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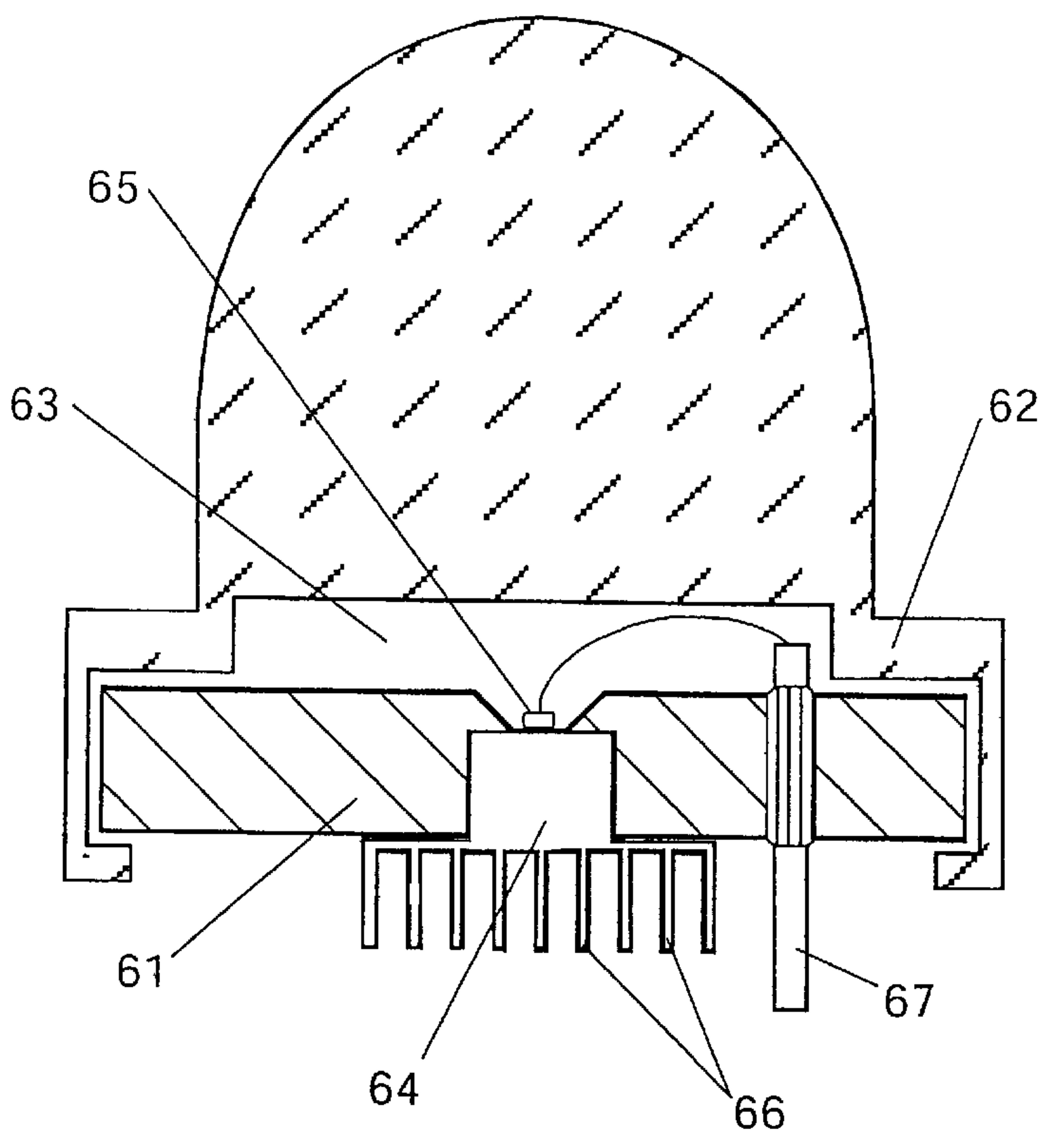
(54) Title: LIGHT EMITTING DIODE WITH INTEGRAL HEAT DISSIPATION MEANS



(57) Abrégé/Abstract:
Light emitting diodes are arranged with a package having an integral heat dissipation mechanism. A material having a high thermal conductivity is well coupled to a semiconductor chip providing a path for heat to be drawn away from the chip which is susceptible to overheat. In certain versions, heat dissipation mechanisms are also provided with a second terminal end which further facilitates removal of heat from the device package. The highly conductive path is formed integrally with other LED package components and cooperates therewith to provide additional support for LED functionality.

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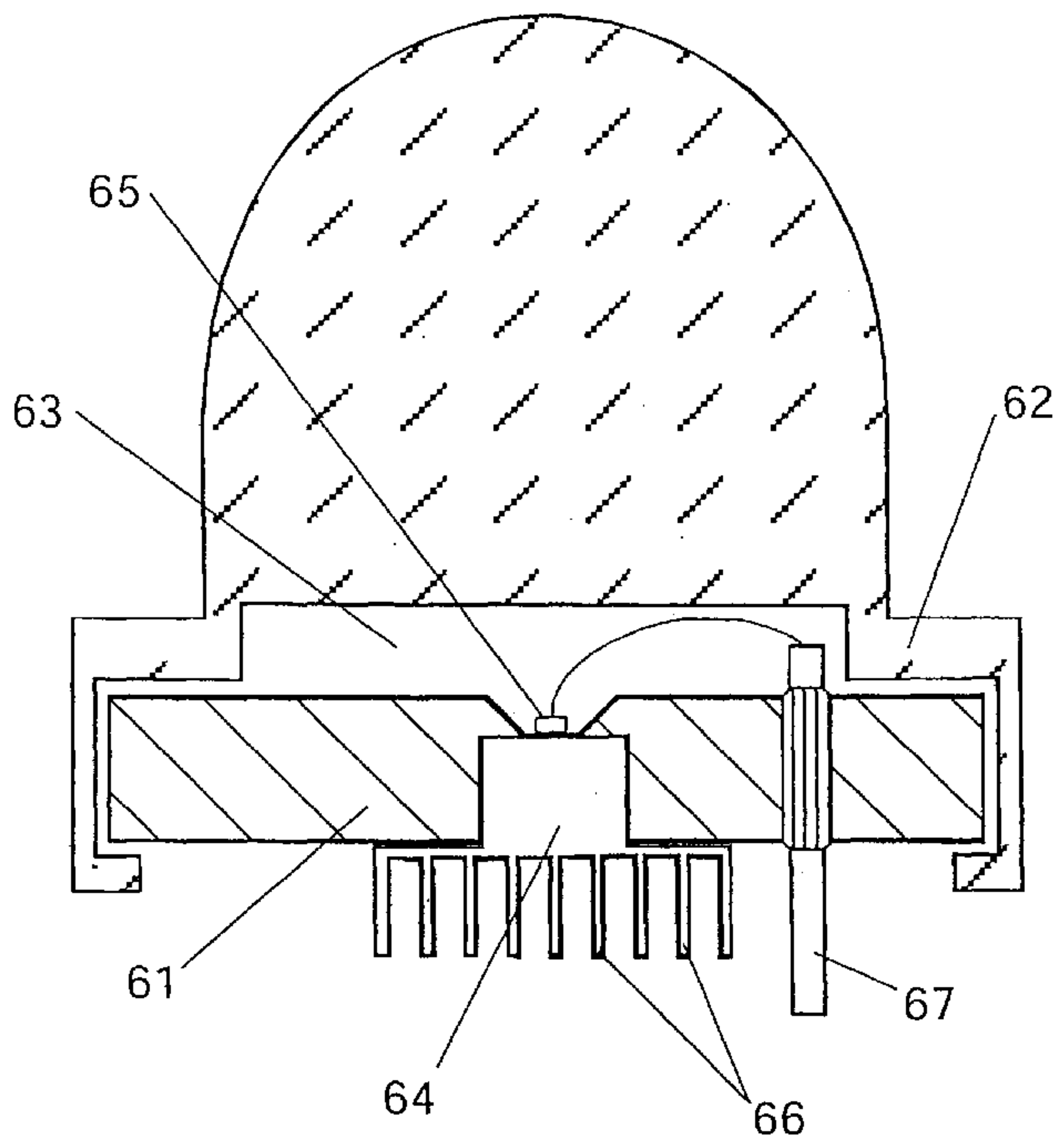
(54) **Title:** LIGHT EMITTING DIODE WITH INTEGRAL HEAT DISSIPATION MEANS



(57) **Abstract:** Light emitting diodes are arranged with a package having an integral heat dissipation mechanism. A material having a high thermal conductivity is well coupled to a semiconductor chip providing a path for heat to be drawn away from the chip which is susceptible to overheat. In certain versions, heat dissipation mechanisms are also provided with a second terminal end which further facilitates removal of heat from the device package. The highly conductive path is formed integrally with other LED package components and cooperates therewith to provide additional support for LED functionality.

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Light Emitting Diode with Integral Heat Dissipation Means

The following invention disclosure is generally concerned with the art of semiconductor electronics packaging and in particular with forming a thermal conductive path integrally with device packaging.

Light emitting diodes are presently made in huge quantities. Generally speaking, they are very standard in their construct and form. As such, optical engineers enjoy buying them in bulk and configuring devices and systems from these standardized packages. However, limitations associated with standard designs prevent use of LEDs in some high performance arrangements. For example, in high brightness applications, several LEDs may be ganged together to produce a bright light. This is an inferior solution and one not useful in certain systems. A preferred solution may be to drive the LED at a high current to produce more light. However, this is not possible because standard LED packages trap heat and self destruct when too much current is applied. An LED package generally is comprised of a hard polycarbonate material which completely surrounds the semiconductor. When excess heat is trapped, the polycarbonate expands and tends to break. Further, the heat tends to cause junction breakdown in the semiconductor as well. Heat is a light emitting diode's worst enemy.

Thus, skilled practitioners of the art have tried to couple heat away from LEDs to improve their performance. In particular, heat sink arrangements have been introduced to carry heat away from the diodes. These heat sinks are sometimes provided with heat coupling suitable for standard LED packages. In example, the polycarbonate material may be in intimate contact with a heat sink. While these arrangements serve their purpose to some extent, they are limited because common LED packages are not arranged to cooperate with heat removal mechanisms.

While considerable efforts in the material sciences are made to improve the efficiency of semiconductor diode junctions used in LEDs, these improvements come slowly and with fractional gains at large expense. The chemistry and physics of diode junctions changes slowly in time. Most notably in recent developments, high brightness blue colored chips are becoming more readily available. Diodes which emit blue colored light are difficult to produce because blue light is comprised of higher energy photons which are not easily produced in normal band gap junctions. The 'gap' between bands of allowed energies must be quite large to form a high energy blue photon. To form a large gap, specialized materials and dopants are used in the semiconductor growth and doping. Although these materials will produce blue photons, they do so with less efficiency than materials used to produce other colors. More of the input electrical energy is converted to heat than to blue light. This is problematic as the heat is lost as waste. It is desirable that one should have the highest possible quantum efficiency to reduce this loss.

Improving the quantum efficiency of the junction is not the only way to realize high output from a diode. Where waste is not of significant consequence, one might simply increase the current to produce a greater flux of light output. However, this approach is left with the problem of heat accumulation. Heat produced at the diode junction tends to become excessive and damage the diode as well as the package components. LEDs are typically encased in a hard polycarbonate material which is susceptible to cracking as it becomes brittle in heat.

A diode will roughly produce light in proportion to the amount of current which is forced through its junction. As one increases the applied current, the junction produces more light. This is true, with a very real limitation. As the current is increased, the heat produced at the junction is also increased. That heat, when it becomes excessive, tends to destroy the diode. The diode will self destruct and cease to function as the heat damages the physical structure of the semiconductor. Accordingly, common diodes are rated to operate normally at about 20 milliamps. They will continue to produce greater light outputs beyond 20 milliamps with a lifetime penalty. After a significant current is applied beyond twenty milliamps, the device will break and become forever damaged. A primary reason the device breaks is due to heat in the junction. If heat can be drawn away from the junction at a rate faster than it is produced there, then damage to the junction will not occur. Thus, one can increase the current without limit so long as the corresponding heat produced as a result can be drawn from the junction at a rate greater than which it is produced.

A common LED is made with metallic leads fashioned as two electrical conductors, i.e. an anode and a cathode lead to provide an electrical contact with the semiconductor materials. An assembly is arranged and a polycarbonate bonding material is applied to seal elements together whereby the polycarbonate totally encases the diode, the electrodes among other elements. Typically, the metallic leads also provide mechanical and optical services in the overall structure as well. As the metal leads are rigid and strong, LEDs are generally mounted, for example into a circuit board, via their electrical leads which protrude from the bottom of the polycarbonate cover which typically includes a lens in its top surface.

The two electrodes provide an electrical path to the semiconductor device which is best set into a mirror or reflective conic section element. The reflector is generally formed into the metallic lead. A thin wire may be connected from a first electrode to a top surface of the diode. This assembly and arrangement is placed into a mold of polycarbonate material in a liquid state before being polymerized or subject to other curing. The cover may be formed as a very hard plastic having a lens thereon its top surface. When current is forced through the electrodes, light is produced in the junction and reflects from the conic reflector and passes to the lens in the plastic cover. Some of the heat generated at the diode passes down the electrical lead as it is metal and an excellent thermal conductor. Although some heat passes to the opposing lead via the thin wire, this thermal path is limited because the gauge of the wire is generally quite small. Some heat also passes via the polycarbonate cover to the surrounding atmosphere. This is also severely limited because polycarbonate materials do not conduct heat efficiently. When current is increased to produce more light, the device can not draw heat from the junction at a rate sufficient to keep the operating temperature below a damage threshold. Thus, the device will overheat and die. An improved thermal dissipation mechanism would allow a greater quantity of heat to be removed from the device and thus allow a higher current and brighter device.

Inventor Flannagan teaches in US patent 4,394,600 a matrix arrangement of light emitting diodes with a common heat carrying plane with interesting thermal properties. Similarly, Temple et al, present their inventions as US patent 4,905,075 and suggest a semiconductor package formed in view of heating considerations. Itoh et al also present LED arrays with thermal conductor elements in US 5,113,232. US patent 5,311,060 also teaches of a heat sink arrangement incorporated with a semiconductor package.

Hochstein presents LED arrays with special thermal configurations in his US patents numbered 5,785,418 and 6,045,240. Sheridan et al teach a pad including a heat sink and thermal insulation area which relates to electronic devices. In disclosures entitled "Laser Diode Package with Heat Sink" and "Process for Manufacturing a Laser Diode Having a Heat Sink" Marshall et al show use of well designed semiconductor packages to improve heat problems. In addition, the same inventors include US patent 5,985,684 as a separate invention. Stephens et al teach similar special arrangements in both US patents 5,913,108 and 6,310,900. These inventors, among others, recognize the benefits of removing heat in a semiconductor device to improve performance.

While the systems and inventions of the art are designed to achieve particular goals and objectives, some of those being no less than remarkable, these inventions have limitations which prevent their use in new ways now possible. These inventions of the art are not used and cannot be used to realize the advantages and objectives of the present invention.

Comes now, Abromov, Vladimir; Agafonov, Dimitry; Shishov, Alexander; and Scherbakov, Nikolai with inventions of light emitting diodes including devices having specialized means of drawing heat away from critical regions. It is a primary function of these devices to provide high intens ity outputs while preserving lifetime. It is a contrast to prior art methods and devices that these systems do not suffer from the normal problems associated with over- heating when being driven at high current levels. A fundamental difference between devices of these inventions and those of the art can be found when considering its special construction relating to a package with an integrated heat conductive path. More particularly, an element of high thermal conductivity, a 'thermal conductor' is integrated as part of an LED package design. The thermal conductor is arranged to provide excellent heat coupling directly with the semiconductor chip; in some cases providing both electrical and thermal contact. The thermal conductor is also fashioned whereby heat drawn from the semiconductor is further passed into a heat sink system. Thermal conductors are arranged to cooperate with the entire LED package and components thereof. For example, a thermal conductor may serve as an electrical conductor as well. A thermal conductor may also be arranged as an optical reflective element.

It is a primary object of these inventions to provide light emitting diodes with improved packaging.

It is an object of these inventions to provide light emitting diodes with improved packaging for high current high brightness operation. It is a further object to provide a thermal conductive path leading away from a semiconductor diode junction.

A better understanding can be had with reference to detailed description of preferred embodiments and with reference to appended drawings. Embodiments presented are particular ways to realize these inventions and are not inclusive of all ways possible. Therefore, there may exist embodiments that do not deviate from the spirit and scope of this disclosure as set forth by the claims, but do not appear here as specific examples. It will be appreciated that a great plurality of alternative versions are possible.

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims and drawings where:

Figure 1 is a cross sectional drawing of a first version;

Figure 2 is an expanded view of Figure 1 with added detail;

Figure 3 is a similar cross sectional drawing of another version;

Figure 4 illustrates in cross section an LED package arranged with a special thermal conductor;

Figure 5 shows a version of a thermal conductor with an optical element formed therein;

Figure 6 shows a thermal conductor having a special termination end.

In accordance with each of the preferred embodiments of these invention, there is provided high current, high brightness light emitting diodes having an integral thermal conduction path. It will be appreciated that each of the embodiments described include unique apparatus and that the apparatus of one preferred embodiment may be different than the apparatus of another embodiment.

For purposes of this disclosure, an LED sometimes includes a light emitting semiconductor diode and the package into which it is arranged. A 'support package' may include electrical elements, optical elements, and thermal elements among others. Thus, the packaging of a semiconductor chip to produce a light source is considered part of the entire device sometimes referred to as an 'LED'.

Accordingly, an LED is more precisely a device comprised of two major systems. LEDs are made of a semiconductor diode element in cooperation with a package system. The ‘diode’ is a special semiconductor device of two material types arranged to form a special junction region having light emitting properties. The 'package' contains electrical leads, mounting support, optical lensing, and thermal conductors. Altho ugh, the LED acronym only suggests the 'diode', it is affirmed here that 'LED' also is intended to include the packaging for purposes of this disclosure. In devices of these inventions, mechanisms are provided to draw he at away from the diode junction at an exceptional rate. Although such means can be provided in a great plurality of ways, one will appreciate certain features unique to the arrangements first taught here.

Preferred versions of these inventions have a thermal conductor element included integrally with the device package. In particular, an element having rotational symmetry or axial symmetry forms a platform onto which a semiconductor or semiconductors may be placed into intimate thermal contact. Further, the thermal conductor is integrated with a base element which supports other system components including a cover and electrical leads for example. Figure 1 illustrates some major components of an LED of these inventions including a thermal conductor. A hard plastic cover element 1 may be molded into a special shape including a lens at its upper surface. A base member 2 forms support upon which the cover and other elements are coupled. In particular, the cover may be pushed tightly onto the base to form an enclosed cavity between the base and an interior surface of the cover as it is placed onto the base member. The base may further support passage of electrical conductor or 'lead' 3 by way of holes bored there through.

Sometimes these holes in the base substrate are referred to as 'vias'. To prevent electrical conduction from the lead to the base which may be metallic, a special insulator material lines the hole in the base. This insulator 4 may be formed of a glass, ceramic or rubber material for example. An important element of the package includes a thermal conductor 5. This thermal conductor is intimately and thermally connected directly to the semiconductor chip 6 whereby heat is encouraged to easily passes away from the diode junction into the thermal conductor. Heat may be drawn toward the opposite end of the thermal conductor where it may leave. As shown in the diagram, the semiconductor may sit symmetrically within a recess formed in the base in the shape of a conic section 7. Light emitted from the chip leaves the semiconductor and falls incident upon the conic surfaces which may be polished. The light is then reflected upward into the cover element and away from the thermal conductor. The thermal conductor may also provide electrical contact to the bottom side of the semiconductor. This electroconductivity may be extended to the base member. As some preferred versions include bases made from materials which are electrically conductive, such as steel, electrical contact from the bottom side of the semiconductor may continue through the thermal conductor further through the base and finally into a common electrical lead 8. The cover element includes a skirt portion 9 which is configured to engage the base with precision. The cover skirt may provide alignment function as well as mechanical holding means.

In certain preferred versions, a soft and flexible gel material fills the cavity between the cover and the base. As mentioned above, polycarbonate material when subject to heat, tends to fracture. Thus, by placing a gel between the cover and the base, a flexible buffer prevents damage due to uneven expansion of rigid members. The gel further enhances the function of the thermal conductor as it provides a more complete heat circuit from the top and sides of the semiconductor chip to the base and directly to the thermal conductor.

Figure 2 is an expanded view of Figure 1 to illustrate further detail with regard to gel element which is part of the package. The top and sides of the semiconductor are thermally coupled to the thermal conductor because the gel is also a material having appreciably high thermal conductivity; far higher than air and polycarbonate materials used in other LED packages. This arrangement provides maximum coupling between the semiconductor 25 and the thermal conductor 24. With regard to the Figure, the same base shown in Figure 1 with the electrical lead 22 passing there through the base and providing contact with the top surface of the semiconductor via a wire bond connection.

The plastic cover 23 is illustrated with only its bottom surface showing as forming a cavity between the cover and the base. Into this cavity, the gel 26 is inserted or applied.

The gel may be applied before setting the cover to the base and that action can be helpful in assuring the gel forms good and solid contact between the gel and other components. The cover tends to push the flexible gel into tiny cracks and spaces 27, in particular between the semiconductor sides and the conic section reflector, and pressure is applied when the cover is joined with the base. In this arrangement, the semiconductor is perfectly surrounded by material having high thermal conductivity, and a clear thermal path, i.e. through the thermal conductor, which operates to draw heat away from the semiconductor.

Although most important elements are well illustrated in Figures 1 and 2, details of some alternative secondary elements of these LED devices are important in some versions. For example, LEDs typically have a reflecting element to turn light emitted substantially in a horizontal plane, towards the top of the device. In common LEDs that reflector is formed as a conic section into either of the electrical connectors. It is not necessary nor desirable to form a conic section reflector into electrical conductor leads in these inventions. Rather, a reflector may be formed into the base member as in the previous example, alternatively into the thermal conductor, or into the cover element.

Figure 3 is a cross section diagram of another preferred version of these inventions having a thermal conductor element formed as an integral part of the device package. This version stands in contrast to the previous in several ways. First, this device employs a plurality of semiconductor elements. As such these devices consume a greater footprint at the semiconductor – thermal conductor junction. The space required to accommodate the plurality of chips is large in comparison to the single chip case. As such, coupling between the reflector is necessarily different. The reflector is improved if it is larger and placed farther away from the chip/s. Accordingly, the second difference in this version is a reflector built into the cover element at its under surface. To accommodate independent drive of each of the chips, a corresponding plurality of electrical leads is led through the base element. With reference to the drawing figure, optically transparent cover 31 includes reflector surface 32. This surface may be formed into the plastic material from which the cover is comprised and metalized with a thin coating of reflective material such as chrome. The thermal conductor 33 supports a platform onto which the entire plurality of chips might be soldered. In the present case three chips are shown, however, it is fully anticipated that any number of chips might be placed there without loss of generality. Careful note should be made with regard to the relationship between the height of the thermal conductor and the position of the undersurface of the cover which includes the reflector. The chips must be properly located with respect to the features of the undersurface of the cover in order for it to operate properly to efficiently couple light into a controlled output beam. The base 34 may be formed in a similar manner as the previous example and it easily supports a plurality of via holes, one each for each electrical conductor. One wire bond for each semiconductor might be arranged to be in electrical communication with either electrical lead. Although semiconductor 36 appears without a connection, the cross section drawing does not support objects which extend from the page, thus one will appreciate its existence without it being shown explicitly. If the base provides a common electrical connection, via the metallic thermal conductor, then each electrical lead 37 is isolated from the base via insulators 37. Finally the top surface 39 of the cover might include a lens formed as a surface relief pattern. This is sometimes and commonly known as a Fresnel type lens. As was used in the previous example, this version also benefits from addition of a gel material between the undersurface of the cover and the base/thermal conductor. In this case, the thermal conductor is in greater contact with the gel but the operation and service is the same or similar. As the undersurface of the cover is quite complex in shape, gel material is optimally used there as it forms itself under pressure to any complex shape.

Figure 4 illustrates yet another version. This variation extends the principle of having a cover 41 with a complex curved underside. The LED package includes a base 42 of steel material and a thermal conductor 43 of copper material. Electrical lead 44 passes through via lined with insulative material 45 to provide a wire bond to the top surface of the semiconductor. Light emitted from the semiconductor falls incident on lens 46 which is part of the optical elements formed into the undersurface of the cover. Space 47 between the base and the cover may be filled with gel or may be left with an air buffer. Curved surface 48 forms a parabolic section reflector. The parabola shape may be used where it is desirable to couple the light into a highly collimated beam. Ray trace diagram 49 shows that light which glances off the lens falls to the reflector where it rejoins the light propagating toward the top surface of the cover. Although a parabolic shape is shown for this example, it is done so to illustrate one of possible shapes. A conic section similarly provides acceptable function.

Figure 5 illustrates yet another important example. In this case, a conic section reflector is formed directly into the thermal conductor element as a recess whereby the recess also has a flat portion or 'floor' to receive the semiconductor chip thereon. A semiconductor diode can be placed into the floor of the recess while the walls of the conic section are made reflective via polishing or coating. In this way, the semiconductor forms a strong thermal coupling with respect to the thermal conductor while being optically coupled to the top of the cover element by way of the reflector. Light from the diode is reflected in a direction towards the top of the package ; away from the thermal conductor, while at the same time, heat is drawn downward away from the semiconductor. One will more fully appreciate this arrangement in consideration of drawing Figure 5. A base 51, is provided as a foundation. Cover element 52 couples thereto said base at the base periphery.

This coupling may include a mechanical pressure fit or/and adhesive. Thermal conductor 53 is formed with recess 54 partly in the shape of a conic section having a floor. A semiconductor sets in the recess on the floor of the thermal conductor in intimate thermal contact therewith. Wire provides electrical contact from the lead to the top surface of the semiconductor chip. Light emitted from the diode junction falls incident upon the reflector and is directed toward the lens in the top surface of the cover. Heat generated in the diode is drawn quickly away from the junction and into the bulk material from which the thermal conductor is formed. Heat thereafter is transmitted to a terminal end of the thermal conductor 55. This end may be put into contact with a heat sink of a greater system in agreement with design considerations. An important aspect of some versions of the cover is further illustrated here. As it is desirable to provide precise alignment between a lens and the reflector/chip the cover and base elements may incorporate an indexing means 56 to assure the symmetry axes of these elements are colinear. Further, special skirt 57 may provide mechanical interlocking between the base and the cover whereby it is not easily removed there from. Careful study of the diagram proves that the very bottom edge of the skirt does not extend downwardly as far as the terminal end of the thermal conductor as indicated in the drawing by dashed lines and 'D'. In this way, the thermal conductor is nicely exposed and may be easily coupled to heat sinks arranged with understanding of the designs. This is very important in versions where the thermal conductor is to be coupled to an exterior heat sink. A stand alone LED package can be inserted into a well designed receptacle such that the thermal conductor portion of the LED package contacts a heat sink.

Excellent thermal contact may be made between the thermal conductor and a heat sink which is part of an overall system design. In that way, a large heat dump may be provided for advanced applications demanding the highest performance. Another important feature which also relates to alignment is the placement of an adhesive. Consider the gap in the horizontal plane 58 and the gap in the vertical 59. It is well established in the art that glue placed between the cover and the base in the horizon cannot be applied evenly enough to allow good alignment; glue tends to gather in one spot or another causing an offset from the vertical and rendering the output not well centered. If adhesive is put into the gap 59 rather than between the horizontal surfaces of the base and cover, then in conjunction with the indexing means, excellent alignment is achieved.

In versions where the device is to operate without an external heat dump yet high brightness operation is desired, it becomes necessary to form a heat transfer mechanism at the terminal end of the thermal conductor away from the chip. In convection systems which rely on air flow to cool the m, a transfer mechanism may include a cooling fins set built integrally with the thermal conductor. A thermal conductor is made part of the LED package and forms excellent thermal coupling between the semiconductor chip and the air surroundings. Figure 6 illustrates. Base element 61 and cover element 62 having a lens formed thereon when pressed together form a cavity 63 into which a gel material is inserted in a similar fashion described in previous examples. However, in this embodiment, a thermal conductor 64 is arranged to provide a high flux thermal path from semiconductor 65 at a first terminal end to its opposite terminal end comprised of a cooling fins arrangement 66. Heat is efficiently drawn away from the diode junction and towards the cooling fins and thereafter transferred into the surrounding atmosphere. Electrical lead 67 can be fashioned to cooperate with the base in the normal way while remaining aside of the cooling fins arrangement.

Some preferred versions of these thermal conductors includes devices made of copper or a copper alloy. Copper is a superior material having a very high thermal conductivity. It is inexpensive and easy to machine. Its lifetime and electrical properties cooperate in every way with the properties necessary for good LED package design.

Thus it is a preferred material with the note that similar highly conductive materials may also be suitable.

One will now fully appreciate how high current, high brightness LEDs may be formed with a heat management arrangement for high performance. Although the present invention has been described in considerable detail with clear and concise language and with reference to certain preferred versions thereof including the best mode anticipated by the inventor, other versions are possible. Therefore, the spirit and scope of the invention should not be limited by the description of the preferred versions contained therein, but rather by the claims appended hereto.

Claims

1) Light sources comprising at least one light emitting semiconductor diode and a support package, said support package comprising: a base member, a cover member, a thermal conductor and bipolar electrical leads, said base member comprising a rigid material formed as a substrate operable for receiving said cover thereon, further operable for providing passage of at least one of the electrical leads there through; said cover member comprising optically transparent material operable for being coupled with said base; said thermal conductor disposed at said base in thermal contact with said semiconductor diode whereby heat generated at said diode is drawn away from the semiconductor chip; and said bipolar electrical leads arranged to provide electrical contact with respect to said semiconductor diode.

2) Light sources of claim 1, said cover member formed to fit intimately with said base whereby an enclosed cavity is formed between the base and the cover.

3) Light sources of claim 2, an optically transparent soft gel is inserted in the cavity between the base and the cover whereby heat expansion is accommodated by the flexible gel and not appreciably transmitted to the hard cover.

4) Light sources of claim 1, said base and thermal conductor are formed integrally from a single piece of material.

5) Light sources of claim 4, said base is made from a copper or copper alloy material.

6) Light sources of claim 1, said base is made from a copper or copper alloy material.

7) Light sources of claim 1, cover comprises a lens having axial symmetry, here the lens axis is aligned with the semiconductor whereby light emitted there from is efficiently coupled to a light beam.

8) Light sources of claim 1, said thermal conductor having a top surface to which the semiconductor is soldered to provide both thermal and electrical contact, the thermal conductor further being affixed to said base.

9) Light sources of claim 8, a substantially conic reflector is formed into the base and the semiconductor is disposed within the conic reflector such that light emitted there from is reflected away from the thermal conductor and towards a top surface of the cover, said base is made of an electrically conductive material, at least one electrical lead is coupled in base through an insulator via.

10) Light sources of claim 9, said thermal conductor is cylindrically symmetrical and soldered or welded to the base, said semiconductor is soldered to a first terminal end of thermal conductor, top of semiconductor is wire bonded to cathode conductor; anode conductor is electrically one with base and thermal conductor, thermal conductor has a second terminal end operable for being thermally received by a heat sink.

11) Light sources of claim 1, said light source comprising a plurality of semiconductor diodes set atop the thermal conductor, a corresponding plurality of electrical leads provided through vias in the base; a conic section reflector formed into a undersurface of the cover.

12) Light sources of claim 11, said thermal conductor is also operable for carrying electrical current and serves as a common ground electrical lead for each of the semiconductor diodes.

13) Light sources of claim 11, top of cover is Fresnel surface relief lens.

14) Light sources of claim 1, said cover has complex curved underside to form a parabolic section reflector and a refractive lens.

15) Light sources of claim 1, said thermal conductor has a reflector formed therein said semiconductor being spatially coupled to said reflector such that light emitted there from is reflected in a direction away from the thermal conductor and towards lens in the cover.

16) Light sources of claim 15, said cover and said base further comprising complementary indexing means arranged to align the lens with base and thermal conductor upon which the diode is set to cause alignment between the diode and lens in the cover, further, that said reflector is conic or parabolic.

17) Light sources of claim 7, said cover being affixed to said base via an adhesive, the adhesive lying in a joint forming a cylinder only such that orthogonal horizontal flat radial surface between the cover and base meet flush without adhesive there between to assure precision alignment of lens with respect to the axis.

18) Light sources of claim 1, said cover includes a bottom skirt portion and said thermal conductor extends slightly beyond the cover skirt such that when the light source is installed into a system, a terminal end of the thermal conductor is exposed to facilitate contact with a heat sink.

19) Light sources of claim 1, heat conductor is terminated at a heat transfer mechanism built integrally with the thermal conductor.

20) Light sources of claim 19, said base comprised of steel material has mechanical accommodation for thermal conductor to provide a solid mechanical fit between the two.

21) Light sources of claim 19, said heat transfer mechanism is an arrangement of cooling fins.

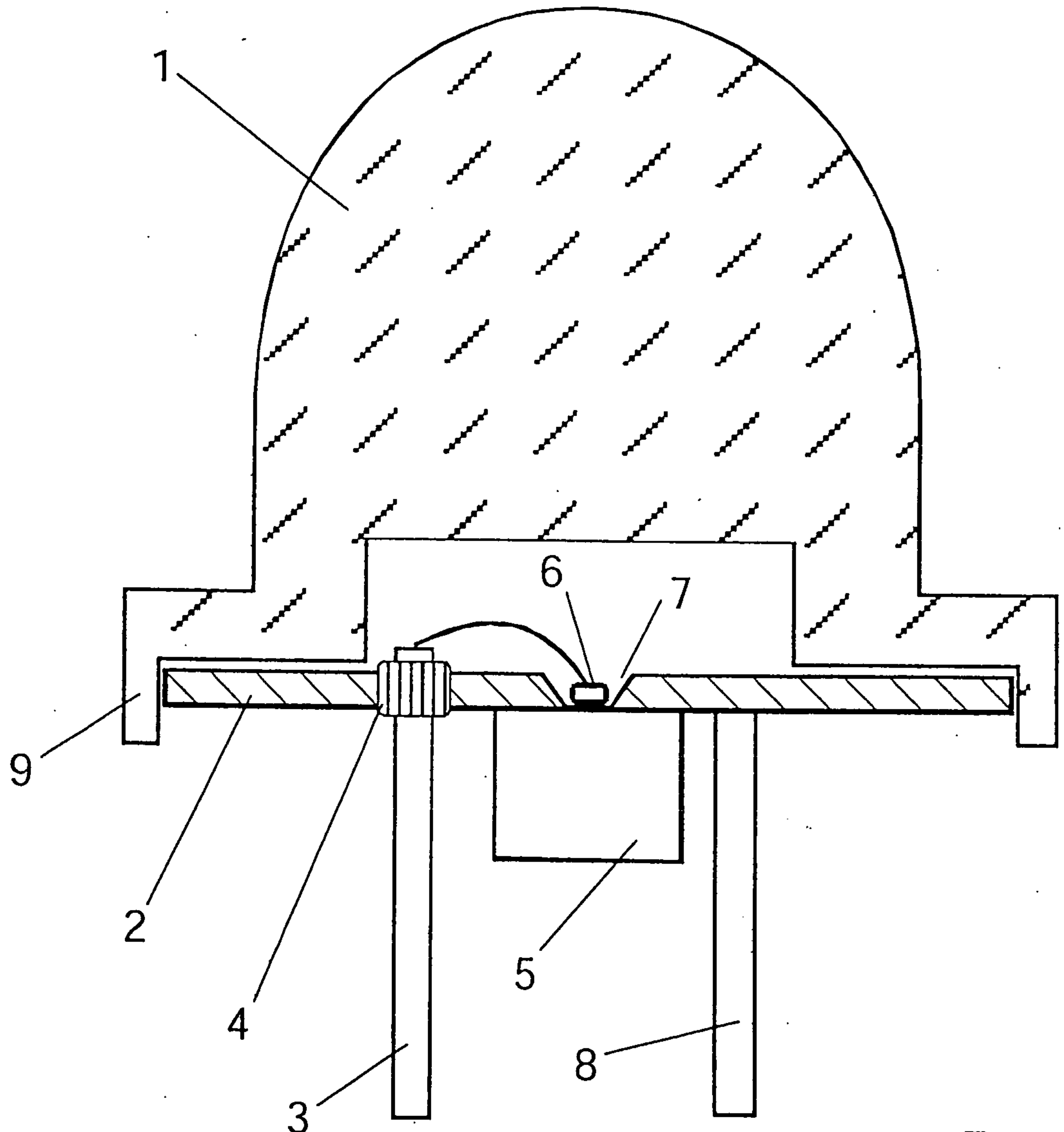


Fig. 1

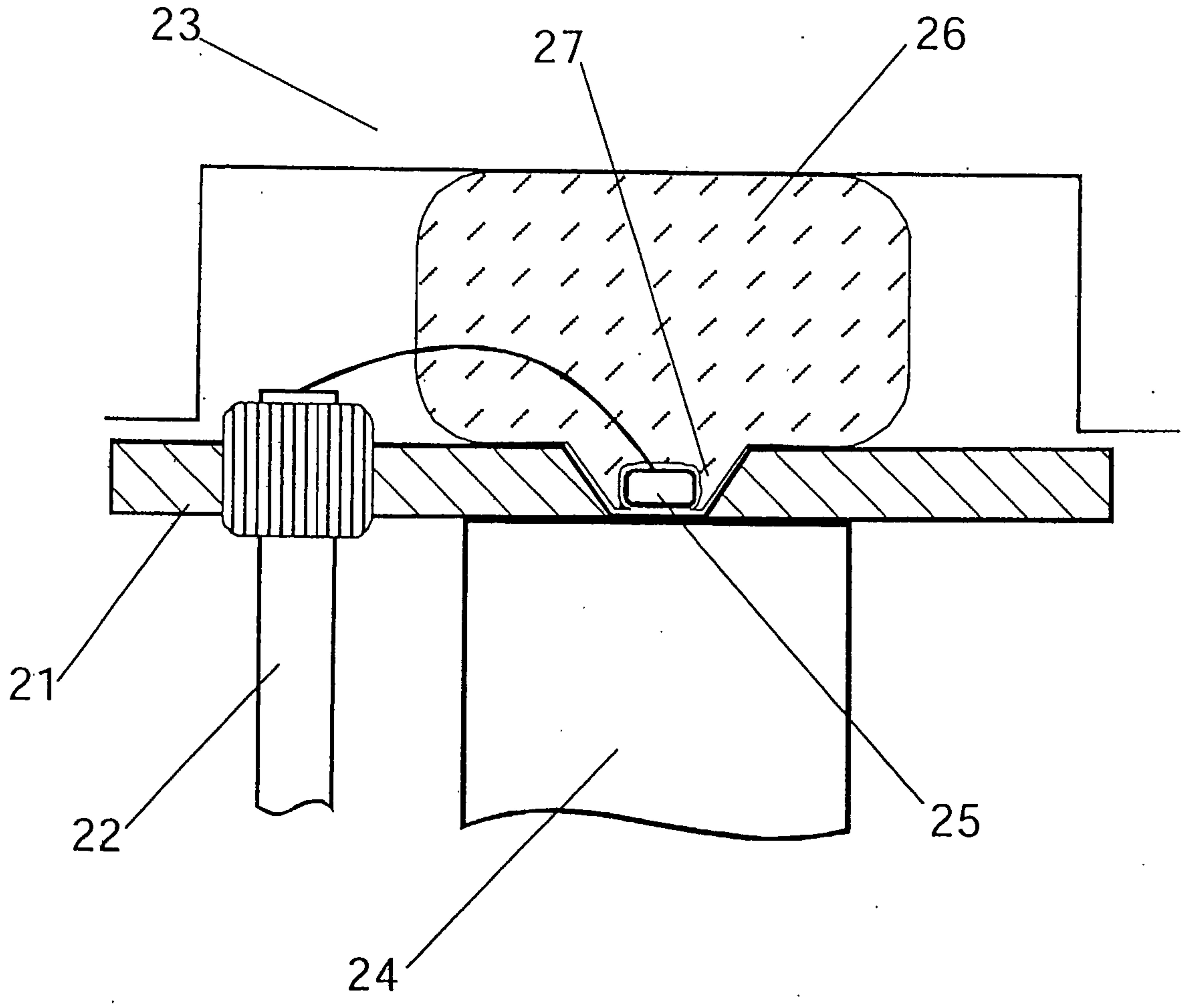


Fig. 2

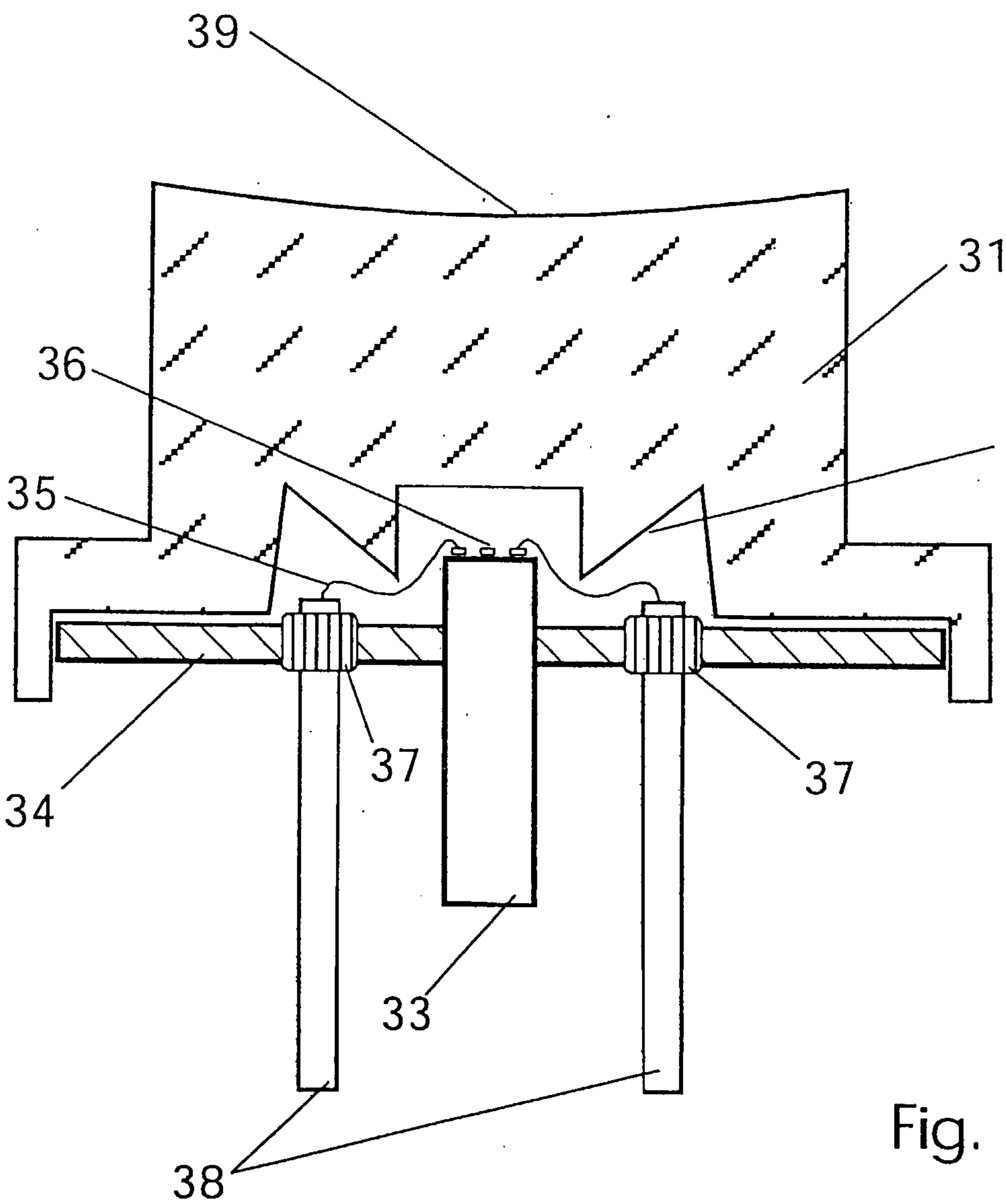


Fig. 3

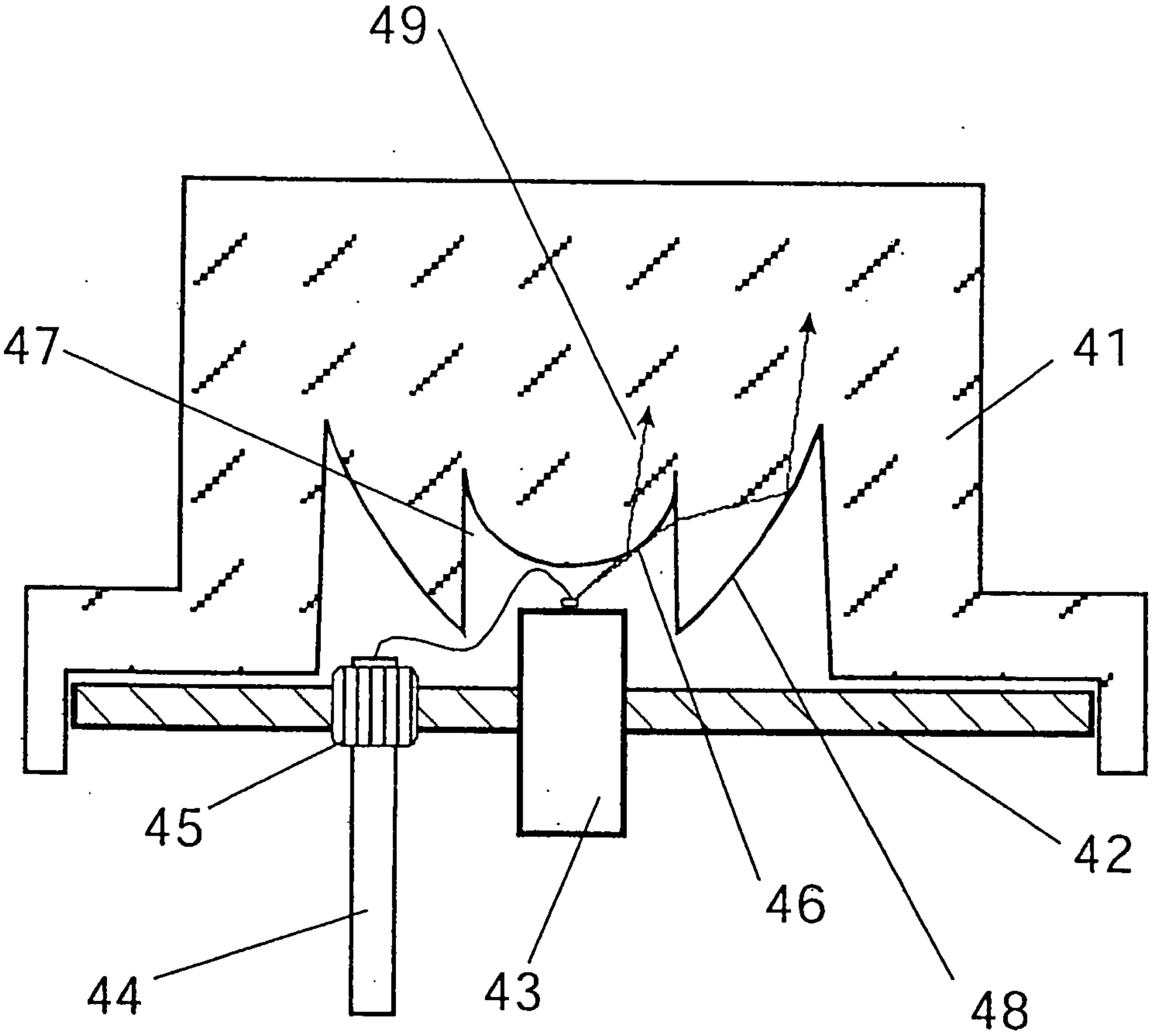


Fig. 4

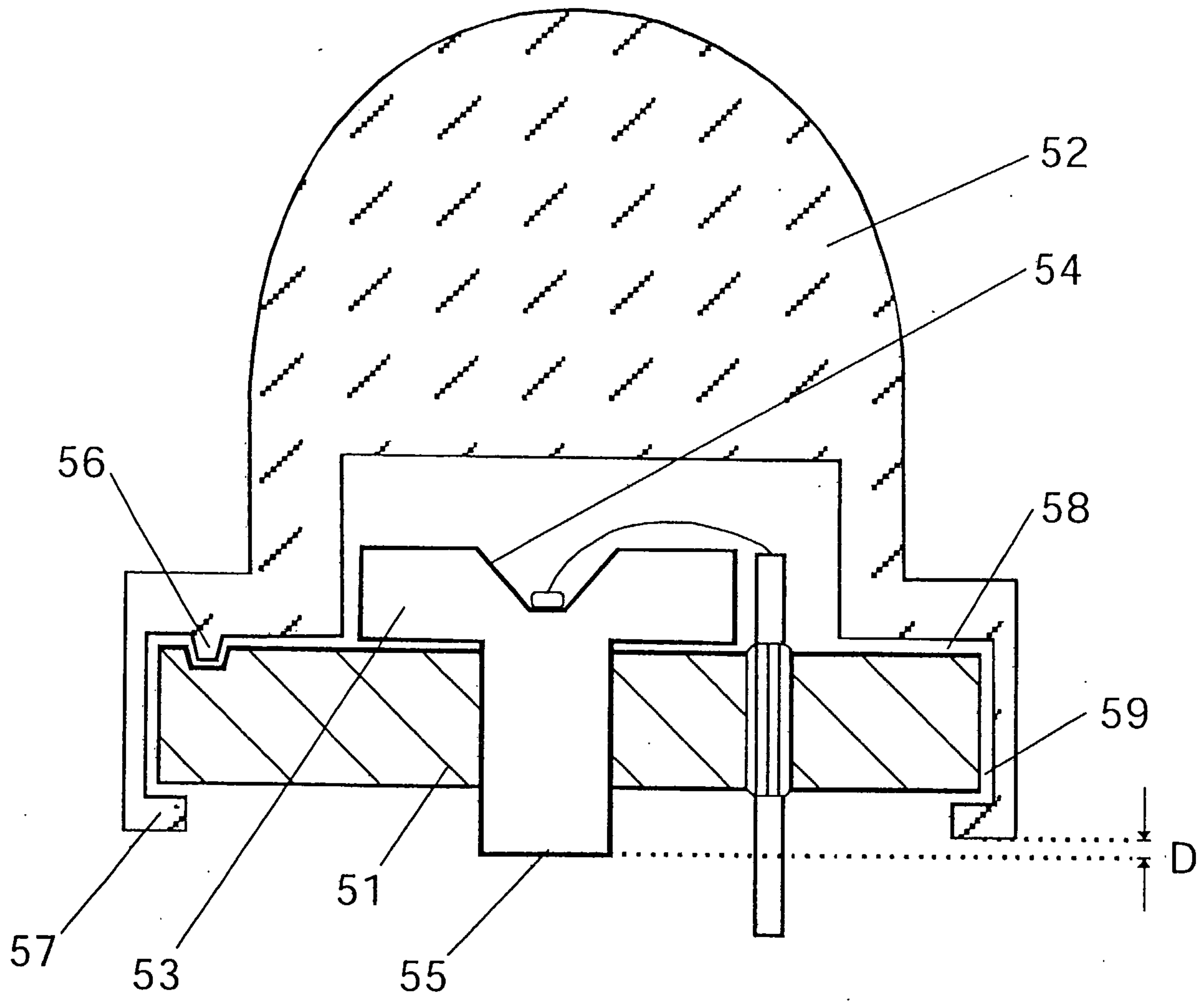


Fig. 5

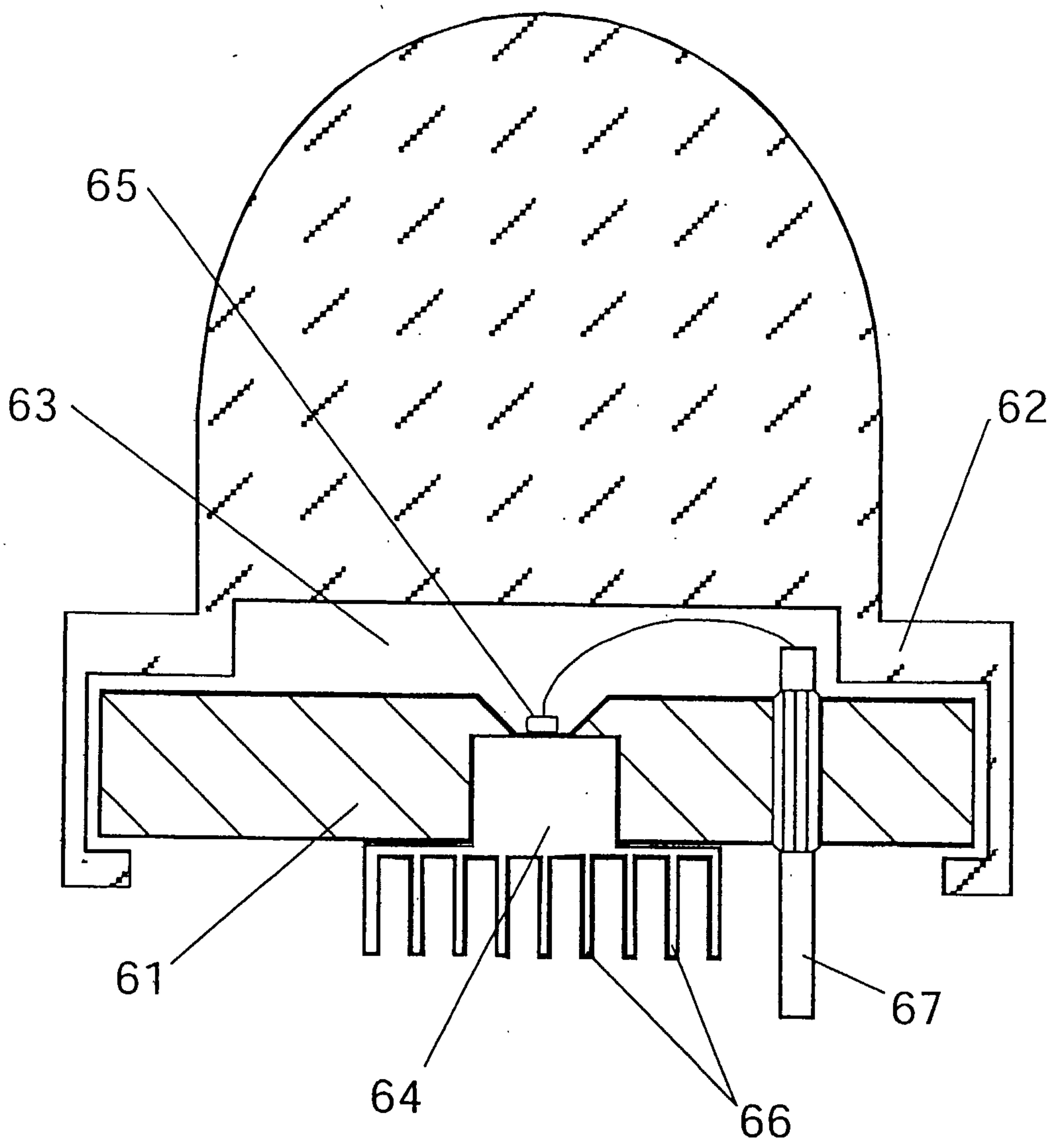
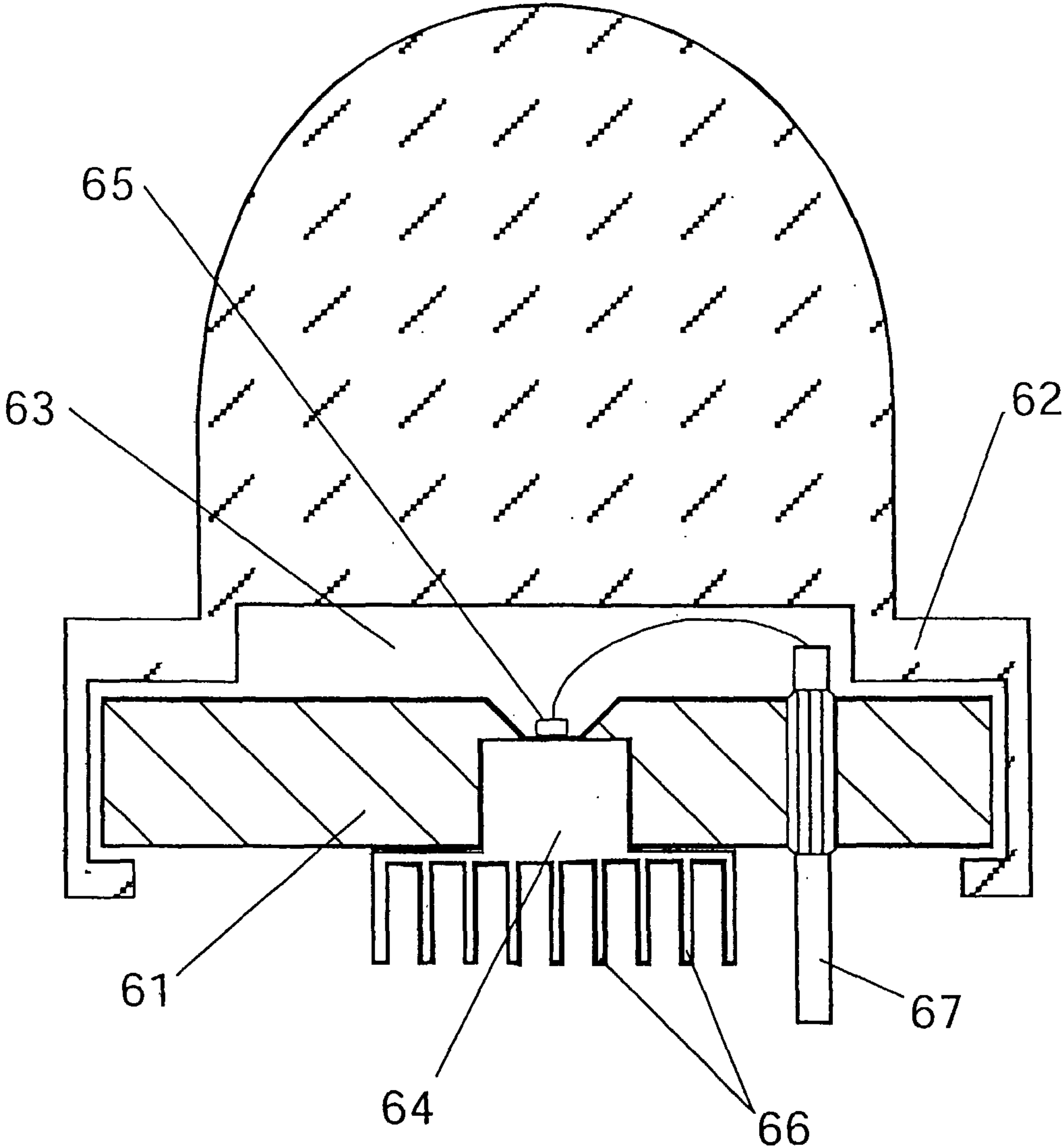


Fig. 6



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