If they are made of different materials, the materials may be, for example, of similar coefficients of thermal expansion for minimizing thermal stress during operation or cool down of the curing light device.

[0060] In an exemplary embodiment, as shown in FIG. 7, the proximal end portion 112 may end in a light-emitting end, for example, the head and neck portion 103, as shown in FIG. 1, which includes a light source 130. The light source 130 is shown in FIG. 7 as an LED, though it may be any suitable light source, as noted above, including, but not limited to, a single LED device, a single LED device array, a plurality of LED arrays, a single diode laser device, an array of diode laser devices, a Vertical Cavity Surface Emitting Laser (VCSEL) device or array of devices, or one or more LED or laser modules. The wavelength of light emitted from the light source may be any desired wavelength or combination of different wavelengths, chosen according to the characteristics of the photoinitiator(s) in the light-activated material to be

cured. Any of the semiconductor and heat sink arrangements described herein may be used to construct desired lights.

[0061] In an exemplary embodiment, a single LumiLeds™-type LED light source 130 may be mounted towards the head and neck portion 103 of the proximal end 112 of the housing 101. The light source may be a Luxeon™ V Star light source which may include up to four LEDs mounted on a single sub-mount and encapsulated by a single lens. Such a light source is disclosed in U.S. Patent No. 6,498,355 to Harrah et al and U.S. Patent No. 6,274,924 to Carey et al, which are both assigned to LumiLeds Lighting of San Jose, California, the entire disclosure of which is incorporated herein by reference. The Luxeon™ V Star light source is available in a blue color, Lambertian radiation pattern, and produces about 525 mW/cm<sup>2</sup>. Other wavelengths are also possible.

[0062] As shown in FIG. 5, the light source 130 may include any or all of the following: a slug 36, a sub-mount 37, up to four LEDs 38 mounted thereto, a lead frame 39, and a metal lead 41 extending through the lead frame. A plastic lens 35 having a hemispherical dome shape may also cover the one to four LEDs.

[0063] In one embodiment, the curing light further includes an extension portion (not specifically shown) such as a light transport, a light pipe, a light guide, or similar structure, for directing or transporting light to a desired location of a work surface such as a patient's mouth. The light module may also be located towards the proximal end 112. Generally, however, the light module is located in the housing 101. The head and neck portion 103 may also form part of the light transport system.

[0064] An elongated surface or mounting member (not shown), which may be made of, for example, copper or a brass material, may be used for mounting the light source 130 (as shown in FIG. 5) thereon. The mounting member may include an elongated base section and a mounting section including a mounting deck. The light source 130 may be mounted on the mounting section and the mounting member may be configured to reside within the head and neck portion 103 of the proximal end 112.

[0065] As noted, the extension may be a light guide or light transport tube for directing the light onto a working surface. In one embodiment, the light source 130 and the reflector 46 may be located away from the emitting end of the housing 101 so that the locus of heat dissipation of the curing light will be comparatively remote from the patient.

[0066] The heat sink 120, exemplified as an elongated heat sink in FIGs. 1 and 7 (although other geometries are possible), is shown to be positioned inside the housing 101, in close proximity to the light source 130, to conduct, or dissipate heat from the light source 130. In some embodiments, the light source 130 may be mounted on a mounting platform 121 on the heat sink 120. If the light source 130 is located away from the proximal end or in an extension portion, then the heat sink 120 is similarly located.

[0067] In another embodiment, the heat sink 130 may be configured to have fins, corrugations, or other geometric features adapted to provide a large surface area for convective cooling of the heat sink 120. In still another embodiment, the curing light device 100 includes an electric motor mechanically coupled to a fan or turbine. The fan or turbine may be adapted to draw or urge ambient air across a surface of the heat sink 120 to provide cooling of the heat

sink 120. In one embodiment, this cooling occurs when the curing light is at rest or being recharged. In another embodiment, the cooling means is present inside a charger base or cradle 200, as shown in FIG. 9 for recharging the curing light. In other embodiments, the charger base or cradle 200 may not have a fan 201 or cooling means, but instead or additionally, many include a display panel (not shown) for displaying a condition of the battery.

[0068] The heat sink 120 may be made of any suitable material that is efficient in heat conduction or dissipation. The heat sink of the invention includes monolithic heat sinks and combinational heat sinks. Combinational Heat sinks are often a combination of two different kinds of materials, the first with a low thermal expansion rate and the second with high thermal conductivity. Monolithic heat sinks may be made of one material. Examples of some heat sink materials which may be used in lights depicted herein include copper, aluminum, silver, magnesium, steel, silicon carbide, boron nitride, tungsten, molybdenum, cobalt, chrome, Si, SiO<sub>2</sub>, SiC, AlSi, AlSiC, natural diamond, monocrystalline diamond, polycrystalline diamond, polycrystalline diamond compacts, diamond deposited through chemical vapor deposition and diamond deposited through physical vapor deposition, and composite materials or compounds. As mentioned, any materials with adequate heat conductance and/or dissipation properties may be used. If desired, a heat sink 120 may have fins or other surface modifications or structures to increase surface area and enhance heat dissipation.

[0069] Thermoelectric type heat sinks and heat sinks employing a phase change materials are also useful, especially those with phase change materials, as disclosed in a co-pending patent application, 10/XXX,XXX, entitled "Dental Light

Devices Having an Improved Heat Sink", to be filed concurrently; and a U.S. Patent Application No. 60/585,224, filed July 2, 2004, entitled "Dental Light Devices with Phase Change Heat Sink"; incorporated herein by reference.

[0070] Heat sinks having a phase change material may more efficiently remove or divert heat from a light source or sources with a given weight of heat sink material when compared to a heat sink made of a solid block of thermally conductive material such as metal. Such a heat sink may even efficiently remove or divert heat from a curing light device when a reduced weight of the material is used. Using a phase change material enclosed inside a hollow thermally conductive material such as a metal heat sink instead of a conventional solid metal heat sink can decrease the weight of the curing light and increase the time the heat sink takes to reach the "shut off" temperature, as it is called in the dental curing light industry. The period prior to reaching the shut off temperature is called the "run time". Increasing the "run time", i.e., the time that the light can remain on, increases the time when a dentist can perform the curing or whitening procedure.

[0071] In one embodiment, a rechargeable dental curing light including at least one phase change material is disclosed. In another embodiment, a dental whitening light including at least one phase change material is disclosed. The heat sink includes a block of thermally conductive material, such as metal, having a bore or void space which is at least partially filled with a phase change material.

[0072] The heat sink may be constructed by hollowing out a thermally conductive material, such as metal, and at least partially filling the void with at least one phase change

material prior to capping it to secure the phase change material inside, such that the at least one phase change material is substantially contained or surrounded by a thermally conductive material such as metal normally used in the construction of a conventional heat sink.

[0073] Alternatively, the heat sink may be cast or machined from a thermally conductive material, such as metal, to create walls surrounding a bore or void. The bore or void is partially filled with at least one phase change material prior to capping it to secure the material inside.

[0074] In one embodiment, the inventive heat sink may be used by itself. In another embodiment, it may be used in addition to a fan, in conjunction with a conventional metal block heat sink or combinations thereof.

[0075] The inventive heat sink may be installed into the dental curing light, imaging or whitening light source in the same manner a conventional metal block heat sink is installed, such as by attaching it to the heat generating source, i.e., the light source, which may include any of the ones mentioned above or combinations thereof, or by attaching it to another heat sink.

[0076] Suitable phase change material may include organic materials, inorganic materials and combinations thereof. These materials can undergo substantially reversible phase changes, and can typically go through a large, if not an infinite number of cycles without losing their effectiveness. Organic phase change materials include paraffin waxes, 2,2-dimethyl-n-docosane ( $C_{24}H_{50}$ ), trimyristin,  $((C_{13}H_{27}COO)_3C_3H_3)$ , and 1,3-methyl pentacosane ( $C_{26}H_{54}$ ). Inorganic materials such as hydrated salts including sodium hydrogen phosphate

dodecahydrate ( $\text{Na}_2\text{HPO}_4 \cdot 12 \text{H}_2\text{O}$ ), sodium sulfate decahydrate ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ), ferric chloride hexahydrate ( $\text{FeCl}_3 \cdot 6 \text{H}_2\text{O}$ ), and TH29 (a hydrated salt having a melting temperature of  $29^\circ\text{C}$ , available from TEAP Energy of Wangara, Australia) or metallic alloys, such as Ostalloy 117 or UM47 (available from Umicore Electro-Optic Materials) are also contemplated. Exemplary materials are solids at ambient temperature, having melting points between about  $30^\circ\text{C}$  and about  $50^\circ\text{C}$ , more for example, between about  $35^\circ\text{C}$  and about  $45^\circ\text{C}$ . Also, the exemplary materials have a high specific heat, for example, at least about 1.7, more for example, at least about 1.9, when they are in the state at ambient temperature. In addition, the phase change materials may, for example, have a specific heat of at least about 1.5, more for example, at least about 1.6, when they are in the state at the elevated temperatures.

[0077] The phase change material may also have a high latent heat of fusion for storing significant amounts of heat energy. This latent heat of fusion may be, for example, at least about 30 kJ/kg, more for example, at least about 200 kJ/kg.

[0078] Thermal conductivity of the materials is a factor in determining the rate of heat transfer from the thermally conductive casing to the phase change material and vice versa. The thermal conductivity of the phase change material may be, for example, at least about  $0.5 \text{ W/m}^\circ\text{C}$  in the state at ambient temperature and at least about  $0.45 \text{ W/m}^\circ\text{C}$  in the state at elevated temperature.

[0079] In one embodiment, the heat sink 120 may include a first power conductor 19a and a second power conductor 19b for conducting heat away from the light source.

[0080] In an exemplary embodiment, the reflector 46 may be mounted inside the housing towards the head and neck portion 103 of the proximal end 112, as shown in FIGs. 3, 7 and 8. The reflector 46 may be configured to reflect light generated by the light source 130 to a desired location on the work surface, such as a patient's mouth, or towards the tip 10, as shown in FIG. 3.

[0081] The reflector 46 is of a cylindrical shape, as exemplified in FIGs. 4-6. In one embodiment, the reflector 46 may be used to retain the light source 130 within the emitting end 103 of the curing light device.

[0082] In the present embodiment, the reflector 46 may include a threaded portion 46a, a reflective surface 46b and an LED aperture 46c. The reflector 46 may be mounted to the curing light 100 by inserting into the head and neck portion 103, as shown in FIGs. 5 and 6. The attachment may be facilitated by fixing formations, for example, threads, grooves, channels, depressions, protrusions or similar, on both the neck section 15 and the reflector 46 (not shown), for example, if protrusions are present on either the reflector 46 or the neck section 15 and corresponding grooves may be present on either to receive them. The reflector may also fit into the curing light by means of a friction fit or the reflector may be retained with an adhesive, such as structural bonding adhesive including an epoxy, one or two part, polyurethane adhesives, one or two parts, a cyanoacrylate based adhesive, or a foam mounting adhesive. The foam mounting adhesive may also aid in shock absorption.

[0083] The reflector 46 may also be molded onto the end of the head and neck portion 103 and housed inside the proximal end 112, in addition to being threadably connected to the head

and neck portion 103 of the proximal portion 112 via grooves or external threads on the outside of the cylindrical body 46. The external threads may be mated to the threads or grooves on the inside of the head and neck portion 103 of the housing 101. The reflector 46 may also be attached by means of an adhesive, such as any structural bonding adhesive including an epoxy, one or two part, polyurethane adhesives, one or two parts, a cyanoacrylate based adhesive, or a foam mounting adhesive. The foam mounting adhesive may also aid in shock absorption.

[0084] In one embodiment, the reflector 46 may be either permanently attached to the head and neck portion 103 of the housing 101, or to an extension thereof. In another embodiment, the reflector 46 may be made to be removable. If an extension portion (not shown) is present, the extension may include a permanently attached or integrally molded reflector, and may be made to be removable from the head and neck portion 103 of the proximal end 112 of the housing 101 as one part.

[0085] The housing 101, and an embodiment of a reflector, may be made of any polymeric material such as, for example, a polymer that can be molded or cast; or a metal or metallic alloy. Suitable polymers include polyethylene, polypropylene, polybutylene, polystyrene, polyester, acrylic polymers, polyvinylchloride, polyamide, or polyetherimide like ULTEM®; a polymeric alloy such as Xenoy® resin, which is a composite of polycarbonate and polybutyleneterephthalate or Lexan® plastic, which is a copolymer of polycarbonate and isophthalate terephthalate resorcinol resin (all available from GE Plastics), liquid crystal polymers, such as an aromatic polyester or an aromatic polyester amide containing, as a constituent, at least one compound selected from the group consisting of an aromatic hydroxycarboxylic acid (such as

hydroxybenzoate (rigid monomer), hydroxynaphthoate (flexible monomer), an aromatic hydroxyamine and an aromatic diamine, (exemplified in U.S. Patent Nos. 6,242,063, 6,274,242, 6,643,552 and 6,797,198, the contents of which are incorporated herein by reference), polyesterimide anhydrides with terminal anhydride group or lateral anhydrides (exemplified in U.S. Patent No. 6,730,377, the content of which is incorporated herein by reference) or combinations thereof.

[0086] In addition, any polymeric composite such as engineering prepregs or composites, which are polymers filled with pigments, carbon particles, silica, glass fibers, conductive particles such as metal particles or conductive polymers, or mixtures thereof may also be used. For example, a blend of polycarbonate and ABS (Acrylonitrile Butadiene Styrene) may be used for the housing 101a.

[0087] Generally, materials usable in housing 101 include, for example, polymeric materials or composites having high temperature resistance.

[0088] Suitable metal or metallic alloys may include stainless steel; aluminum; an alloy such as Ni/Ti alloy; any amorphous metals including those available from Liquid Metal, Inc. or similar ones, such as those described in U.S. Patent No. 6,682,611, and U.S. Patent Application No. 2004/0121283, the entire contents of which are incorporated herein by reference.

[0089] A liquid crystal polymer or a cholesteric liquid crystal polymer, such as one that can reflect rather than transmit light energy, may be used in various embodiments of the invention. For example, a liquid crystal polymer or a cholesteric liquid crystal polymer may be used as a coating on

an interior surface 101 of the light module housing 101, to minimize the waste of light energy generated by the light source (as described, for example, in U.S. Patent Nos. 4,293,435, 5,332,522, 6,043,861, 6,046,791, 6,573,963, and 6,836,314, the contents of which are incorporated herein by reference).

[0090] In an exemplary embodiment, the reflector 46 may be metallized on its interior surface 46b so as to create a reflective surface. Depending on the thickness of the metal coating, the amount of reflection may be varied. For example, the reflector exhibits a high degree of reflectivity.

[0091] The reflective surface may also shape and focus the light emitted by the light source 130. In some embodiments, a focusing lens may also be used. The direction of light reflection depends on the shape or curvature of the reflective surface 46b. For example, a concave surface may be used, or a certain degree of curvature of the surface may be designed to influence the direction of the reflected light, individually or collectively. Thus, the shape and the curvature of the reflective surface will help to shape and focus the light to any desired direction.

[0092] The reflector 46 may be, for example, molded or cast out of a high temperature polymer, in much the same way as the polymers used for the construction of the housing 101. In another embodiment, the reflector 46 may be, for example, injection molded using a mold. This produces higher degree of reproducibility of the reflectors 46. The polymers, as noted, may also be those that can be molded or cast and coated.

[0093] In one embodiment, the reflective surface may be, for example, metallic, and may be formed through coating. Any one or more coating techniques for forming a thin film coating

may be used. Such techniques include any methods of metallization of a polymeric surface such as Gas-phase coating techniques. These techniques are generally known as physical vapor deposition (PVD), chemical vapor deposition (CVD), and plasma deposition. These techniques commonly involve generating a gas-phase coating material that condenses onto or reacts with a substrate surface. Various gas-phase deposition methods are described in "Thin Films: Film Formation Techniques," Encyclopedia of Chemical Technology, 4<sup>sup</sup>.th ed., vol. 23 (New York, 1997), pp. 1040-76, incorporated herein by reference.

[0094] PVD is a vacuum process where the coating material is vaporized by evaporation, by sublimation, or by bombardment with energetic ions from a plasma (sputtering). The vaporized material condenses to form a solid film on the substrate. The deposited material is generally metallic or ceramic in nature (see Encyclopedia of Chemical Technology as cited above).

[0095] CVD processes involve reacting two or more gas-phase species (precursors) to form solid metallic and/or ceramic coatings on a surface (see Encyclopedia of Chemical Technology as cited above). In a high-temperature CVD method, the reactions occur on surfaces that can be heated at 300° C. to 1000° C. or more, and thus the substrates are limited to materials that can withstand relatively high temperatures. At the same time, in a plasma-enhanced CVD method, the reactions are activated by a plasma, and therefore the substrate temperature can be significantly lower, and polymers such as polystyrene and polyester may also be used in the construction of the reflector.

[0096] Plasma deposition, also known as plasma polymerization, is analogous to plasma-enhanced CVD, except that the precursor materials and the deposited coatings are

typically organic in nature. The plasma significantly breaks up the precursor molecules into a distribution of molecular fragments and atoms that randomly recombine on a surface to generate a solid coating (see Encyclopedia of Chemical Technology as cited above). A characteristic of a plasma-deposited coating is the presence of a wide range of functional groups, including many types of functional groups not contained in the precursor molecules, thus it is less amenable to use in the present invention.

[0097] Other embodiments of the invention may include a reflecting surface that includes anodized aluminum, and a reflecting surface formed by vapor deposition of dielectric layers onto metallic layers. For example, a metallic layer may be deposited on an anodized surface as a base reflection layer, followed by deposition of a low refractive index and then a high refractive index dielectric layer. Such materials include those available from Alannod, Ltd. of the United Kingdom, and may include a cholesteric liquid crystal polymer.

[0098] Cholesteric liquid crystal polymers can reflect rather than transmit light energy, and may be used either as a surface coating layer or as the main ingredient of the reflector, as described, for example, in U.S. Patent Nos. 4,293,435, 5,332,522, 6,043,861, 6,046,791, 6,573,963, and 6,836,314, the contents of which are incorporated herein by reference. Other materials with similar properties may also be employed in the invention.

[0099] The coating methods used in the invention may include, for example, those that may be operated at lower temperatures to create a thin and substantially continuous layer on a polymeric surface. Such methods may add to the versatility and flexibility in the choice of materials, both

the polymeric material and the metallic coating. Some metallic coating may be reflective only as a thin coating. These may thus be used, as well as lower temperature polymers.

[00100] Any metal that is amenable to being coated as a relatively thin film to generate a reflective surface may be used. Some examples include aluminum, indium/tin oxide, silver, gold and mixtures thereof. Aluminum may also be in the form of anodized aluminum.

[00101] In one embodiment, reflector 46 and an extension, or at least portions the head and neck portion 103, may be, for example, made out of the same material, similar material, or material having similar coefficients of thermal expansion. For example, a polycarbonate material may be used so that there is little or no difference in the coefficients of thermal expansions. Where different coefficients of thermal expansion are present, as is found in a reflector 46 made of metal and a plastic extension, the result may be hoop stress imparted from the metal reflector into the housing as the reflector expands at a rate greater than the extension. Such hoop stress may lead to premature failure of the unit. Such failure is minimized or eliminated by the present embodiment of the invention.

[00102] The plastic molded reflector 46 also offers increased impact resistance in various embodiments of the invention. When the plastic reflector 46 is molded out of the same material as the extension housing, the two components, when mated as system, form a much more impact resistant configuration than a metal reflector bonded into the plastic extension during drop test. Without wishing to be bound to a theory, it is surmised that during drop tests with the system having a metal reflector, more of the load is directly transmitted to the extension, increasing the potential for

high stress levels in the extension and failure of the extension. Additionally, metal reflectors are usually bonded to the housing using a bonding adhesive. Because the metal reflector does not absorb impact, it may simply separate from the extension when the curing light is dropped, breaking its adhesive bond.

[00103] The reflector, 46, may be, for example, molded, as the molding process is highly repeatable. A mold may be made and the optical geometry of the inside of the reflector remains substantially invariant over the molding process, from part to part. This compares very favorably with the manufacturing process involved in making metal reflectors. In particular, individually machining metal reflectors may create a potential for high variability in the geometry and the surface reflectivity. This variability may be evident not just from reflector to reflector, but over the surface of a single reflector. This variability may lead to lower illumination efficiencies.

[00104] The plastic reflector also allows for a vacuum metallization process to be used to create a mirror like finish, thus yielding a high, to very high, level of efficiency in the illumination system. This is especially true in comparison to a polished surface of a machined metal part, since polishing is more likely to create pits and non-uniformity in the metal surface depending on the abrasive polishing materials and methods used.

[00105] Since the molding process is amenable to mass production, the use of a plastic molded part that is metallized also yields a more efficient illumination system for a given price in comparison to a machined metal part.

[00106] In addition, plastic reflectors may have an extra advantage of being adapted to be formed in any color. Experimentation has found that molding the reflector out of a white plastic may yield better reflectivity.

[00107] In one embodiment, the thickness of the reflective layer may be sufficiently thin so as not to substantially affect the thermal expansion of the base polymer, or the mechanical properties of the reflector.

[00108] The lens cap 20 may be, for example, made of the same or different material as the reflector and/or housing, all of which material may have approximately similar coefficients of thermal expansion, for the reasons discussed above. The lens cap 20 is generally transparent, if it serves only to protect the light source 130 and/or the reflector 46. The lens cap 20 may also be reflective or focusing for guiding and/or focusing the light towards the tip 10. The lens cap 20 may, for example, have a substantially flat portion towards its proximal end or its proximal end may also be dome-shaped, as shown FIGs. 2 and 2a. In general, the reflector 46 and/or the lens cap 20 determine the location of the focus of the beam prior to the arrival of the beam at the tip 10. Thus, as noted before, the tip may only serve to vary the size or diameter of the beam by the size or diameter of its aperture 12.

[00109] The tip 10 may, for example, again be made of the same material as that suitable for the housing 101, lens cap 20 or reflector 46. If different materials are used, those having similar coefficients of thermal expansion as that of the other parts are typically chosen. If the head and neck portion 103 of the housing 101, the reflector 46, the lens cap 20 and tip 10 are all made of the same material or different

materials having similar coefficients of thermal expansion, then the thermal expansion stresses may be minimized, as noted above.

[00110] Further, for example, the tip 10 may be substantially opaque, either white or colored, or internally reflective so that the only substantial exit point for any light entering the tip is through the aperture 12. In one embodiment, for example, at least a portion of the interior surface of the tip 10 may be reflective for reflecting any light towards the aperture. The reflective surface of the tip may include any of the reflective materials discussed above, or it may include any transparent or translucent material capable of refracting light to prevent leakage from the walls of the tip. The tip may also include materials that are transparent to certain wavelengths, but opaque to others, such as, for example, a material transparent to visible light, but opaque to ultra-violet light.

[00111] In an exemplary embodiment of the invention, the lens cap 20 and the tip 10 may be formed as a unit, attached as a unit, and the entire unit may be detachable. The attachment between the lens cap 20 and the tip 10 may be permanent or removable.

[00112] In a further embodiment of the invention, the tip 10 and the lens cap 20 may also be integrally molded together. The material used for both may be the same or different.

[00113] In some embodiments, the curing light housing 101 includes a polymer, and a polymeric molded reflector having a reflective coating on its inside surface. A polymeric lens cap fits over the proximal end of the housing and a polymeric detachable tip fits over the lens cap. The reflective coating

may be a metal coating, formed by any coating method including vacuum deposition, as noted above, for minimizing thermal stress during operation of the curing light.

[00114] In one aspect, the reflector 46 and at least the portion of the housing 101 close to the reflector 46 may be integrally molded together. The lens cap 20, for example, then fits over the head and neck portion of the housing 101 and the tip 10 fits over the lens cap 20.

[00115] In another aspect, the reflector 46 may be attached to the housing. The attachment may be effected by an adhesive, and/or grooves or threads present on either one or both mating surfaces. The attachment may be permanent or temporary (i.e., removable and replaceable). The lens cap 20, again for example, fits over the head and neck portion 103 of the housing 101 and the tip 10 fits over the lens cap 20.

[00116] The threaded portion 46a of the reflector 46 may be towards the end distal 48, surrounding the LED aperture 46c. The threaded section 46a may be adapted to receive a lens cap 20 which may include corresponding grooves for threading onto the reflector 46, as exemplified in FIG. 8. The lens cap 20 may serve to seal the light emitting end 103 of the curing light 100 and may also serve to focus the light from light source 130.

[00117] The invention may also relate to a series of tips 10 having apertures 12 of varying diameters for effecting varying the sizes of spot curing of composites. Thus, the tips 10 of the present invention may be fashioned to give precise and minute spot curing or partial curing of composites.

[00118] Having described the invention in the preferred embodiments, the invention is further embodied in the appending claims set forth below.

## Claims:

1. A curing light for curing light sensitive composites comprising:
  - a light module housing having a proximal end and a distal end;
  - a lens cap near the proximal end of the housing; and
  - an opaque tip having a conical-shaped body, an interior, an exterior, an apex, and an aperture at the apex, adapted for enveloping at least a portion of the lens cap.
2. The curing light of claim 1 wherein at least a portion of said interior surface of the tip comprises a reflective surface or an opaque surface.
3. The curing light of claim 1 or 2 wherein said lens cap is selected from a group consisting of a protective cover, a dome, a clear cover, a focusing lens, a light guide, a reflector and combinations thereof.
4. The curing light of claim 1 or 3 wherein said tip comprises a circular ring section having an inside side-wall adapted to envelope at least a portion of the lens cap in a friction fit.
5. The curing light of claim 1 or 4 wherein said lens cap comprises an outside wall having a substantially uniform diameter over at least a portion of said outside wall.
6. The curing light of any of the preceding claims wherein said tip and a portion of the lens cap enveloped by the tip comprises the same material or different materials having similar coefficients of thermal expansion.

7. A curing light device suitable for curing light curable dental composite materials comprising:

a light module housing including a distal end and a proximal end, with the proximal end of the housing being the light emitting end;

at least one molded reflector located towards the proximal end of the light module housing;

a lens cap fitted over the proximal end of the housing;  
and

an opaque tip having a conical-shaped body, an interior, an exterior, an apex, and an aperture at the apex, adapted for enveloping at least a portion of the lens cap.

8. The curing light of claim 7 wherein said molded reflector and at least a portion of the housing to which the reflector is attached comprises of similar materials or materials having similar coefficients of thermal expansion.

9. The curing light of claim 7 or 8 wherein said lens cap is selected from the group consisting of a lens cover, a dome, a focusing lens, a clear cover, a light guide, a reflector or combinations thereof.

10. The curing light of any of claims 7-9 wherein said molded reflector comprises an inside surface, at least a portions of the inside surface is reflective.

11. The curing light of claim 10 wherein said reflective surface comprises a thin coating of metal.

12. The curing light of claim 10 wherein said reflective surface is concave.

13. The curing light of any of claims 7-12 wherein said wherein said tip comprises a circular ring section having an inside side-wall adapted to envelope at least a portion of the lens cap in a friction fit.
14. The curing light of any of claims 7-13 wherein said interior of the tip further comprises at least one protrusion for repeatably positioning the tip over the lens cap.
15. The curing light of claim 14 wherein said tip, the lens cap, the molded reflector and the portion of the housing mounted to the molded reflector comprises the same material or different materials having similar coefficients of thermal expansion.
16. The curing light of any of the preceding claims wherein said lens cap comprises at least one raised structure on the outside wall.
17. The curing light of claim 16 wherein said raised structure is selected from the group consisting of a protrusion, a bump, a ridge, a rim or combinations thereof.
18. The curing light of any of claims 4-6, and 13-17, wherein said circular ring comprises at least one structure for mating with a corresponding raised structure on the outside wall of the lens cap.
19. The curing light of claim 18 wherein said structure is selected from the group consisting of a depression, a groove, a channel, an enlarged diameter portion, or combinations thereof.

19. The curing light of claim 18 or 19 wherein said structure is on the inside side-wall of the circular ring section.

20. The curing light of any of the preceding claims wherein said interior of the tip further comprises at least one protrusion for repeatably positioning the tip over the lens cap.

21. The curing light of any of the preceding claims wherein the aperture of the tip controls the footprint of a beam of light emitted by the curing light.

22. The curing light of any of the preceding claims wherein the lens cap and the tip are attached as a unit and the entire unit is detachable.

23. The curing light of any of the preceding claims further comprising a heat sink comprising a phase change material.

24. A tip for controlling the footprint of a beam of light from a curing light comprises:

    a conical-shaped body having an interior, an exterior, an apex, and an aperture at the apex;

    at least one circular ring section having an inside side-wall adapted to envelope at least a portion of a lens cap in a friction fit.

25. The tip of claim 24 wherein said circular ring comprises at least one structure for mating with a corresponding raised structure on the outside wall of the lens cap.

26. The tip of claim 25 wherein said structure is selected from the group consisting of a depression, a groove, a

channel, an enlarged diameter portion, or combinations thereof.

27. The tip of claim 24, 25 or 26 wherein at least a portion of said interior surface of the tip comprises a reflective surface or an opaque surface.

28. The tip of any of claims 24-27 wherein said tip is selected from a series of tips having varying diameter apertures for effecting spot curing of composites.

29. The tip of any of claims 24-28 wherein said interior of the tip further comprises at least one protrusion for repeatably positioning the tip over the lens cap.

30. The tip of any of claims 24-29 wherein said aperture has a smaller diameter than the diameter of the lens cap.

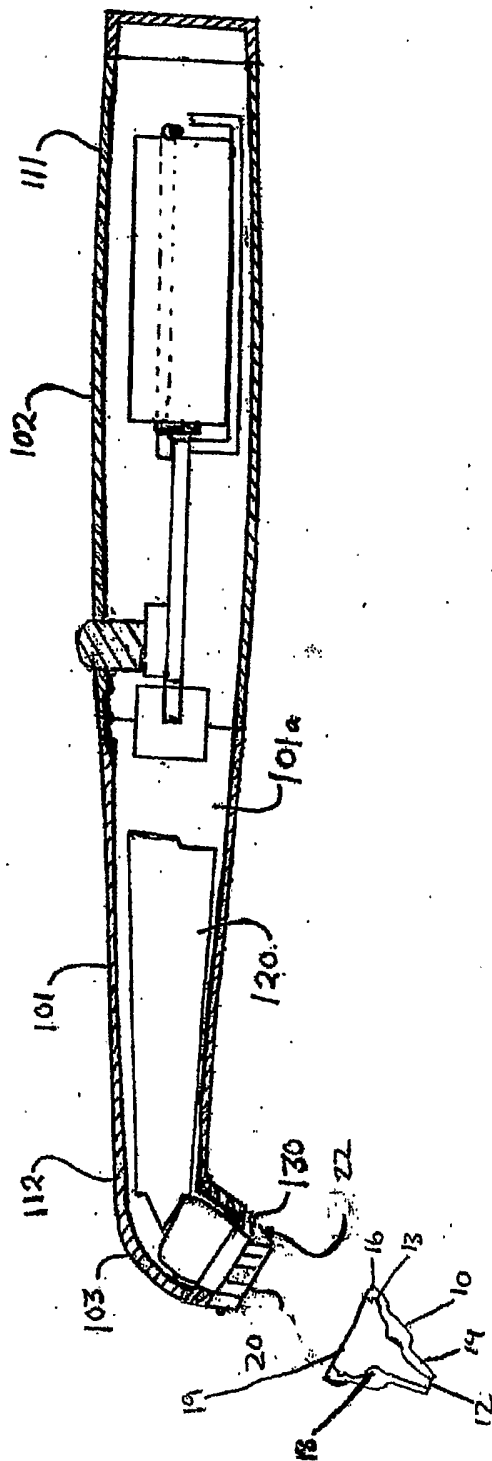
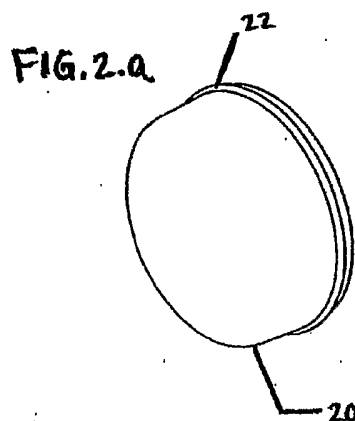
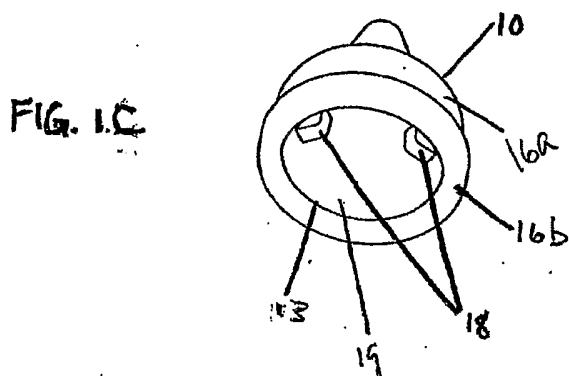
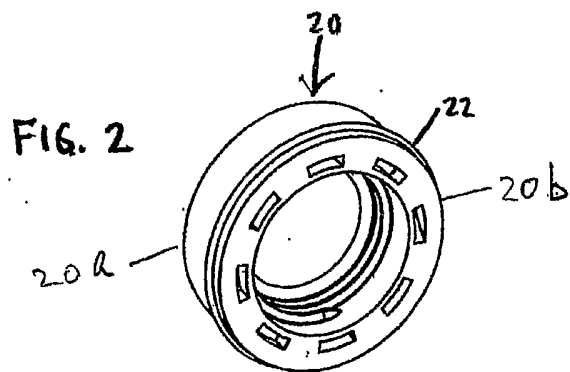
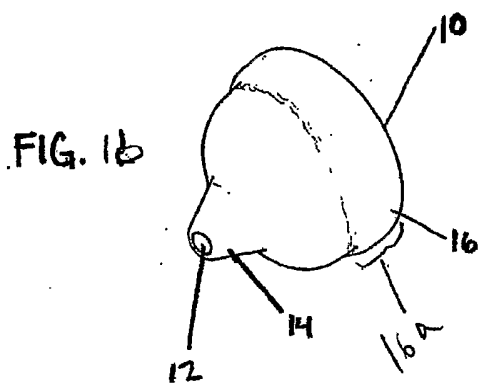
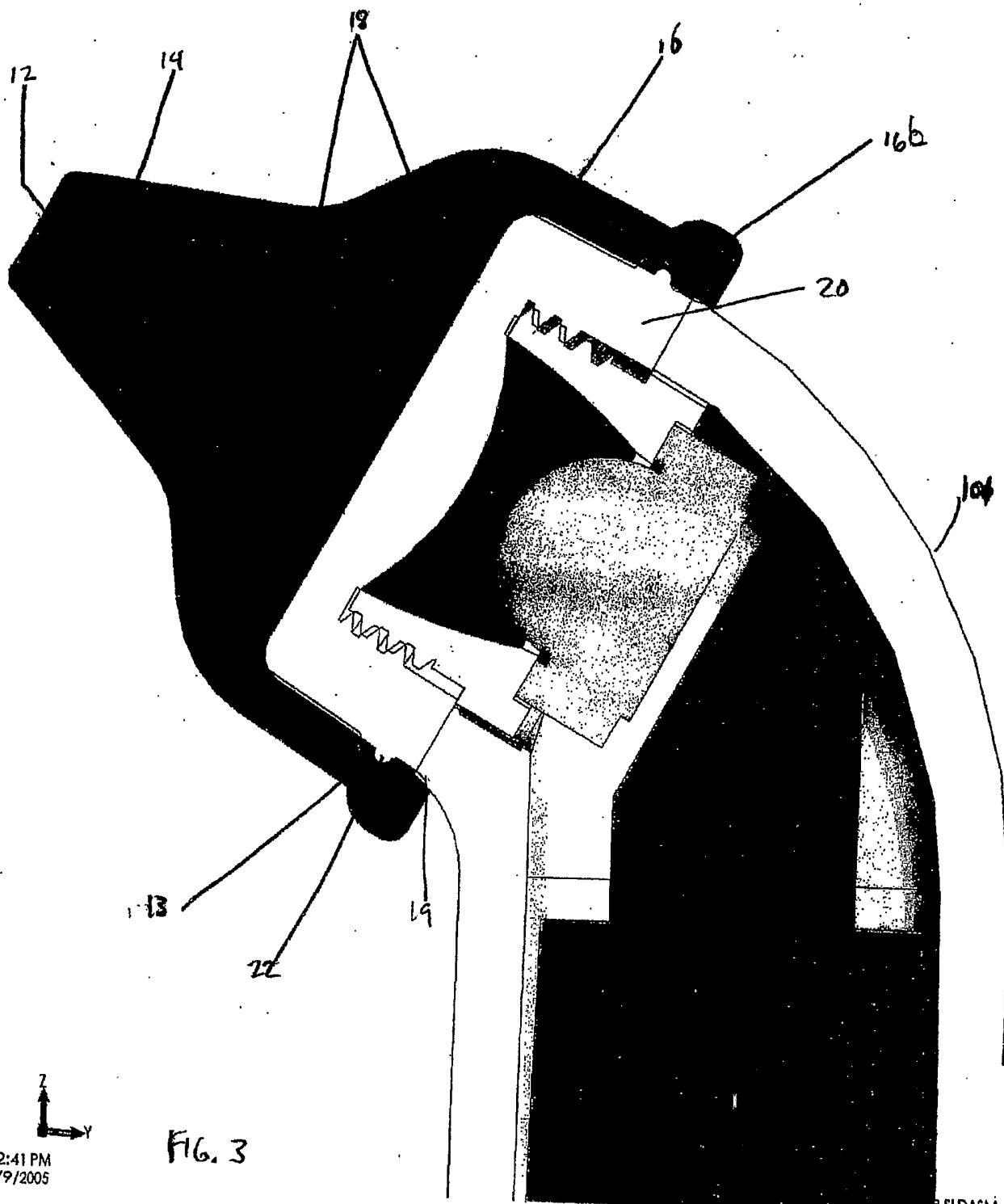


FIG. 1

FIG. 1a





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FIG. 3

B.SLDASM

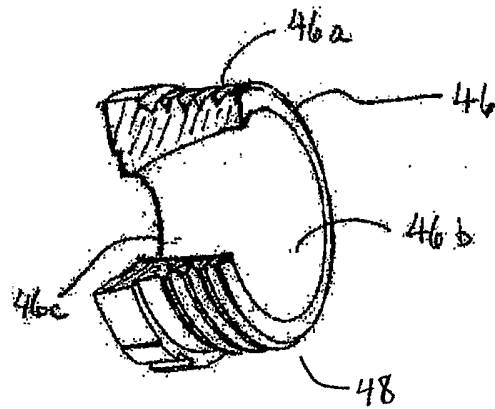


Fig. 4

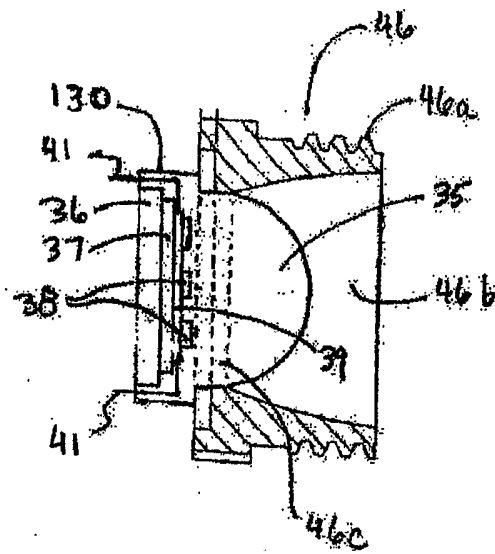
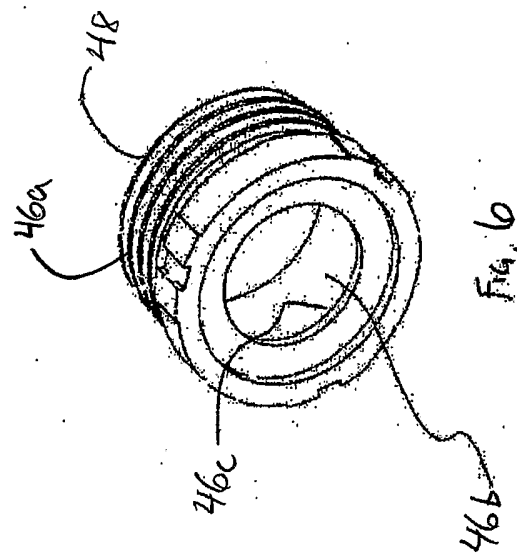


FIG. 5



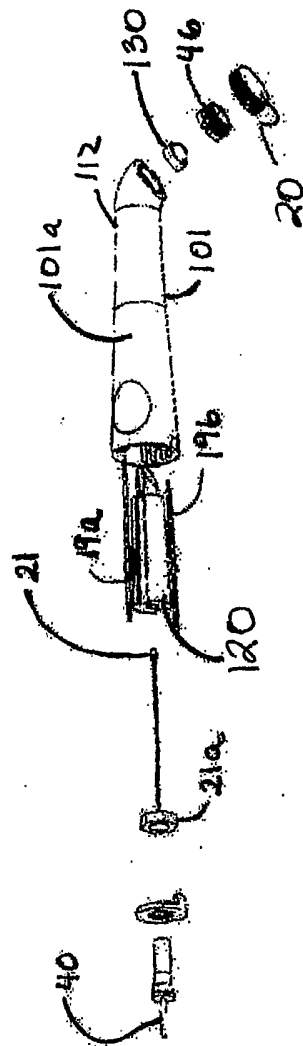
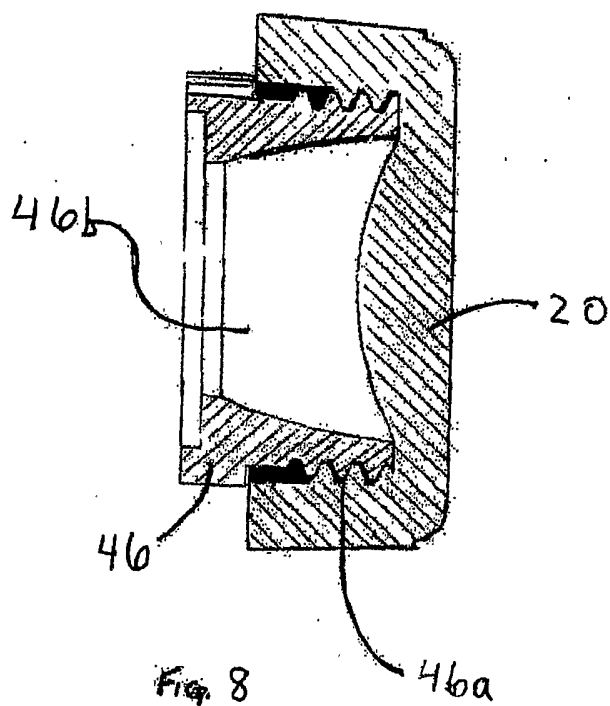


Fig 7



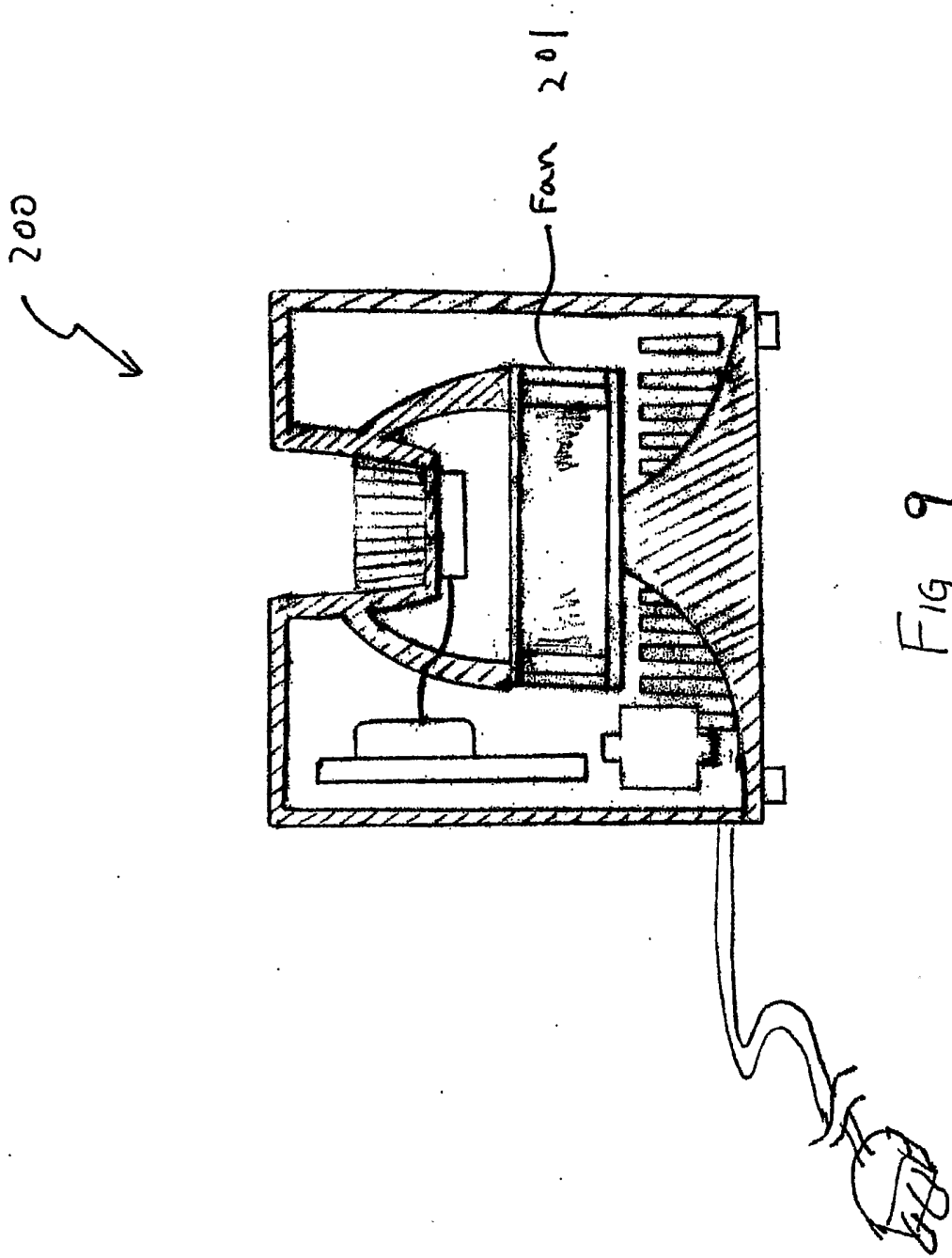


Fig 9