

[54] **OPTOELECTRONIC SEMICONDUCTOR
DEVICE**

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[22] Filed: **Sept. 23, 1968**
[21] Appl. No.: **761,685**

[30] **Foreign Application Priority Data**
Sept. 27, 1967 Germany.....T 34891
[52] **U.S. Cl.**.....**250/218, 250/239, 340/234,**
340/237 R, 340/244 R, 356/133, 356/136
[51] **Int. Cl.**.....**G01n 21/26, G01n 21/46, G02b 21/00,**
H01j 39/02
[58] **Field of Search**.....**250/239, 218; 356/135, 133;**
340/234, 237, 244

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[57] **ABSTRACT**

An optoelectronic or photosensitive semiconductor device in which a light-emitting element and a light-responsive element are arranged in a common casing, the degree of photocoupling between the two elements being dependent entirely on conditions exterior of the casing. In one embodiment, the two elements are embedded in a light-permeable mass, the boundary surface of which, together with a medium surrounding the mass, forms a surface whose reflection characteristic is dependent on the indices of refraction of the mass and of the medium, the elements themselves being so arranged that when the index of refraction of the medium is such that the boundary reflects the light coming from the light-emitting element, the reflected light is picked up by the light-responsive element, with the amount of light being picked up being dependent on, and thus an indication of, the medium surrounding the mass. In another embodiment, light emitted by the light-emitting element is free to exit the mass and, if reflected by an object outside the mass, is picked up by the light-responsive element.

7 Claims, 4 Drawing Figures

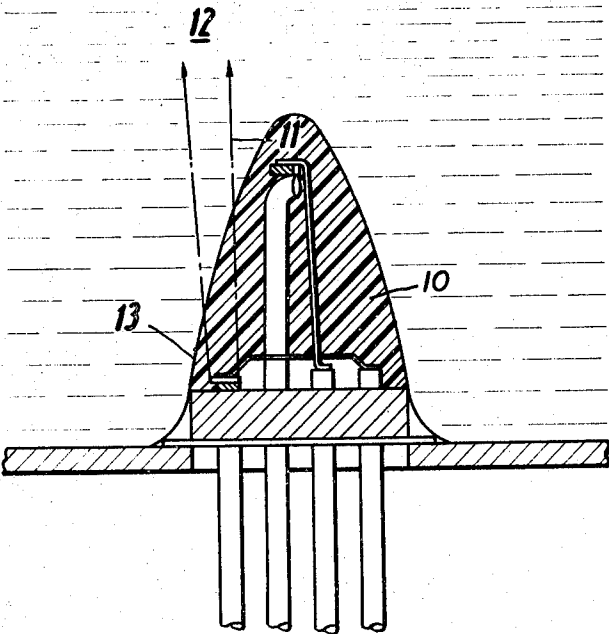


Fig. 1

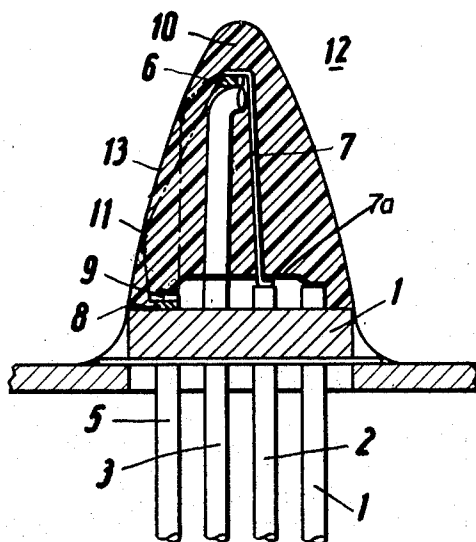
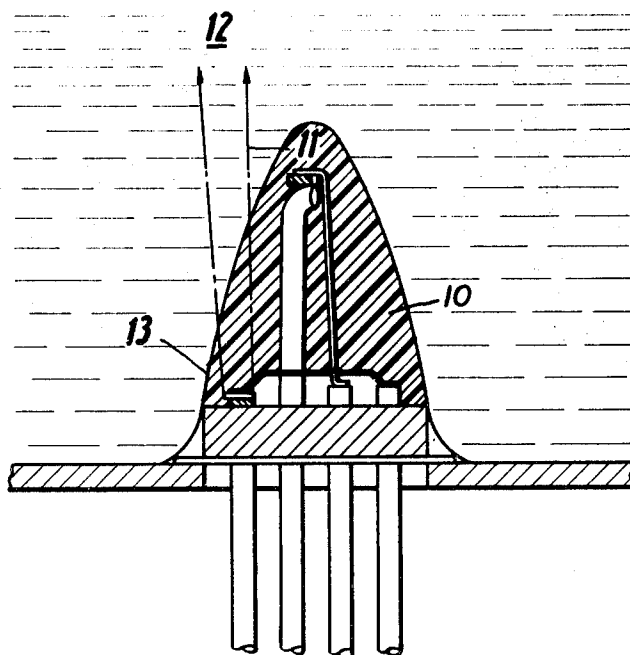


Fig. 2



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Fig. 3

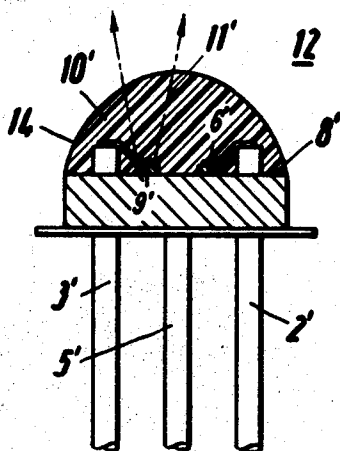
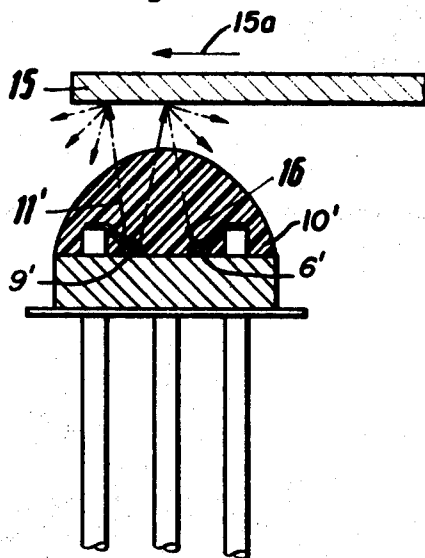


Fig. 4



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OPTOELECTRONIC SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

There exist various types of photosensitive devices by means of which the absence or presence of various types of objects can be determined. Such devices include a light-emitting element and a light-responsive element, which must be strategically placed so that the light going from the former to the latter will follow a path which cuts across the space occupied by the object the presence or absence of which is to be determined. This creates a number of difficulties, not only insofar as the placement of the elements is concerned, but also insofar as manufacturing and installation costs are concerned.

It is, therefore, the object of the present invention to provide a way in which to overcome the above drawbacks.

BRIEF DESCRIPTION OF THE INVENTION

With the above object in view, the present invention relates to an optoelectronic semiconductor device having a light-emitting element as well as a light-responsive element, the two elements being arranged in a common light-permeable casing in such a way as to make possible the determination of a characteristic of the medium surrounding the casing, or of an object next to the casing, from the degree of the optoelectronic coupling between the two elements.

Thanks to the fact that, in accordance with the present invention and in contradistinction to the known prior art, the light source as well as the light receiver or pickup are accommodated in a common housing, the manufacture and construction of indicator apparatus incorporating light-responsive elements is significantly simplified and the cost and installation of this type equipment, which is generally used for recording and counting, is reduced.

More particularly, the present invention resides in a photosensitive device in which the light-emitting and light-responsive elements are embedded in a common light-permeable casing, the elements being so arranged that the amount of light picked up by the light-responsive element is dependent on conditions which are entirely exterior of the casing.

According to one embodiment of the present invention, the elements are embedded in a mass, the boundary surface between the mass and the medium surrounding the mass forming a surface whose reflection characteristic is dependent on the indices of refraction of the mass and of the medium, the index of refraction of the mass being so selected and the elements being so arranged that when the medium outside the mass is gaseous, light emitted by the light-emitting element is reflected by the boundary surface so as to strike the light-sensitive element, whereas, when the medium is a liquid, virtually none of the light is reflected. In practice, the amount of light which is reflected will depend on the index of refraction of the liquid.

According to another embodiment, the light emitted by the light-emitting element exits from the light-permeable mass but is picked up if reflected by an opaque object outside of the mass.

Thanks to the above arrangement, the type of medium surrounding the casing, or the presence of an object outside of the casing, can be determined and the device can be used, for example, to respond to and control a liquid level in that the output obtained from the light-responsive element will depend on whether or not, and how much, light strikes this element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are sectional views of one embodiment of a device according to the present invention which is suitable for indicating and controlling liquid levels, the two figures showing the operation of the device when the same is surrounded by two different media.

FIGS. 3 and 4 are sectional views of another embodiment of a device according to the present invention, the two figures showing the operation of the device when used for counting and recording passing objects.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and first to FIG. 1 thereof, the same shows a semiconductor device comprising a socket 1, through which extend three electrode leads 2, 3, 4, which are electrically insulated from the socket and from each other, there being a fourth electrode lead 5 which is electrically conductively connected to the metallic bottom of the socket 1. The lead 3 is shown as extending upwardly beyond the bottom of the socket, there being a light-responsive element 6 arranged at the top of lead 3, one electrode of this element 6 being electrically connected with the top of the lead 3. This element 6 is, for example, a silicon photodiode or photoresistor, whose other electrode is connected, by way of a thin connecting wire 7, with one of the other lead, such as the lead 2 as shown in FIG. 1. If desired, the connecting wire 7 can be dispensed with by extending the lead 2 upwardly and by bending the ends of leads 2 and 3 in such a way that the light-responsive element 6 is between the ends of the two leads and is thus electrically connected to both. In any event, the light-responsive element is located generally above the center of the socket.

A light-emitting element 9, for example, a gallium-arsenide luminescence-type diode, is arranged in the region of the edge of the bottom surface 8 of the socket and has one of its electrodes electrically connected with another of the leads, e.g., the lead 5 as shown, the other electrode of the element 9 being connected to the fourth lead 4 via a further connecting wire 7a.

The socket 1 as well as the electrode connections and the semiconductor elements 6 and 9 are embedded in a light-permeable mass 10, such as glass, synthetic resin, or a mixture of the two. This light-permeable mass 10 thus forms a closed casing and, as shown in FIG. 1, has a conical configuration which enlarges in the direction from the top, as viewed in FIG. 1, toward the socket.

If, now, the element 9 is excited by means of an electric current flowing therethrough, the element will emit a beam of light 11, which will strike the boundary surface 13 between the light-permeable mass 10 and the surrounding medium 12 at a very large angle of incidence (this being the angle between the light beam and the perpendicular to the boundary surface at the point of incidence), namely, an angle of incidence which is but slightly less than 90°. If the medium 12 surrounding the casing 10 is a gaseous medium, the angle of incidence will be greater than the critical angle and the entire light beam 11 will be reflected at the boundary surface 13 and will impinge on the light-sensitive layer of the element 6, the precise position of which is such as to be in the path of light emitted by element 9 and reflected by the boundary surface 13. Thus, the light-sensitive characteristic of the element 6 will be markedly affected by the large amount of light which strikes the element 6 when the device is surrounded by a gaseous medium.

If, however, the device is immersed in a liquid as shown in FIG. 2, the angle of incidence will be less than the critical angle and the boundary surface 13 between the casing 10 and the medium 12 will not reflect the light beam 11; instead, the same will freely exit the mass and pass through the boundary surface 13 and into the liquid medium. The element 6 is thus not subjected to illumination emanating from the element 9.

It will thus be seen that whether or not the arrangement is in a liquid can be determined by measuring the characteristic of the element 6, since this characteristic will be markedly different depending on whether the casing 10 is surrounded by a gaseous or a liquid medium. This can be done electrically, via the leads 2 and 3, in a manner well known in the art. The electrical output of this measurement can then be used to give an indication of the height of a liquid level, or for controlling switching systems, pumps, motors, or the like, for example, for the purpose of controlling a liquid level under various conditions, such as in washing machines, in fountains, or in storage tanks containing water, gasoline, oil, or any other liquid.

In the preceding discussion, it was assumed that the liquid is a clear liquid. If, however, the liquid is not clear but a light-dispersing such as milk, some of the light emanating from the element 9 will strike the element 6. The amount of this light will depend on the opaqueness or cloudiness of the liquid, so that the characteristic of the element 6 can be used as a measure of the light-dispersing characteristic of the liquid. Thus, the purity or cloudiness of the liquid surrounding the casing 10 can be determined, as this will affect the light sensitive characteristic of element 6.

The following is an illustrative and not limitative example of the embodiment described above. The light-responsive element 6 is a silicon diode, and the element 9 is a GaAs luminescence diode. The mass 10 is made of epoxy resin and has an index of refraction of about 1.5. In normal operation the excitation current applied to element 9 is 100 m.A. DC. When the arrangement is surrounded by air and the maximum light from element 9 is reflected by the boundary surface 13 to impinge on element 6, the output current is 9 μ A.; when the arrangement is submerged in clear water, the output current of element 6 is 1 μ A. With the arrangement being submerged in milk, there was obtained an output from elements 6 of 13 μ A.; in water with a milk content of 10 percent, the output was 2 μ A.; in water with a milk content of 50 percent, the output was 7 μ A.; in oil and in gasoline, the output was the same as in water (about 1 μ A.).

FIG. 3 shows another embodiment of a device according to the present invention wherein both the light-emitting and the light-responsive elements 9' and 6', which may again be constituted by a gallium-arsenide luminescence diode and a silicon photodiode, respectively, each having one of their electrodes in direct electrical contact with the bottom surface 8' of the socket 1. The two elements 6', 9', are arranged generally in the center of the bottom surface, the same normally being circular. In this embodiment, the lead 5' is electrically connected with the socket while the other two leads, namely 2' and 3', are insulated from the socket and contact the other electrodes of the two semiconductor elements, respectively. The light-permeable mass 10', in which the other components are embedded or which, if made of resin, may be molded to the other components, is shown as arching upwardly in a substantially hemispherical configuration.

If, now, as shown in FIG. 3, the element 9' is excited and puts out a light beam 11', the same strikes the spherical boundary surface 14 between the mass 10' and the surrounding medium 12—normally air—at practically a right angle, so that if there is nothing near the device which would reflect the light, the element 6' will receive virtually no light. If, however, an opaque object 15 is moved past the arrangement in the direction of the arrow 15a, as shown in FIG. 4, a portion 16 of the light beam 11' is reflected and will strike the element 6', which responds by changing its characteristic as the result of the impinging light. In this way, the passage of an article can be noted, the output signal of the device being applied to any suitable recording apparatus or counter, or otherwise be processed to utilize the information.

In both the above-described device as well as in that described in connection with FIGS. 1 and 2, the light emitting element can be energized to emit alternating light, so as to make the device as independent as possible from ambient light conditions.

The following is an illustrative and not limitative example of the embodiment described in connection with FIGS. 3 and 4, the same incorporating similar light-emitting and light-sensitive elements and a similar light-permeable mass as that which described in conjunction with the specific example of the embodiment of FIGS. 1 and 2. When no light from element 9' was reflected on element 6', the output of the latter was 100 μ A.; when an opaque plate was passed within a distance from the element of approximately 0.5 mm., sufficient light was reflected onto the element 6' to obtain from it an output of 300 μ A.

It will be understood that the above description of the present invention is susceptible to various modifications, changes and adaptations. For example, the precise spatial location of the light-emitting and light-responsive elements can be varied, as can the shape and composition of the light-permeable mass, and the number of leads, the latter depending on whether the elements will have a common lead and/or the number of electrodes of the elements. For instance, if the light-sensitive element is a phototransistor instead of a diode, an additional lead will be provided.

The terms "light-emitting," "light-responsive" and "light-permeable" as used throughout the instant specification and claims, are intended to comprehend not only visible light but also invisible light and other radiation having characteristics which are technologically and scientifically equivalent to light radiations.

I claim:

1. An optoelectronic semiconductor device comprising, in combination:

a. a radiation-permeable mass selected from the group consisting of resin, glass, and a mixture of resin and glass, and constructed in the form of a closed casing having a hemispherical or conical configuration having an index of refraction and defining an outer boundary surface.

b. a radiation-emitting gallium-arsenide luminescence-type diode embedded in said mass and arranged to emit a beam of radiation at an angle of incidence with respect to said boundary surface which is less than the critical angle at said boundary surface when said boundary surface is surrounded by a liquid medium to permit substantially all of the radiated beam to freely exit from said mass, and greater than the critical angle at said boundary surface when said boundary surface is surrounded by a gaseous medium to reflect substantially all of the radiated beam as a function of the index of refraction of said gaseous medium;

c. a radiation-responsive semiconductor element embedded in said mass and arranged in the path of radiation reflected from said boundary surface to receive same; and

d. a socket connected to said mass which mass enlarges toward said socket, and leads extending through said socket and connected to the radiation emitting diode and the radiation-responsive element, the radiation emitting diode being arranged on said socket and said radiation responsive semiconductor element being spaced from said socket and supported on one end of one of said leads, which lead extends beyond said socket and into said mass.

2. An optoelectronic semiconductor device comprising, in combination:

a. a radiation-permeable mass forming a closed hemispherical casing;

b. a radiation-emitting gallium-arsenide luminescence diode embedded in said mass near the center of said hemispherical casing and arranged to emit radiation which exits from said mass without being reflected;

c. a radiation-responsive silicon photodiode embedded in said mass near the center of said hemispherical casing and adjacent the radiation-emitting diode and arranged to receive radiation emitted by said radiation-emitting diode and reflected by striking an opaque object to be detected outside of said mass; and

d. a socket connected to said mass and having a bottom surface on which said diodes are mounted, which mass enlarges toward said socket, and leads extending through said socket and connected to said diodes.

3. An optoelectronic semiconductor device comprising, in combination;

a. a radiation-permeable mass forming a closed casing;

b. a radiation-emitting element embedded in said mass;

c. a radiation-responsive element embedded in said mass for receiving radiation emitted by said radiation-emitting element and reflected back into the mass; and

d. a socket connected to said mass and having a bottom surface on which at least said radiation-emitting element is mounted, which mass enlarges toward said socket, and leads extending through said socket and connected to said elements.

4. A device as defined in claim 3, wherein said radiation-responsive element is mounted on said bottom surface.

5. A device as defined in claim 3 wherein said mass is hemi-

spherical or conical.

6. A device as defined in claim 3 wherein said radiation-emitting element is a gallium-arsenide luminescence-type diode.

5 7. A device as defined in claim 3 wherein said radiation-responsive element is a silicon photodiode, a phototransistor, or a photoresistor.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,639,770 Dated February 1st, 1972

Inventor(s) Walter Zizelmann

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

In the heading of the patent, line 4, change "Patentverwertungsgesellschaft" to --Patentverwertungsgesellschaft--. Column 2, line 60, change "11" to --11'--.

Signed and sealed this 8th day of August 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents