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(54) Title: LINEAR LED LIGHTING ARRANGEMENT INCLUDING LIGHT EMITTING PHOSPHOR

(57) Abstract: A solid-state linear lamp comprises a co-extruded component, the co-extruded component comprising an elongate lens and a layer of photoluminescent material. The elongate lens is for shaping light emitted from the lamp and comprises an elongate interior cavity. The layer of a photoluminescent material is located on an interior wall of the elongate interior cavity. The lamp further comprises an array of solid-state light emitters configured to emit light into the elongate interior cavity.

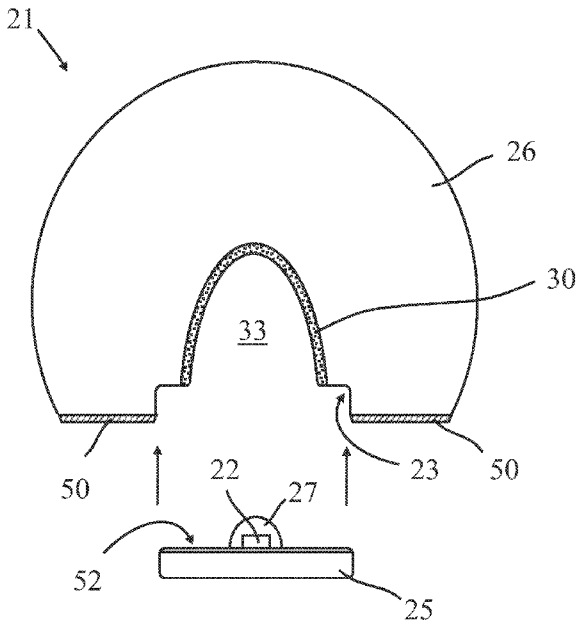


FIG. 8

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LINEAR LED LIGHTING ARRANGEMENT INCLUDING LIGHT EMITTING PHOSPHOR

BACKGROUND OF THE INVENTION

Field of the invention

[0001] This invention relates to solid-state linear lighting applications which comprise a light emitting phosphor, photoluminescent material, to generate light of a desired color that is in a different part of the wavelength spectrum from the solid-state light emitter(s). In particular, although not exclusively, the invention concerns LED-based lighting arrangements which generate light in the visible part of the spectrum and in particular, although not exclusively white light. Moreover the invention provides an optical component for such a lighting arrangement and methods of fabricating a lighting arrangement and an optical component.

State of the art

[0002] White light emitting diodes (LEDs) are known in the art and are a relatively recent innovation. It was not until LEDs emitting in the blue/ultraviolet of the electromagnetic spectrum were developed that it became practical to develop white light sources based on LEDs. As is known, white light generating LEDs ("white LEDs") include a phosphor that is a photoluminescent material, which absorbs a portion of the radiation emitted by the LED and re-emits radiation of a different color (wavelength). For example the LED emits blue light in the visible part of the spectrum and the phosphor re-emits yellow light. Alternatively the phosphor can emit a combination of green and red light, green and yellow or yellow and red light. The portion of the visible blue light emitted by the LED which is not absorbed by the phosphor mixes with the yellow light emitted to provide light which appears to the eye as being white. It is predicted that white LEDs could potentially replace incandescent light sources due to their long operating lifetimes, typically many 100,000 of hours, and their high efficiency. Already high brightness LEDs are used in vehicle brake lights and indicators as well as traffic lights and flash lights.

[0003] To increase the intensity of light emitted from an LED it is known to include a lens made of a plastics material or glass to focus the light emission and to thereby increase intensity.

Referring to FIG. **1** a high brightness white LED **2** is shown. The LED **2** comprises an LED chip **4** which is mounted within a plastic or metal reflection cup **6** and the LED chip is then encapsulated within an encapsulating material, typically an epoxy resin **8**. The encapsulation material includes the phosphor material for providing color conversion. Typically the inner surface of the cup **6** is silvered to reflect stray light towards a lens **10** which is mounted on the surface of the encapsulating epoxy resin **8**.

[0004] It is appreciated that such an arrangement has limitations and the present invention arose in an endeavor to mitigate, at least in part, these limitations. For example for high intensity LEDs having a high intensity output larger than 1W, the high temperature at the output of the LED combined with its close proximity the phosphor material can give rise to a light characteristic which is temperature dependent and in some cases thermal degradation of the phosphor material can occur. Moreover the uniformity of color of light emitted by such LEDs can be difficult to maintain with the phosphor distributed within the epoxy resin since light passing through different path lengths will encounter and be absorbed by differing amounts of phosphor. Furthermore the fabrication of such LEDs is time consuming due to the encapsulation and subsequent placement of the lens.

SUMMARY OF THE INVENTION

[0005] In accordance with an embodiment of the invention, a linear lighting arrangement is provided which includes a linear transparent optical lens that serves to mix and distribute of lights emitted from LED(s) and phosphor. The phosphor layer in in a curved shape within an interior cavity of the linear optical lens. The LED(s) on a linear PCB is located remotely from the phosphor layer. In some embodiments, the lens is preferably manufactured with a rough surface for efficient extraction of light. The linear lighting arrangement may be referred to herein by example as a "linear lamp".

[0006] In some embodiments, a linear lamp comprises an array of LED chips mounted on a support, e.g. a printed circuit board that fits within inside indentations/slots on the lens, where an inner cavity/chamber is formed in the interior of the lens. The walls of the chamber include a layer of phosphor. The surface of the circuit board may be formed or covered with a reflective material to reflect light from the LED chip away from the circuit board and towards the phosphor. The light emitted by the LED chip is converted by the phosphor into

photoluminescent light, and the color quality of the final light emission output of the lamp is based (at least in part) upon the combination of the wavelength of the photoluminescent light emitted by the phosphor with the wavelength of any remaining light from the LED chip that pass through the phosphor. The color of light emitted from the lighting arrangement can be controlled by appropriate selection of the phosphor composition as well as the thickness and/or loading of phosphor within the phosphor layer which will determine the proportion of output light originating from the phosphor. To ensure a uniform output color the phosphor layer is preferably of uniform thickness and has a typical thickness in a range 20 to 500 μm.

[0007] The arrangement and shape of the lens may be configured to affect the actual pattern of the emitted light from the lamp. The lens in some embodiments has a semi-circular profile that permits focusing and distribution of the emitted light output from lamp in desired directions, e.g. for a range of coverage substantially corresponding to the radial angles of the lens from a center axis of the lamp. The lens can be made of any suitable material, e.g. a plastics material such as polycarbonates, acrylic, silicone or glass such as silica based glass or any material.

[0008] The arrangement and shape of the phosphor may be configured to affect the distribution of the emitted light from the lamp. Some embodiments provide for a conical profile for the phosphor that enhances the amount of light that is distributed from the sides of the lamp. An alternate design is directed to a lamp in which the phosphor has a profile that is more semi-circular in nature, rather than conical, which provides relatively greater distributions of light towards the center of the distribution area. The exact shape of the phosphor and/or the lens can be selected and combined to provide any suitable output pattern and distribution as desired. Another benefit is that the lens also serves to provide a chamber in which light is mixed within highly transparent solid with minimal loss. An example of this occurs when a lamp includes both red and blue LEDs in the chamber, and the chamber allows the light from these LEDs (e.g., the red light) to be uniformly distributed inside the lens.

[0009] In some embodiments, the chamber in the lens provides a cavity within the lamp, which has a volume that is large enough for insertion of the array of LEDs within the cavity. This permits the LED to be located, wholly or partially, within the interior of the lens and/or phosphor. The approach of implementing a cavity/chamber within the lens makes for very simple assembly and improved efficiency due to avoiding losses from an exterior mixing chamber.

[0010] Some embodiments implement the optical material of the lens with a clear or transparent property provides the benefit of creating a linear optic/linear lens. Alternatively, the lens can be configured to operate as a light pipe that provides collimation at the light source so the light travels inside the pipe for an extended distance without exiting the sides. The optical component can be configured with appropriately curved sides to provide collimation functionality. In an alternative embodiment the lens is not configured to extend along the entire length of the reflector. Instead, the lens generally forms a curved or dome-like shape that only partially fills the interior volume formed by the reflector. A co-extrusion process can be used to manufacture the structure of the phosphor layer, lens, and reflector. The concept of co-extruding the phosphor and lens as a single component is considered inventive in its own right.

[0011] In some embodiments, further operating efficiencies for the lamp are provided by including an optical medium within the chamber, e.g., a solid optical medium. The optical medium within the chamber comprises a material possessing an index of refraction that more closely matches the index of refraction for the phosphor, the LEDs, and/or any type of encapsulating material that may exist on top of the LEDs. The optical medium may be selected of a material, e.g. silicone, to generally fall within or match the index of refraction for materials typically used for the phosphor, the LEDs, and/or any encapsulating material that be used to surround the LEDs. In some embodiments, the lamp structure comprises a multi-layered "sandwich" structure in which a specific shape of the phosphor layer is embedded between a front lens and solid fill inside the chamber. This structure can be manufactured by, for example, co-extrusion of all three layers.

[0012] Some embodiments of a linear lamp include an elongate lens having an integrally formed chamber that runs the length of the lens, where the chamber is shaped to provide a desired light distribution pattern. A linear array of LEDs is located on a circuit board, and a reflective material is provided which include apertures for the LEDs. The circuit board is mounted onto a heat sink. The assembly comprising the heat sink, circuit board, and reflective material is attached to the lens using a pair of endplates to be set at indented end portions of the lens. In embodiments where the linear lamp is intended to be direct replacements for standard fluorescent lamps, end caps are provided which include appropriate connectors such as a G5 or G13 bipin connectors to fit into standard fluorescent lamp fixtures. External reflectors may also be used in conjunction with the lamp to direct output light into desired directions.

[0013] The angle of coverage for the lens is configurable to adjust the illumination pattern of the lamp. Increasing the angle of coverage to 360 degrees would result in a lamp having a full 360 degrees of illumination. The bottom portion of the lens is configured such that the lens provides a semi-circular profile having and illumination angle, e.g., at a radial angle at greater than or less than 180 degrees relative to a central axis of the lamp. The angle of the bottom portion of the lens can also be adjusted to adjust the illumination pattern of the lamp, which is tilted in either an outwards direction or an inwards direction.

[0014] A light diffusing layer can be provided in some embodiments to improve the visual appearance of the lighting device in an OFF state to an observer. The light diffusing layer includes particles of a light diffractive material that can substantially reduce the passage of external excitation light that would otherwise cause the wavelength conversion component to re-emit light of a wavelength having a yellowish/orange color. The particles of a light diffractive material in the light diffusing layer are selected, for example, to have a size range that increases its probability of scattering blue light, which means that less of the external blue light passes through the light diffusing layer to excite the wavelength conversion layer. The light diffractive particle size can be selected such that the particles will scatter blue light relatively more (e.g. at least twice as much) as they will scatter light generated by the phosphor material. Preferably, to enhance the white appearance of the lighting device in an OFF state, the light diffractive material within the light diffusing layer is a "nano-particle" having an average particle size of less than about 150nm. For light sources that emit lights having other colors, the nano-particle may correspond to other average sizes. For example, the light diffractive material within the light diffusing layer for an UV light source may have an average particle size of less than about 100nm. Embodiments of the present invention can be used to reduce the amount of phosphor materials that is required to manufacture an LED lighting product, thereby reducing the cost of manufacturing such products given the relatively costly nature of the phosphor materials. In particular, the addition of a light diffusing layer composed of particles of a light diffractive material can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. Different approaches can be used to introduce light scattering materials into an LED lamp, which can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. In addition, the light diffusing layer can be used in combination with additional scattering (or reflective/diffractive) particles in the

wavelength conversion component to further reduce the amount of phosphor material that is required to generate a selected color of emitted light. One possible approach is in which the light scattering material is included within a separate layer. Another possible approach is in which the light scattering material is included within the layer containing the phosphor. Yet another possible approach is in which the light scattering material is introduced into the lens. Any combination of the above may also be implemented. For example, the light scattering material can be introduced into both the layer of phosphor and the lens. In addition, the light scattering material can be included within both a separate layer and the layer of phosphor. Moreover, the light scattering material can be included within each of the separate layer, the layer of phosphor, and the lens.

[0015] Alternative approaches can be taken to improve the off-state white appearance of the lamp. For example, texturing can be incorporated into the exterior surface of the lamp to improve the off-state white appearance of the lamp, e.g. in the exterior surface of the lens. Yet another possible approach is to implement a thin white layer directly after the yellow phosphor layer and before the clear linear optic. This three layer structure would be white appearance in the off-state but the primary optic would still be clear (not diffused/cloudy). This approach has the benefit of preserving the light distribution pattern of the linear lens optics while still providing a white appearance.

[0016] The approach of using an interior cavity as a "mixing chamber" can be applied to non-linear lamps as well. In some embodiments, an LED lighting arrangement is provided where the lens comprises a solid semi-spherical shape, and the LED chip is mounted within the chamber of the lighting arrangement such that it is wholly contained within the interior of the profile of the phosphor. However, the lens can be fabricated to provide any suitable shape as desired. For example, an alternate LED lighting arrangement in accordance with an embodiment of the invention is where the lens comprises a solid ovoid shape.

[0017] With regard to linear lamp embodiments, any suitable manufacturing process may be employed to manufacture the lamp assembly. For example, a printing process can be employed where ink is printed using screen printing directly onto the lens surface. Other printing techniques can be used to print and/or coat the phosphor, such using roller coaters to coat the phosphor ink onto the lens. Spray coating is another technique that may be used to coat the phosphor onto the lens. Lamination can also be performed to manufacture the linear lamp. In

this approach, a separate sheet of phosphor material is manufactured, e.g. with or without a clear carrier layer. The sheet of phosphor is then laminated onto the light lens/pipe structure. A co-extrusion process can be performed to manufacture the linear lamp arrangement. Two extruders can be used to feed into a single tool to create both the layer of phosphor and the materials of the lens, where the two layers are simultaneously created and manufactured together in this approach. If the chamber in the lens includes a solid optical medium, then a co-extrusion approach can be used to manufacture the three layers with three extruders.

[0018] In some embodiments, a multi-layered optic component is provided which integrally includes a phosphor portion, a lens, and a reflector portion. A triple-extrusion process can be utilized to manufacture the multi-layered optic component, where three extruders are used to feed into a single tool to create the layer of phosphor, the materials of the lens, and the material of the reflector. Three extruders are used to feed into a single tool to create the three separate layers of materials, including phosphor, the materials of the lens, and the materials of the reflector. The three layers are simultaneously created and manufactured together in this approach. This approach can be used with a wide variety of source materials, e.g. PC-Polycarbonate, PMMA-Poly(methyl methacrylate), and PET-Polyethylene Terephthalate, including most or all thermoform plastics. This triple-extrusion process can generally use pellets identical or similar to pellets used for injection molding materials. If the chamber in the lens includes a solid optical medium, then a quadruple-extrusion approach can be used to manufacture the multiple layers with four extruders.

[0019] In some embodiments, the circuit board having the array of LEDs is mounted to, and in thermal communication with, a support body. The reflector is formed having a lower flange portion that extends away from the central portion of the multi-layered optic component. The flange portion is configured to slot within a channel in support body

[0020] In some embodiments, a co-extrusion process is utilized that manufactures the multi-layered optic component having the array of LEDs, where the LEDs **22** are attached to a structure that is fed into the co-extrusion equipment, such that the multi-layered optic component is affixed to the circuit board having the LEDs as it is being formed.

[0021] The inner chamber of the lamp may be filled with an optical medium. The optical medium within the chamber comprises a material, e.g., a solid material, possessing an index of refraction that more closely matches the index of refraction for the phosphor, the LEDs, and/or

any type of encapsulating material that may exist on top of the LEDs. The optical medium may be selected of any suitable material, e.g. silicone, to generally fall within or match the index of refraction for materials typically used for the phosphor, the LEDs, and/or any encapsulating material that be used to surround the LEDs. If the chamber in the lens includes a solid optical medium, then a co-extrusion approach can be used to manufacture the multi-layered optic component to also include the optical medium, e.g., by adding an extruder that for the material of the optical medium.

[0022] A light diffusing/scattering material can be used in conjunction with the multi-layered optic component. The light diffusing/scattering material is useful to reduce the quantity of phosphor material that is required to generate a selected color of emitted light. The light diffusing/scattering material is also useful to improve the off-state white appearance of the lamp. The light diffusing/scattering material may be included into any of the layers of the multi-layered optic. For example, the light diffusing/scattering material can be incorporated into the layer containing the phosphor, added to the lens, included as an entirely separate layer, or any combination of the above.

[0023] In any of the disclosed embodiments, the combination of the solid optical medium and the phosphor can be replaced by a layer of material that entirely fills the volume surrounding the LEDs, but which also includes the phosphor integrally within that layer of material. This provides a hybrid remote-phosphor/non-remote-phosphor approach whereby the phosphor is located in the layer of material that fills the interior cavity, but some of the phosphor is located in close proximity to the LEDs (in the inner portion of the material adjacent to the LEDs), but much of the phosphor is actually quite distant to the LEDs (in the outer portion of the material away from the LEDs). This approach therefore provides much of the advantages of remote-phosphor designs, while also maximizing light conversion efficiencies (due to elimination of mismatches in indices of refraction from eliminating air interfaces). Manufacturing may also be cheaper and easier, since the extrusion processes and apparatuses only need to extrude the single layer of materials, rather than an extruder for the phosphor material and a separate extruder for the optical medium material.

[0024] Some embodiments comprise a reflector having high side walls. The side walls are useful to focus the light emitted form lamp into a desired direction.

[0025] According to some embodiments, one or more linear lighting arrangements are placed

inside of an envelope to form a replacement for a standard incandescent light bulb. The lamp may include standard electrical connectors (e.g., standard Edison-type connectors) that allow lamp to be used in conventional lighting devices. The linear lighting arrangements are vertically oriented, extending axially within the lamp. Internally, the LEDs within the linear lighting arrangements are oriented radially from the central axis of lamp. This configuration provides a good overall emission pattern from lamp over a wide range of emission angles, with the exact dimensions (e.g., length, width) of the linear lighting arrangements selected to provide a desired emission profile. The envelope may be configured in any suitable shape. In some embodiments, envelope comprises a standard light-bulb shape. This permits the lamp to be used in any application/location that could otherwise be implemented with a standard incandescent light bulb. The envelope may include or be used in conjunction with a diffuser. In some embodiments, scattering particles are provided at the envelope, either as an additional layer of material or directly incorporated within the material of envelope.

[0026] Inline testing may be employed using any of the above approaches to control and minimize variations in the final manufactured product. With a co-extrusion system, one possible approach to perform in-line testing is to mount a colorimeter or spectrometer that actively measures the product color while it was being extruded. This measurement tool would generally be mounted inline after the cooling bath and dryer but prior to cutting. The color measurement provides real-time feedback to the extrusion system which adjusts layer thickness by varying the relative pressures of the two extrusion screws. The phosphor layer is manufactured to be either thicker or thinner to tune the color of the product in real-time while the extrusion is taking place. This allows one to have single bin accuracy while being able to perform quality checks in real-time during the extrusion process. Similar inline testing could be used with printing and coating methods.

[0027] In some embodiments, the length L_1 for the exterior surface of the lens exceeds the length L_2 of the surface of the phosphor portion. The length L_2 in some approaches is at least two times L_1.

[0028] An optical component may comprise a cylindrical body of axial length l and radius r having a hemispherical end and a planar end which is mountable to an LED package, where the phosphor is provided on the cylindrical and hemispherical surfaces of the component. In some embodiments, the aspect ratio is 3:1 (although other ratios may be employed in certain

embodiments).

[0029] According to some embodiments of the invention, SQE loss is significantly eliminated or reduced by implementing some or all of the following factors into a lamp design: (i) remote phosphor; (ii) a coupling optic; and (iii) phosphor wavelength conversion layer with an aspect ratio greater than 1:1.

[0030] It will be understood that features of the embodiments described herein may be combined without departing from the scope of the invention. Moreover, multiple claim dependencies are contemplated. For instance, the subject matter disclosed in foregoing paragraphs [0005] to [0029] may be combined in any combination

[0031] Further details of aspects, objects, and advantages of the invention are described below in the detailed description, drawings, and claims. Both the foregoing general description and the following detailed description are exemplary and explanatory, and are not intended to be limiting as to the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] FIG. **1** is a schematic representation of a known white LED as already described;

[0033] FIGS. **2** to **7** are schematic representations of LED lighting arrangements;

[0034] FIG. **8** is an end view of an LED linear lamp lighting arrangement in accordance with an embodiment of the invention;

[0035] FIGS. **9-12** are schematic representations of an LED linear lamp lighting arrangement in accordance with an embodiment of the invention;

[0036] FIG. **13** is an end view of an LED linear lamp lighting arrangement in accordance with an alternate embodiment of the invention;

[0037] FIGS. **14A** and **14B** are an end views of additional embodiments of LED linear lamp lighting arrangements;

[0038] FIGS. **15-17** are schematic representations of LED linear lamp lighting arrangement with scattering particles;

[0039] FIG. **18** is a schematic sectional representation of a LED lighting arrangement with an interior chamber;

[0040] FIG. **19** is a schematic sectional representation of a LED lighting arrangement with an interior chamber and an ovoid lens shape;

[0041] FIGS. **20-22** are schematic representations of alternate LED linear lamp lighting arrangements with scattering particles;

[0042] FIG. **23** is a schematic end view of a LED linear lamp component;

[0043] FIG. **24** is a diagram of emission patterns for an example lamp utilizing the component of FIG. **23**;

[0044] FIG. **25** is a schematic end view of a LED linear lamp component;

[0045] FIG. **26** is a diagram of emission patterns for an example lamp utilizing the component of FIG. **25**;

[0046] FIG. **27A** is a schematic representation of a LED linear lamp lighting arrangement in which the lens provides collimation functionality;

[0047] FIG. **27B** is a schematic representation of an alternative LED linear lamp lighting arrangement;

[0048] FIG. **28** is an end view LED linear lamp component in which a specific aspect ratio is provided;

[0049] FIG. **29** illustrates the end view of a lamp having a multi-layered optic component according to some embodiments of the invention;

[0050] FIG. **30** illustrates the end view of a lamp having a multi-layered optic component, where an optical medium is placed within the chamber;

[0051] FIG. **31** illustrates the end view of a lamp having a multi-layered optic component, which further includes scattering particles;

[0052] FIG. **32** illustrates the end view of a lamp having a multi-layered optic component, where an optical medium placed within the chamber comprises photoluminescent material;

[0053] FIG. **33** illustrates the end view of a lamp having a multi-layered optic component, where the reflector comprises high walls; and

[0054] FIGS. **34** and **35** are perspective views LED lamps having vertically oriented linear light arrangements.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0055] In order that the present invention is better understood, embodiments of the invention will now be described by way of example only with reference to the accompanying drawings.

[0056] Referring to FIG. **2** there is shown a LED lighting arrangement **20** for generating light

of a selected color for example white light. The lighting arrangement **20** comprises a LED chip **22**, preferably a Gallium Nitride chip, which is operable to produce light, radiation, preferably of wavelength in a range 300 to 500nm. The LED chip **22** is mounted inside a stainless steel enclosure or reflection cup **24** which has metallic silver deposited on its inner surface to reflect light towards the output of the lighting arrangement. A convex lens **26** is provided to focus light output from the arrangement. In the illustrated example, the lens **26** is substantially hemispherical in form. The lens **26** can be made of a plastics material such as polycarbonates, acrylic, silicone or glass such as silica based glass or any material substantially transparent to the wavelengths of light generated by the LED chip **22**.

[0057] In FIG. **2** the lens **26** has a planar, substantially flat, surface **28** onto which there is provided a layer of phosphor **30** before the lens is mounted to the enclosure **22**. The phosphor **30** can comprise any photoluminescent material such as a nitride and/or sulfate phosphor materials, oxy-nitrides and oxy-sulfate phosphors, garnet materials (YAG) or a quantum dot material. The phosphor which is typically in the form of a powder is mixed with an adhesive material such as epoxy or a silicone resin, or a transparent polymer material and the mixture is then applied to the surface of the lens to provide the phosphor layer **30**. The mixture can be applied by painting, dropping or spraying or other deposition techniques which will be readily apparent to those skilled in the art. Moreover the phosphor mixture preferably further includes a light diffusing material such as titanium oxide, silica or alumina to ensure a more uniform light output.

[0058] The color of light emitted from the lighting arrangement can be controlled by appropriate selection of the phosphor composition as well as the thickness of the phosphor layer and/or weight loading of phosphor which will determine the proportion of output light originating from the phosphor. To ensure a uniform output color the phosphor layer is preferably of uniform thickness and has a typical thickness in a range 20 to 500 μm.

[0059] An advantage of such lighting arrangements is that no phosphor need be incorporated within the encapsulation materials in the LED package. Moreover the color of the light output by the arrangement can be readily changed by providing a different lens having an appropriate phosphor layer. This enables large scale production of a common laser package. Moreover such a lens provides direct color conversion in an LED lighting arrangement.

[0060] Referring to FIG. **3** there is shown a further LED lighting arrangement **20** in which the phosphor **30** is provided as a layer on the outer convex surface **32** of the lens **26**. In this

embodiment the lens **26** is dome shaped in form.

[0061] FIG. **4** shows an LED lighting arrangement **20** in which the lens **26** comprises a substantially hemispherical shell and the phosphor **30** is provided on the inner surface **34** of the lens **26**. An advantage of providing the phosphor on the inner surface is that the lens **26** then provides environmental protection for the LED and phosphor. Alternatively the phosphor can be applied as a layer of the outer surface of the lens 26 (not shown).

[0062] FIG. **7** shows an LED lighting arrangement **20** in which the optical component comprise a solid substantially spherical lens **26** and the phosphor is provided on at least a part of the spherical surface **44**. In a preferred arrangement, as illustrated, the phosphor is applied to only a portion of the surface, which surface is then mounted within the volume defined by the enclosure. By mounting the lens **26** in this way this provides environmental protection of the phosphor **30**.

[0063] FIG. **5** illustrates an LED lighting arrangement **20** in which the lens **26**, optical component, comprises a substantially spherical shell and the phosphor **30** is deposited as a layer on at least a part of the inner **36** or outer spherical 38 surfaces and the LED chip 22 is mounted within the spherical shell. To ensure uniform emission of radiation a plurality of LED chips are advantageously incorporated in which the chip are oriented such that they each emit light in differing directions. Such a form is preferred as a light source for replacing existing incandescent light sources (light bulbs).

[0064] Referring to FIG. **6** there is shown a further LED lighting arrangement **20** in which the optical component **26** comprises a hollow cylindrical form and the phosphor is applied to the inner **40** or outer **42** curved surfaces. In such an arrangement the laser chip preferably comprises a linear array of laser chips that are arranged along the axis of the cylinder. Alternatively the lens **26** can comprise a solid cylinder (not shown).

[0065] The embodiment of FIG. **6** generally depicts an example of a linear lighting arrangement/linear lamp **21**, which is a lighting apparatus typically having a long tubular profile. These lamps are common in many office or workspace environments, and many commercial and institutional buildings will routinely incorporate lighting fixtures and ceiling recesses/troughs in ceilings to fit standard size linear lamps (such as standard tubular T5, T8, and T12 lamps).

[0066] Linear lamps are normally implemented with fluorescent tube technology, encompassing gas discharge lamps that use electricity to excite mercury vapors. However, there

are many disadvantages with conventional fluorescent-based lamps. For example, the mercury within the fluorescent lamp is considered poisonous, and breakage of the fluorescent lamp, particularly in ducts or air passages, may require expensive cleanup efforts to remove the mercury (as recommended by the Environmental Protection Agency). Moreover, fluorescent lamps can be quite costly to manufacture, due in part to the requirement of using a ballast to regulate the current in such lamps. In addition, fluorescent lamps have fairly high defects rates and relatively low operating lives.

[0067] In contrast, LED-based linear lamps overcome these problems associated with fluorescent lamps. Unlike fluorescent lamps, LED-based linear lamps do not require any mercury. LED-based lamps are able to generate higher lumens per wattage as compared to fluorescent lamps, while having lower defects rates and higher operating life expectancies.

[0068] The approach shown in FIG. **6** provides an arrangement in which light generated by the linear lamp is emitted in all directions. The layer of phosphor **30** and the lens/optical component **26** entirely surround the linear array of LEDs **22**. The light produced by the lamp is therefore emitted over an entire 360 degrees of direction from the center axis of the lamp.

[0069] FIG. **8** illustrates a LED-based linear lamp **21** in accordance with an embodiment of the invention, in which light is emitted in selected directions from the linear lamp. The array of LED chips **22** are mounted on a support, e.g. a printed circuit board **25**, that fits within inside indentations **23** on lens **26**. An inner cavity/chamber **33** is formed in the interior of the lens 26. The walls of the chamber **33** include a layer of phosphor **30**. The LED chip **22** in some embodiments comprises a Gallium Nitride chip which is operable to produce light, radiation, preferably of wavelength in a range 300 to 500nm. The surface of the circuit board **25** may be formed or covered with a reflective material **52** to reflect light from the LED chip **22** away from the circuit board **25** and towards the phosphor **30**.

[0070] Each of the LEDs in the array of LED chips **22** may be covered or otherwise encapsulated with a light extracting cover **27**. The light extracting cover **27** reduces excessive mismatches between the index of refraction of the LEDs **22** and the index of refraction of the air within the interior chamber **33**. Any mismatch in the indices of refraction can cause a significant portion of the LED light to be lost from the total LED light output. By including light extracting cover **27**, this helps to reduce excessive mismatches in the indices of refraction, facilitating an increase the overall light conversion efficiency of lamp **21**.

[0071] The light emitted by the LED chip **22** is converted by the phosphor **30** into photoluminescent light. The color quality of the final light emission output of the lamp is based (at least in part) upon the combination of the wavelength of the photoluminescent light emitted by the phosphor **30** with the wavelength of any remaining light from the LED chip **22** that pass through the phosphor **30**. The color of light emitted from the lighting arrangement can be controlled by appropriate selection of the phosphor composition as well as the thickness and/or loading density of phosphor within the phosphor layer which will determine the proportion of output light originating from the phosphor. To ensure a uniform output color the phosphor layer is preferably of uniform thickness and has a typical thickness in a range 20 to 500 μm.

[0072] The actual pattern of the emitted light from the lamp **21** is affected by the arrangement of the lens **26**. The lens **26** in the current embodiment has a semi-circular profile that permits focusing and distribution of the emitted light output from lamp **21** in desired directions, e.g. for a range of coverage substantially corresponding to the radial angles of the lens **26** from a center axis of the lamp. The lens **26** can be made of any suitable material, e.g. a plastics material such as polycarbonates or glass such as silica based glass or any material.

[0073] The distribution of light from the lamp **21** is also affected by the shape of the phosphor **30** in chamber **33**. The lamp **21** shown in FIG. **8** has a conical profile for the phosphor **30** that enhances the amount of light that is distributed from the sides of the lamp **21**. FIG. **13** illustrates an alternate design in which the phosphor **30** has a profile that is more semi-circular in nature, rather than conical. This approach provides relatively greater distributions of light towards the center of the distribution area. The exact shape of the phosphor **30** and/or the lens **26** can be selected and combined to provide any suitable output pattern and distribution as desired.

[0074] The chamber **33** provides a cavity (also referred to herein as a "mixing chamber") within the lamp **21**, which has a volume that is large enough for insertion of the LED **22** within the cavity. This permits the LED **22** to be located, wholly or partially, within the interior of the lens **26** and/or phosphor **30**.

[0075] In the approach of FIG. **8**, the indentation/slot **23** is incorporated into the outer profile of the lens **26** to accommodate direct placement of the PCB **25** or Chip-On-Board (COB) array. In the approach of FIG. **14**, a slot formed within the lens **26** to permit the PCB **25** to slide and support into the slot. The PCB or COB surface has a reflective layer or coating **52** placed on it to reflect LED-emitted light towards the phosphor **30**. The bottom surface of the lens **26** may

also be covered with a reflective material **50**. The approach of implementing a cavity/chamber **33** within the lens **26** makes for very simple assembly and improved efficiency due to avoiding losses from an exterior mixing chamber.

[0076] A benefit provided by this arrangement is that the chamber provides for mixing of light within highly transparent solid with minimal loss. An example of this occurs when a lamp includes both red and blue LEDs in the chamber, and the chamber allows the light from these LEDs (e.g., the red light) to be uniformly distributed inside the lens. There are various reasons for the advantages provided by the internal mixing chamber. For example, one reason is because the arrangement of the internal mixing chamber provides for cross-wall emissions of light. Even though reflectors are still provided on the "floor" of the lamp, much of the light that moves through the mixing chamber will cross from one wall of the phosphor to another wall without needing to reflect from the reflectors, improving the efficiency of the lamp for its light production. Another benefit provided by the arrangement is that it removes the point source impact of having individual LEDSs in the lamp. Each LED is a point source of light (e.g., blue or red light), but because the LEDs are within the chamber that has its walls covered with phosphor, the light emitted by the phosphor will visibly obscure the point source effects of the LEDs. Yet another advantage is the directionality provided by the current arrangement. Since most fluorescent replacement lamps will be inserted into ceiling or wall fixtures, it is likely that the emitted light will be provided in a desired direction, e.g., away from the ceiling or wall. The present embodiment of using the lens and internal chamber configuration enhances the directionality of the emitted light in the desired directions. Another benefit provided by embodiments of the invention is that the amount of phosphor needed to manufacture the lamp can be minimized for a given size of the lamp. Even though the external dimensions of the lamp may be quite large due to the size of the lens, the smaller surface area of the internal chamber means that a much smaller amount of phosphor is actually required for the lamp. A further benefit of the small internal chamber is that it reduces the apparent size of the phosphor component when viewing the lamp in an off-state.

[0077] Leaving the optical material of the lens **26** with a clear or transparent property also provides the benefit of creating a linear optic/linear lens. Alternatively, the lens can be configured to operate as a light pipe that provides collimation at the light source so the light travels inside the pipe for an extended distance without exiting the sides. For example, FIG. **27A**

shows a lamp where the optical component **26** is configured with appropriately curved sides to provide collimation functionality. In this arrangement, the light emitted from the phosphor **30** that impact the walls of the lens **26** at certain angles will reflect away from those walls in a downwards direction, e.g., based at least in part upon the light pipe effects of the lens **26**. This result is achievable without the need to include reflective material **50** on the walls of the lens **26**, although inclusion of reflective material **50** will improve the efficiency at which light is emitted in the downwards direction.

[0078] FIG. **27B** shows an alternative embodiment of a lamp **21** where the lens **26** is not configured to extend along the entire length of the reflector **50**. Instead, the lens **26** generally forms a curved or dome-like shape that only partially fills the interior volume formed by the reflector **50**. Appropriate configuration of the lens **26** and reflector **50** permit this approach to form a direct lamp replacement having any desired light emission characteristics. In both the approaches of FIG. **27A** and **27B**, a co-extrusion process can be used to manufacture the structure of the phosphor layer, lens, and reflector.

[0079] In the embodiment of FIG. **8**, the light is generally unstructured without a collimator. However the current embodiment does create a linear lens optic with the clear material that is coupled to a smaller linear light source (the phosphor layer). The combined system allows one to accurately control the light distribution pattern with minimal losses because there is no air interface between the remote phosphor layer and optics. The cross section in the figures shows a light source and single optic coupled together into a single unit. It is possible to configure specific linear beam patterns by designing the shape of the linear lens relative to the light source. In effect, the lens **26** can be used to shape the emitted properties of the light that is generated by the lamp, e.g., by focusing the emitted light from the lamp.

[0080] In some embodiments, further operating efficiencies for the lamp are provided by including an optical medium within the chamber **33**. The optical medium within the chamber **33** comprises a material, e.g., a solid material, possessing an index of refraction that more closely matches the index of refraction for the phosphor **30**, the LEDs **22**, and/or any type of encapsulating material that may exist on top of the LEDs **22**. One reason or using the optical medium is to eliminate air interfaces that exist between the LEDs **22** and the phosphor **30**. The problem addressed by this embodiment is that there is a mismatch between the index of refraction of the material of the phosphor **30** and the index of refraction of the air within the

interior volume **33** of the lamp **21**. This mismatch in the indices of refraction for the interfaces between air and the lamp components may cause a significant portion of the light to be lost in the form of heat generation. As a result, lesser amounts of light and excessive amounts of heat are generated for a given quantity of input power. By filling the chamber **33** with an optical medium **56**, this approach permits light to be emitted to, within, and/or through the interior volume of the lamp without having to incur losses caused by excessive mismatches in the indices of refraction for an air interface. The optical medium **56** may be selected of a material, e.g. silicone, to generally fall within or match the index of refraction for materials typically used for the phosphor **30**, the LEDs **22**, and/or any encapsulating material that be used to surround the LEDs **22**. Further details regarding an exemplary approach to implement the optical medium are described in U.S. Provisional Application Ser. No. 61/657,702, filed on June 8, 2012, entitled "Solid-State Lamps With Improved Emission Efficiency And Photoluminescence Wavelength Conversion Components Therefor", which is hereby incorporated by reference in its entirety.

[0081] FIGS. **9**, **10**, **11**, and **12** provide illustrations of the components of a linear lamp **21** according to particular embodiments of the invention. FIG. **9** is an end view and FIG. **12** is an exploded end view of the linear lamp **21**. FIG. **10** is an exploded perspective view of the lamp **21**, which is further magnified in FIG. **11**. The linear lamp **21** includes an elongate lens **26** having an integrally formed chamber **33** that runs the length of the lens **26**. The chamber **33** is shaped to provide a desired light distribution pattern. In this current example of the linear lamp **21**, the cavity **33** is shown with a dome-shaped profile. A layer of phosphor **30** is placed within the chamber **33**.

[0082] A linear array of LEDs **22** is located on a circuit board **25**. Any suitable approach can be taken to implement the array of LEDs **22**. For example, the LED array may be implemented using a chip-on-board (COB) configuration. A reflective material **52** (e.g., reflective tape or paper) is provided which include apertures for the LEDs **22**. The circuit board **25** is mounted onto a heat sink **54**. The assembly comprising the heat sink **54**, circuit board **25**, and reflective material **52** is attached to the lens **26** using a pair of endplates **29** to be set at the indented end portion of the lens **26**. The endplate **29** includes a set of four screw holes (not shown in FIG. **9**). The top two screw holes are for insertion of screws to openings in the lens **26**. The bottom two screws are for insertion of screws to openings in the heat sink **54**.

[0083] In embodiments where the linear lamp **21** is intended to be direct replacements for

standard fluorescent lamps such as t5, T8 or T12 fluorescent tubes, end caps (not shown) are provided which include appropriate connectors such as a G5 or G13 bi-pin connectors to fit into standard fluorescent lamp fixtures. External reflectors (not shown) may also be used in conjunction with lamp **21** to direct output light from the lamp **21** into desired directions. The direction of orientation for lamp **21** would be adjusted as appropriate. For example, the lamp would normally be directed in a downwards direction (e.g. with the lens **26** facing downwards below a reflector) when installed into a ceiling fixture.

[0084] The bottom portion of the lens **26** is configurable to adjust the illumination pattern of the lamp **21**, e.g., by adjusting the radial angle of coverage for the lens **26** as measured from a central axis of the lamp. If the profile of the lens extends over a full 360 degrees from a central axis, this would result in a lamp having 360 degrees of illumination, e.g., as shown in the lamp of FIG. **6**. The angle of the bottom portion of the lens can also be adjusted to adjust the illumination pattern of the lamp. FIG. **14A** illustrates the end view of an embodiment of the invention in which the bottom portion of the lens **26** is configured such that the lens **26** provides a semi-circular profile having a radial angle at slightly greater than 180 degrees relative to a central axis of the lamp **21**, e.g., where the portions **50** are tilted in an outward direction to improve the spread of light emitted by the lamp. An alternate embodiment can be configured such that the bottom portion of the lens **26** is tilted in an inwards direction. FIG. **14B** illustrates the end view of an embodiment of the invention in which the bottom portion of the lens **26** is configured such that the lens **26** provides a semi-circular profile having a radial angle at slightly less than 180 degrees relative to a central axis of the lamp **21**, e.g., where the portions **50** are tilted in an inward direction to improve the concentration of light emitted by the lamp in a selected direction.

[0085] One problem associated with LED lighting device that is addressed by embodiments of the invention is the non-white color appearance of the device in an OFF state. During an ON state, the LED chip or die generates blue light and some portion of the blue light is thereafter absorbed by the phosphor(s) to re-emit yellow light (or a combination of green and red light, green and yellow light, green and orange or yellow and red light). The portion of the blue light generated by the LED that is not absorbed by the phosphor combined with the light emitted by the phosphor provides light which appears to the human eye as being nearly white in color. However, in an OFF state, the LED chip or die does not generate any blue light. Instead, light

that is produced by the remote phosphor lighting apparatus is based at least in part upon external light (e.g. sunlight or room lights) that excites the phosphor material in the wavelength conversion component, and which therefore generates a yellowish, yellow-orange or orange color in the photoluminescence light. Since the LED chip or die is not generating any blue light, this means that there will not be any residual blue light to combine with the yellow/orange light from the photoluminescence light of the wavelength conversion component (e.g. phosphor **30**) to generate white appearing light. As a result, the lighting device will appear to be yellowish, yellow-orange or orange in color. This may be undesirable to the potential purchaser or customer that is seeking a white-appearing light.

[0086] According to the embodiment of FIG. **15**, a light diffusing layer **31** provides the benefit of addressing this problem by improving the visual appearance of the device in an OFF state to an observer. In part, this is because the light diffusing layer **31** includes particles of a light diffractive material that can substantially reduce the passage of external excitation light that would otherwise cause the wavelength conversion component to re-emit light of a wavelength having a yellowish/orange color. The particles of a light diffractive material in the light diffusing layer **31** are selected, for example, to have a size range that increases its probability of scattering blue light, which means that less of the external blue light passes through the light diffusing layer to excite the wavelength conversion layer. Therefore, the remote phosphor lighting apparatus will have more of a white appearance in an OFF state since the wavelength conversion component is emitting less yellow/red light.

[0087] The light diffractive particle size can be selected such that the particles will scatter blue light relatively more (e.g. at least twice as much) as they will scatter light generated by the phosphor material. Such a light diffusing layer ensures that during an OFF state, a higher proportion of the external blue light received by the device will be scattered and directed by the light diffractive material away from the wavelength conversion layer, decreasing the probability of externally originated photons interacting with a phosphor material particle and minimizing the generation of the yellowish/orange photoluminescent light. However, during an ON state, phosphor generated light caused by excitation light from the LED light source can nevertheless pass through the diffusing layer with a lower probability of being scattered. Preferably, to enhance the white appearance of the lighting device in an OFF state, the light diffractive material within the light diffusing layer is a “nano-particle” having an average particle size of less than

about 150nm. For light sources that emit lights having other colors, the nano-particle may correspond to other average sizes. For example, the light diffractive material within the light diffusing layer for an UV light source may have an average particle size of less than about 100nm.

[0088] Therefore, by appropriate selection of the average particle size of the light scattering material, it is possible to configure the light diffusing layer such that it scatters excitation light (e.g. blue light) more readily than other colors, namely green and red as emitted by the photoluminescence materials. For example, TiO_2 particles with an average particle size of 100nm to 150nm are more than twice as likely to scatter blue light (450nm to 480nm) than they will scatter green light (510nm to 550nm) or red light (630nm to 740nm). As another example, TiO_2 particles with an average particle size of 100nm will scatter blue light nearly three times (2.9=0.97/0.33) more than it will scatter green or red light. For TiO_2 particles with an average particle size of 200nm these will scatter blue light over twice (2.3=1.6/0.7) as much as they will scatter green or red light. In accordance with some embodiments of the invention, the light diffractive particle size is preferably selected such that the particles will scatter blue light relatively at least twice as much as light generated by the phosphor material(s).

[0089] Another problem with remote phosphor devices that can be addressed by embodiments of the invention is the variation in color of emitted light with emission angle. This problem is commonly called COA (Color Over Angle). Remote phosphor layers allow a certain amount of blue light to escape as the blue component of white light. This is directional light coming from the LEDs. The RGY (Red Green Yellow) light coming from the phosphor is lambertian. Therefore the directionality of the blue light may be different than that of the RGY light causing a "halo" effect at the edges with color looking "cooler" in the direction of the blue LED light and "warmer" at the edges where the light is all RGY. The addition of nano-diffuser selectively diffuses blue light – causing it to have the same lambertian pattern as the RGY light and creating a very uniform color over angle. Traditional LEDs also have this problem which can be improved by remote phosphor using this technology. Remote phosphor devices are often subject to perceptible non-uniformity in color when viewed from different angles. Embodiments of the invention correct for this problem, since the addition of a light diffusing layer in direct contact with the wavelength conversion layer significantly increases the uniformity of color of emitted light with emission angle θ.

[0090] Embodiments of the present invention can be used to reduce the amount of phosphor materials that is required to manufacture an LED lighting product, thereby reducing the cost of manufacturing such products given the relatively costly nature of the phosphor materials. In particular, the addition of a light diffusing layer composed of particles of a light diffractive material can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. This means that relatively less phosphor is required to manufacture a wavelength conversion component as compared to comparable prior art approaches. As a result, it will be much less costly to manufacture lighting apparatuses that employ such wavelength conversion components, particularly for remote phosphor lighting devices. In operation, the diffusing layer increases the probability that a photon will result in the generation of photoluminescence light by reflecting light back into the wavelength conversion layer. Therefore, inclusion of a diffusing layer with the wavelength conversion layer can reduce the quantity of phosphor material required to generate a given color emission product, e.g. by up to 40%.

[0091] FIGS. **15**, **16**, and **17** illustrate different approaches to introduce light scattering materials into an LED lamp, which can substantially reduce the quantity of phosphor material required to generate a selected color of emitted light. In addition, the light diffusing layer can be used in combination with additional scattering (or reflective/diffractive) particles in the wavelength conversion component to further reduce the amount of phosphor material that is required to generate a selected color of emitted light. FIG. **15** illustrates an approach in which the light scattering material **31** is included within a separate layer. FIG. **16** illustrates an approach in which the light scattering material **31** is included within the layer containing the phosphor **30**. FIG. **17** illustrates an alternative approach in which the light scattering material **31** is introduced into the lens **26**. Any combination of the above may also be implemented. For example, the light scattering material **31** can be introduced into both the layer of phosphor **30** and the lens **26**. In addition, the light scattering material can be included within both a separate layer **31** and the layer of phosphor **30**. Moreover, the light scattering material **31** can be included within each of the separate layer, the layer of phosphor **30**, and the lens **26**.

[0092] Alternative approaches can be taken to improve the off-state white appearance of the lamp. For example, texturing can be incorporated into the exterior surface of the lamp to improve the off-state white appearance of the lamp, e.g. in the exterior surface of the lens **26**.

[0093] Yet another possible approach is to implement a thin white layer directly after the yellow phosphor layer and before the clear linear optic. This three layer structure would be white appearance in the off-state but the primary optic would still be clear (not diffused/cloudy). This approach has the benefit of preserving the light distribution pattern of the linear lens optics while still providing white appearance.

[0094] Further details regarding an exemplary approach to implement scattering particles are described in U.S. Patent Application Ser. No. 11/185,550, filed on October 13, 2011, entitled "Wavelength Conversion Component With Scattering Particles", which is hereby incorporated by reference in its entirety.

[0095] The approach of using an interior cavity as a "mixing chamber" can be applied to non-linear lamps as well. FIG. **18** shows a LED lighting arrangement **20** in accordance with an embodiment of the invention where the lens **26** comprises a solid semi-spherical shape. The LED chip **22** is mounted within the chamber **33** of the lighting arrangement **20**, such that it is wholly contained within the interior of the profile of the phosphor **30**. An indentation **23** is formed within the lens **26** to receive the PCB **25**.

[0096] The lens **26** can be fabricated to provide any suitable shape as desired. For example, FIG. **20** shows an alternate LED lighting arrangement in accordance with an embodiment of the invention where the lens **26** comprises a solid ovoid shape. As before, the LED chip **22** is mounted within the chamber **33** of the lighting arrangement, such that it is wholly contained within the interior of the profile of the phosphor **30**. An indentation **23** is formed within the lens **26** to receive the PCB **25**.

[0097] Any of the embodiments described earlier can be configured as a linear lamp. For example, the embodiment of FIG. **2** shows a lamp having a convex lens **26** that is provided to focus light output from the arrangement, where the lens **26** is substantially hemispherical in form. The lens **26** has a planar, substantially flat, surface **28** onto which there is provided a layer of phosphor **30** before the lens is mounted to the enclosure **24**. FIG. **20** illustrates a linear lamp with a cross-sectional profile having a similar structure. The linear lamp comprises an elongate lens **26** that is semi-circular in its cross-sectional shape, where the base of the lens **26** has a planar surface **28** onto which there is provided an elongate layer of phosphor **30**. The LED **22** is mounted to a support surface where it is exterior to the lens **26**.

[0098] Similarly, the previously described embodiment of FIG. **3** is directed to an LED

lighting arrangement in which the phosphor **30** is provided as a layer on the outer convex surface **32** of the lens **26**. In this embodiment the lens **26** is dome shaped in form. FIG. **21** illustrates a linear lamp with a cross-sectional profile having a similar structure. The linear lamp comprises an elongate lens **26** that is semi-circular in its profile, where the phosphor **30** is provided as a layer on the outer surface of the lens **26**.

[0099] The previously described embodiment of FIG. **4** is directed to an LED lighting arrangement in which the lens **26** comprises a substantially hemispherical shell and the phosphor **30** is provided on either the inner or outer surface of the lens **26**. FIG. **22** illustrates a linear lamp with a cross-sectional profile having a similar structure, in which the linear lamp comprises an elongate lens **26** having semi-circular shell profile, where the phosphor **30** is provided as a layer on the inner or outer surface of the lens **26**.

[00100] FIG. **23** illustrates an example configuration for the profile of a lamp according to some embodiments of the invention. The arrangement of this figure shows a phosphor portion **30** with a conical (or candle) sectional shape within the chamber **33**. When implemented as a T8 replacement lamp, the overall diameter d=25.54 mm (1 inch), l=20.70 mm, h=9.62 mm, and w=8 mm. The length L_1 for the exterior surface of the lens **26** exceeds the length L_2 of the surface of the phosphor portion **30**. In some embodiments L_2 is at least two times L_1. The surface area of the phosphor material is 10.5 in^2 / ft.

[00101] FIG. **24** is a diagram showing the emission patterns for light distributed by one example implementation of the lamp of FIG. **23**. The dotted line shows the emission pattern for an example lamp that does not include a lens **26**. The solid line shows the emission pattern for an example lamp that does include a lens **26**. It can be seen that the lens serves to shape the emitted light such that a greater concentration generally occur towards 0 degrees on the chart (towards the tip of the conical shape of the phosphor portion **30**).

[00102] FIG. **25** illustrates another example configuration for the profile of a lamp according to some embodiments of the invention. The arrangement of this figure shows a phosphor portion **33** with a generally dome sectional shape within the chamber **33**. When implemented as a T8 replacement lamp, the diameter d has a 1 inch (25.4 m) length and where l=20.70 mm, and w=8 mm, same as the embodiment of FIG. **23**. However, the value of h in this embodiment is 6 mm. As before, the length L_1 for the exterior surface of the lens **26** significantly exceeds the length L_2 of the surface of the phosphor portion **30**, e.g., where L_2 is at

least two times L_1. The surface area of the phosphor material is 7.8 in^2 / ft.

[00103] FIG. **26** is a diagram showing the emission patterns for light distributed by one example implementation of the lamp of FIG. **25**. The dotted line shows the emission pattern for an example lamp that does not include a lens **26**. The solid line shows the emission pattern for an example lamp that does include a lens **26**. As before, it can be seen that the lens serves to shape the emitted light such that a greater concentration generally occur towards 0 degrees on the chart (towards the tip of the dome shape of the phosphor portion 30).

[00104] These diagrams show a clear difference between the emission pattern of the lamp of FIG. **23** and the emission pattern for the lamp of FIG. **25**. The approach of using the dome-shaped cross-sectional profile provides a more uniform pattern in the near field (at or near the tube surface) light distribution and better far field beam control. The conical sectional shape of FIG. **23** provides a greater distribution of light along the sides of the lamp. In contrast, the dome-shaped sectional profile of FIG. **25** provides a greater distribution of light towards the top of the lamp. This highlights the ability to shape the light produced by the lamp by configuring the shape of the sectional profile of the phosphor/chamber in the lens. The approach of using the dome-shaped cross-sectional profile generally corresponds to less phosphor surface area than the cone-shaped sectional profile, which potentially translates to a less costly lamp design.

[00105] The arrangement of the lamp can also be configured to improve its light producing efficiency (also referred to herein as "System Quantum Efficiency" or SQE) and to reduce SQE light loss, where system quantum efficiency can be defined as the ratio of the total number of photons produced by the system to the number of photons generated by the LED. Many white LEDs and LED arrays are typically constructed of blue LEDs encapsulated with a layer of silicone containing particles of a powdered phosphor material or covered using an optical component (optic) including the phosphor material. The system quantum efficiency (SQE) of the known white LED and LED arrays is negatively affected by the loss of the total light output of the lamp during conversion of the blue LED light to white light, where the majority of light loss is not due to the photoluminescence conversion process but rather due to absorption losses for light (both photoluminescence and LED light) that is emitted back into the LED(s). Due to the photoluminescence conversion process being isotropic, photoluminescence light will be emitted in all directions and hence up to about 50% will be generated in a direction back towards the LED(s) giving rise to re-absorption and loss of photoluminescence light by the LED(s).

[00106] By appropriately configuring the aspect ratio of the phosphor portion **30**, it is possible to eliminate or significantly reduce the SQE losses of the lamp. The aspect ratio of the phosphor portion **30** is the ratio of the area of the phosphor layer to the area of the LED package. FIG. **28** is an example of such a component that comprises a cylindrical body of axial length **l** and radius **r** having a hemispherical end and a planar end which is mountable to an LED package. The phosphor is provided on the cylindrical and hemispherical surfaces of the component. In this exemplary embodiment the area of LED package (i.e. the planar base of the component) is πr^2 whilst the surface area of the wavelength conversion component (phosphor) is $2\pi r^2+2\pi rl$. As a result the aspect ratio is $2(r+l)/r : 1$. For a component in which the length $l=0.5r$, that is a component whose length in an axial direction is one and a half times its diameter, the aspect ratio is preferably 3:1 (although other ratios may be employed in certain embodiments). For such a component the solid optic within chamber **33** transmits the majority of light to the opposite side of the phosphor optic and very little light returns to the LED and package base. Travelling through the solid optic has no refractive index changes so there is virtually 100% efficiency. Therefore the goal of this design is to maximize light emission by minimizing the amount of light returning to the LED package.

[00107] According to some embodiments of the invention, SQE loss is significantly eliminated or reduced by implementing the following combination of factors:

i) remote phosphor - the phosphor portion is separated from the LEDs;

ii) a coupling optic - An optical material having a high refractive index material is coupled directly to LEDs and the phosphor conversion component. This material should have a refractive index of 1.4 or greater (>1.5 preferred). Good optical coupling between the blue LEDs and the clear optic is used to ensure that it effectively acts as a light transport layer. By eliminating air interfaces and refractive index mismatches, virtually all light generated by the LEDs will travel with virtually no or minimal loss to the wavelength conversion component (phosphor layer).

iii) phosphor wavelength conversion layer with an aspect ratio greater than 1:1 – the phosphor layer is separated from the blue LEDs by the clear coupling optic. Ideally the outer phosphor optic is the same refractive index as the clear layer and has no gap or other optical loss in the interface to the clear optic. The phosphor outer layer optic has an aspect ratio of 1:1 or greater such that the total surface area of the outer phosphor layer in contact with the clear

coupling optic is at least three times the area of the LED package surface coupled to the clear coupling optic.

[00108] In operation blue light travels through the clear coupling optic with effectively no loss. When the blue light excites the phosphor layer and the photoluminescence light can now travel equally in any direction due to the elimination of the optical medium/air interface. Due to the high aspect ratio of the photoluminescence wavelength conversion component a majority of light (both phosphor generated light and scattered LED light) will not travel back to the LED package. Instead most light will travel through the clear optic to the other side and exit out of the phosphor layer on the opposing side. Once converted, YGR (Yellow, Green, Red) light easily passes through the phosphor layer. In summary, the majority of light is no longer re-cycled directly between the phosphor and the package/LEDs as it is in standard LED configurations.

[00109] With regard to linear lamp embodiments, any suitable manufacturing process may be employed to manufacture the lamp assembly. For example, a printing process can be employed where ink is printed using screen printing directly onto the lens surface. Other printing techniques can be used to print and/or coat the phosphor, such using roller coaters to coat the phosphor ink onto the lens. Spray coating is another technique that may be used to coat the phosphor onto the lens.

[00110] Lamination can also be performed to manufacture the linear lamp. In this approach, a separate sheet of phosphor material is manufactured, e.g. with or without a clear carrier layer. The sheet of phosphor is then laminated onto the light lens/pipe structure.

[00111] A co-extrusion process can be performed to manufacture a multi-layered linear lighting arrangement. Two extruders are used to feed into a single tool to create both the layer of phosphor and the materials of the lens. The two layers are simultaneously created and manufactured together in this approach. This approach can be used with a wide variety of source materials, e.g. PC-Polycarbonate, PMMA-Poly(methyl methacrylate), and PET-Polyethylene Terephthalate, including most or all thermoform plastics. This co-extrusion process can generally use pellets identical or similar to pellets used for injection molding materials. If the chamber in the lens includes a solid optical medium, then a co-extrusion approach can be used to manufacture the three layers with three extruders.

[00112] As noted above, a slot can be incorporated in the profile of the extrusion to accommodate the PCB or COB array. The use of an interior cavity approach makes for simple

assembly and improved efficiency due to avoiding losses from an exterior mixing chamber. In some embodiments, the LEDs are mounted inside a linear mixing chamber and the extrusion is attached to the linear mixing chamber.

[00113] FIG. **29** illustrates the end view of another lamp according to some embodiments of the invention. The arrangement of this figure shows a multi-layered optic component, where the multi-layered optic component integrally includes a phosphor portion **30**, a lens **26**, and a reflector portion **50**. As before, the phosphor portion **30** comprises a generally dome sectional shape that surrounds chamber **33**. The lens **26** also comprises an exterior sectional profile having a dome shape. The reflector **50** is formed of any material that is capable of substantially reflecting light, and is intended to function by reflecting some or all of the phosphor-generated light from phosphor portion **30** away from the base of the lamp **21**. In some embodiments, the reflector **50** comprises a white polycarbonate material.

[00114] A triple-extrusion process can be utilized to manufacture the multi-layered optic component, where three extruders are used to feed into a single tool to create the layer of phosphor, the materials of the lens, and the material of the reflector. Three extruders are used to feed into a single tool to create the three separate layers of materials, including phosphor, the materials of the lens, and the materials of the reflector. The three layers are simultaneously created and manufactured together in this approach. This approach can be used with a wide variety of source materials, e.g. PC-Polycarbonate, PMMA-Poly(methyl methacrylate), and PET-Polyethylene Terephthalate, including most or all thermoform plastics. This triple-extrusion process can generally use pellets identical or similar to pellets used for injection molding materials. If the chamber in the lens includes a solid optical medium, then a quadruple-extrusion approach can be used to manufacture the multiple layers with four extruders.

[00115] In some embodiments, the circuit board **25** having the array of LEDs **22** is mounted to, and in thermal communication with, a support body **54**. The reflector **50** is formed having a lower flange portion that extends away from the central portion of the multi-layered optic component. The flange portion is configured to slot within a channel in support body **54**. This allows the lamp **21** to be easily implemented by mounting support body **54** anywhere that a linear lamp is needed, and then attaching the multi-layered optic component to the support body by sliding the flange portion into the appropriate channels in the support body **54**.

[00116] In alternate embodiments, the lamp is not manufactured by first mounting the

LEDs **22** to the circuit board **25** that is attached to the support body **54**. Instead, a co-extrusion process is utilized that manufactures the multi-layered optic component having the array of LEDs **22**. In this embodiment, the LEDs **22** are attached to a flexible circuit board **25** that fed into the co-extrusion equipment, such that the multi-layered optic component is affixed to the circuit board having the LEDs as it is being formed.

[00117] FIG. **30** illustrates an embodiment where the chamber is filled with an optical medium **56**. The optical medium within the chamber **33** comprises a material, e.g., a solid material, possessing an index of refraction that more closely matches the index of refraction for the phosphor **30**, the LEDs **22**, and/or any type of encapsulating material **27** that may exist on top of the LEDs **22**. As previously noted, one reason for using the optical medium **56** is to eliminate air interfaces that exist between the LEDs **22** and the phosphor **30**. This reduces and/or eliminates any mismatches between the index of refraction of the material of the phosphor **30** and the index of refraction of the air within the interior volume **33** of the lamp **21**. By reducing/preventing these mismatches in the indices of refraction, this removes the interfaces between air and the lamp components that may cause a significant portion of the light to be lost in the form of heat generation. By filling the chamber **33** with an optical medium **56**, light is permitted to be emitted to, within, and/or through the interior volume of the lamp without having to incur losses caused by excessive mismatches in the indices of refraction for an air interface. The optical medium may be selected of any suitable material, e.g. silicone, to generally fall within or match the index of refraction for materials typically used for the phosphor **30**, the LEDs **22**, and/or any encapsulating material that be used to surround the LEDs **22**.

[00118] If the chamber **33** in the lens includes a solid optical medium **56**, then a co-extrusion approach can be used to manufacture the multi-layered optic component to also include the optical medium **56**, e.g., by adding an extruder that for the material of the optical medium **56**. If the optical medium **56** comprises a liquid material, then the liquid material can be injected or inserted into chamber **33** after the multi-layered optic component has been mounted onto the support body **54**. If desired, a curing process (e.g., using UV light) can further be used to solidify the liquid material of the optical medium **56**.

[00119] A light diffusing/scattering material can be used in conjunction with the multi-layered optic component. The light diffusing/scattering material is useful to reduce the quantity of phosphor material that is required to generate a selected color of emitted light. The light

diffusing/scattering material is also useful to improve the off-state white appearance of the lamp **21**.

[00120] The light diffusing/scattering material may be included into any of the layers of the multi-layered optic. For example, the light diffusing/scattering material can be incorporated into the layer containing the phosphor **30**, added to the lens **26**, included as an entirely separate layer, or any combination. FIG. **31** shows an embodiment in which the light diffusing/scattering material **31** has been incorporated into the material of the lens **26** in the multi-layered optic component.

[00121] In any of the disclosed embodiments, the combination of the solid optical medium **56** and the phosphor **30** can be replaced by a layer of material that entirely fills the volume surrounding the LED **22**, but which also includes the phosphor integrally within that layer of material. This approach is illustrated in FIG. **32**. Here, the lamp **21** does not have a thin separate layer of phosphor. Instead, the entirety of the interior volume that surrounds the LED **22** is filled with material that also includes the phosphor **30**. This provides a hybrid remote-phosphor/non-remote-phosphor approach whereby the phosphor is located in the layer of material that fills the interior cavity, but some of the phosphor is located in close proximity to the LEDs **22** (in the inner portion of the material adjacent to the LED), but much of the phosphor is actually quite distant to the LEDs **22** (in the outer portion of the material away from the LED).

[00122] This approach therefore provides much of the advantages of remote-phosphor designs, while also maximizing light conversion efficiencies (due to elimination of mismatches in indices of refraction from eliminating air interfaces). Manufacturing may also be cheaper and easier, since the extrusion processes and apparatuses only need to extrude the single layer of materials, rather than an extruder for the phosphor material and a separate extruder for the optical medium material.

[00123] FIG. **33** shows another embodiment in which the reflector **50** comprises high side walls. The side walls are useful to focus the light emitted form lamp **21** into a desired direction. The side walls of the reflector **50** can be configured, however, in any manner needed to generate a desired light emission pattern from the lamp **21**.

[00124] FIG. **34** illustrates an embodiment of a lamp **100** in which one or more linear lighting arrangements **21** are placed inside of an envelope **62** to form a replacement for a standard incandescent light bulb. As such, lamp **100** may include standard electrical connectors

60 (e.g., standard Edison-type connectors) that allow lamp **100** to be used in conventional lighting devices.

[00125] The linear lighting arrangements **21** function as the lighting elements in the lamp **100**. The linear lighting arrangements **21** are vertically oriented, extending axially within the lamp **100**, with end caps **29** placed at the end (e.g., distal end) of the linear lighting arrangements **21**. Internally, the LEDs within the linear lighting arrangements **21** are oriented radially from the central axis of lamp **100**. This configuration provides a good overall emission pattern from lamp **100** over a wide range of emission angles, with the exact dimensions (e.g., length, width) of the linear lighting arrangements **21** selected to provide a desired emission profile.

[00126] The envelope **62** may be configured in any suitable shape. In some embodiments, envelope **62** comprises a standard light-bulb shape. This permits the lamp **100** to be used in any application/location that could otherwise be implemented with a standard incandescent light bulb. The envelope **62** may include or be used in conjunction with a diffuser. In some embodiments, scattering particles are provided at the envelope **62**, either as an additional layer of material or directly incorporated within the material of envelope **62**.

[00127] Any number of linear lighting arrangements **21** may be included in the lamp **100**. Two linear lighting arrangements **21** are shown in the embodiment of FIG. **34**. FIG. **35** illustrates an embodiment where three linear lighting arrangements **21** are arranged within the lamp **100**. The exact number of linear lighting arrangements **21** to be placed into lamp **100** is selected to provide achieve desired performance characteristics. Examples of further LED bulbs implemented using linear lighting arrangements are disclosed in co-pending U.S. patent application Serial No. 29/443,392, filed January 16, 2013, entitled "LED Light Bulbs", which is hereby incorporated by reference in its entirety.

[00128] Inline testing may be employed using any of the above approaches to control and minimize variations in the final manufactured product. The approach of U.S. Application Serial No. 13/273,201, filed October 13, 2011 describes an approach for implementing in-line process controls to minimize perceptible variation in the amount of photo-luminescent material that is deposited in the wavelength conversion components. The approach described in this co-pending application can be used in conjunction with embodiments of the present invention, and is hereby incorporated by reference in its entirety.

[00129] With a co-extrusion system, one possible approach to perform in-line testing is to

mount a colorimeter or spectrometer that actively measures the product color while it was being extruded. This measurement tool would generally be mounted inline after the cooling bath and dryer but prior to cutting. The color measurement provides real-time feedback to the extrusion system which adjusts layer thickness by varying the relative pressures of the two extrusion screws. The phosphor layer is manufactured to be either thicker or thinner to tune the color of the product in real-time while the extrusion is taking place. This allows one to have single bin accuracy while being able to perform quality checks in real-time during the extrusion process. Similar inline testing could be used with printing and coating methods.

[00130] It will be understood that the present invention may be defined by way of the following clauses and the combination of features described therein.

[00131] According to clause 1, there is provided a lamp comprising: a co-extruded component, the co-extruded component comprising an elongate lens and a layer of photoluminescent material, wherein the elongate lens and the layer of photoluminescent material are co-extruded together to form the co-extruded component; the elongate lens for shaping light emitted from the lamp, wherein the elongate lens comprises an elongate interior cavity; the layer of a photoluminescent material on an interior wall of the elongate interior cavity; and an array of solid-state light emitters configured to emit light into the elongate interior cavity.

[00132] Clause 2: the lamp of clause 1, wherein the lens corresponds to a curved exterior wall.

[00133] Clause 3: the lamp of clause 2, wherein the curved exterior wall comprises a generally semicircular cross-sectional profile.

[00134] Clause 4: the lamp of any preceding clause, wherein the interior wall of the elongate interior cavity corresponds to generally curved interior walls.

[00135] Clause 5: the lamp of any preceding clause, wherein the layer of the photoluminescent material comprises a generally conical cross-sectional profile.

[00136] Clause 6: the lamp of any preceding clause, wherein the layer of the photoluminescent material comprises a generally semi-circular or dome-shaped cross-sectional profile.

[00137] Clause 7: the lamp of any preceding clause, wherein the lens comprises a slot to fit a circuit board having the linear array of solid-state light emitters.

[00138] Clause 8: the lamp of any preceding clause, further comprising a diffusing

material.

[00139] Clause 9: the lamp of any preceding clause, wherein the diffusing material comprises an exterior layer of material on the lens.

[00140] Clause 10: the lamp of any one of clauses 8 or 9, wherein the diffusing material is within the lens or the layer of the photoluminescent material.

[00141] Clause 11: the lamp of any preceding clause, further comprising a reflector comprising a reflective surface to reflect light emitted through the lens.

[00142] Clause 12: the lamp of clause 11, wherein the reflector is co-extruded with the elongate lens and the layer of photoluminescent material.

[00143] Clause 13: the lamp of any one of clauses 11 or 12, wherein the reflector, the elongate lens, and the layer of a photoluminescent material are integrally formed as a multi-layered optic component.

[00144] Clause 14: the lamp of any preceding clause, further comprising an end cap affixed to an end of the lens.

[00145] Clause 15: the lamp of any preceding clause, further comprising an optical medium within the cavity.

[00146] Clause 16: the lamp of clause 15, wherein the optical medium is co-extruded with the elongate lens and the layer of photoluminescent material.

[00147] Clause 17: the lamp of any preceding clause, wherein the light emitted from the lamp is shaped by being focused.

[00148] According to clause 18: a method of fabricating an optical component, comprises co-extruding an elongated solid body having a wavelength conversion layer and an optical component layer, the wavelength conversion layer in contact with the optical component layer.

[00149] Clause 19: the method of clause 18, wherein multiple separate extruders are employed to extrude materials of the wavelength conversion layer and the optical component layer.

[00150] Clause 20: the method of any one of clauses 18 or 19, wherein the materials operated upon by the extruders include at least one of PC-Polycarbonate, PMMA-Poly(methyl methacrylate), PET-Polyethylene Terephthalate, and thermoform plastics.

[00151] Clause 21: the method of any one of clauses 18 to 20, and further comprising co-extruding a light diffusive portion.

[00152] Clause 22: the method of any one of clauses 18 to 21, wherein the optical component layer is formed as a curved shape.

[00153] Clause 23: the method of any one of clauses 18 to 22, wherein the optical component layer is a lens.

[00154] Clause 24: the method of any one of clauses 18 to 23, further comprising performing an in-line process control to control deposition of materials for the wavelength conversion layer.

[00155] Clause 25: the method of clause 24, in which color measurement is performed for the in-line process control.

[00156] It will be appreciated that the present invention is not restricted to the specific embodiments described and that modifications can be made which are within the scope of the invention. For example although in the foregoing description reference is made to a lens the phosphor can be deposited onto other optical components such as for example a window through which light passes though is not necessarily focused or directed or a waveguide which guides, directs, light. Moreover the optical component can have many forms which will be readily apparent to those skilled in the art.

CLAIMS

What is claimed is:

1. A lamp comprising:

a co-extruded component, the co-extruded component comprising an elongate lens and a layer of photoluminescent material, wherein the elongate lens and the layer of photoluminescent material are co-extruded together to form the co-extruded component;

the elongate lens for shaping light emitted from the lamp, wherein the elongate lens comprises an elongate interior cavity;

the layer of a photoluminescent material on an interior wall of the elongate interior cavity; and

an array of solid-state light emitters configured to emit light into the elongate interior cavity.

2. The lamp of Claim 1, wherein the lens corresponds to a curved exterior wall.

3. The lamp of Claim 2, wherein the curved exterior wall comprises a generally semicircular cross-sectional profile.

4. The lamp of Claim 1, wherein the interior wall of the elongate interior cavity corresponds to generally curved interior walls.

5. The lamp of Claim 4, wherein the layer of the photoluminescent material comprises a generally conical cross-sectional profile.

6. The lamp of Claim 4, wherein the layer of the photoluminescent material comprises a generally semi-circular or dome-shaped cross-sectional profile.

7. The lamp of Claim 1, wherein the lens comprises a slot to fit a circuit board having the linear array of solid-state light emitters.

8. The lamp of Claim 1, further comprising a diffusing material.

9. The lamp of Claim 8, wherein the diffusing material comprises an exterior layer of material on the lens.

10. The lamp of Claim 8, wherein the diffusing material is within the lens or the layer of the photoluminescent material.

11. The lamp of Claim 1, further comprising a reflector comprising a reflective surface to reflect light emitted through the lens.

12. The lamp of Claim 11, wherein the reflector is co-extruded with the elongate lens and the layer of photoluminescent material.

13. The lamp of Claim 11, wherein the reflector, the elongate lens, and the layer of a photoluminescent material are integrally formed as a multi-layered optic component.

14. The lamp of Claim 1, further comprising an end cap affixed to an end of the lens.

15. The lamp of Claim 1, further comprising an optical medium within the cavity.

16. The lamp of Claim 15, wherein the optical medium is co-extruded with the elongate lens and the layer of photoluminescent material.

17. The lamp of Claim 1, wherein the light emitted from the lamp is shaped by being focused.

18. A method of fabricating an optical component, comprising co-extruding an elongated solid body having a wavelength conversion layer and an optical component layer, the wavelength conversion layer in contact with the optical component layer.

19. The method of claim 18, wherein multiple separate extruders are employed to extrude materials of the wavelength conversion layer and the optical component layer.

20. The method of claim 19, wherein the materials operated upon by the extruders include at least one of PC-Polycarbonate, PMMA-Poly(methyl methacrylate), PET-Polyethylene Terephthalate, and thermoform plastics.

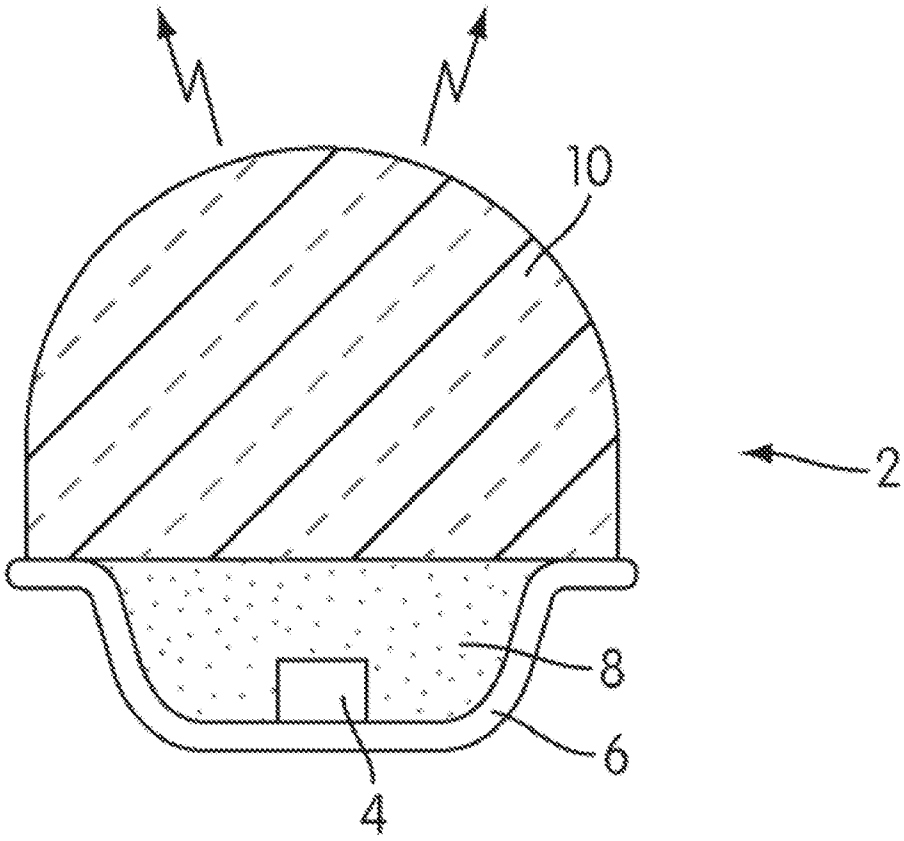
21. The method of Claim 18, further comprising co-extruding a light diffusive portion.

22. The method of Claim 18, wherein the optical component layer is formed as a curved shape.

23. The method of Claim 18, wherein the optical component layer is a lens.

24. The method of Claim 18, further comprising performing an in-line process control to control deposition of materials for the wavelength conversion layer.

25. The method of Claim 24, wherein color measurement is performed for the in-line process control.



PRIOR ART

FIG. 1

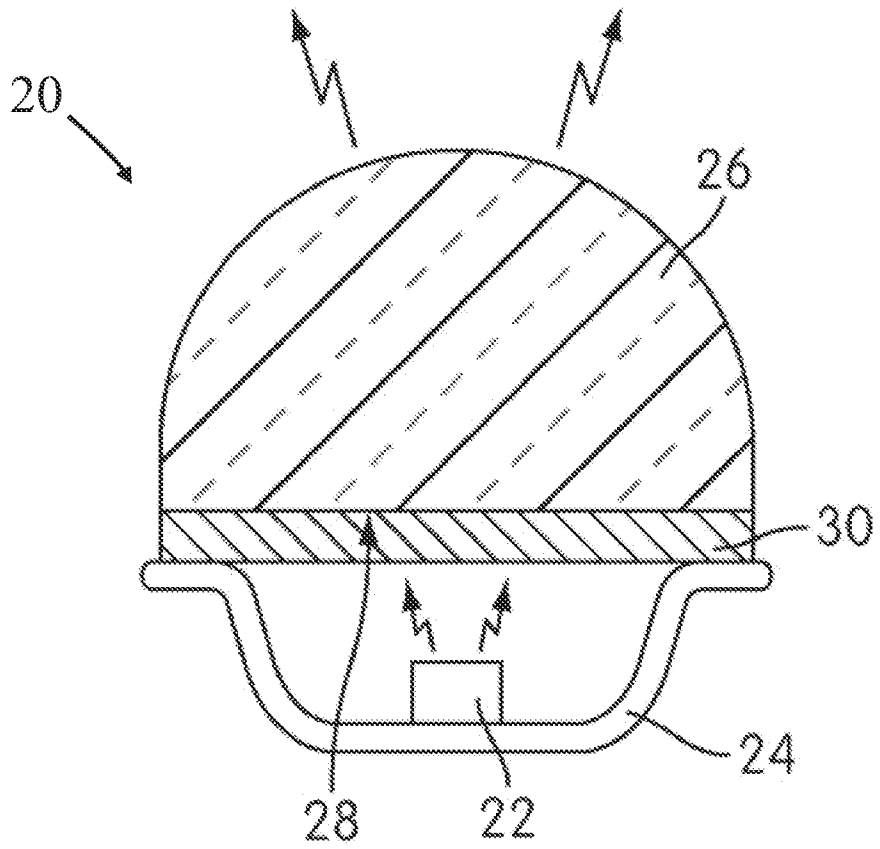


FIG. 2

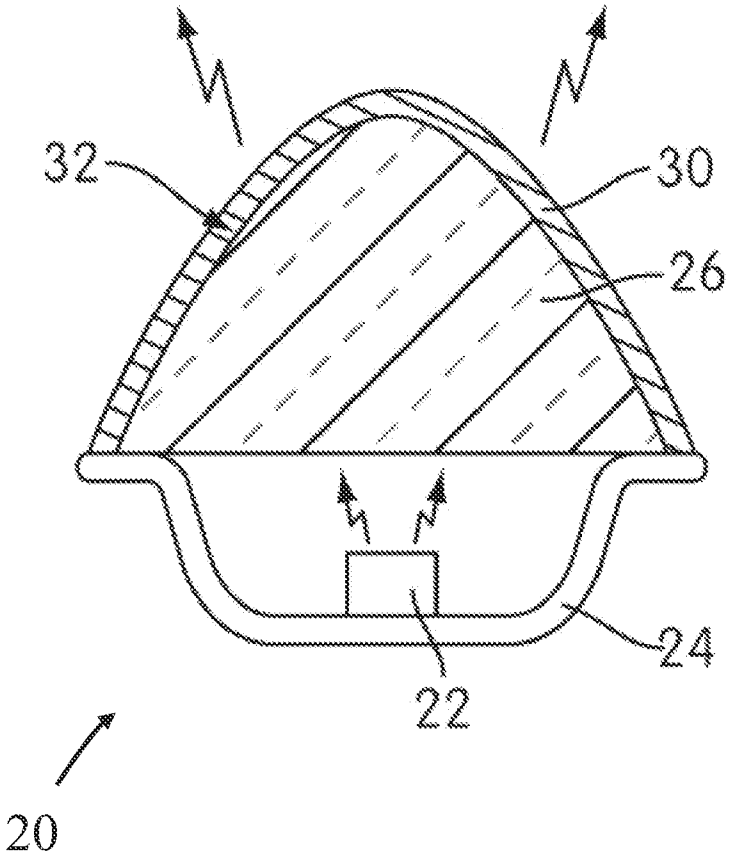


FIG. 3

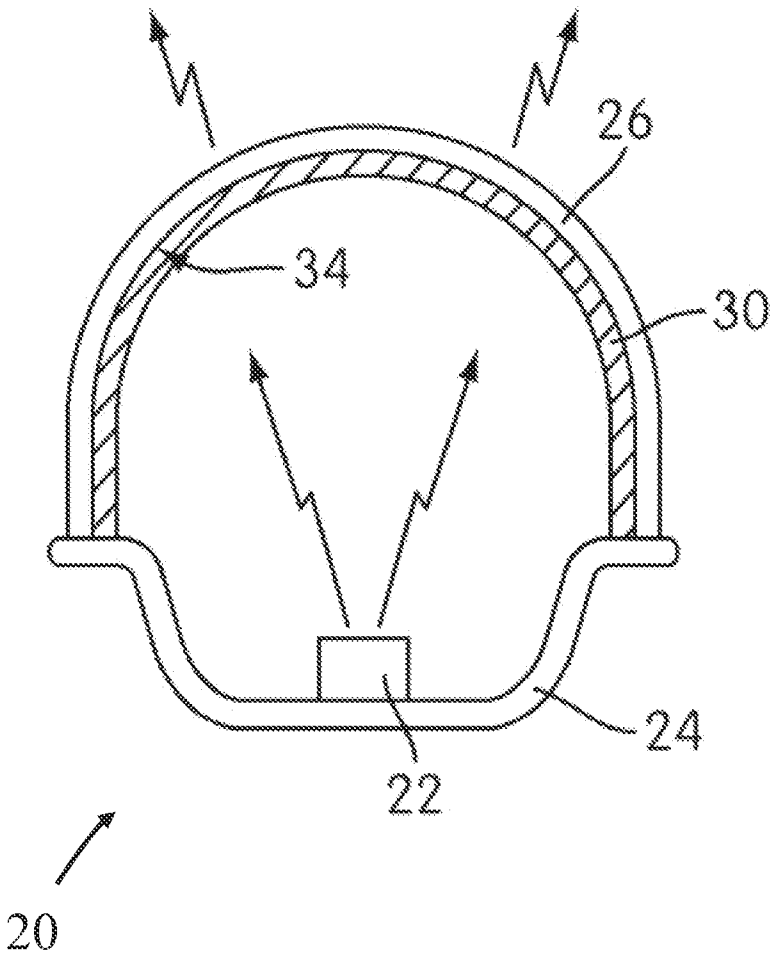


FIG. 4

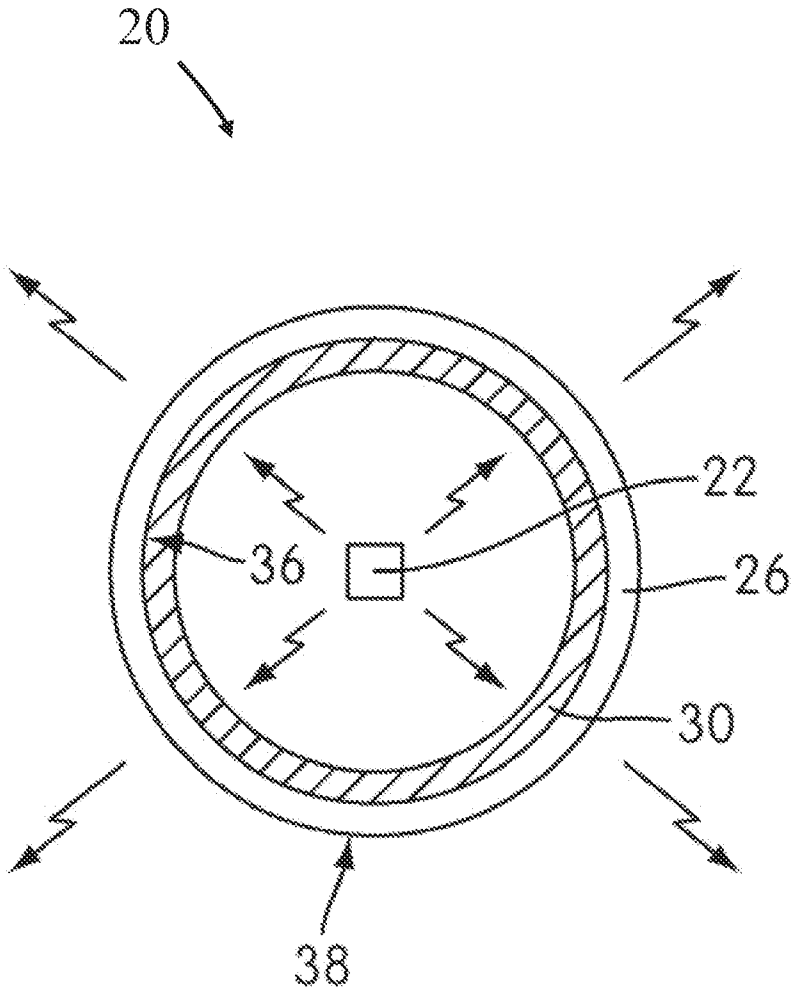


FIG. 5

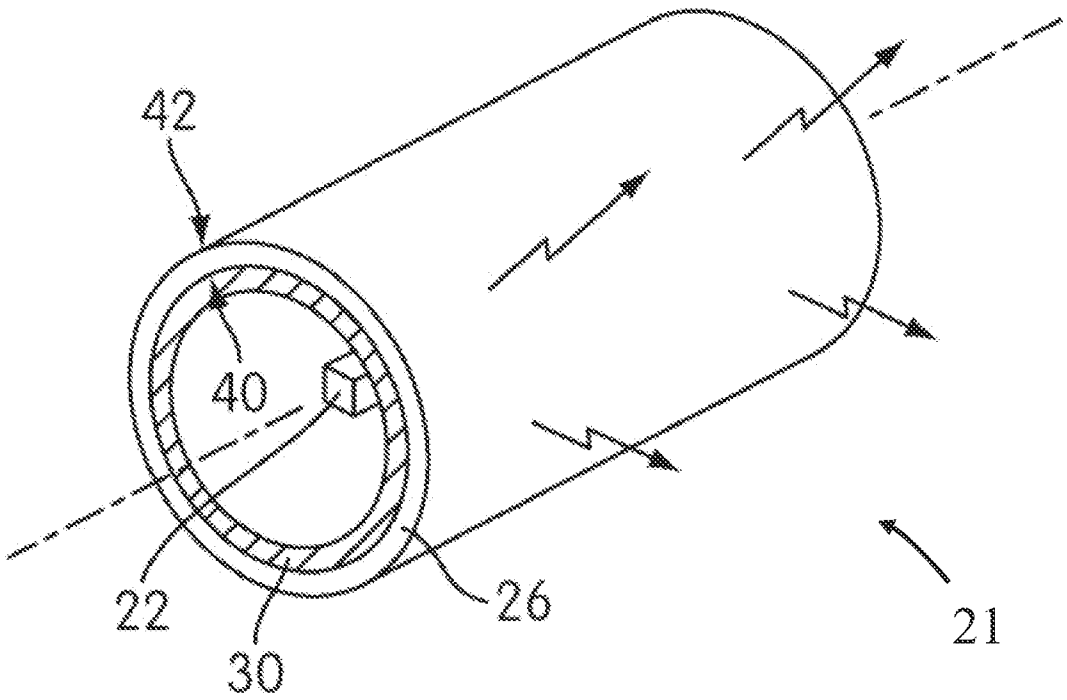


FIG. 6

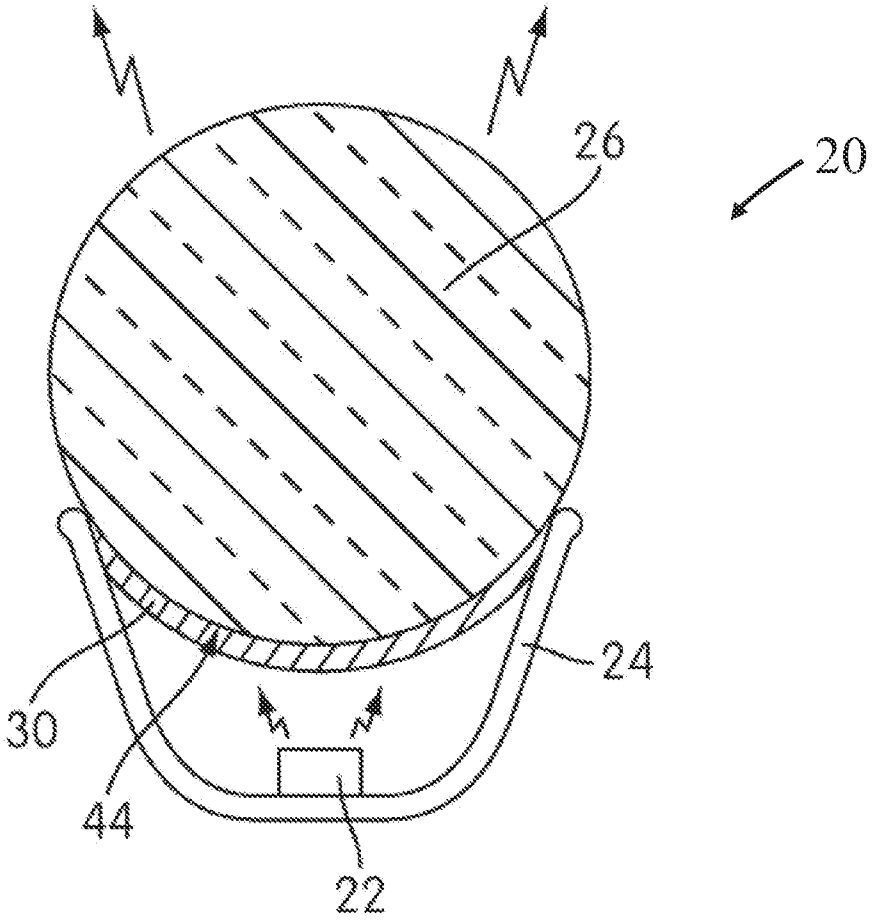


FIG. 7

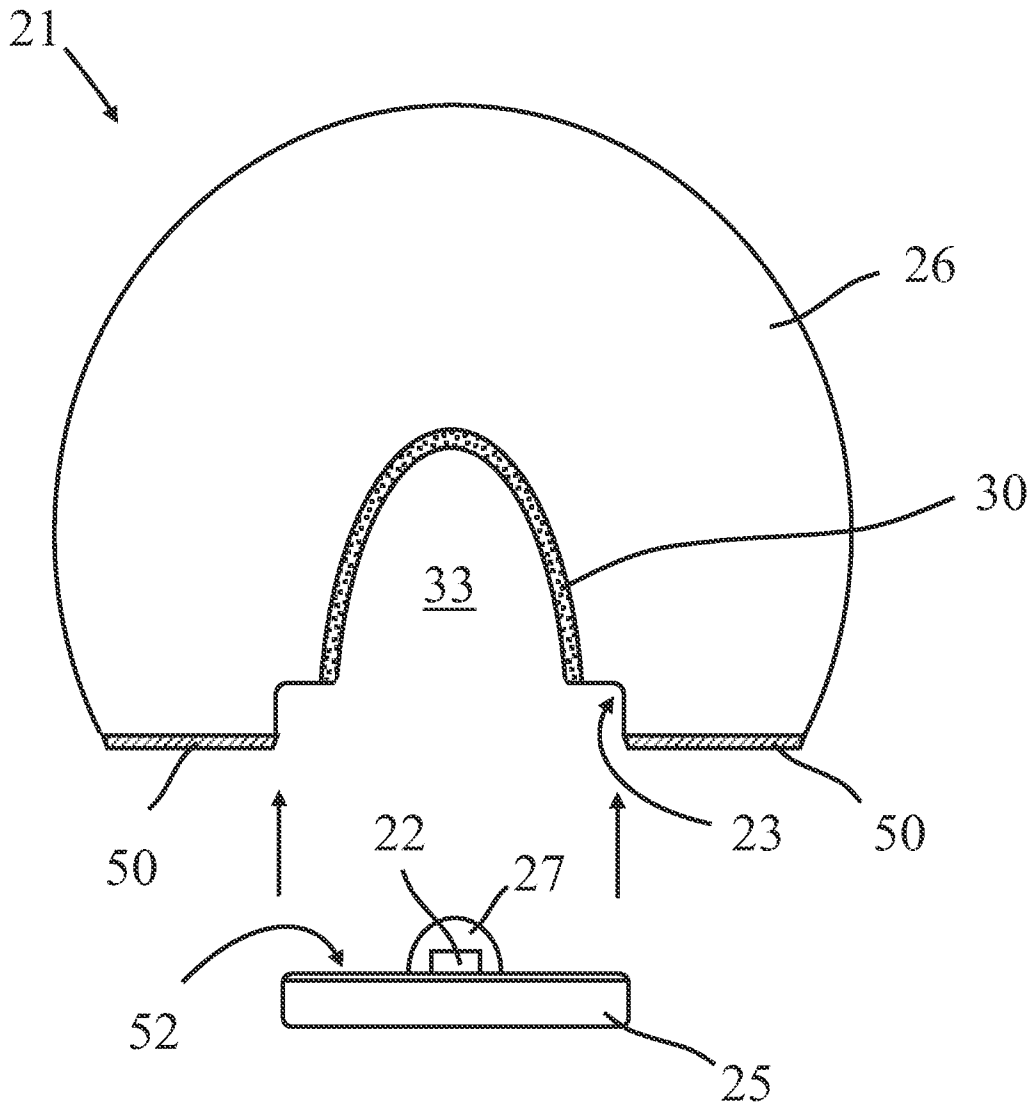


FIG. 8

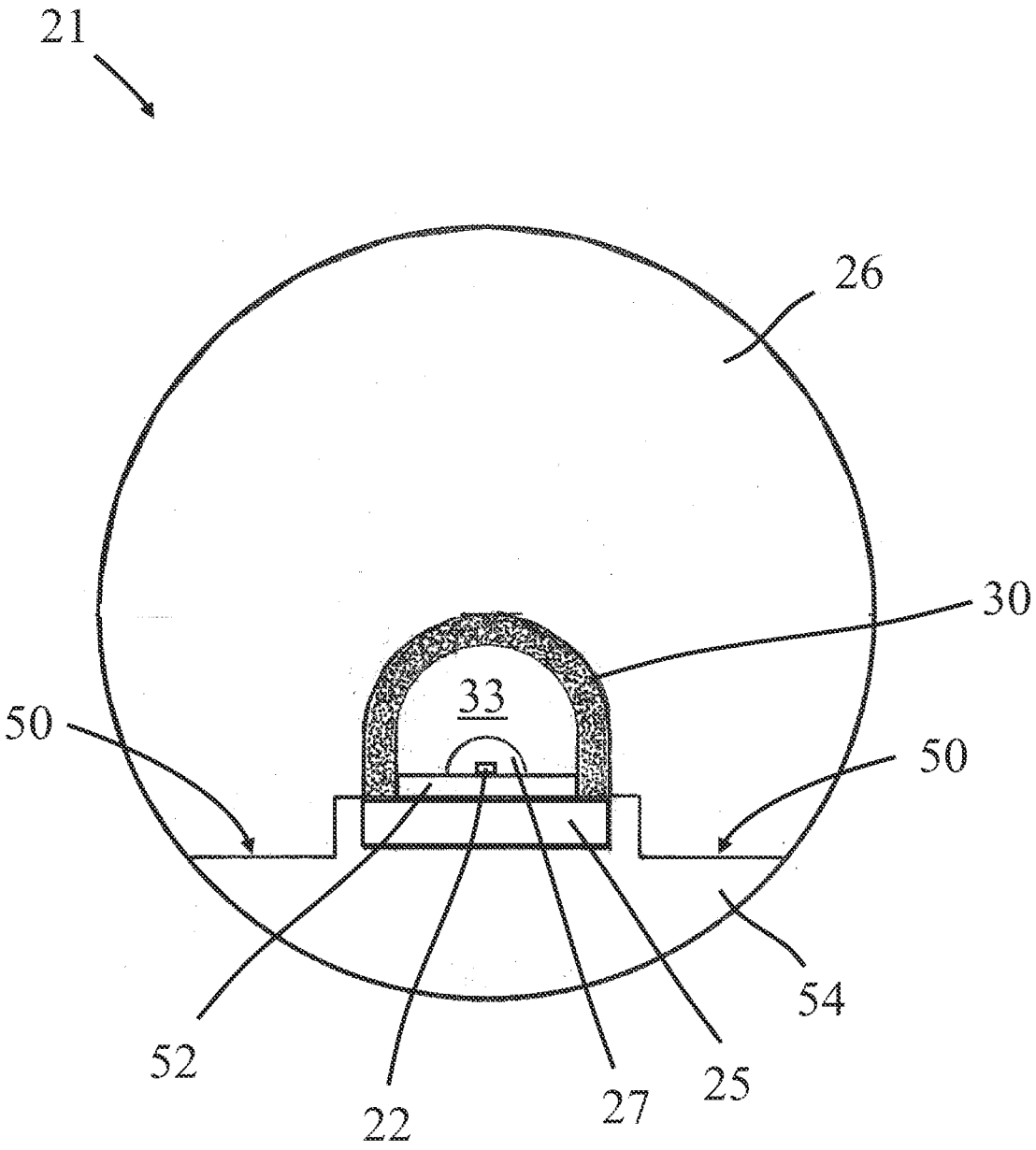


FIG. 9

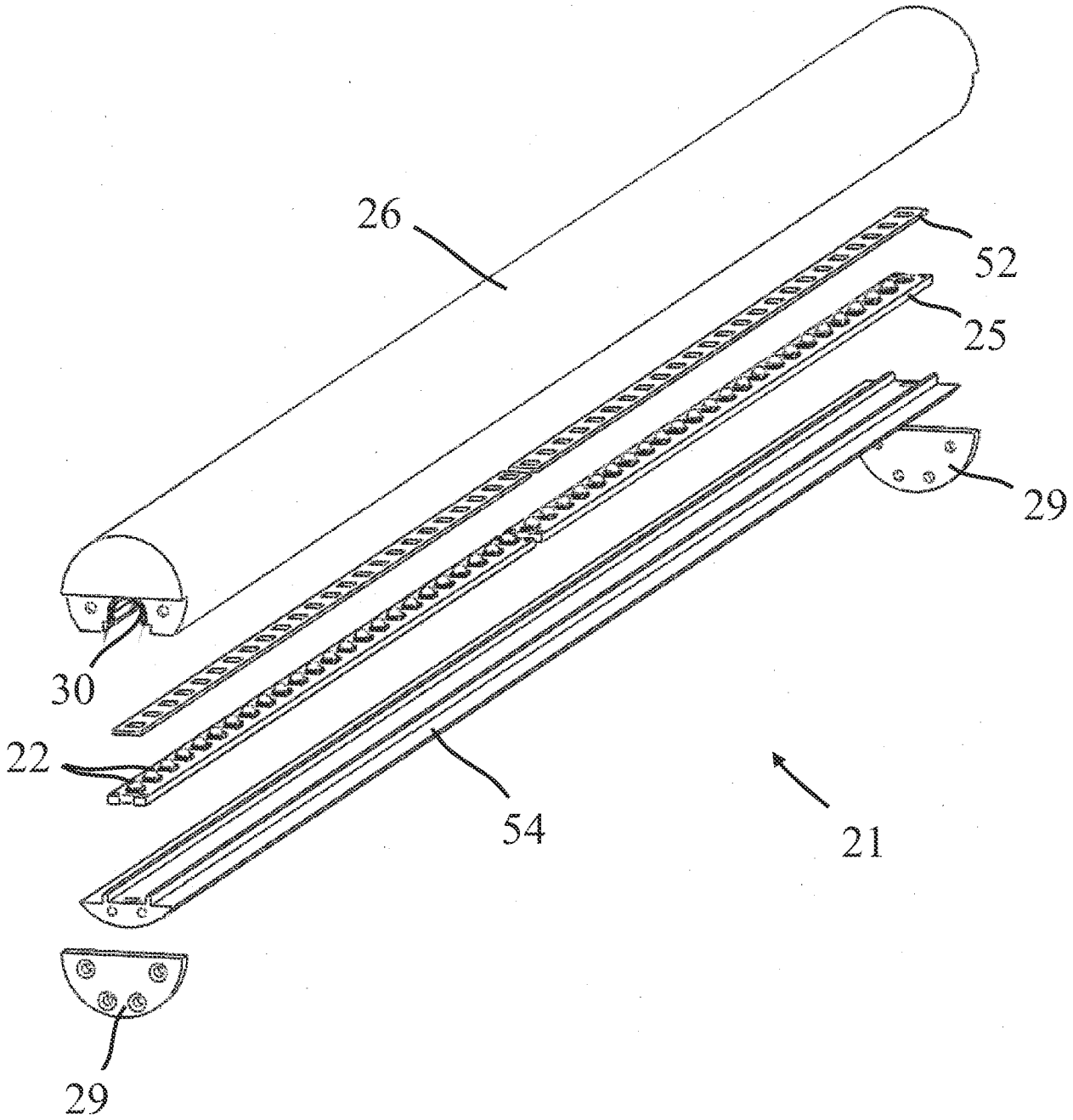


FIG. 10

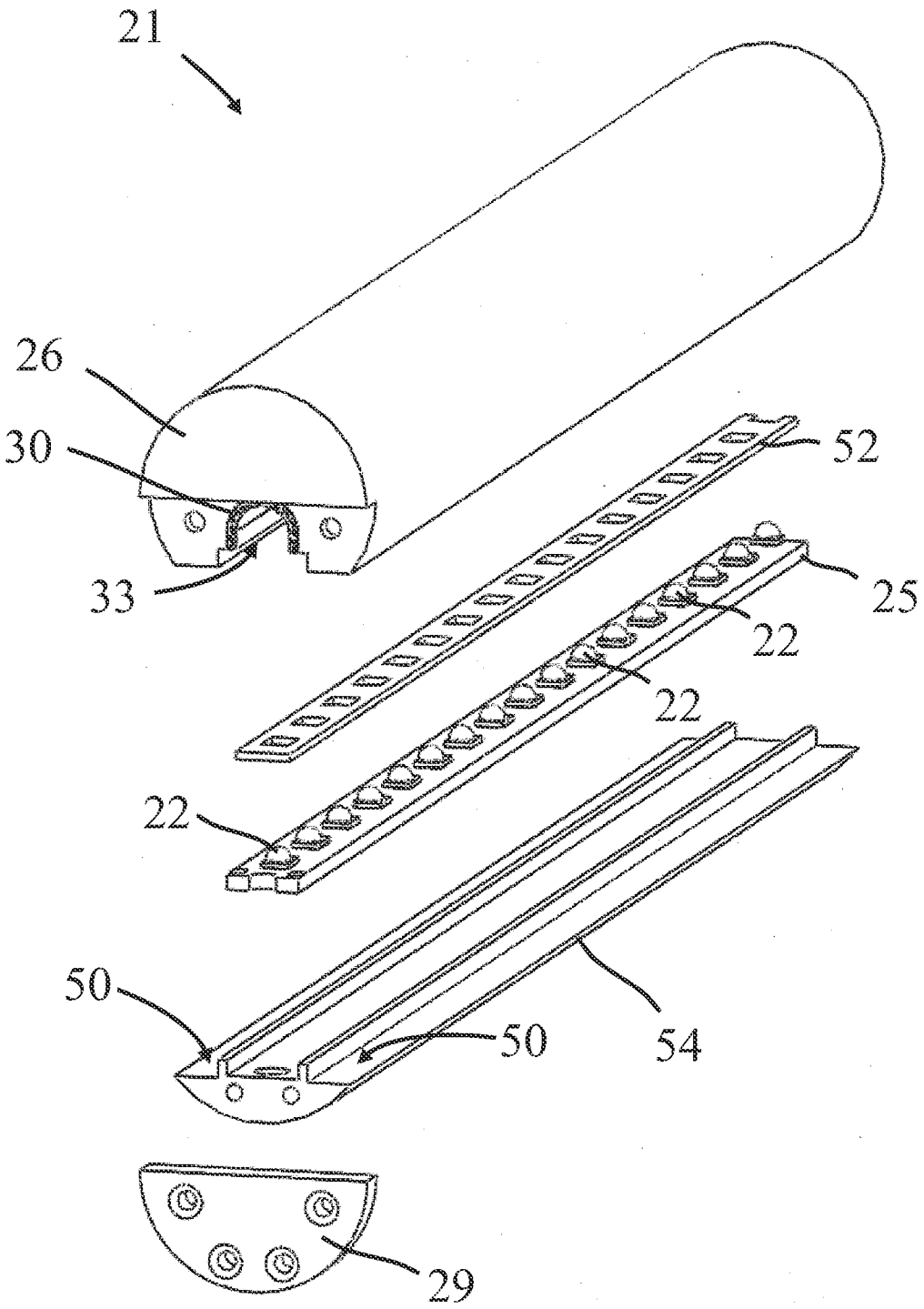


FIG. 11

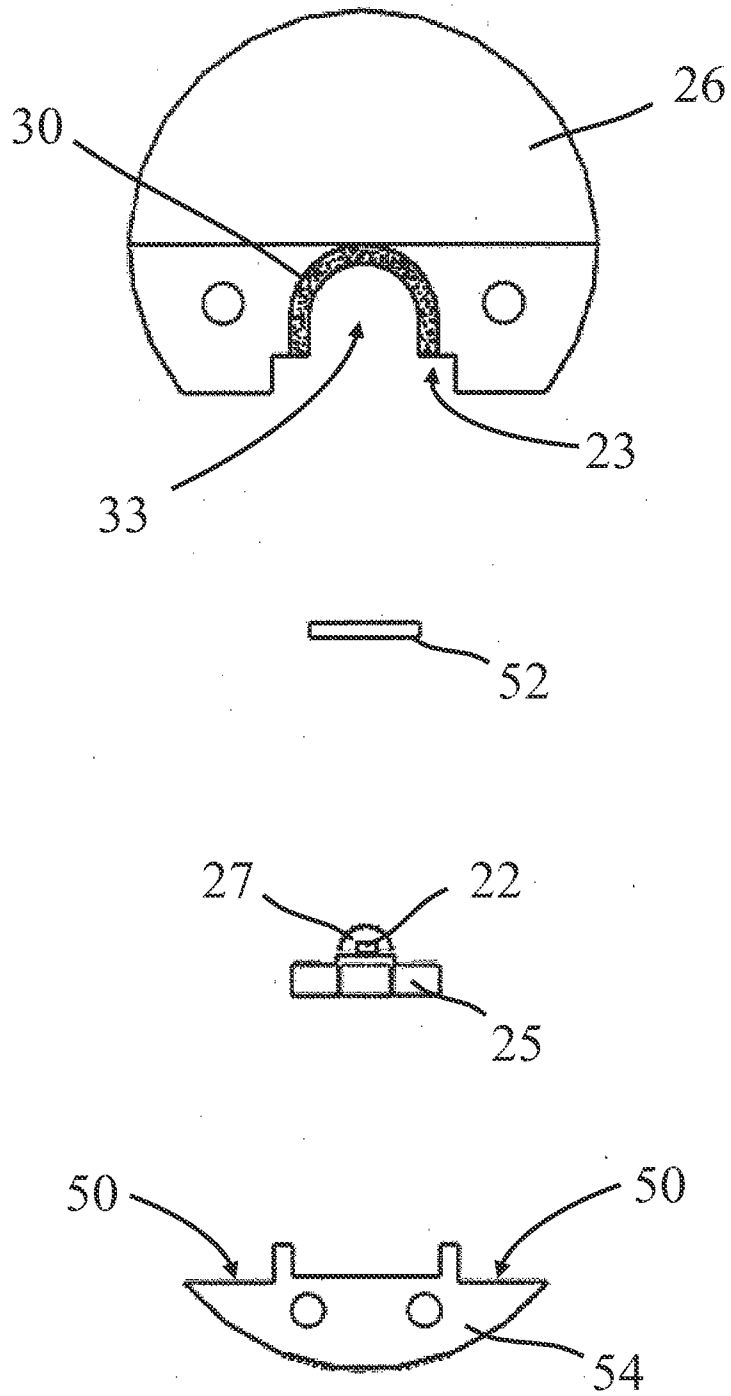


FIG. 12

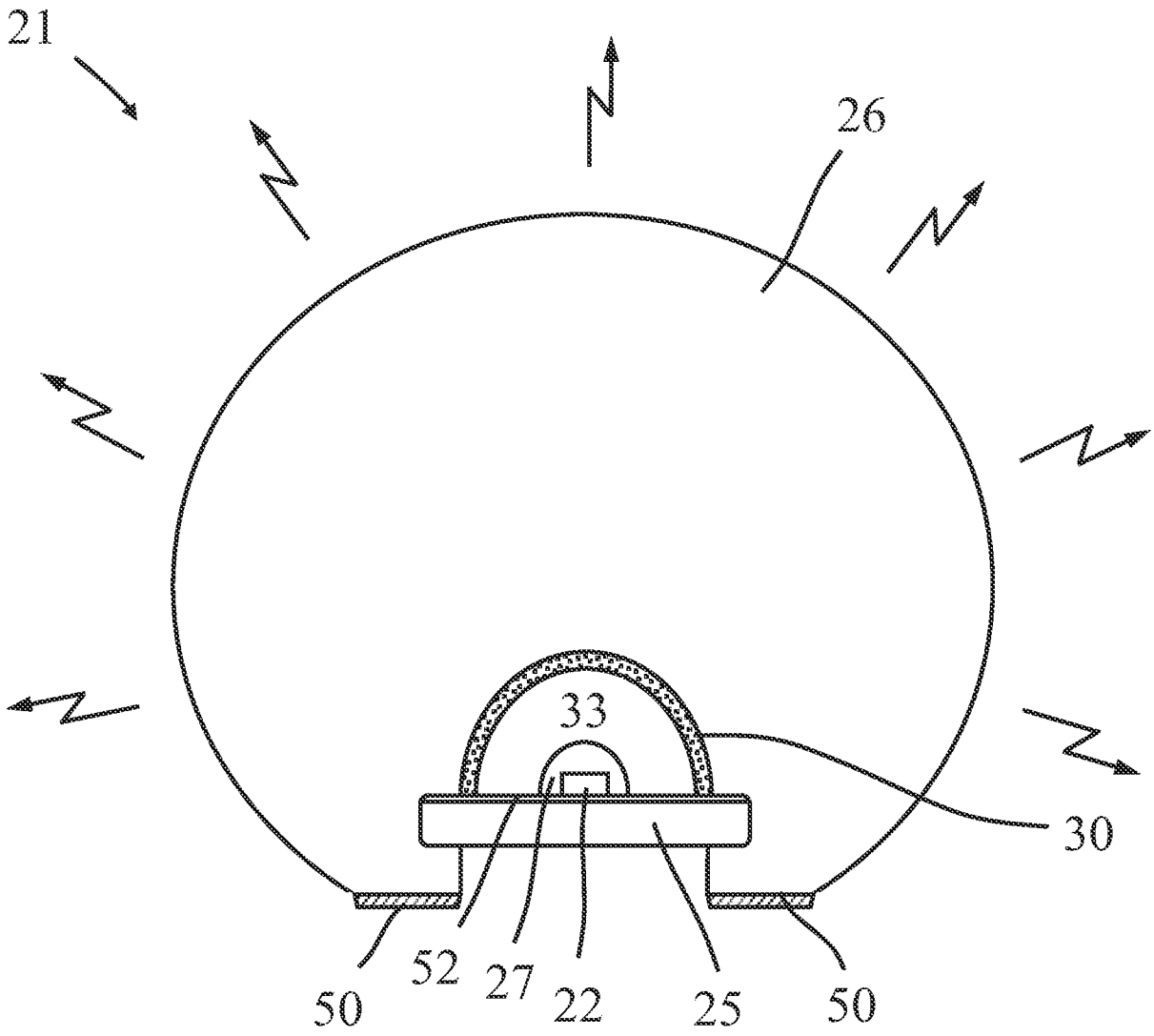


FIG. 13

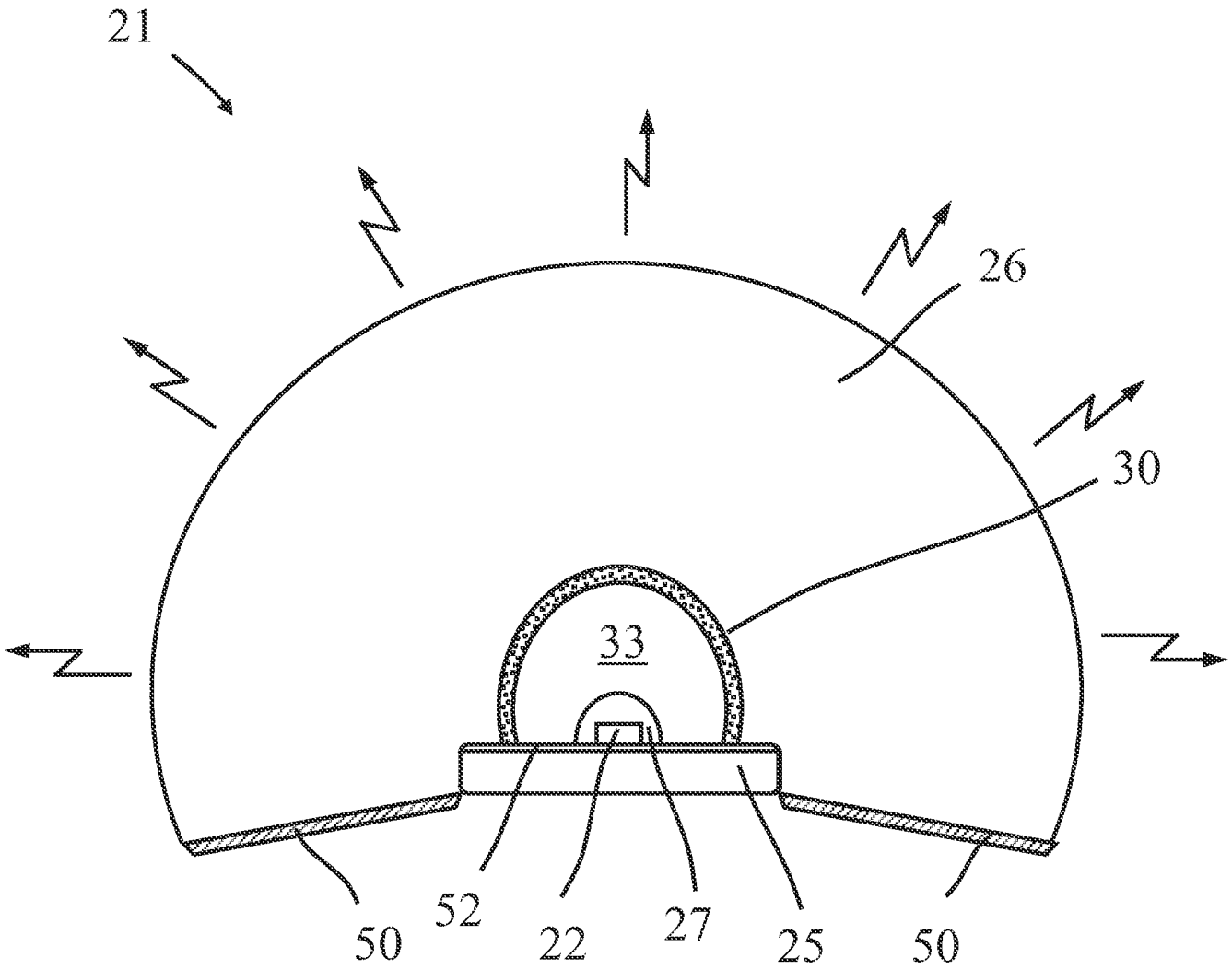


FIG. 14A

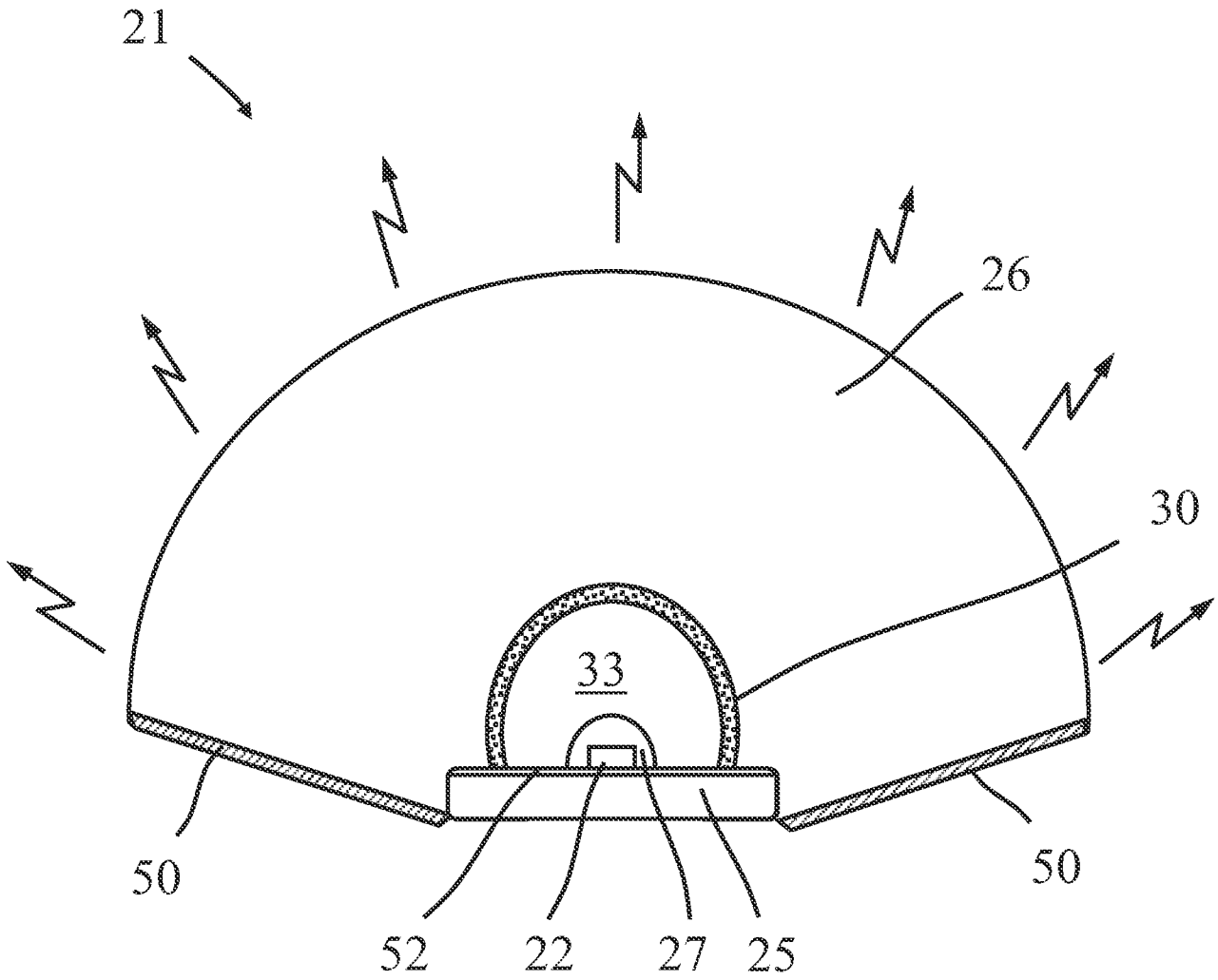


FIG. 14B

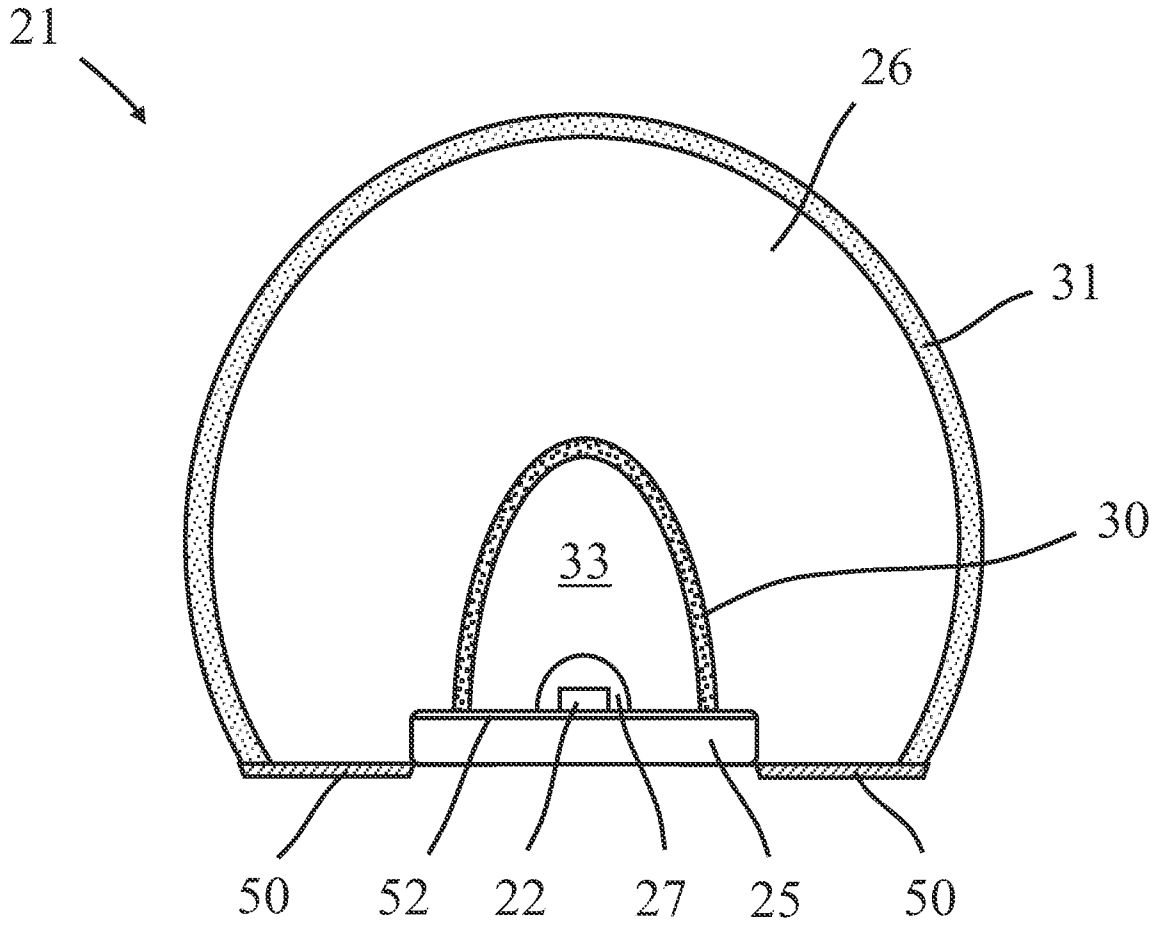


FIG. 15

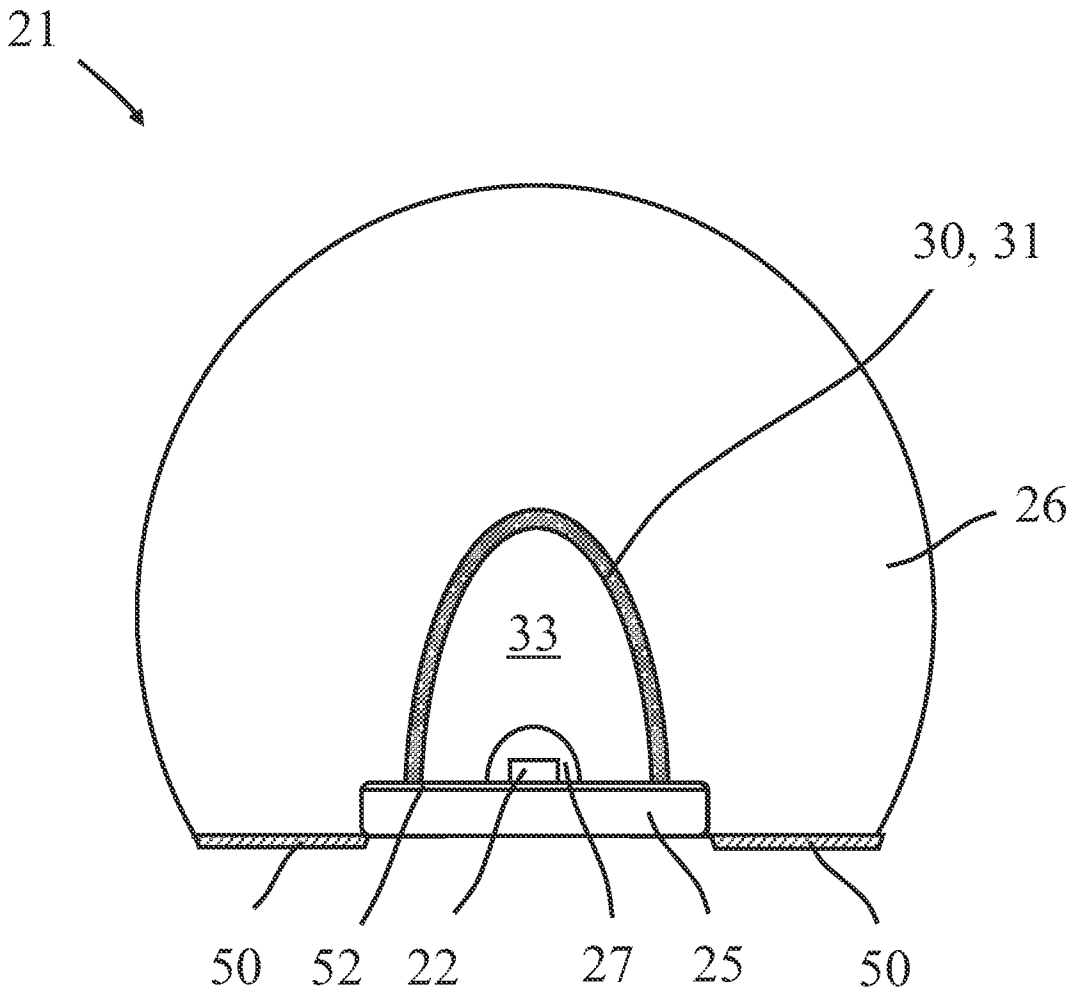


FIG. 16

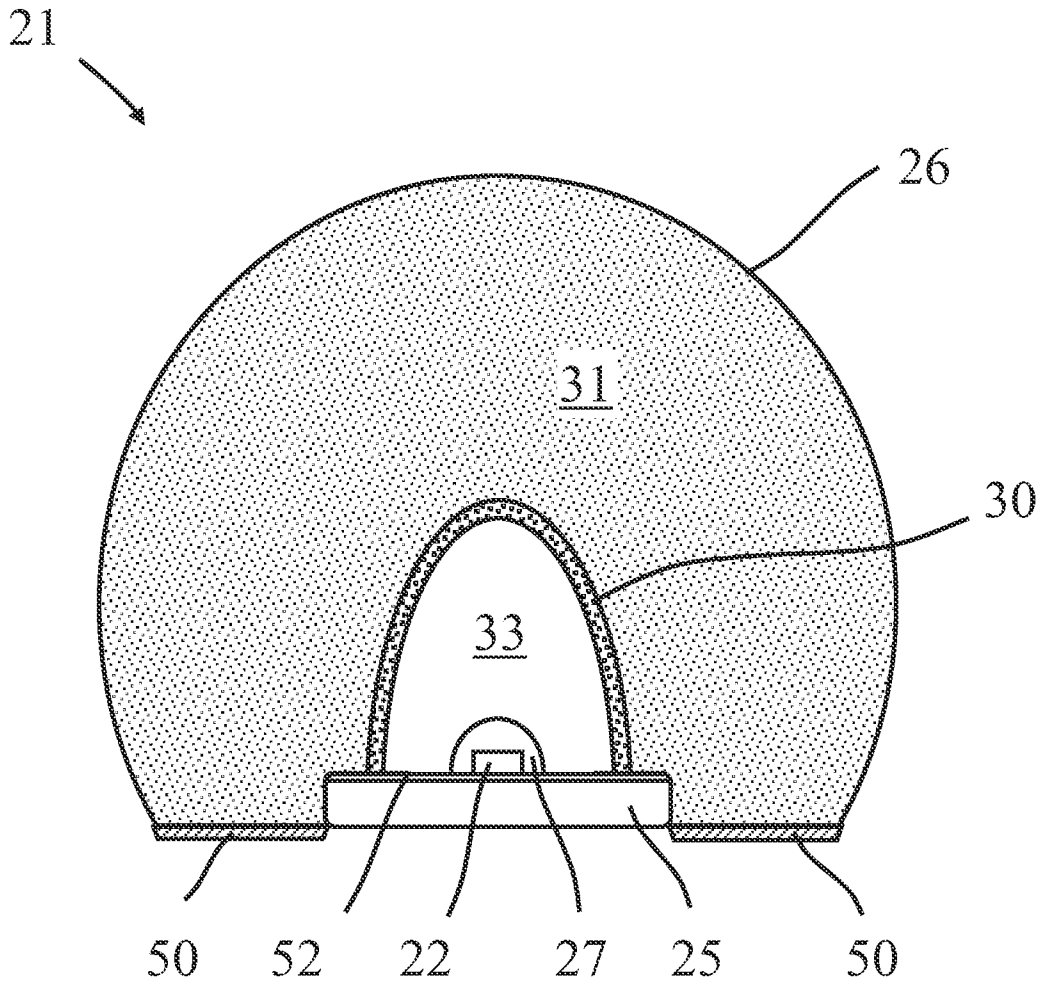


FIG. 17

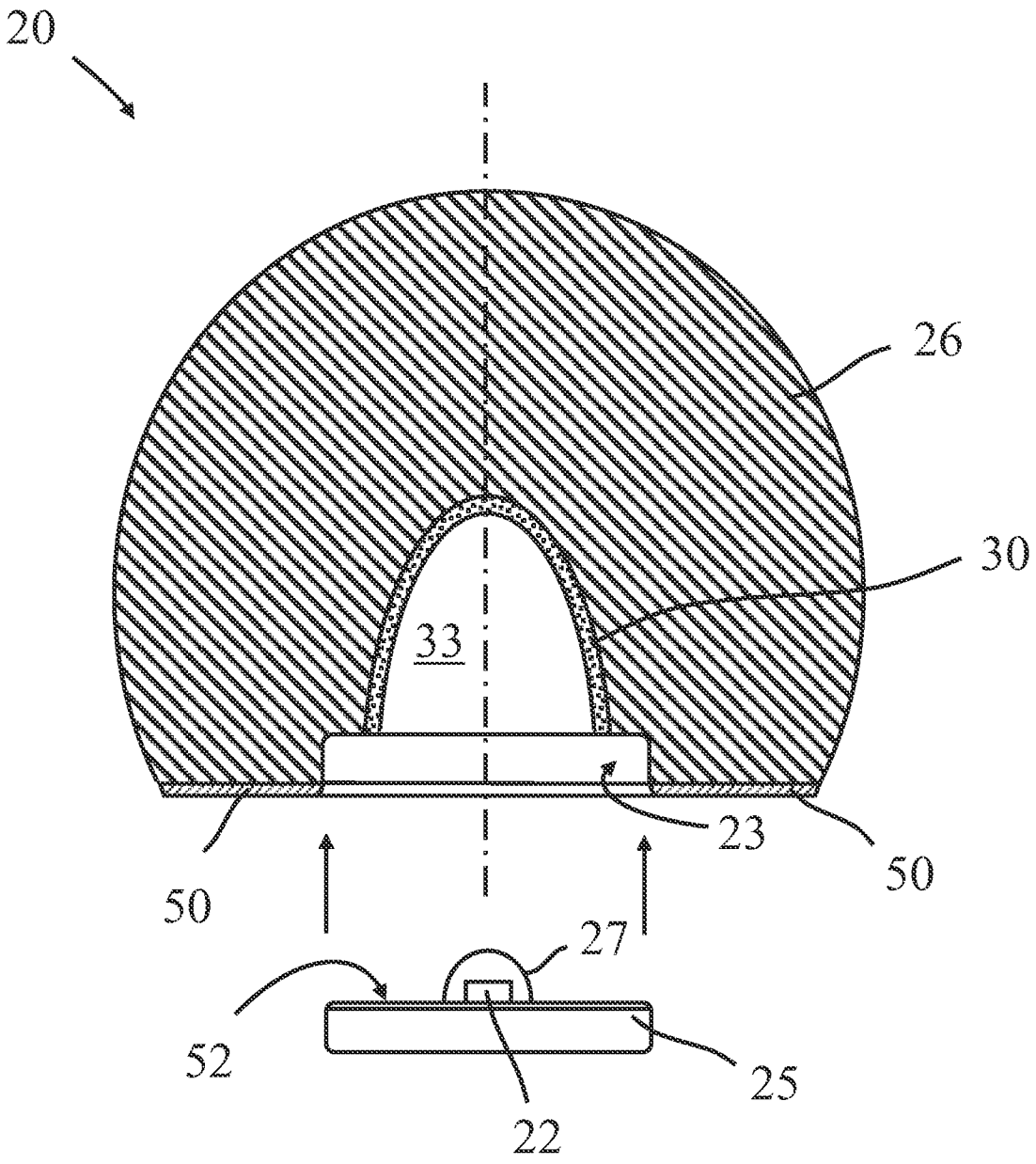


FIG. 18

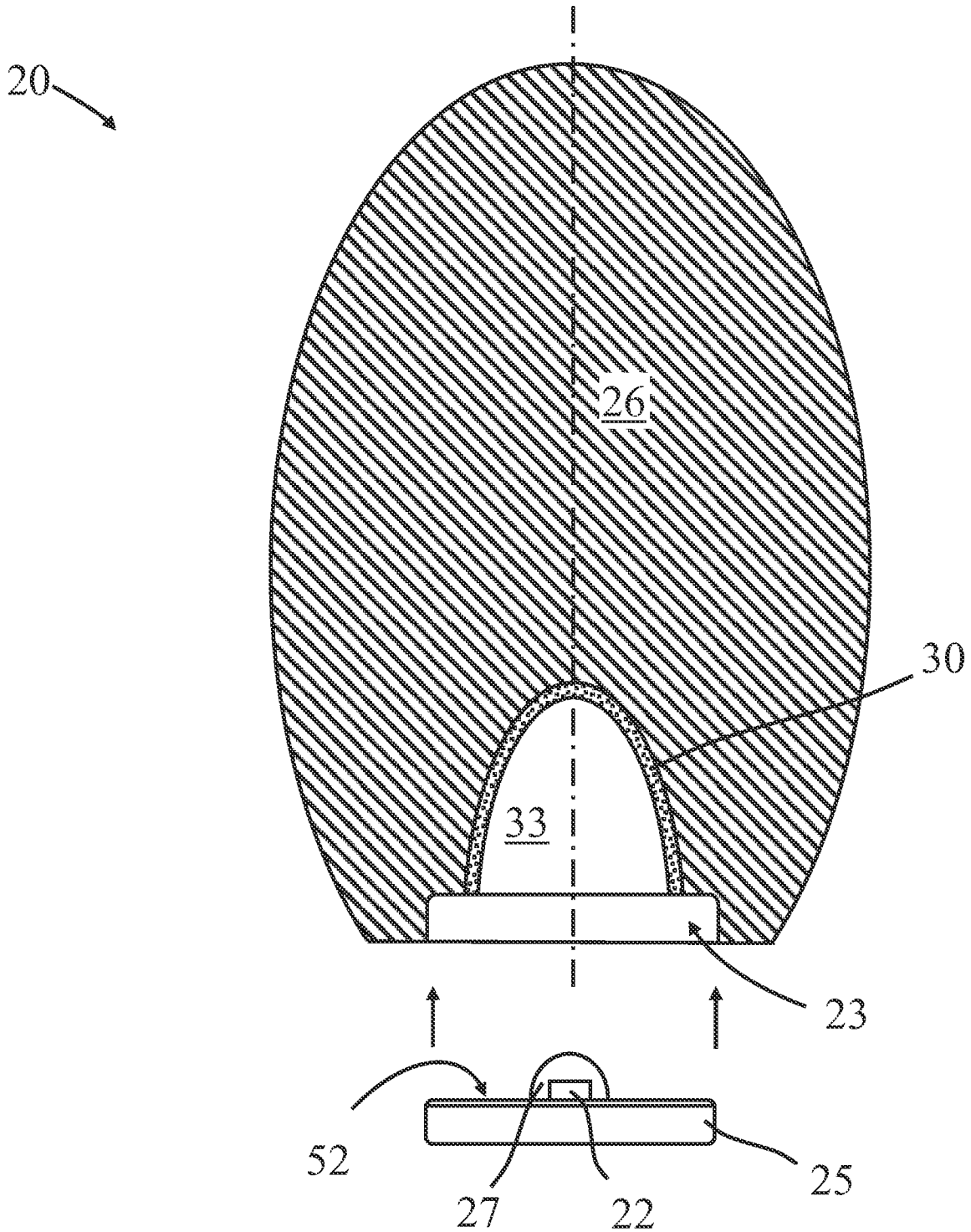


FIG. 19

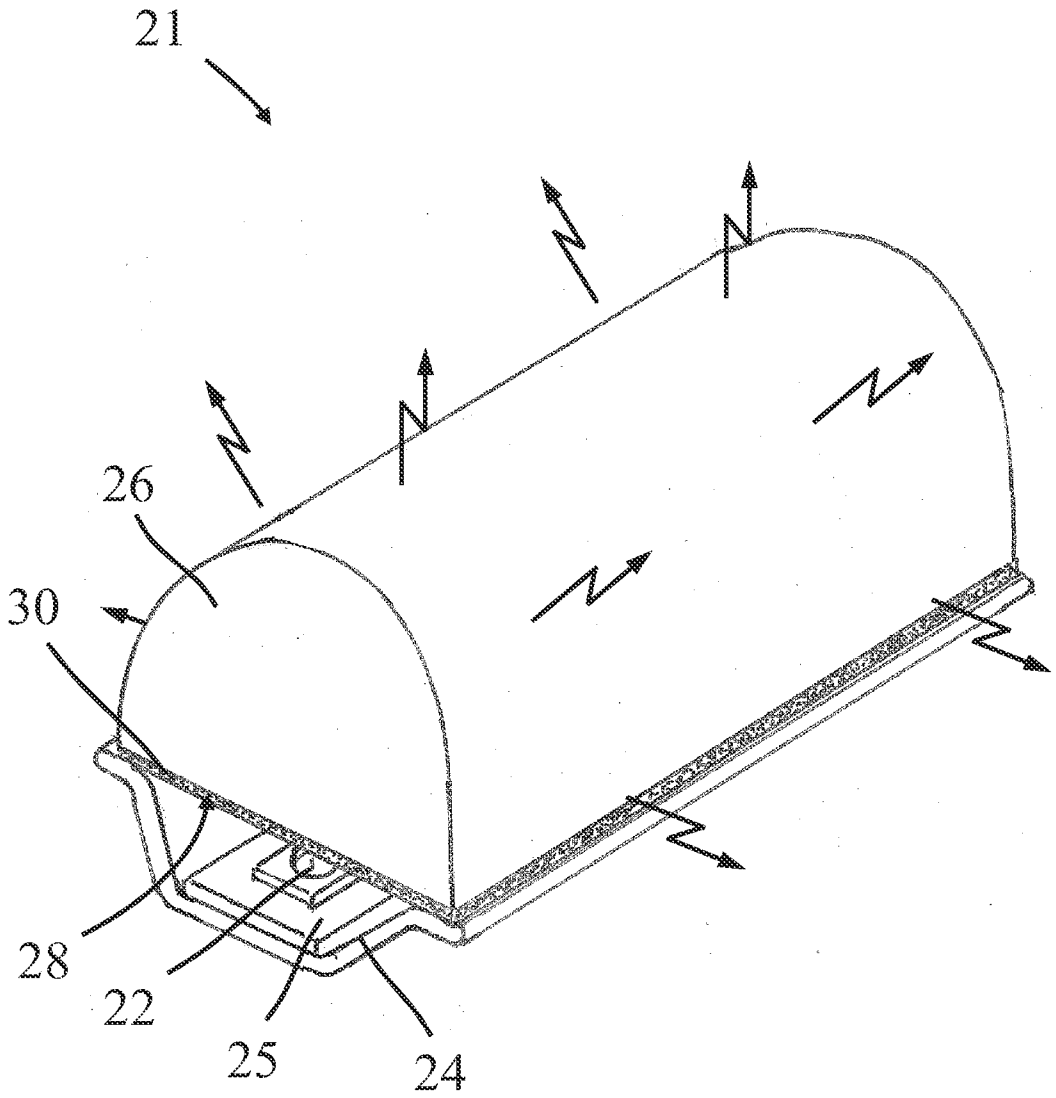


FIG. 20

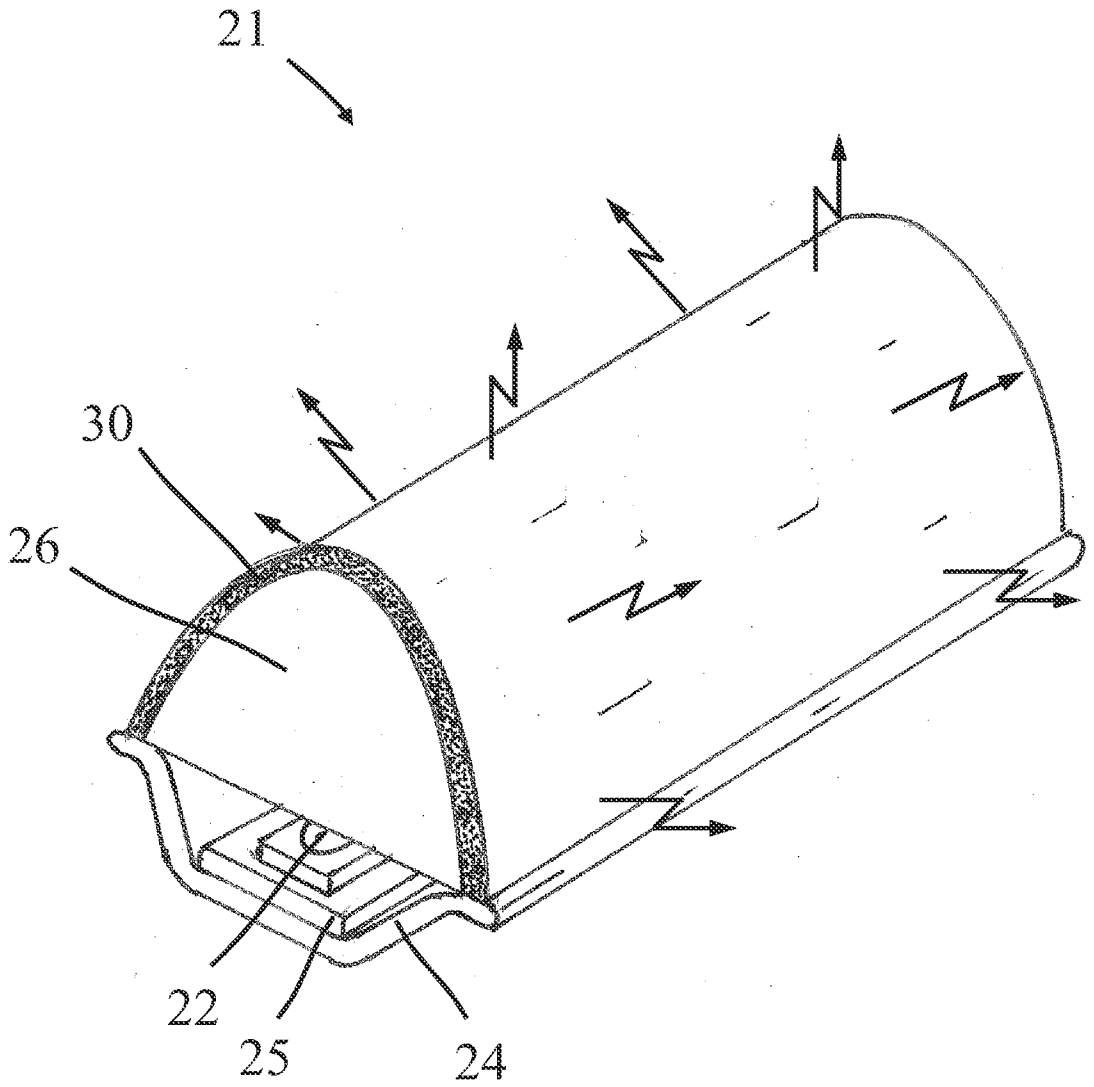


FIG. 21

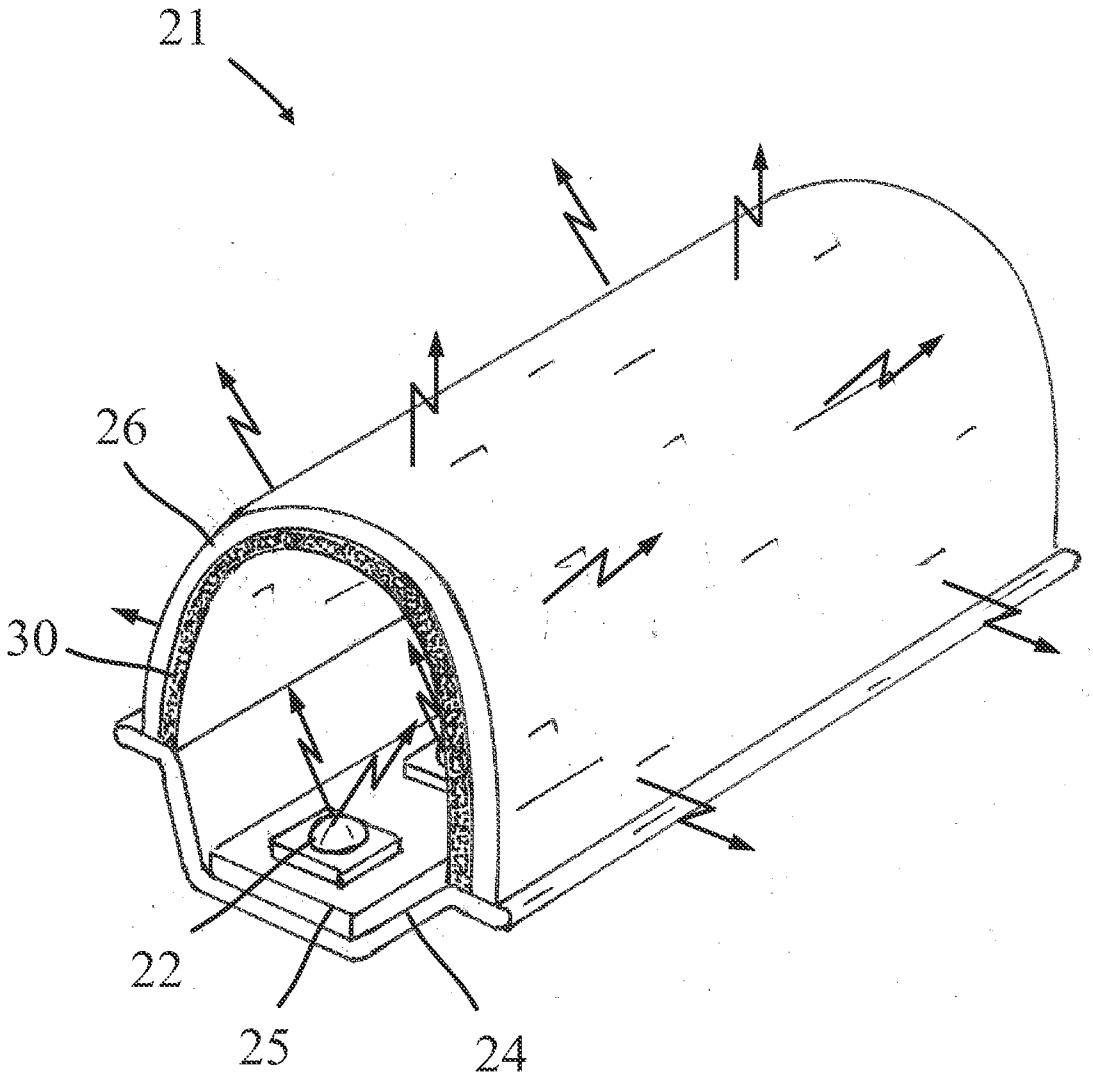


FIG. 22

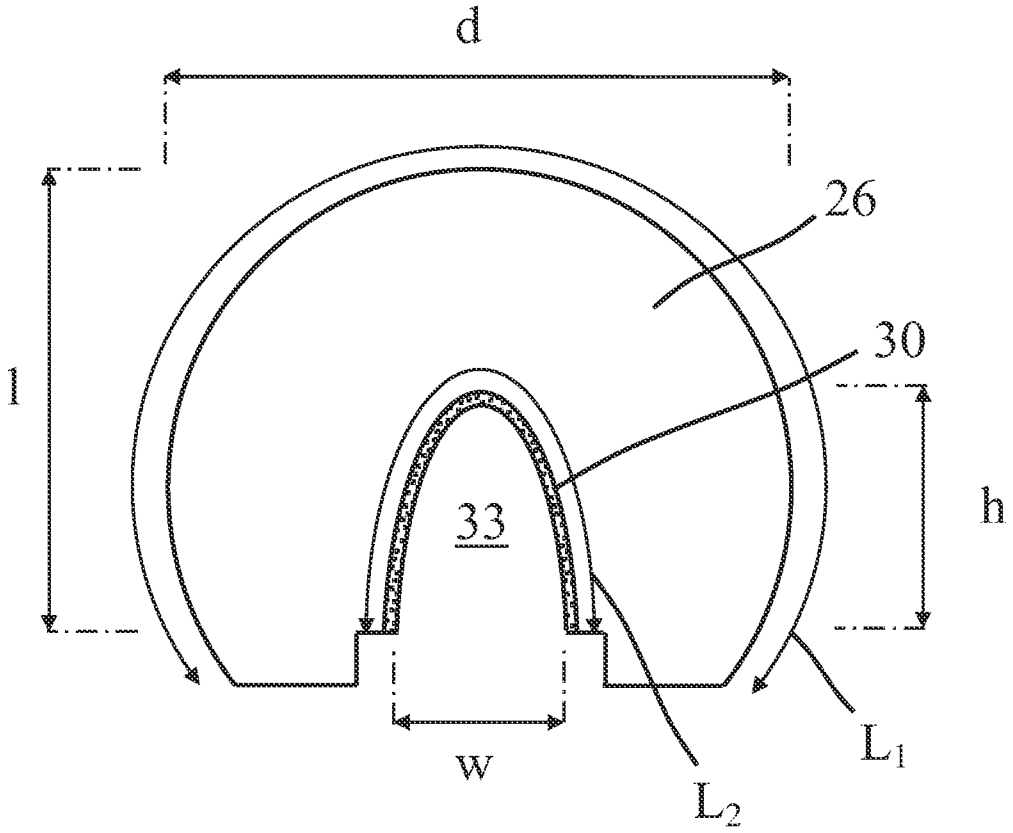


FIG. 23

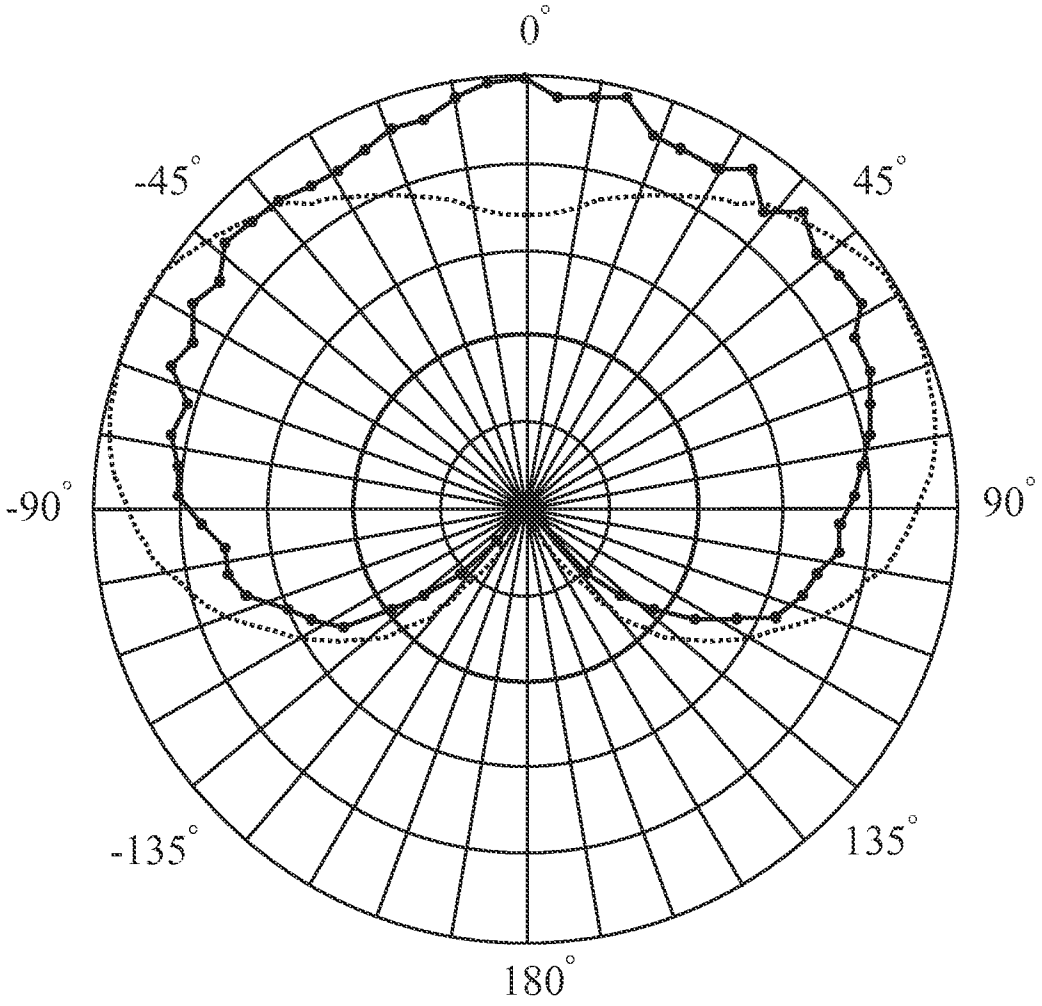


FIG. 24

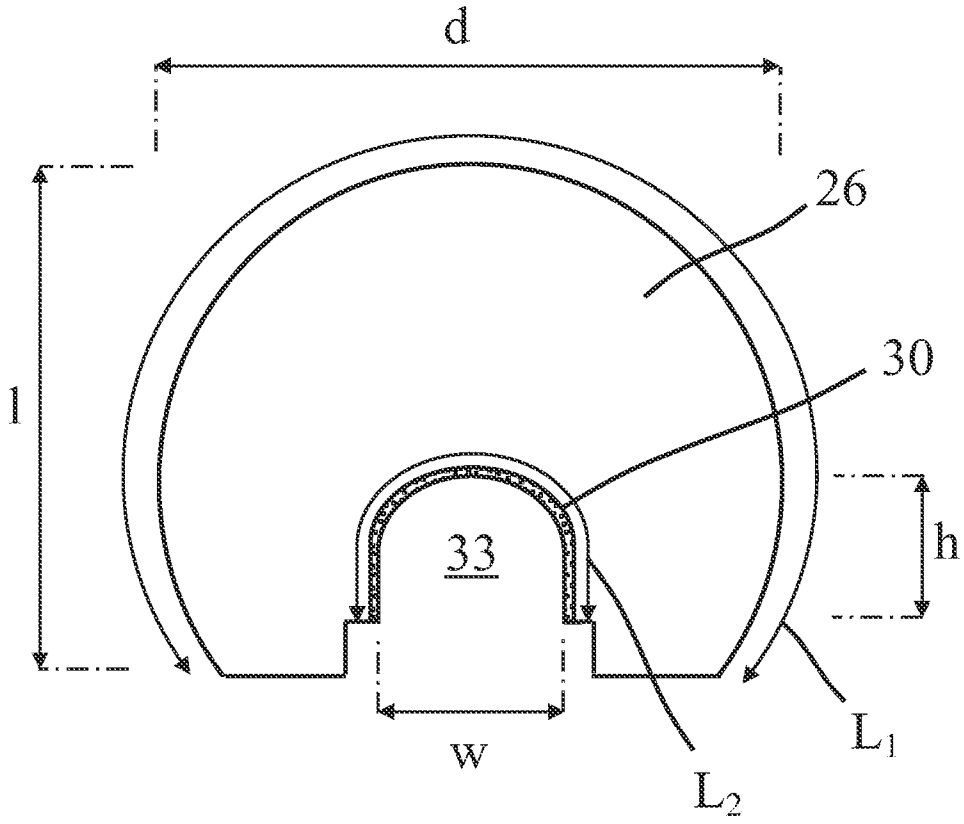


FIG. 25

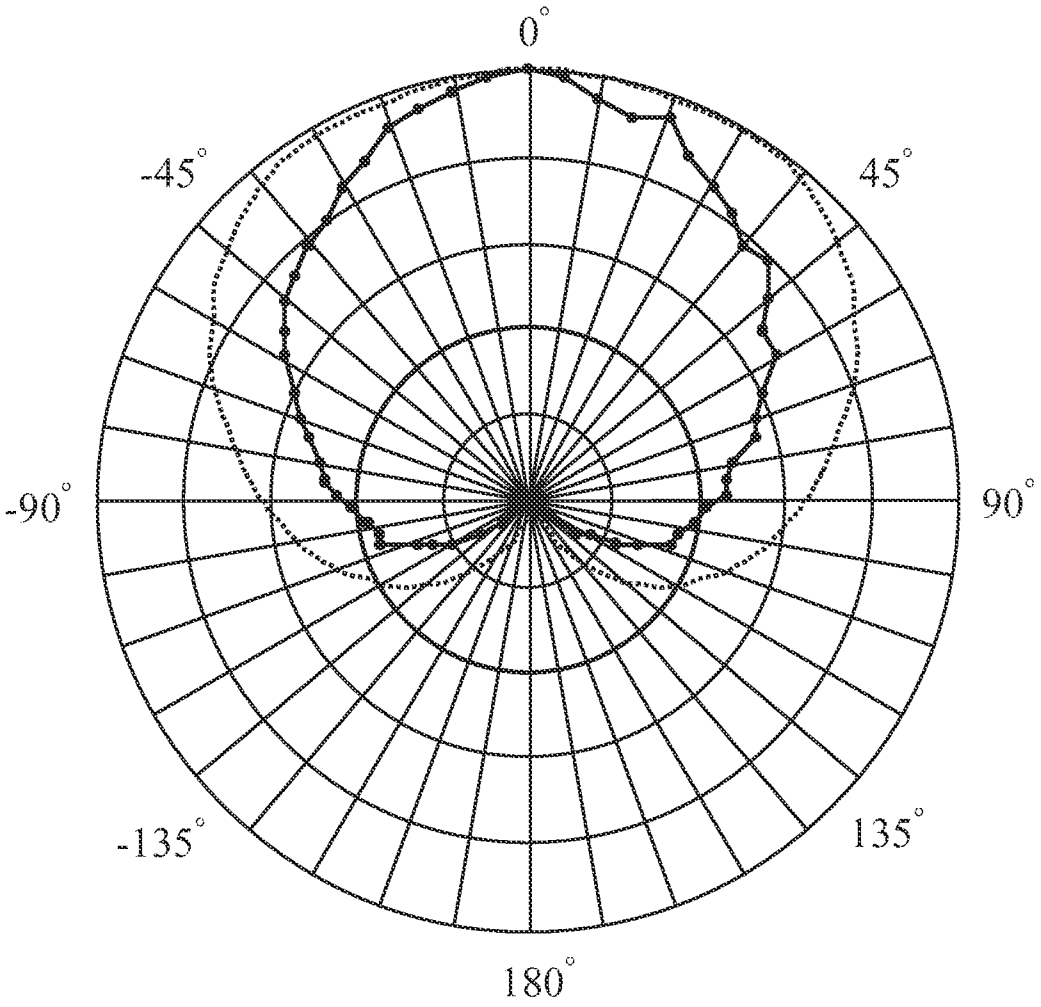


FIG. 26

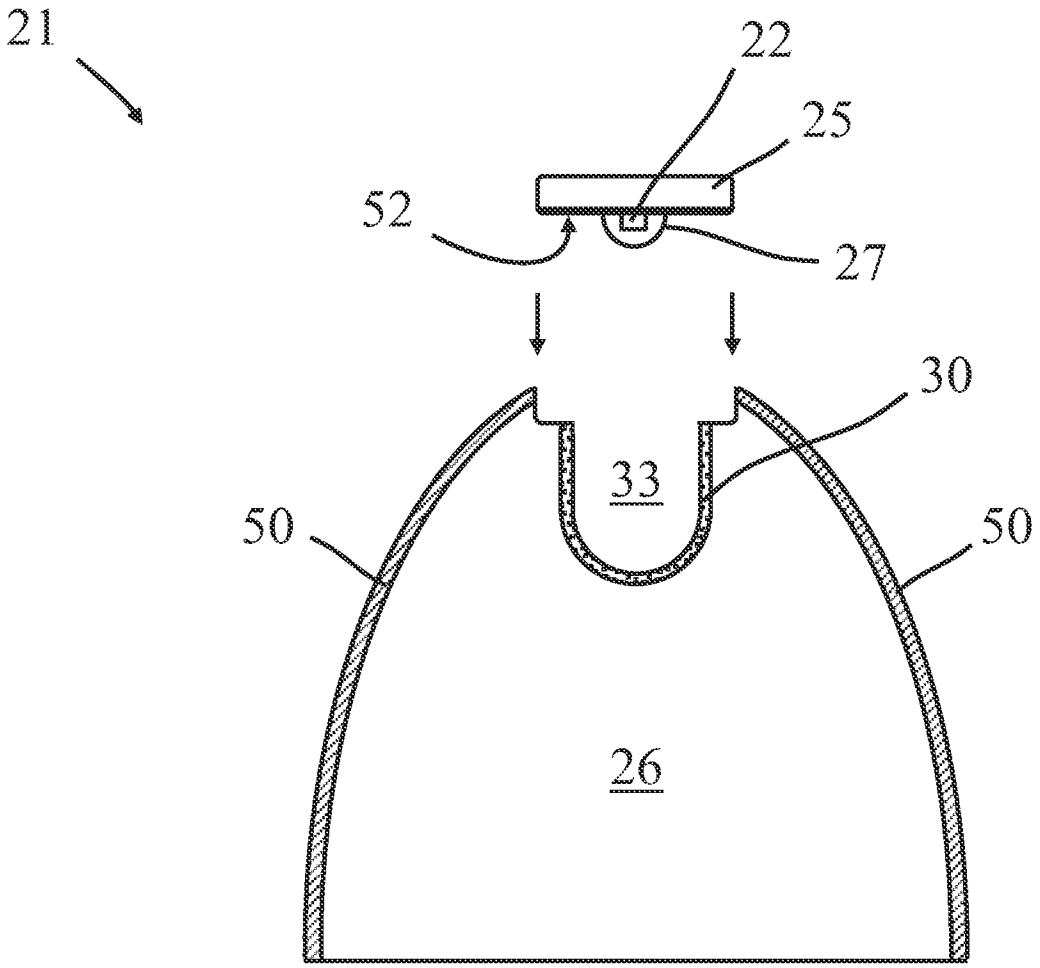


FIG. 27A

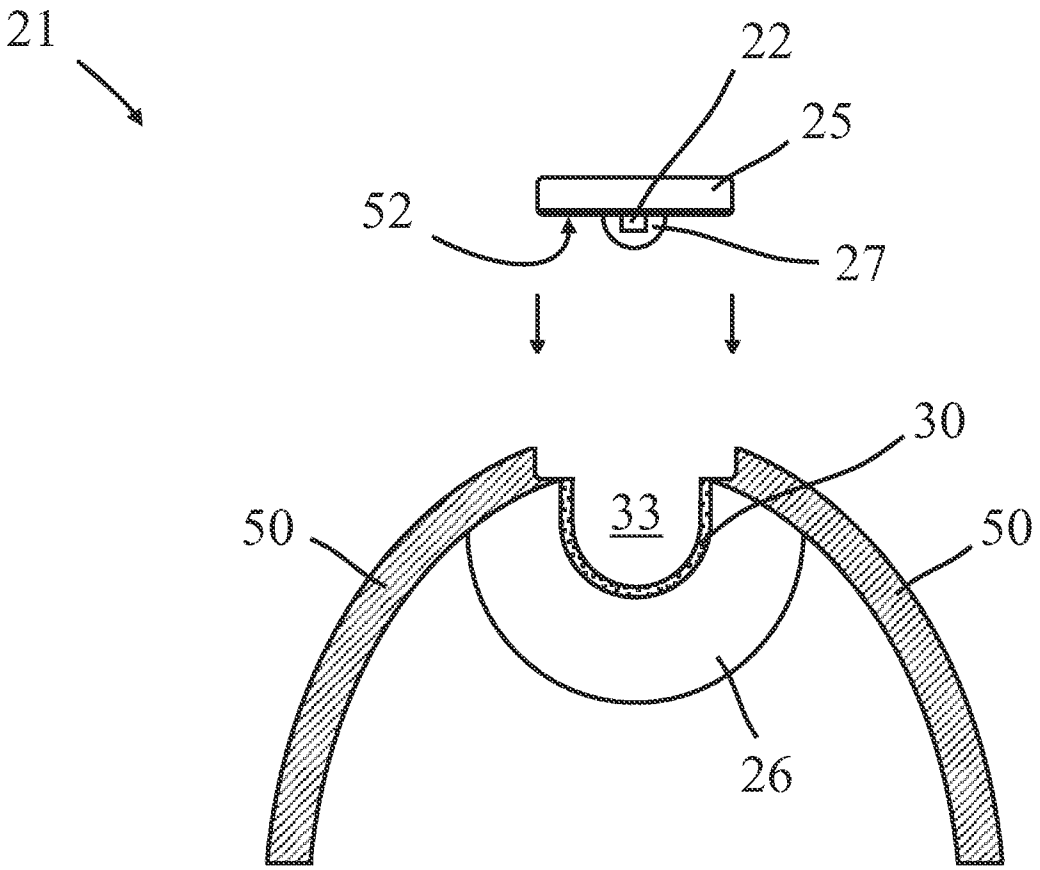


FIG. 27B

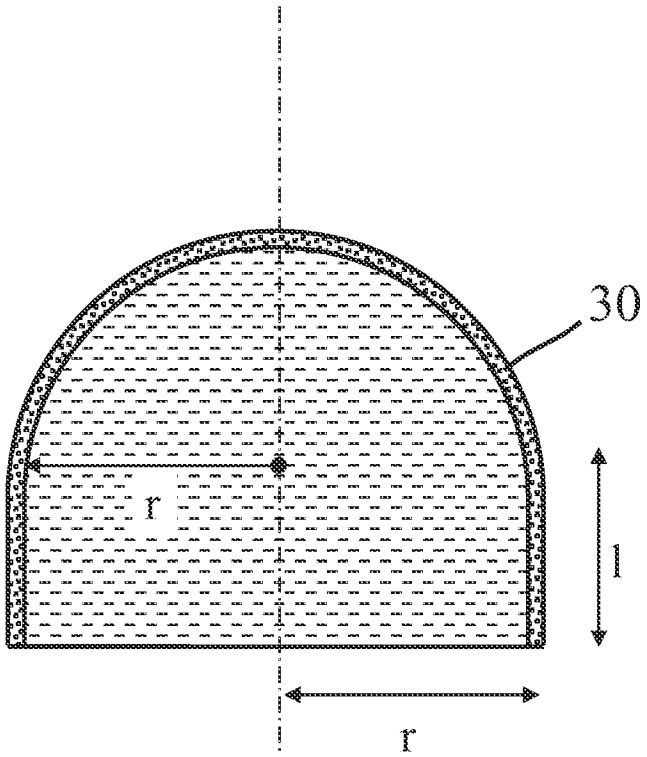


FIG. 28

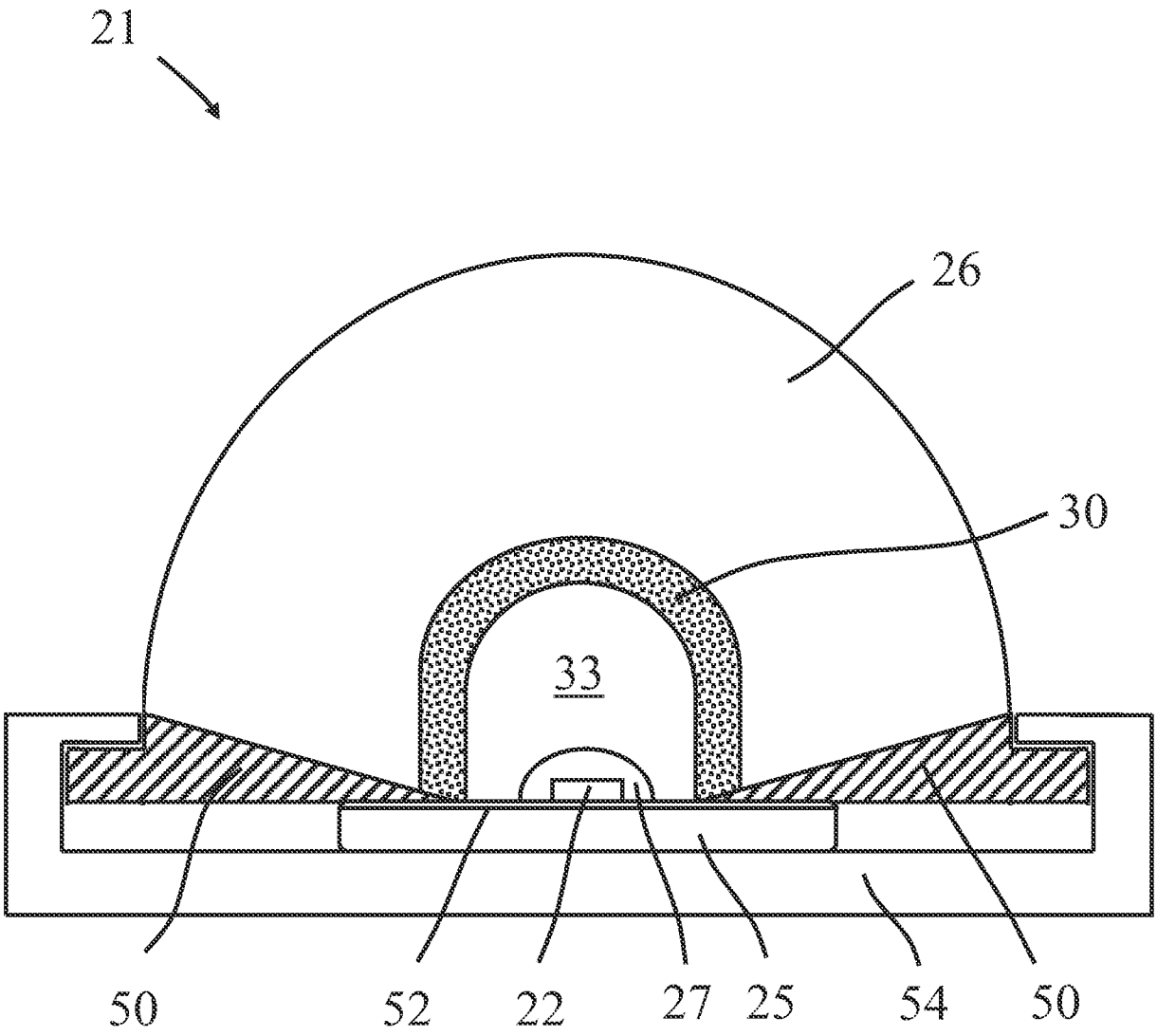


FIG. 29

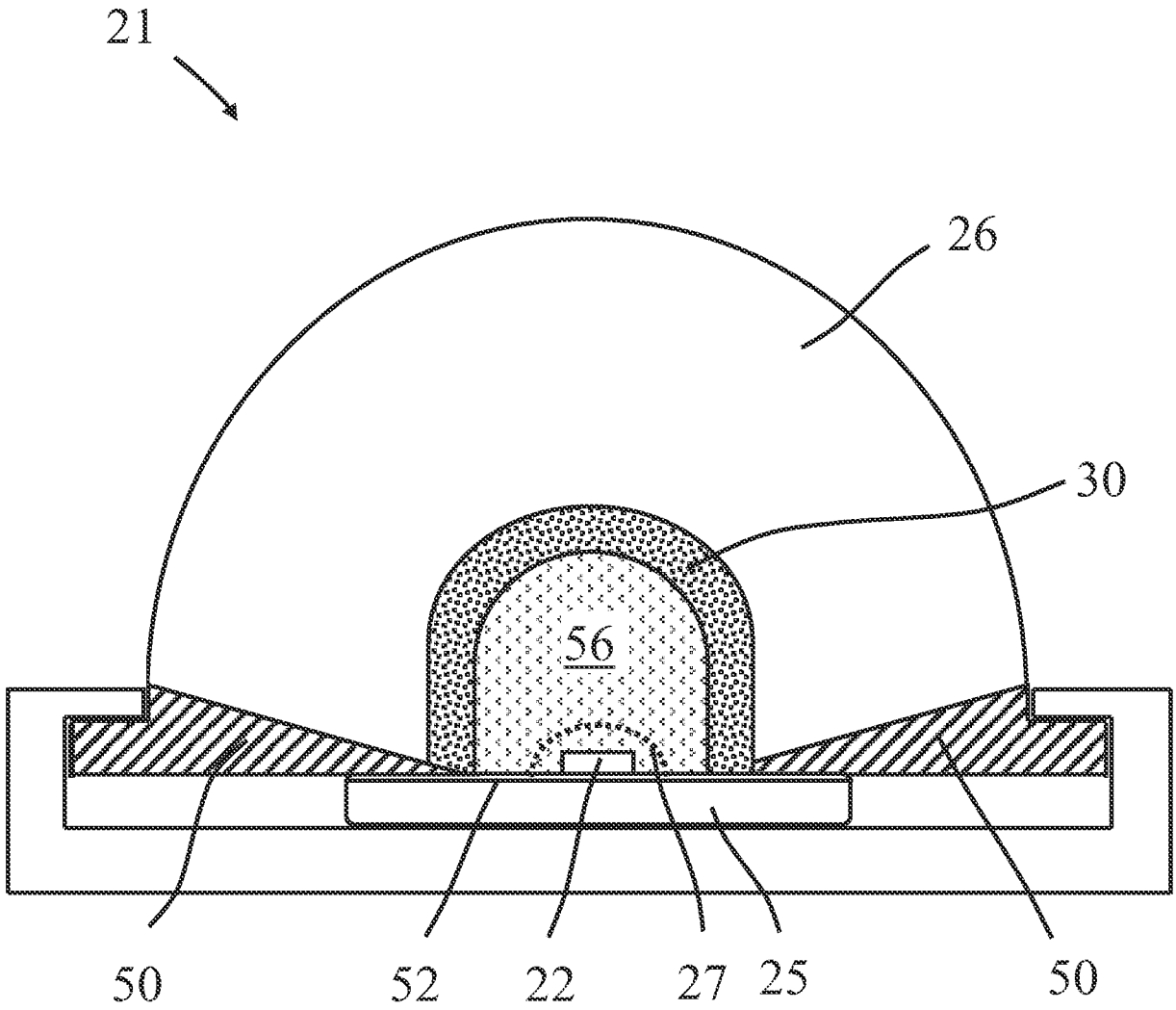


FIG. 30

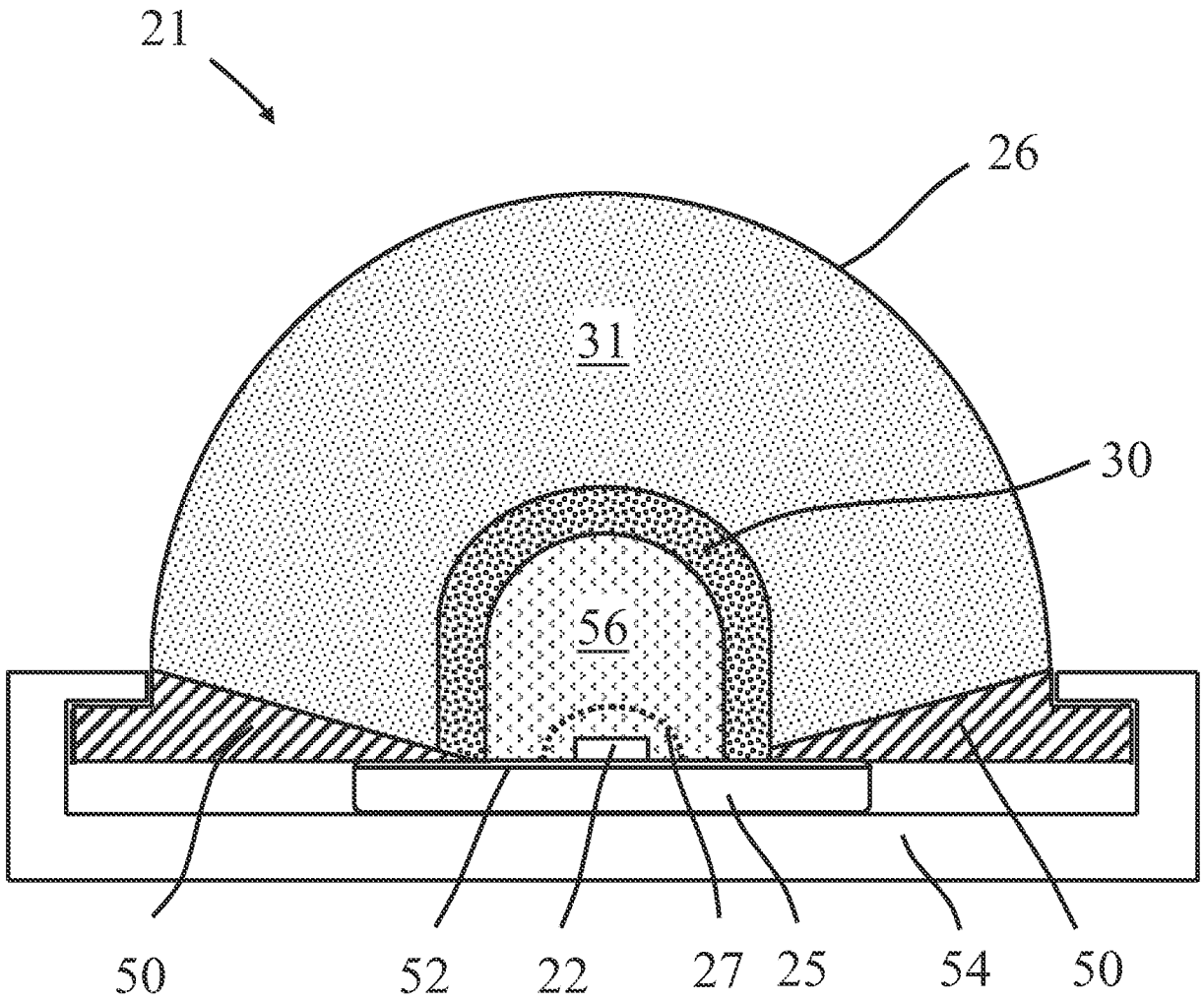


FIG. 31

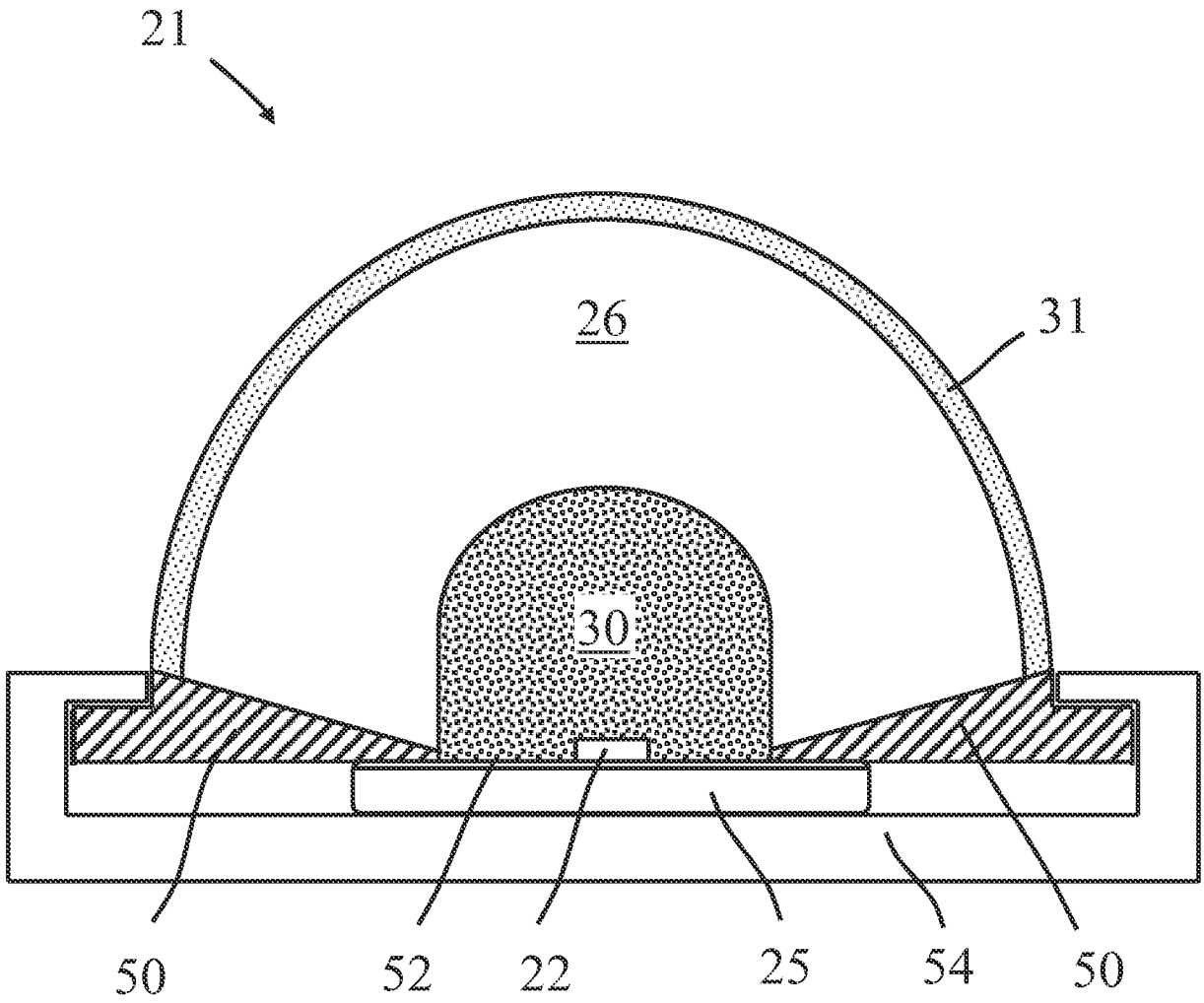


FIG. 32

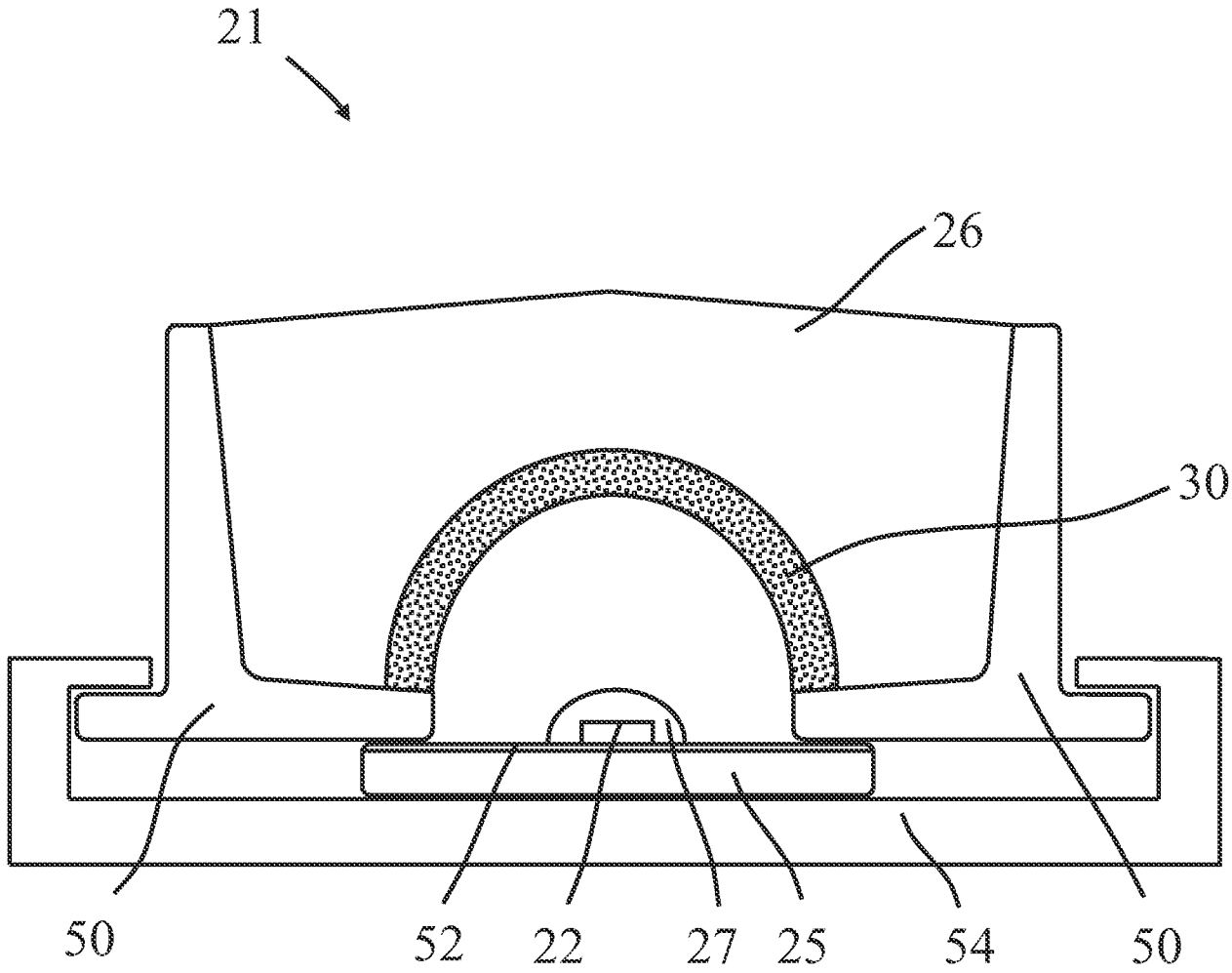


FIG. 33

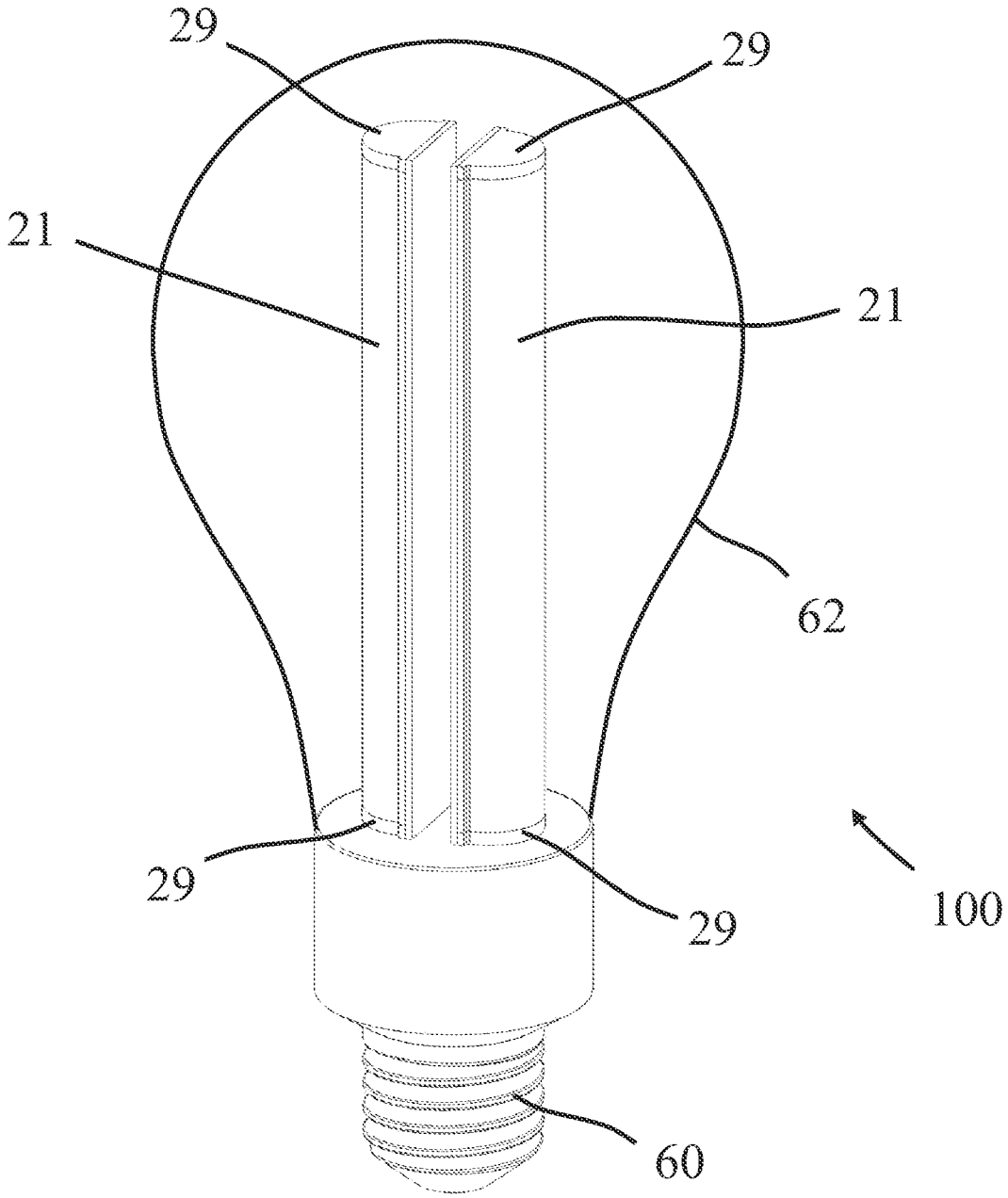


FIG. 34

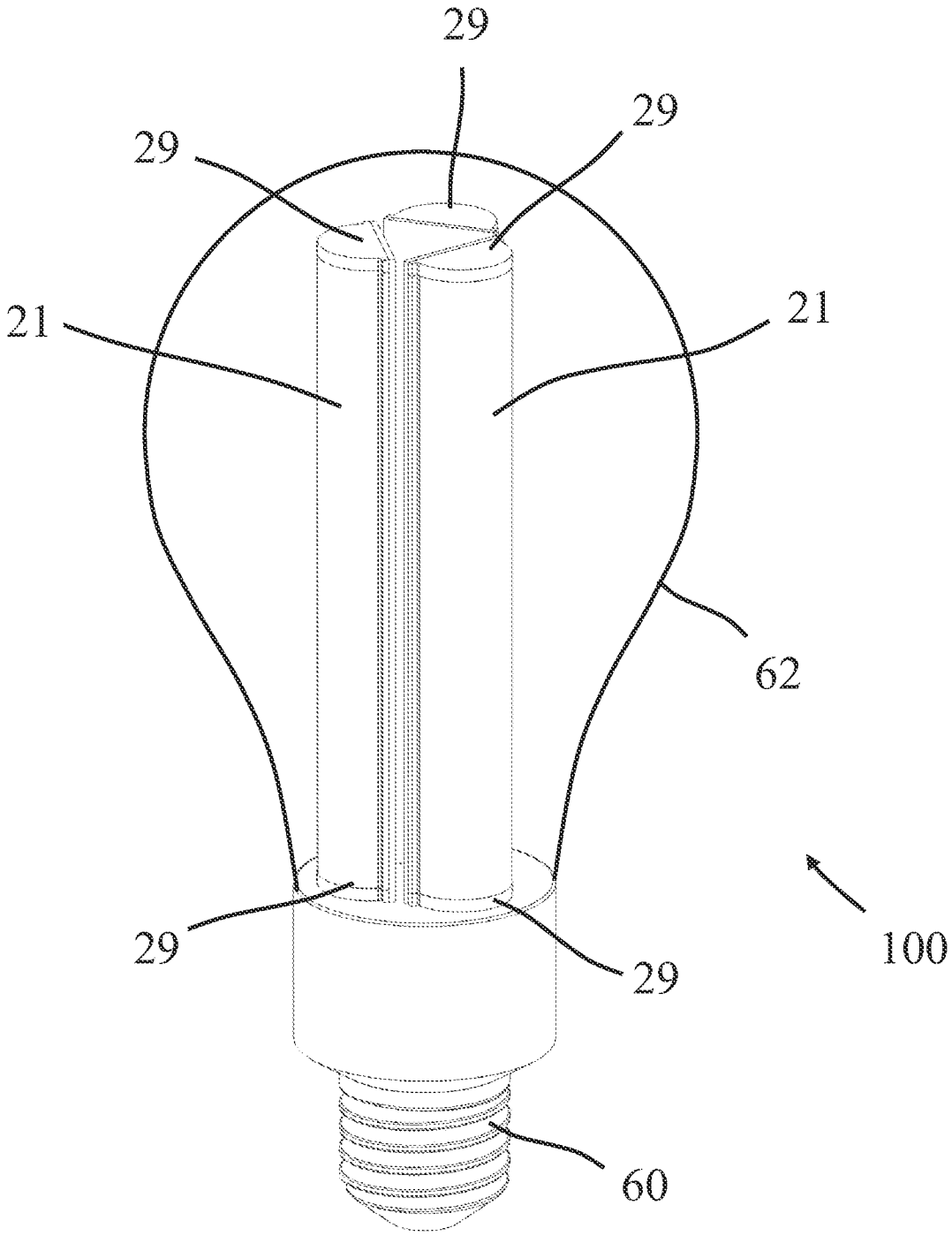


FIG. 35

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/048354

A. CLASSIFICATION OF SUBJECT MATTER

F21S 2/00(2006.01)i, F21V 5/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F21S 2/00; F21V 29/00; H01J 1/62; F21V 9/16; F21V 5/00; F21Y 101/02; H01J 9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: elongate lens, phosphor, solid-state light emitter, lamp, diffusing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005-0093430 A1 (JAMES IBBETSON et al.) 05 May 2005 See paragraphs [0005]-[0072]; and figures 1-18.	18-25
Y		1-17
Y	US 2011-0149548 A1 (HAITAO YANG et al.) 23 June 2011 See paragraphs [0039]-[0057]; and figures 2-12.	1-17
A	JP 2011-192793 A (NIIYAMA HEIJI) 29 September 2011 See paragraphs [0016]-[0045]; and figures 1-8.	1-25
A	US 2008-0062672 A1 (SIEW IT PENG et al.) 13 March 2008 See paragraphs [0008]-[0026]; and figures 1-5.	1-25
A	US 2009-0219713 A1 (DENNIS SIEMIET et al.) 03 September 2009 See paragraphs [0013]-[0032]; and figures 1-3.	1-25

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2013 (27.09.2013)	**27 September 2013 (27.09.2013)**

Name and mailing address of the ISA/KR
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Telephone No. +82-42-481-5560

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/048354

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005-0093430 A1	05/05/2005	CA 2517009 A1	10/09/2004
		CN 1777999 A	24/05/2006
		CN 1777999 B	26/05/2010
		EP 1597777 A2	23/11/2005
		EP 1597777 B1	24/04/2013
		EP 2262006 A2	15/12/2010
		EP 2262006 A3	21/03/2012
		JP 2006-519500 A	24/08/2006
		JP 2011-061230 A	24/03/2011
		JP 2013-093595 A	16/05/2013
		KR 10-2005-0113200 A	01/12/2005
		KR 10-2011-0137403 A	22/12/2011
		MY 142684 A	31/12/2010
		TW 201225339 A	16/06/2012
		WO 2004-077580 A2	10/09/2004
		WO 2004-077580 A3	10/03/2005
US 2011-0149548 A1	23/06/2011	None	
JP 2011-192793 A	29/09/2011	JP 4792531 B2	12/10/2011
US 2008-0062672 A1	13/03/2008	US 2005-0248271 A1	10/11/2005
		US 2008-0064287 A1	13/03/2008
		US 7315119 B2	01/01/2008
		US 7727041 B2	01/06/2010
		US 7733021 B2	08/06/2010
US 2009-0219713 A1	03/09/2009	US 7815338 B2	19/10/2010
		WO 2009-111098 A2	11/09/2009
		WO 2009-111098 A3	29/10/2009