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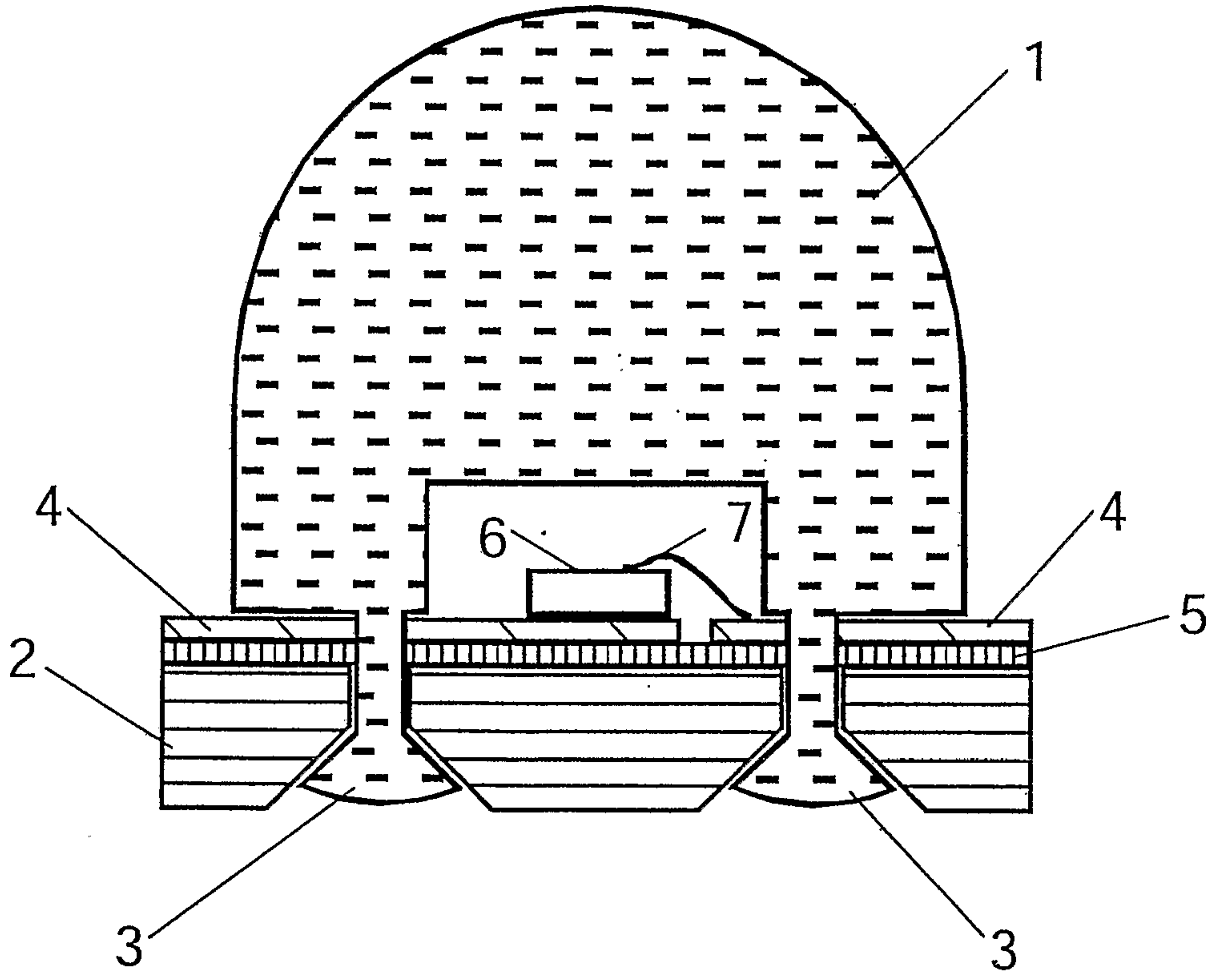

(57) Abrégé/Abstract:
Semiconducto light emitting devices are incorporated with circuit boards and printed circuits to yield high performance illumination systems. Specifically, special circuit boards having high heat conductivity are arranged to support printed circuits to which light emitting diode die may be directly coupled. Lenses are attached to the substrate- printed circuit combination by way of an indexing system such that the lenses are properly aligned to focus light into a high power output beam. Some versions incorporate a novel reflector scheme to improve coupling between light emitted from the semiconductor chip and the output beam.

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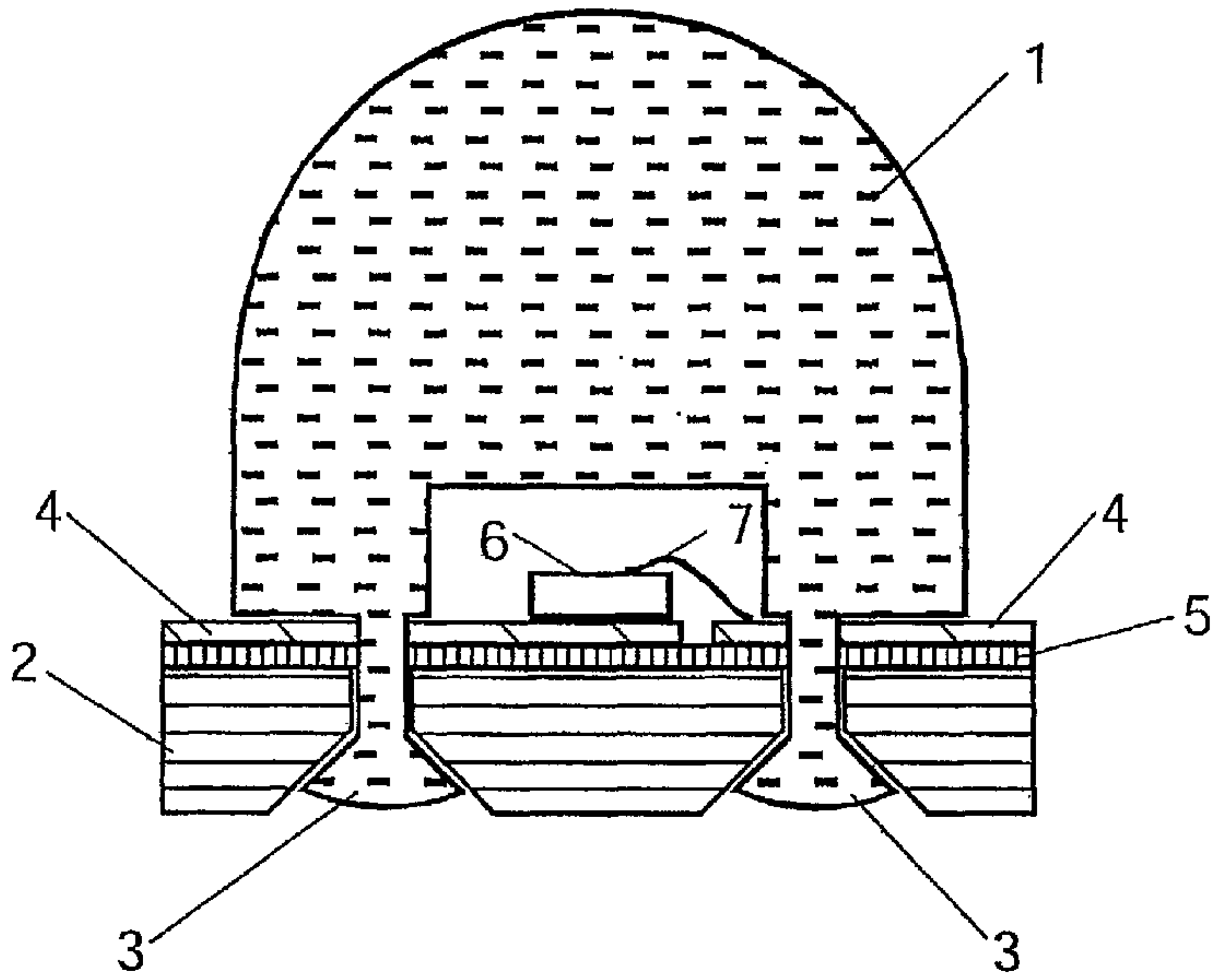

(57) **Abstract:** Semiconducto light emitting devices are incorporated with circuit boards and printed circuits to yield high performance illumination systems. Specifically, special circuit boards having high heat conductivity are arranged to support printed circuits to which light emitting diode die may be directly coupled. Lenses are attached to the substrate- printed circuit combination by way of an indexing system such that the lenses are properly aligned to focus light into a high power output beam. Some versions incorporate a novel reflector scheme to improve coupling between light emitted from the semiconductor chip and the output beam.

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Light Emitting Devices

The following invention disclosure is generally concerned with light emitting systems and specifically concerned with package structures for high performance light emitting devices.

Many manufactures of electronic apparatus have devised clever ways of using a printed circuit board PCB as foundation for the devices. For example, inventor Goh of Singapore has presented a « Board on Chip Ball Grid Array » in US patent application 2002/0000652. It is primarily a package for an integrated circuit and special connection functions. Similarly, Akram teaches 'Board on Chip Packages' where semiconductor chips are adhered to the substrate and circuits thereon directly; this is presented in US patent application 2002/0060369. In US application 2002/0171142, a bumped die and wire bonded board on chip package is presented. This invention by Kinsman relates to interconnecting a semiconductor die to a carrier substrate. US patent 6,104,095 presents a printed circuit board and chip on board package as well. This system includes mechanical means to reduce problems associated with warping of PCBs. US patent 6,420,788 has a multi- layer structure to provide advance chip to PCB bonding strategy.

LEDs constructed on a PCB are taught in PCT application WO 01/45181 A1 by inventor Yoon. Similarly, a semiconductor die is directly coupled to a PCB in publication numbered WO 99/63794. Notwithstanding, techniques have now been discovered which provide very noveluses of combining light emitting semiconductors with PCBs. In contrast to the good and useful inventions mentioned, each having certain features that are no less than remarkable, the instant invention is concerned with packages for LEDs where the semiconductor die is directly coupled to a PCB including special purpose PCBs.

Comes now, Abromov, V.; Agafonov, D.; Shishov, A.; Scherbakov, N.; and Scherbakov, V. with inventions of light emitting devices including systems having sophisticated packages to yield high performance. It is a primary function of these devices to provide illumination sources. Light emitting semiconductor chips are combined with special packages to improve performance. Namely, improved heat transfer is obtained by way of direct coupling of semiconductors to large substrates of high heat capacity. Prior art LED packages typically have a diode coupled to a lead frame. As such, the effective heat path is restricted to the two small wires from which the electrical contacts are made. In these inventions, the semiconductor is closely positioned with strong thermal coupling to a substrate on which the device is manufactured. The substrate operates to efficiently draw heat from the device so that a greater current density may be used with the result being higher output devices. In addition, new packaging structures first presented here greatly simplify manufacturing processes. A high degree of parallelism allows mass manufacturing. Further, the new structures greatly simplify process steps.

In general, a substrate having thereon a relatively flat top surface is prepared with a printed circuit. To the printed circuit, semiconductor crystals are directly mounted via ‘flip chip’ technologies. Thereafter, a cover element including a lens is affixed to the substrate by way of an indexing system. This stands in contrast to the art and intuition. The emission properties of LED chips suggest they must be mounted in a reflector system to realize a beam of light as output. Indeed, LED packages of the art invariably include a receiving cup reflector formed integrally at the end of a metal electronic lead. Packages taught here do not require such structures. Further, these advanced designs provide excellent heat transfer properties allowing the devices to be driven with higher currents to achieve higher outputs.

In addition, light emitting devices of these inventions have printed circuits which form relationships between two or more similar devices. Advanced printed circuit strategies further ease manufacturing complexities to produce new useful arrangements of devices having a plurality of light emitting units.

It is a primary object of these inventions to provide light emitting devices. It is an object of these inventions to provide devices optimized for very high optical flux. It is a further object to provide devices having manufacturing advantages.

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 the invention 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 which illustrates a basic preferred structure;

Figure 2 also is a cross sectional drawing of alternative versions;

Figure 3 shows a special substrate upon which a plurality of unit elements may be fabricated;

Figure 4 illustrates a further manufacturing step whereby electrical traces are applied;

Figure 5 presents a following step where crystals and wirebonds are applied;

Figure 6 illustrates an finalized array of light emitters;

Figure 7 demonstrates other versions, linear in nature, of array emitters built upon a single substrate;

Figure 8 shows an example of an assembled device of linear versions;

Figure 9 is a drawing of a substrate having five subsystems which may be separated;

Figure 10 shows a group assembly with special relationship of printed circuits;

Figure 11 is a perspective drawing of a special system having integral heat sink combined with a substrate; and

Figure 12, also a perspective drawing, shows another special version with recesses formed into a substrate surface.

In accordance with each of the preferred embodiments of the invention, there is provided light emitting apparatus. It will be appreciated that each of the embodiments described include apparatus and that the apparatus of one preferred embodiment may be different than the apparatus of another embodiment.

Packages to supports a semiconductor light emitting diode chip have been the subject of many inventions. The following disclosure is also related to light emitting semiconductor chips and their packaging. In particular, chips are mounted directly to a substrate such as a printed circuit PC board. These 'circuit boards' may be either be like traditional circuit boards made of electrically insulative material or in highest performance versions be made of metallic material such as aluminum or aluminium alloys. Versions employing common PC board materials are useful because they greatly reduce manufacturing costs and enable new device configurations. In particular, LEDs are formed with printed circuits and these components can be made to cooperate to form new designs not possible in known LED design strategies.

Where very high brightness light emitting devices are required, special consideration is given to the substrates used. In particular, metal substrates provide excellent heat transfer means. Thus, high brightness devices are preferably made on metallic substrates. In both cases, printed circuits may be used to couple a plurality of individual light emitting chips. This feature is not found in competing manufacturing technologies.

After a substrate is prepared with a printed circuit and a chip has been directly mounted thereto, the chip is wire bonded to another portion of the printed circuit.

Thereafter, a cover element having a lens thereon is added. The cover element is preferable made of a hard transparent plastic. Cover elements of these inventions have an underside cavity to accommodate the mounted emitter chip. In best versions, that cavity can be filled with a soft gel material to protect the cover from excessive mechanical stress due to thermal heating. The gel also further couples the chip to the substrate thermally.

The cover element also includes a lens at its top surface. Accordingly, the lens should be accurately aligned with respect to the chip to form a uniform output beam. For this reason, these devices include an alignment scheme based on an indexing system.

Mechanical alignment is attained because the indexing system is formed in consideration of the need to accurately place the lens on the same axis and the emitter chip. Indexing means typically includes cooperating mechanical elements formed into to both the cover element and the substrate in agreement with a predetermined alignment scheme.

In special versions, the indexing means not only serves the alignment function but additionally provides the function of affixing the cover element to the substrate.

Preferred cover elements contain an optical element integrated with its underside. A reflector element is used to redirect light emitted substantially in a horizontal plane upwardly toward the cover element lens. These types of reflectors are not found in the art.

When these concepts, configurations and designs are fully appreciated, the manufacturing process is greatly simplified and made highly parallel. Thus many devices can be made simultaneously in process steps. LEDs are made on two dimensional sheets rather than on linear strips known as 'lead frames'.

These concepts and related relationships become more clear in view of the following description with reference to the drawing figures. Figure 1 illustrates a cross sectional diagram of a single unit light emitting device. A cover element 1 formed of transparent polycarbonate material for example is strongly bound to a rigid substrate 2.

While the substrate may be in the form of a printed circuit board formed of 'Textilite' it may also be formed of other materials. For example, metallic substrates having exceptional thermal conduction properties offer excellent basis upon which these light emitting devices may be built. Simple aluminum is sometimes used in best modes of these devices. Through-holes or 'vias' formed into the substrate and cooperating extrusions formed with cover elements may provide an indexing and bonding function.

A polycarbonate cover having two or more pegs may be pushed through the vias and melted against count ersunk cavities in the bottom side of the substrate to form a sort-of plastic rivet 3. In this way, a strong rivet fastener holds the cover element to the substrate with precision and certainty. Electrical contacts 4 may be formed on top of an insulation layer 5. This is a very important aspect of these inventions. Because printed circuit technology permits one great design latitude, it permits a designer exceptional advantages to couple printed circuits directly with light emitting diode die. Diodes of the art and formed onto lead frame elements which can thereafter be used with printed circuit structure, but this strategy has many problems associated therewith which are not found here. In the instant arrangements, crystal die are directly applied to the printed circuit traces.

Where a non- metallic substrate is used it is possible to omit the insulation layer 5. However, when forming these devices on metallic substrates, one must electrically isolate printer circuit traces from the substrate to preve nt short circuits between anode and cathode traces. In best versions anticipated, a metallic substrate such as aluminum may be coated with a very thin layer of aluminum oxide, an excellent insulator, to provide isolation between printed circuits and the substrate. Because it is desirable to have very high heat conduction throughout the device elements, a insulation layer may be quite thin. In this way, the insulation layer provides high electrical insulation while simultaneously providing high thermal conduction. Aluminum oxide layers of a few microns are sometimes preferred in certain versions.

To the printed circuit, a light emitting diode crystal 6 may be bonded. This bond may be formed in a way analogous with the art by way of conductive glues or other appropriate bonding agents suitable for forming electrical contact. The opposing side of the diode chip may be wire bonded to printed circuit traces of opposite pole. Thus, thin gold wire 6 provides further electrical contact to the printed circuit.

This device is presented to show a few very important features. Firstly, the printed circuit may be used to directly couple a plurality of LEDs. A single current source is thereafter operable to source any number of diodes simultaneously. Secondly, these structures provide very highly integrated elements with remarkable heat conduction properties. Elimination of the traditional lead frame promotes a far superior heat management structure. Thirdly, these devices have a structure which greatly facilitates manufacturing processes. Indeed, the highly parallel nature of array assemblies promotes manufacturing simplicity. These and other advantages are not found in the art where arrays of diodes are formed in quite different fashion.

A careful observer will notice an apparent problem with the devices illustrated in Figure 1. A crystal chip emits light in all directions. A common LED chip is placed into a reflective receiving cup, i.e. a conic section, built integrally with the lead frame. Light emitted in a horizontal direction falls incident on the reflector and is redirected upwardly.

This promotes better beam formation in LEDs. A simple immersion type lens also further collimates light to form a nice beam of moderate divergence. In the devices shown in Figure 1, light emitted near the horizontal directions seemingly would not be coupled into an output beam of low divergence. Where it is desirable to have a beam of low divergence, one might apply the following structure to realize this. This is considered a very important enabling structure for some preferred versions.

Figure 2 illustrates a cover element 21 of advanced design. The cover is bound to the substrate 22 as previously described. Printed circuit 23 lies upon optional thin insulation layer 24. Plastic bonding fastener 25 holds the cover element tightly and with very good registration to the sandwich of elements. The diode chip 26 lies within a cavity 27 formed by the under surface 28 of the cover element. In some cases, the cavity may be filled with a special material which provides excellent thermal coupling and alleviates problems related to expansion which causes mechanical stress. The chip is 'flip chip' bonded as well as wire bonded to the printed circuit at respective portions thereof.

A very special surface 29, a surface of revolution which may form a conic section, operates to reflect light emitted in the near horizontal directions from the chip upwardly into the cover element and further into the lens at the cover element top surface. The special surface may be left uncoated or may be coated with an optical reflecting material.

For example, uncoated systems may rely on total internal reflection principles to form a highly effective mirror. Alternatively, a metallic coating on a polished surface forms a high quality mirror reflector. Nearly all LED packages of the art employ reflectors made integrally with the electrical contact, i.e. at least one lead of the lead frame. This very distinctive reflector is made integrally with the cover element rather than either of the electrical leads. In view of the very basic principles presented in Figures 1 and 2, and further of the drawing Figures 3 through 6, one will realize great manufacturing advantages. The reader will please be reminded of the severe performance limiting factor of LEDs when considering the great advantages of the following devices. More particularly, the difficulty of extracting heat from the LED package structures. In addition, the reader should remain mindful of the great manufacturing advantages associated with highly parallel operations and procedures. Thus, very high output light emission devices of these inventions are nicely illustrated in the following example with reference to Figures 3 - 6.

Figure 3 shows a rectangular substrate 31 with pairs of holes 32 distributed carefully about the surface of the substrate. One should be reminded that the substrate is preferably a rigid material suitable for supporting printed circuit board technologies. An electrically insulative material such as Textilite™ may be used in version where the substrate is not a member of the heat transfer mechanism. However, in some preferred versions, the substrate serves the important function of heat transfer and in those cases it is better that the substrate be formed of materials having high thermal conductivity such as metal. Aluminum substrates are highly useful as they are easy to machine, compatible with related process technologies, highly durable and a particularly good heat conductor.

In the case of a metallic substrate, the substrate may be prepared with a special thin layer of electrically insulative material. For example, an aluminum substrate may be coated with an aluminum oxide layer of a few microns. Other materials and thicknesses are possible, but Al2O3 is considered in best versions presently known.

So prepared, substrates with hole pairs as shown can be further processed with printed circuit technologies. Onto the insulation layer of a rigid substrate, a circuit of electrical traces may be formed via conventional means such as lithography. Figure 4 shows an illustrative example of a simple highly parallel circuit which may be useful in high brightness applications. Substrate 41 has twenty five separate sites 42. At each site, a pair of holes 43 are drilled through the substrate. Electrical traces 44 and 45, trace 45 being of opposite pole, are formed onto an insulative layer, for example aluminum oxide, in lithographic printed circuit board processes. Prepared as described, the printed circuit board of figure 4 is suitable for unique application of diode chips and wire bonds. Modern

LED technologies of the art do not include application of diode die directly to printed circuit traces. Indeed, very few include mounting of die outside a reflector recess. Figure 5 illustrates a substrate 51 having electrical traces 52 and 53 thereon. To those traces, a diode chip 54 may be bonded and affixed i.e. with pressure and suitable adhesives. For clarity, the diode is represented in the drawing as having a circular cross section, experts will argue that in practical applications the diode actually has rectangular cross section. This deviation is not significant as the drawing is not intended to reflect scale and shape with regard to the diode element. Further connection from the diode to the other traces may be made via common wire bonding methods to result in a small wire 55 bridged between the top of the diode and the electrical trace 53.

With the substrate arranged with printed circuits and bonded diodes a cover element or cover elements can be applied. These cover elements are preferably plastics such as polycarbonates and they may be formed with optical elements such as common spherical lenses therein. In addition, the cover elements can have a backside with pins arranged to complement the through-holes in the substrate. The cover may be pushed to the top surface of the substrate with the pins aligned to pass through the holes. As such, cover elements are positionally indexed to and precisely aligned with the diodes. In proper place, the cover elements may be permanently affixed by application of pressure and heat to the pin end to form a fastener roughly equivalent to a rivet. Figure 6 illustrates a diode array with lens cover elements set in the positions defined by the substrate through holes. Substrate 61 having printed circuit traces 62 and 63 thereon also have lens elements 64 affixed thereto at each unit site. Careful review of the diagram indicates the lenses are presented with the magnification which would be visible if one were to view an actual device. Thus the traces 62 and 63, diodes 65, and wire bonds 66 seem to be enlarged in the regions bound by the lenses.

Although the previous example is directed to devices having multiple cover elements, each of those elements fitting into a receiving location on the substrate, it is not a requirement that lens elements be independent of one another. It is entirely possible to configure a single integrated cover having a plurality of lens elements to be coupled with a plurality of light emitter chips while having only one indexing and affixing means incorporated therewith. Thus, a great many configurations exist where cover elements, perhaps those molded in a single process, may be pushed to a preconfigured substrate to form an array of light emitters for high light output. A first example of this is described here following with reference to Figures 7 and 8. A strip substrate 71 can be prepared with rectangular indexing holes 72 for precision alignment. As mentioned before, the substrate is preferably a good conductor of heat while having a top surface which is an electrical insulator. Where an application exists and heat removal is not a primary concern, then a substrate array of light emitters can be made on simple materials like Textilite which is not a good heat conductor. In addition, the substrate is further prepared with a printed circuit of bi-polar electrical leads 73 and 74. Thereafter, a light emitter chip 75, a light emitting diode of at least two material layers, is affixed and bonded to either of said traces on one layer side. The second layer side is wire bonded to the conductor trace having the opposing electrical pole. A cover element 77 may be formed in a molding process from polycarbonate material or a suitable alternative transparent plastic. The cover element may have a plurality of lens structures 78 on a topside and underside structures which support optical functionality such as reflector elements. In addition, a cover element also has formed therewith indexing portion 79 which is formed in view of complementary indexing holes of the substrate. It will not provide a deviation from the spirit of these inventions should one choose to use 'pins' on the substrate and 'holes' on the cover. Also, pins and holes are a convenient system, but there certainly exists several other mechanical interlocking systems which also provide an indexing function whereby one element is possitionally aligned with respect to another. Thus, it is explicitly mentioned here that the limitation is met where any of these indexing systems are used to align a cover element with an array of light emitters on a substrate.

When a cover is placed to and indexed with a substrate described the resulting system looks like the drawing of Figure 8. It is restated here that the lenses are drawn such that the magnification is simulated a one views the drawing as if one were looking through an actual lens. Accordingly, Figure 8 comprises a substrate 81, a first printed circuit contact strip 82 and a second electrical contact 83, a cover element 84, indexing means 85, lenses 86, light emitting diode chip 87 and wire bond 88. This arrangement is highly useful as it may be inserted into preconfigured systems whereby appropriate voltage and current is delivered to the amalgam at only two contact points and the entire multi-element device is driven as a high brightness system with advanced heat dissipation properties.

The highly parallel nature of these devices provides considerable manufacturing advantage. Many manufacturing steps can be done at multiple sites simultaneously in two dimensional arrays. Thus, a great plurality of devices can be made at one time. Even where those devices or subsets of those devices are to be later separated in post processing steps. For example, a large array of devices can be formed step-by-step in parallel. Thereafter, repeat units can be cut away or otherwise separated to form independent devices which may be used separate from the others. The apparatus of Figure 9 illustrates this concept further. A master substrate 91 comprised of five regions forms a basis upon which a large plurality of light emitting elements are formed in accordance with principles presented. The five regions are bifurcated at dashed lines 92.

The lines may be merely indicia to guide a cutting 93 process; or may alternatively include a perforation system whereby a break-away function is enabled. The repeat unit 94 includes a substrate region with indexing means, a printed circuit, and a cover element 95 with cooperating indexing means. After parallel processing and assembly of the large substrate of twenty five units, the substrate cut be separated into five regions of five light emitting units each. Each of the 1X5 array elements has an electrical interface which operates to drive all light emitter devices on the device via the appropriate printed circuit.

As experts will surely attest, printed circuits may take many of various forms, each to achieve different objective s. One example which illustrates use of a special printed circuit in conjunction with light emitting diodes of these inventions includes the apparatus sometimes known as a 'center high mounted stop light' or more commonly by its acronym 'CHiMSeL'. A CHiMSeL is used in automobiles having a low voltage systems typically 12/14 volts. LEDs in proper operation intrinsically require a voltage drop of between about 1.5 and 3.5 volts depending upon the device. In an illustrative example, it may be assumed that an individual LED requires a 3.5 volt drop. Thus, to power these devices with a 14 volt system, a special circuit arrangement is required. A series circuit having 4 LED elements each having a 3.5 volt drop forms a 14 volt system. However, these CHiMSeLs are necessarily bright. They are preferably made of a large number of individual LEDs. Thus, the circuit should also support some parallelism.

Figure 10 illustrates how devices of these inventions are used to make high brightness LED devices including arrays of single LEDs directly on a printed circuit. Because the LED chips are in intimate contact with the substrate, these devices have remarkably high heat transfer properties not possible in competing systems which install a plurality of common LEDs onto a circuit board. In those systems, emitting chips are thermally decoupled from the printed circuit board.

Figure 10 shows a substrate 101 having two CHiMSeL devices 102. Each device has a cover element 103 which may also include an array structure of repeat elements. For example, the cover element 103 has lens elements 104, indeed twenty of them in a 5X4 array. The cover element also has indexing means 105 which may be a square peg configured to cooperate and couple with a similar hole in the substrate 101 to effect perfect alignment between the lenses and chip which are mounted to the printed circuit 106. Close inspection of the printed circuit will reveal four members in a serial configuration and each of those members supporting five LED sites in a parallel electric configuration. An applied voltage of 14 volts between points 107 and 108 will result in proper biasing of the LEDs and a very high performance and low cost device. As these devices may be made in groups, manufacturing costs are very low. For illustration, the figure shows two devices made on the same substrate which may be separated 109 in a post processing step and used independently of each other.

While this disclosure primarily uses the term ‘substrate’ and refers to a flat two sided object such as a circuit board, the reader will appreciate that not all ‘substrates’ which are useful here will precisely fit that definition. Quite to the contrary, some very non- flat ‘substrates’ provide excellent benefit. For example, where heat transfer requirements are extreme, a ‘substrate’ may be combined with a heat sink. That is, a substantially flat surface appropriate for having formed thereon a printed circuit is a first portion of a substrate. A second portion of substrates of these types may have a cooling fin arrangement on the opposing side. Figure 11 illustrates. Substrate 111 includes flat top side surface 112 and cooling fin arrangement 113 on the bottom side. Printed circuit traces 114 and 115 may be applied to the top surface in the fashion explained herein. Lens elements 116, in this case Fresnel type lenses, can be affixed to the top surface of the substrate in conjunction with indexing means to provide alignment.

It is possible in very special versions, to configure substrates with reflectors integrated therein. A flat sheet of material can be processed to include a plurality of recesses distributed thereabout the top surface. A pressing step can be applied where conic shaped dents of the order of one millimeter in depth are formed in the material. Thereafter, metalization and polishing steps can be applied to form an optical reflector.

The metalization step may be combined with processes for application of printed circuit traces and the same metal which forms the traces may also serve as the optical reflector.

Otherwise, the remainder of principles presented above remain the same. In example, the cover element may be indexed and affixed to the substrate via adhesives or mechanical interlock systems. A one-to-one correspondence between light emitting crystals and lens elements may be preserved in these versions. Similarly, indexing means which provides precise alignment between lenses and the emitting chips operates the same as before.

Figure 12 is directed to a version of this type. Although a cover element is not shown in the drawing, the figure shows clearly the special substrate and related elements. Substrate 121 is prepared with printed circuit traces 122 and 123. The substrate additionally has indexing means, in this illustration holes 124. Conic shaped recesses 125 are formed into the top surface of the substrate and distributed spatially thereabout.

Into the recesses, light emitting semiconductor crystals 126 are electrically mounted and coupled. Additionally, wire type connectors 127 are provided between the top of the crystal and the printed circuit. Accordingly, a substrate for purposes of these inventions actually means an element having at least one side substantially flat which supports printed circuits thereon. The other side of the substrate may take a non- flat configuration.

The examples above are directed to specific embodiments which illustrate preferred versions of devices and methods of the invention. In the interests of completeness, a more general description of devices and the elements of which they are comprised as well as methods and the steps of which they are comprised is presented herefollowing.

In most general terms, apparatus of the inventions may precisely be described as including light emitting devices having a substrate with a flat surface and a light emitting semiconductor crystal. Further, these devices include electrical conductors and a cover element. The electrical conductors may be thin traces of metalization formed on the flat surface of the substrate. The semiconductor crystal is affixed directly to electronic conductors. The cover element is affixed to said substrate. The electrical conductors may be formed as portions of a printed circuit or circuits. These light emitting semiconductor crystal are diodes having at least two layers each being electrically coupled to said printed circuit.

Substrates used in these devices are planar sheets of material suitable for application of printed circuit processes. For example, one such material is commonly known as Textilite™. Alternatively, substrate materials may include metals or metal alloys. Aluminum may be a best metal for this element. In the case of a metal substrate, it may be further prepared with an electrical insulation layer on the surface. Electrical insulation layers having high heat conductivity coefficients are preferred to preserve the heat transfer from the semiconductor to the substrate. These electrical insulation layer may be applied as thin coatings of material such as aluminum oxide; for example between 1 and 20 microns thick. Substrates can additionally be prepared with perforation means to separate them into separate pieces in a post processing step. Substrates of these devices may also support indexing means such as holes drilled into the substrate. The indexing means may be arranged whereby each portion of a substrate includes its own indexing means. In some special versions, these holes may be further shaped with a countersunk cavity to support affixing the cover element to the substrate by way of a mechanical interlock.

Cover elements are preferably transparent and formed of hard plastic materials having an under surface and an upper surface. These are formed with an under surface defining a cavity which may receive therein the diode crystal. Cover elements may have a lensing function as a top surface includes either a conventional spherical lens or a Fresnel type diffractive lens. Cover elements may be affixed to substrates via adhesives or mechanical interlocking systems or other.

One will now fully appreciate how high performance light emitting devices are realized. 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 emitting apparatus comprising:
a substrate having at least one substantially flat surface;
at least one light emitting semiconductor crystal;
electrical conductors; and
a cover element,
said electrical conductors being thin traces of metalization formed on said substantially flat surface, said light emitting semiconductor crystal being affixed directly on said electronic conductors, said cover element being affixed to said substrate.

2) Light emitting apparatus of claim 1, said electrical conductors are formed as portions of at least one printed circuit.

3) Light emitting apparatus of claim 2, said light emitting crystal is a diode having at least two layers each being electrically coupled to said printed circuit.

4) Light emitting apparatus of claim 3, a first layer is affixed to and directly bonded to said printed circuit.

5) Light emitting apparatus of claim 4, a second layer is wire bonded to said printed circuit.

6) Light emitting apparatus of claim 1, said substrate is a planar sheet of material suitable for application of printed circuit processes thereon.

7) Light emitting apparatus of claim 6, said material is Textilite™.

8) Light emitting apparatus of claim 6, said material is a metal or metal alloy.

9) Light emitting apparatus of claim 8, said substrate is further prepared with an electrical insulation layer thereon at least one surface.

10) Light emitting apparatus of claim 9, said electrical insulation layer has high heat conductivity coefficient.

11) Light emitting apparatus of claim 9, said electrical insulation layer is a thin coating of material.

12) Light emitting apparatus of claim 10, said electrical insulation layer is aluminum oxide.

13) Light emitting apparatus of claim 12, aluminum oxide is between about 1 and 20 microns thick.

14) Light emitting apparatus of claim 8, said substrate is an aluminum alloy.

15) Light emitting apparatus of claim 6, said substrate is prepared with at least one perforation structure whereby the substrate may be cut or broken or otherwise separated into subsets.

16) Light emitting apparatus of claim 6, said substrate further includes an indexing system whereby said cover elements are positioned and aligned with respect to said light emitting semiconductor crystals.

17) Light emitting apparatus of claim 16, said indexing system comprises a plurality of holes spatially distributed about said substrate and a plurality of cooperating pins spatially distributed about said cover element.

18) Light emitting apparatus of claim 1, said cover element is transparent and formed of hard plastic material having an under surface and an upper surface.

19) Light emitting apparatus of claim 18, said under surface forms at least one cavity portion which may receive therein said light emitting semiconductor crystal.

20) Light emitting apparatus of claim 19, said at least one cavity is filled with a soft and pliable gel material which thermally couples said light emitting semiconductor crystal to said cover element and said substantially flat surface whereby expansion due to heating does not tend to fracture said cover element.

21) Light emitting apparatus of claim 18, said upper surface forms an optical element whereby light emitted at said light emitting semiconductor crystal is coupled into a light beam.

22) Light emitting apparatus of claim 18, said under surface further forms a reflective element concentric with said light emitting semiconductor crystal.

23) Light emitting apparatus of claim 22, said reflective element is a mirror formed of metallic coating on a smooth surface in the shape of a conic section.

24) Light emitting apparatus of claim 22, said reflective element is a total internal reflection mirror formed of a smooth surface in the shape of a conic section.

25) Light emitting apparatus of claim 21, said optical element is a spherical surface which forms an air interface whereby light refracted at the surface is coupled into a beam.

26) Light emitting apparatus of claim 21, said optical element is a Fresnel lens formed as a surface relief pattern.

27) Light emitting apparatus of claim 1, further comprising indexing means for coupling said cover element with said substrate.

28) Light emitting apparatus of claim 27, said indexing means is operable for spatially aligning with high accuracy said cover element with respect to a predetermined points on said substrate.

29) Light emitting apparatus of claim 28, said indexing means is comprised of pin and hole complementary pairs, each being either on the substrate or the cover element.

30) Light emitting apparatus of claim 29, said holes are formed into said substrate said holes further having a countersunk cavity in an underside of

the substrate, said pins are formed integrally with said cover element of plastic material.

31) Light emitting apparatus of claim 30, said plastic pins having an end melted to fill said countersunk cavity to form a permanent bound between said cover element and said substrate.

32) Light emitting apparatus of claim 29, said indexing means being disposed on each sub portion of the substrate which may be separated.

33) Light emitting apparatus of claim 28, further comprising means of affixing said cover element to said substrate.

34) Light emitting apparatus of claim 33, means of affixing is an adhesive material.

35) Light emitting apparatus of claim 33, said indexing means further includes mechanical interlocking means to hold said cover element to said substrate.

36) Light emitting apparatus of claim 2, said printed circuit portions are formed in lithographic processes.

37) Light emitting apparatus of claim 36, said printed circuits form parallel electronic connections with a plurality of light emitting semiconductor crystals.

38) Light emitting apparatus of claim 36, said printed circuits form combinations of and parallel electronic circuits.

39) Light emitting apparatus of claim 2, said substrate has a heat sink formed integrally therewith.

40) Light emitting apparatus of claim 2, said substrate further having a plurality of small recesses formed therein and distributed about said substantially flat surface.

41) Light emitting apparatus of claim 40, said small recesses are conic shaped recesses having metalization thereon to form optical reflectors.

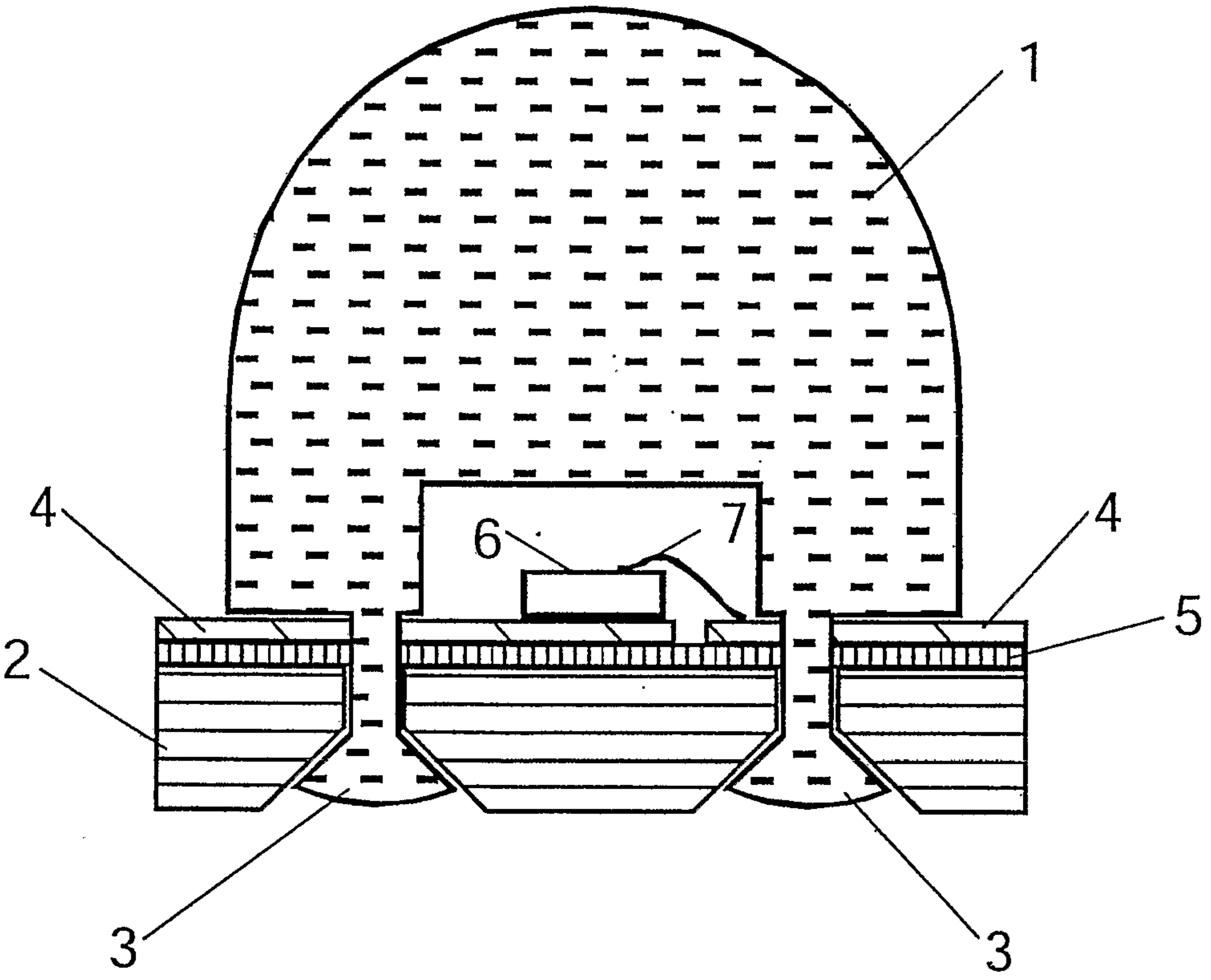


Fig. 1

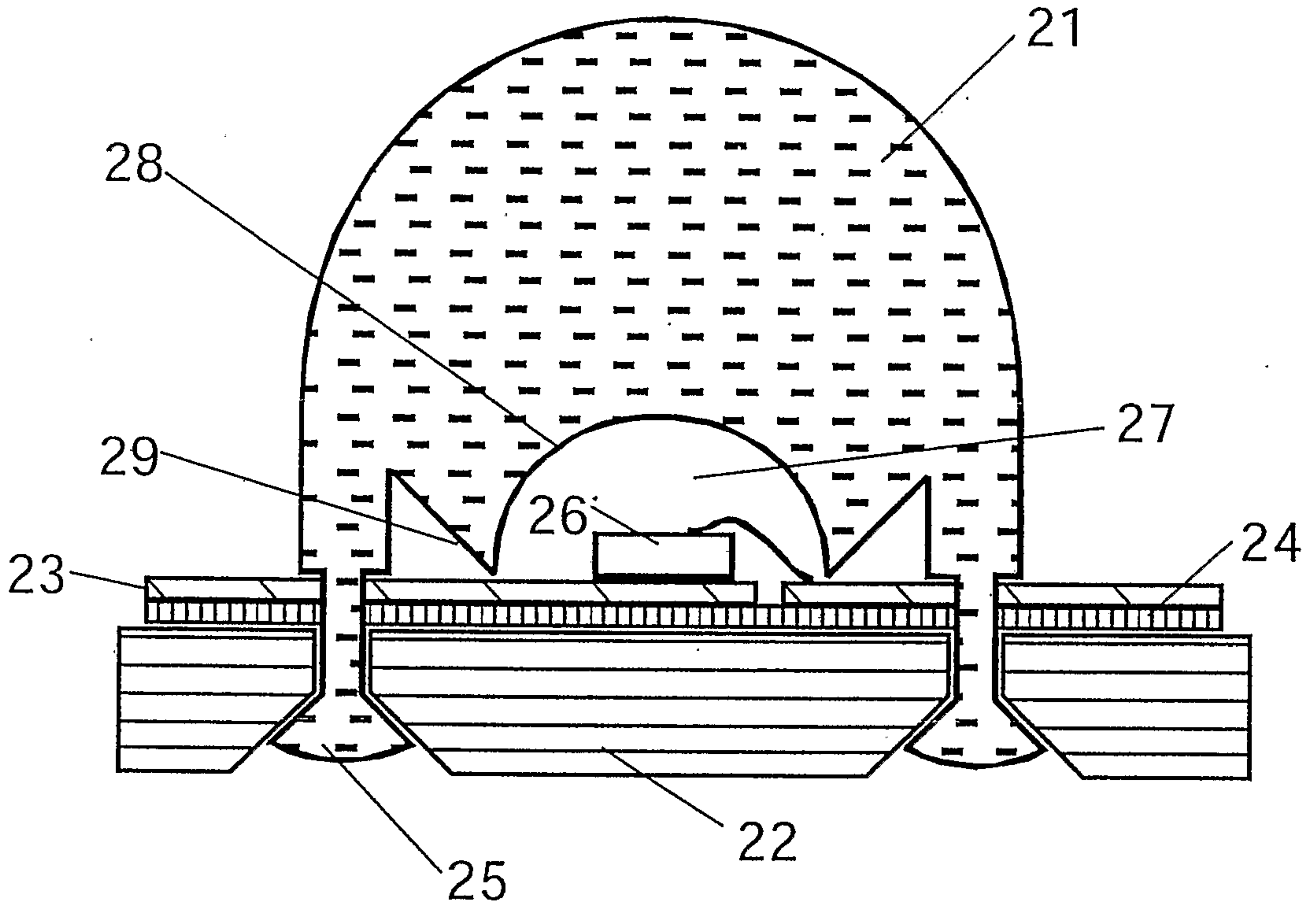


Fig. 2

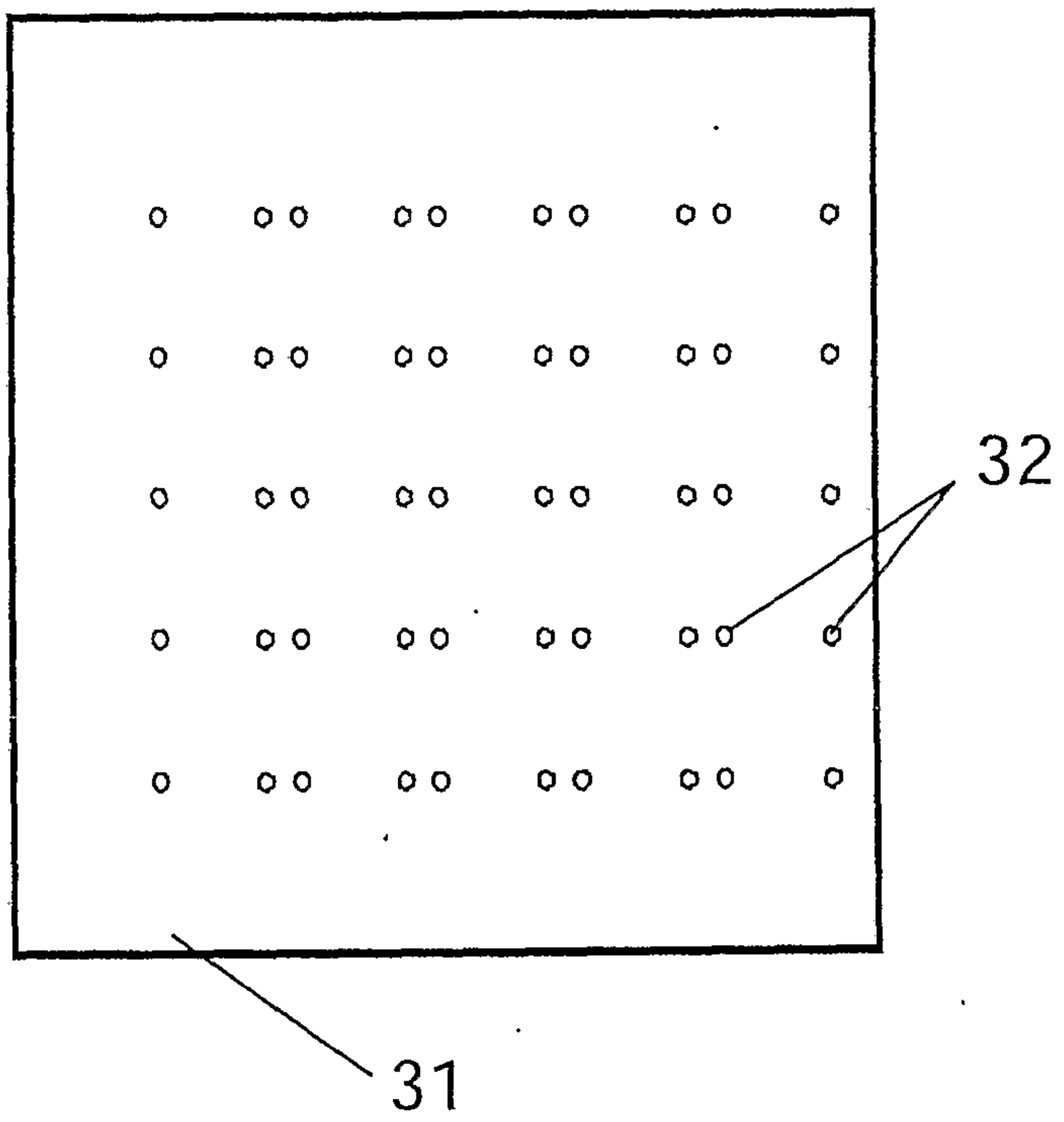


Fig. 3

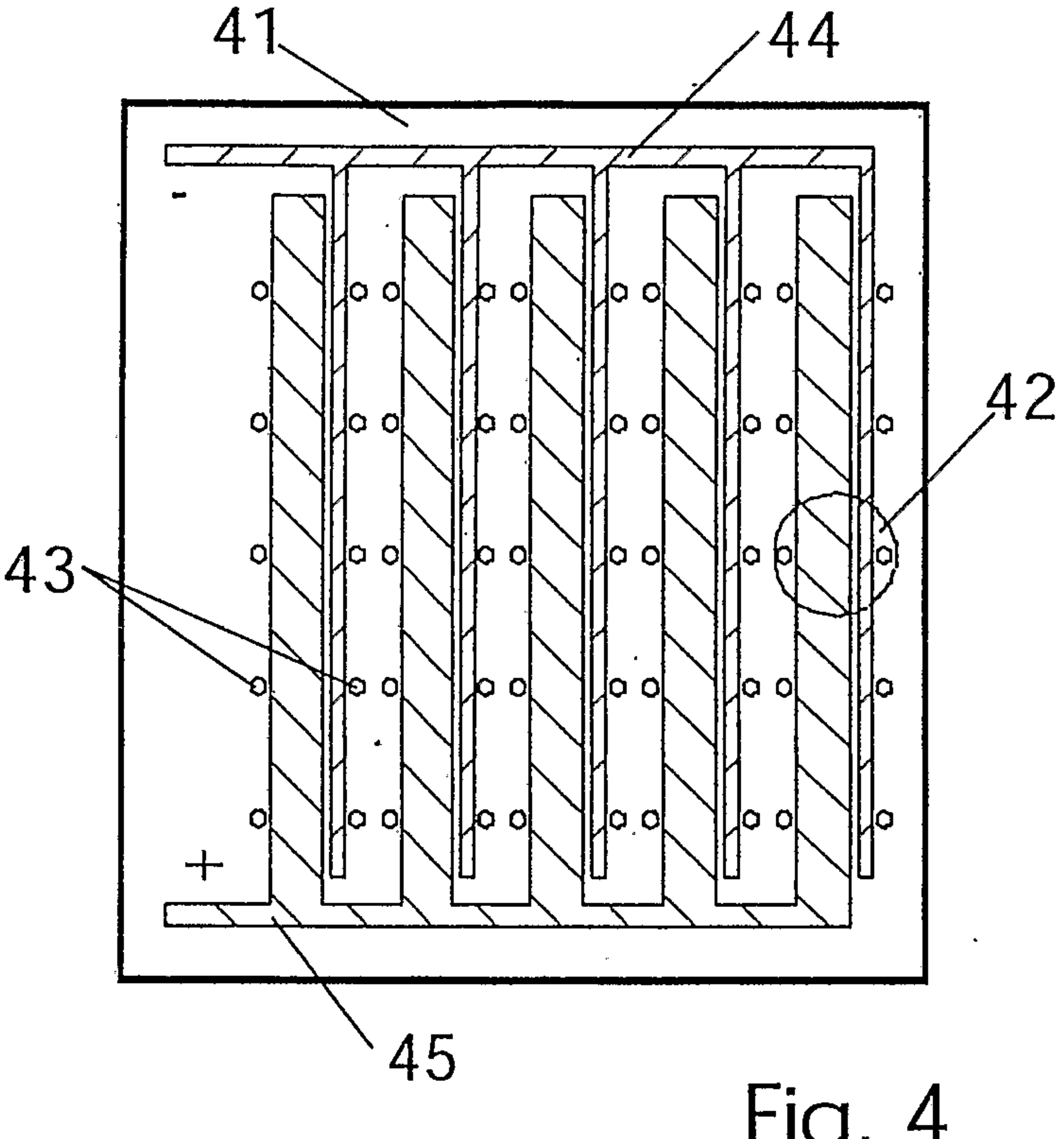


Fig. 4

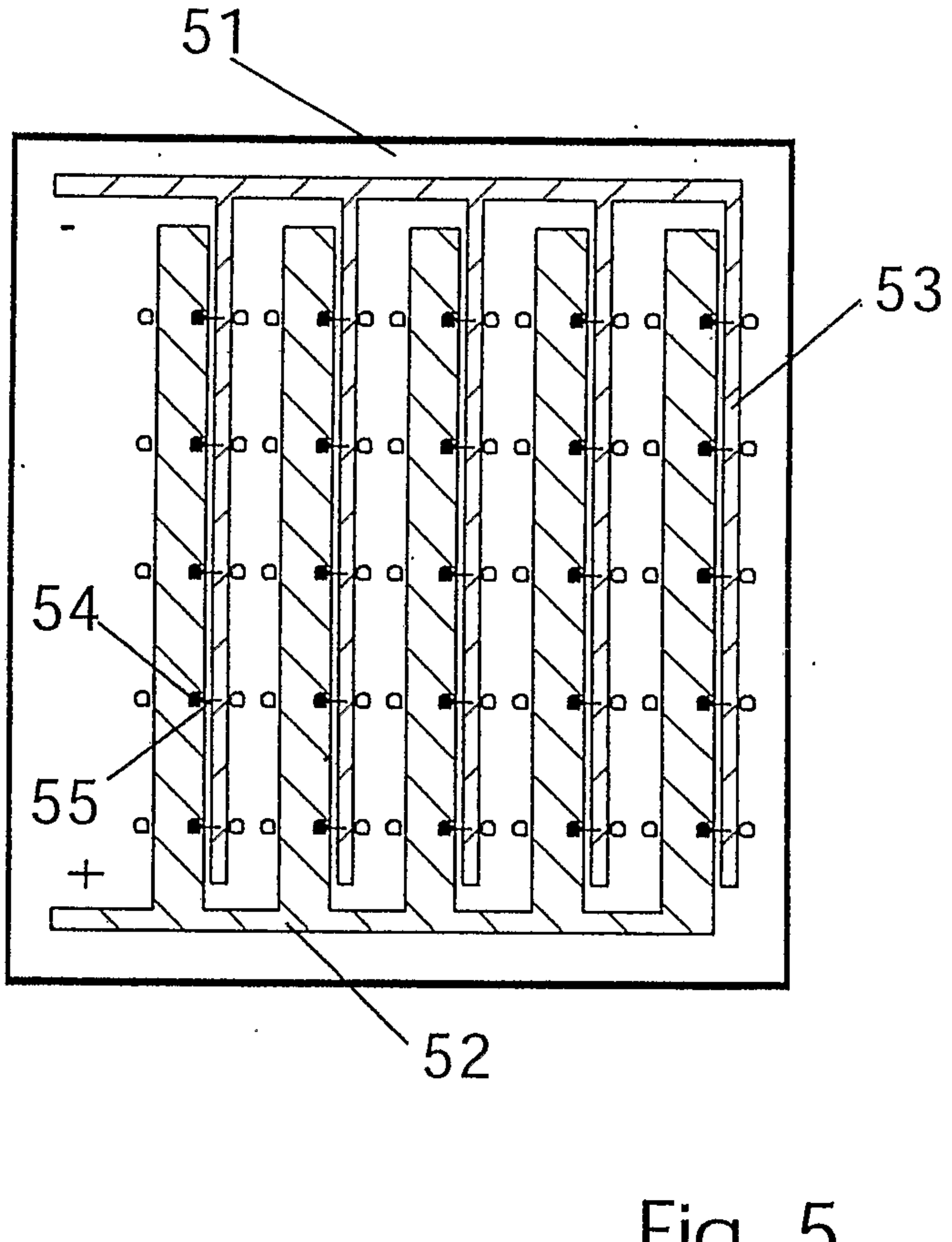


Fig. 5

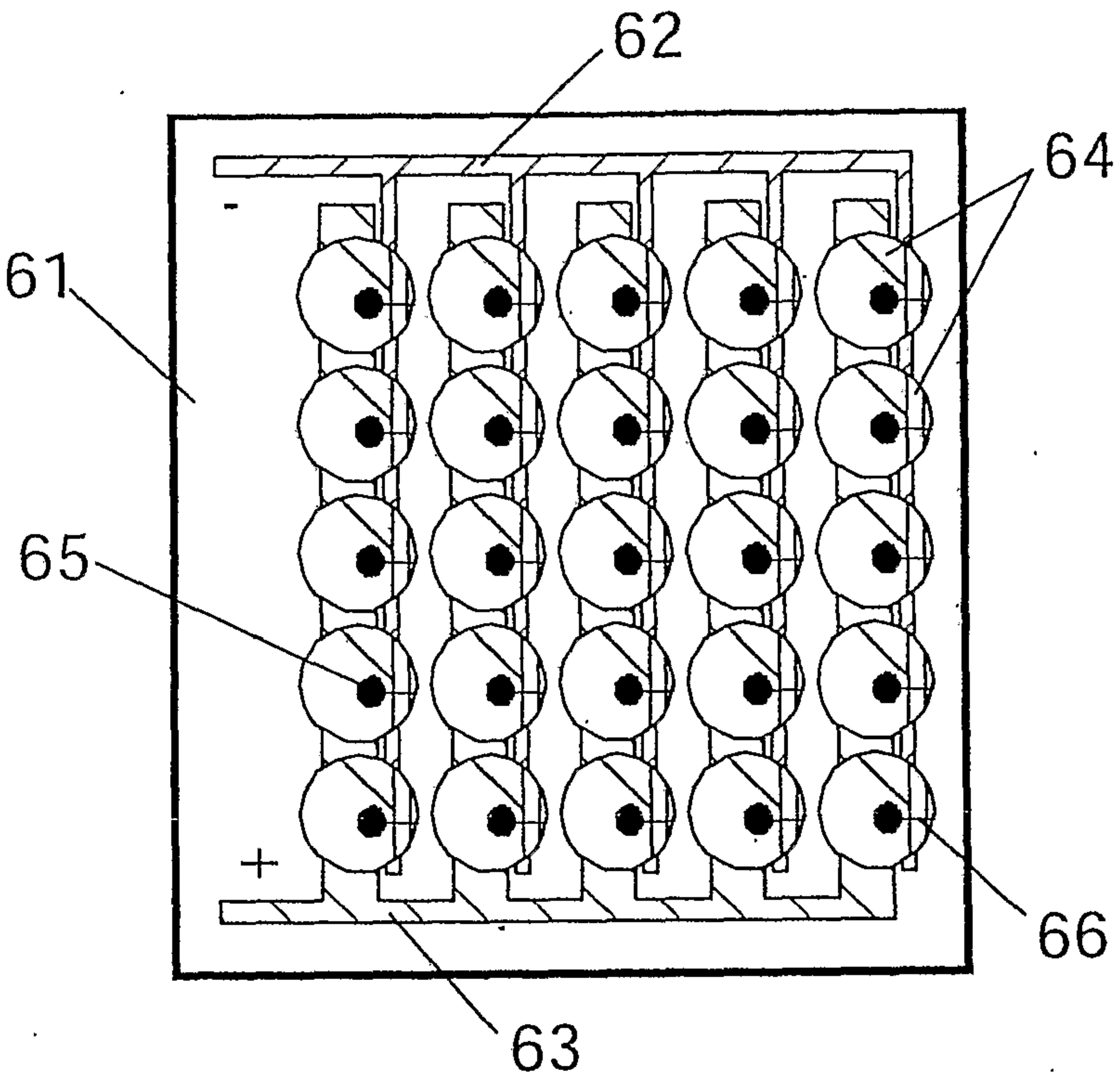


Fig. 6

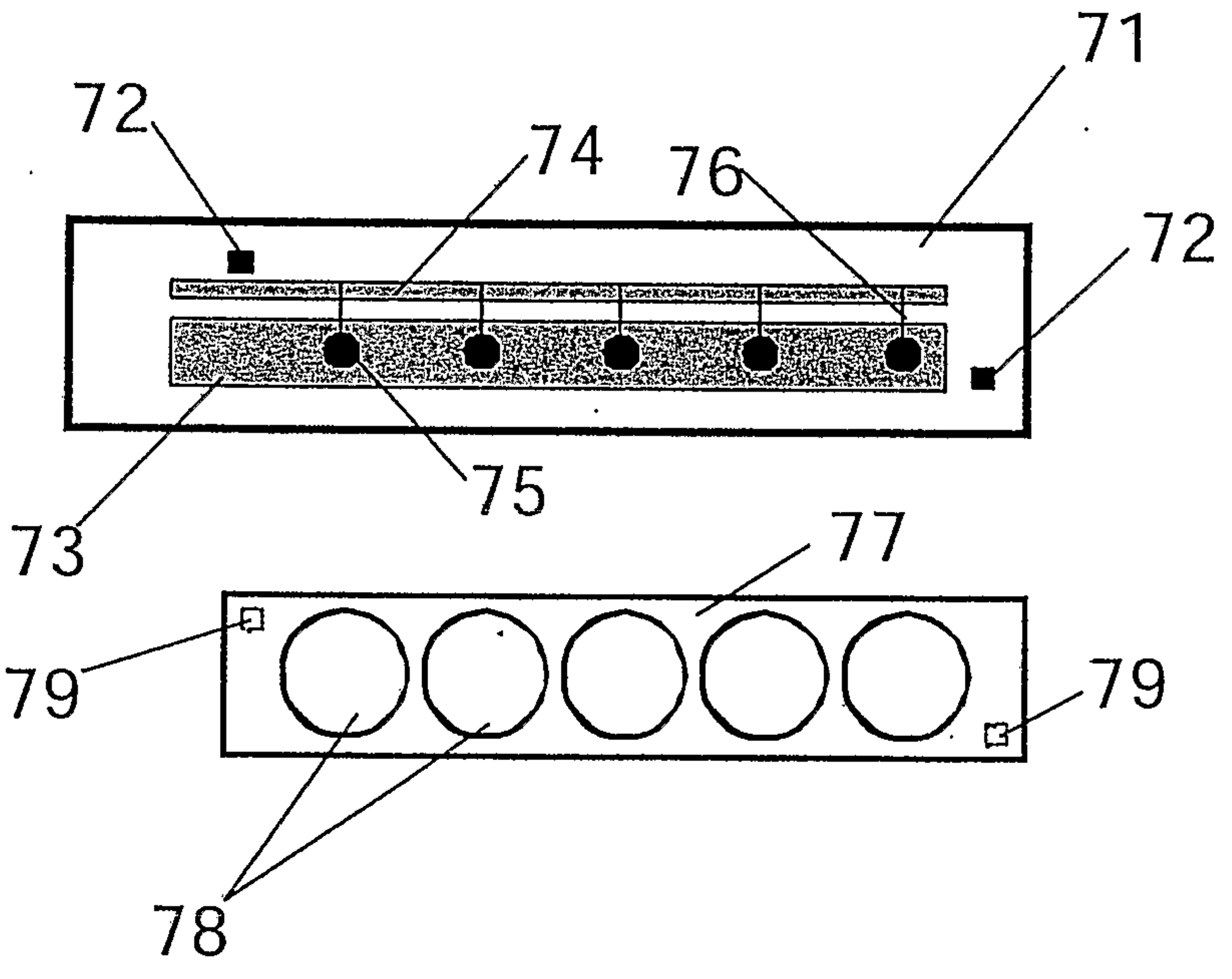


Fig. 7

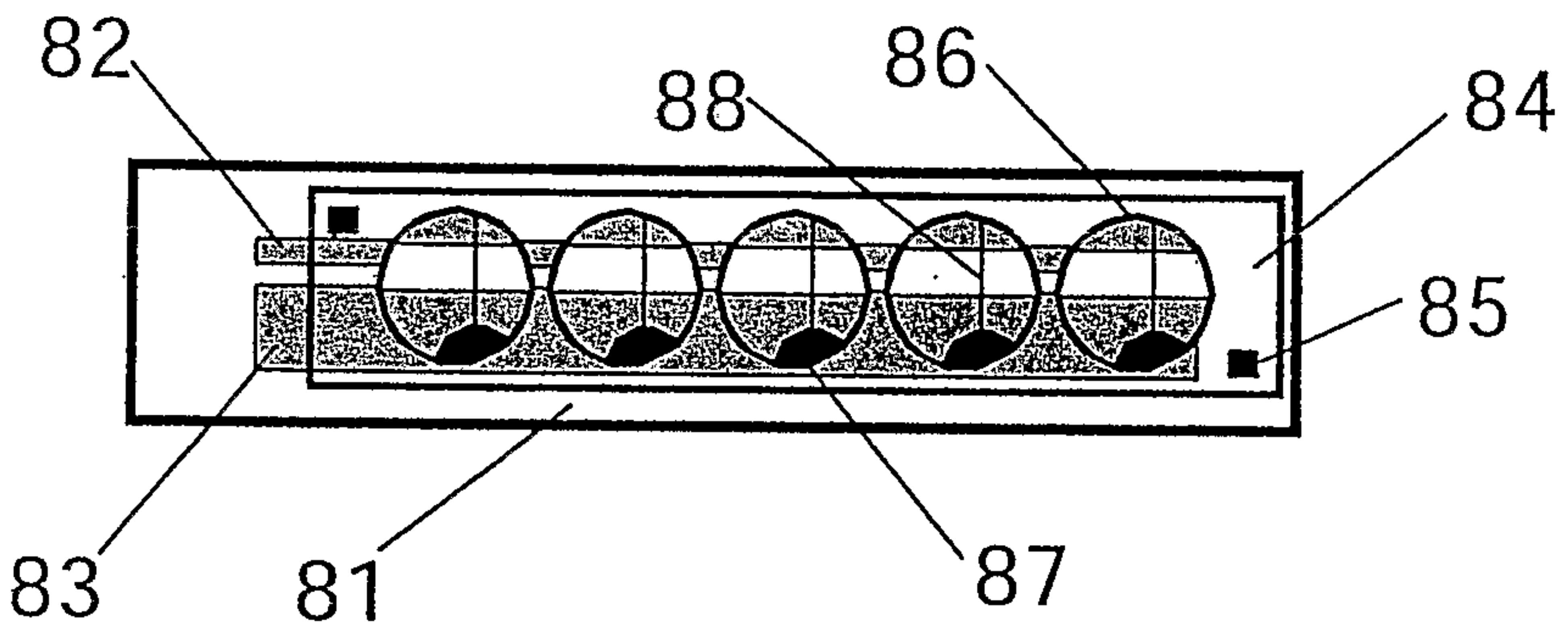


Fig. 8

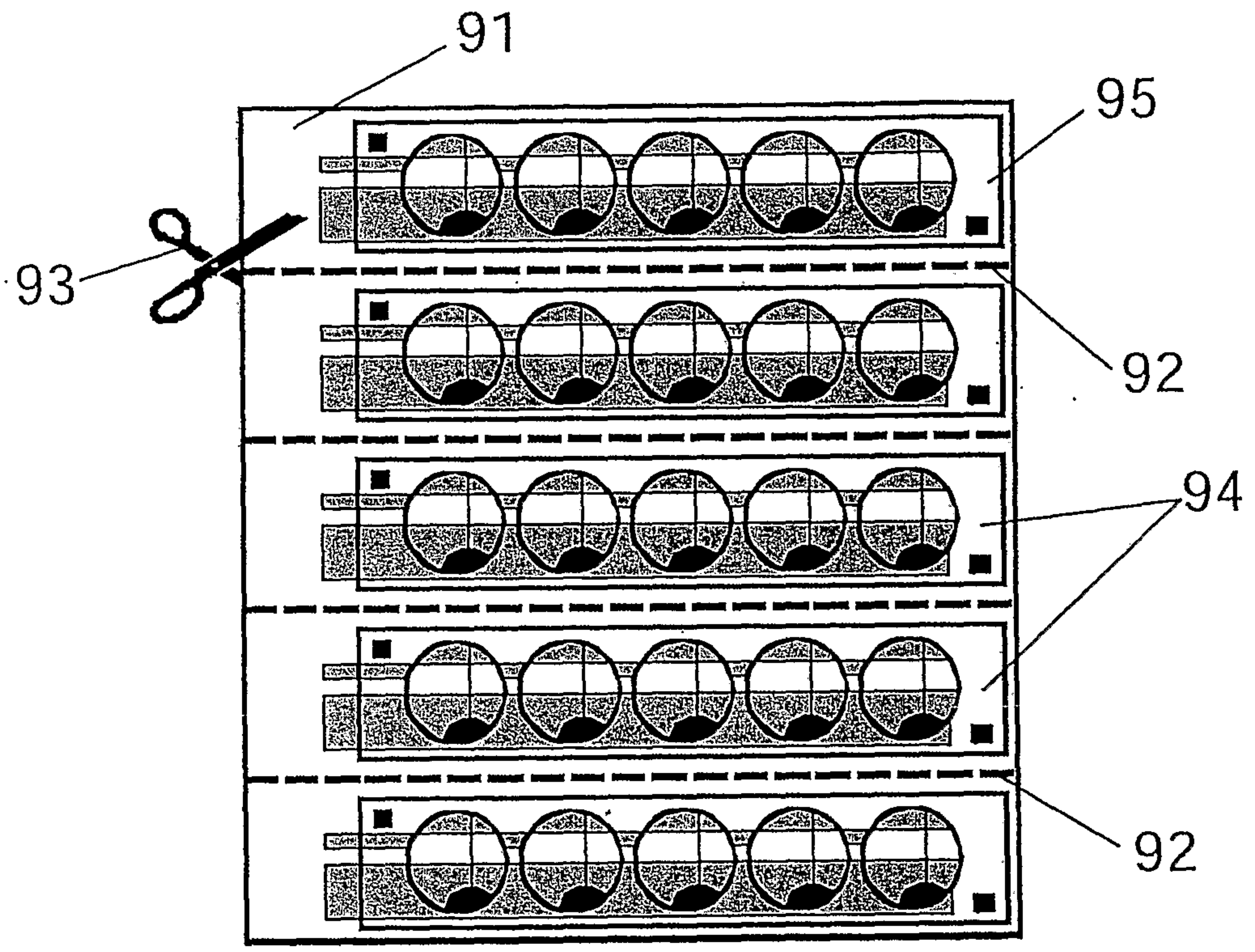


Fig. 9

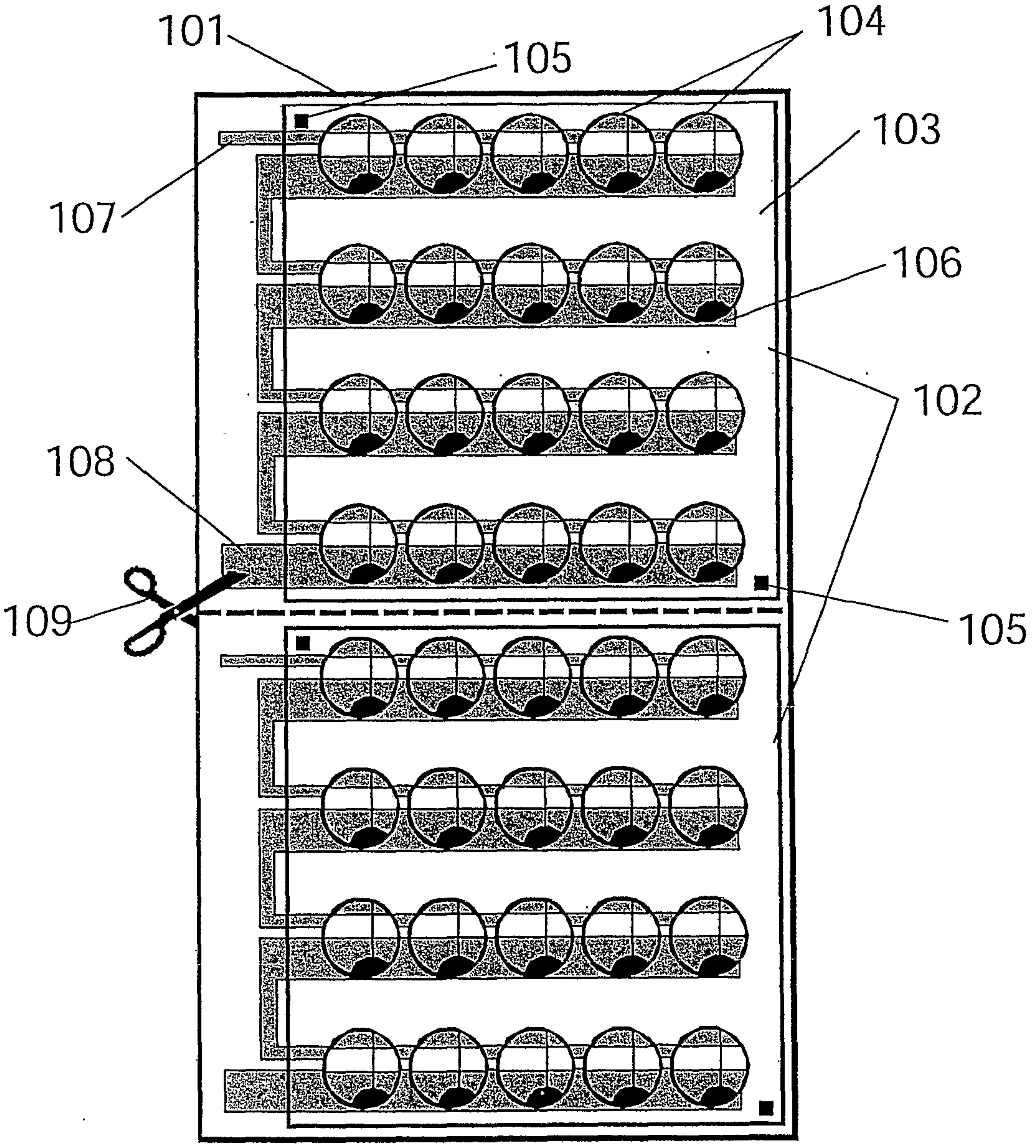


Fig. 10

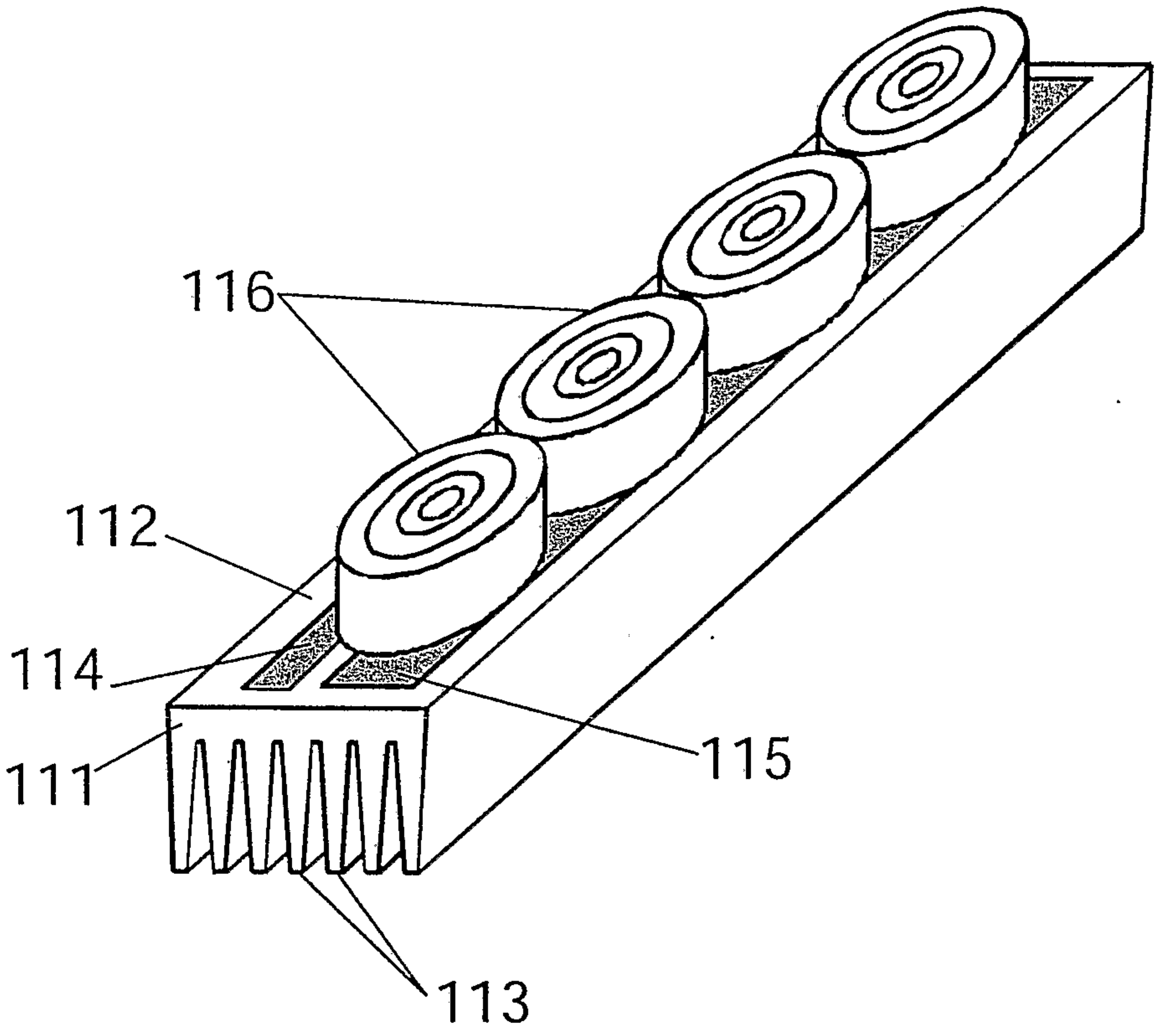


Fig. 11

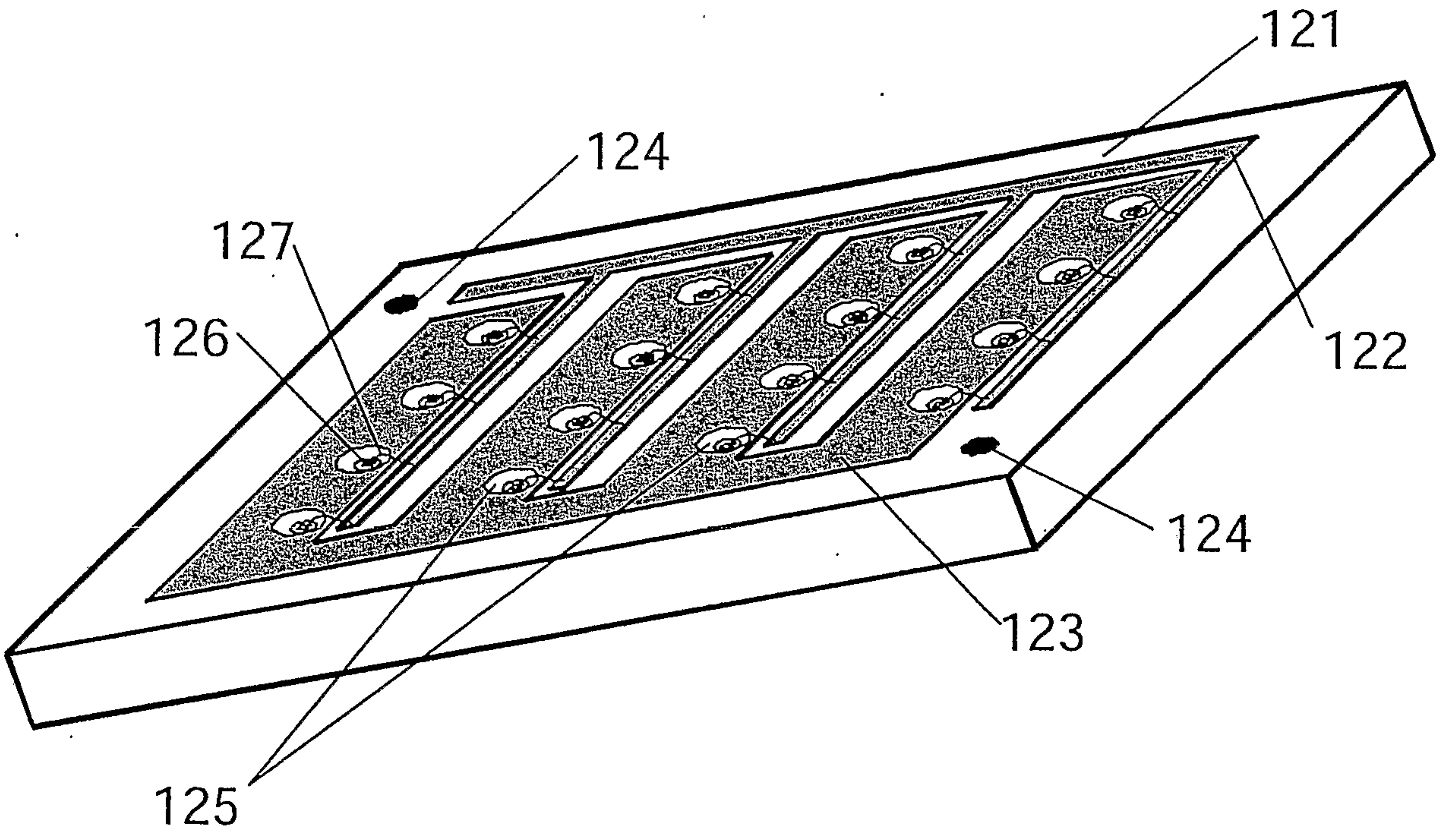
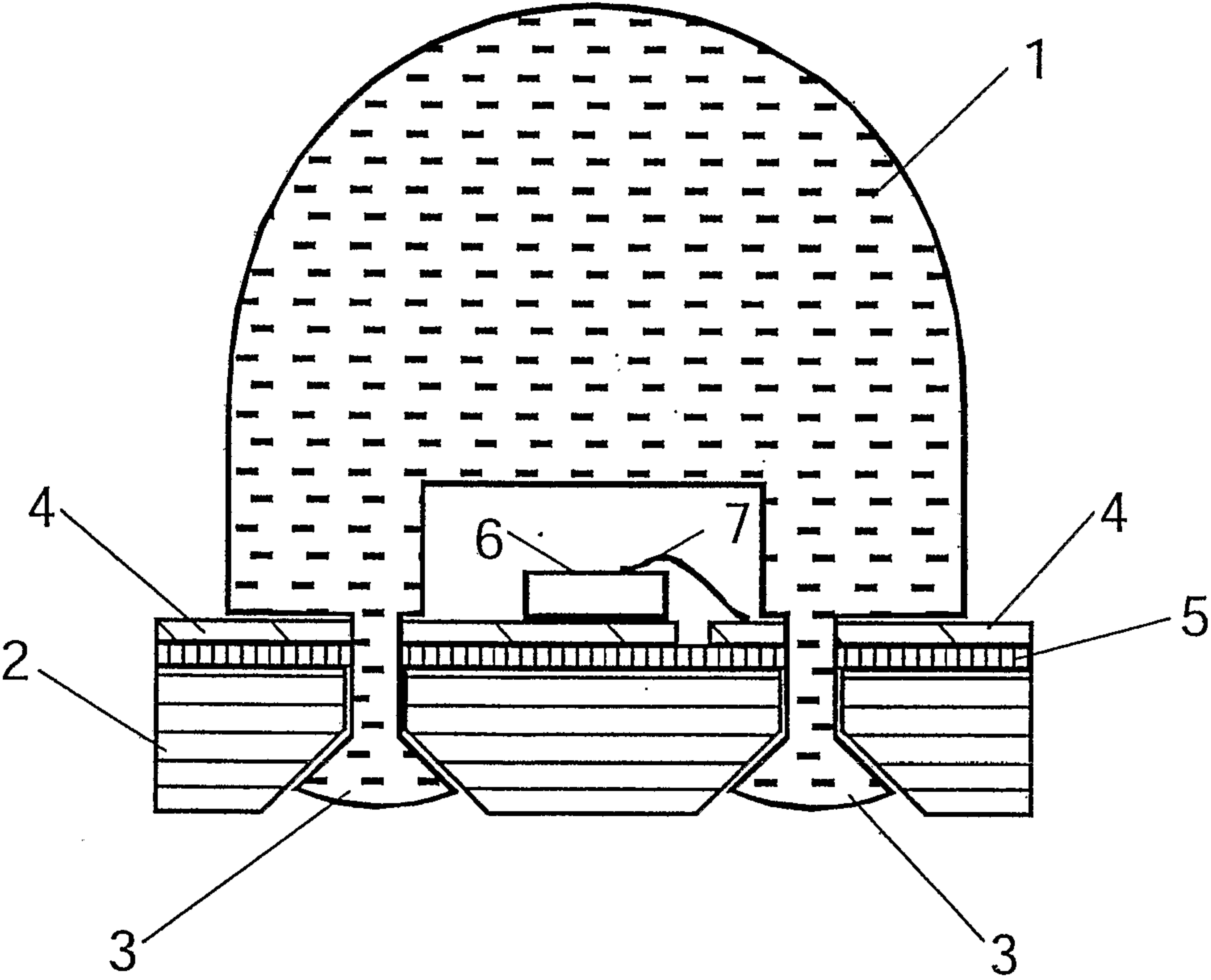


Fig. 12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