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 NOW BY CHANGE OF NAME
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 SEMICONDUCTOR PHOTOCONDUCTING DEVICE
 Filed Nov. 30, 1951

2,669,663

Fig. 1.

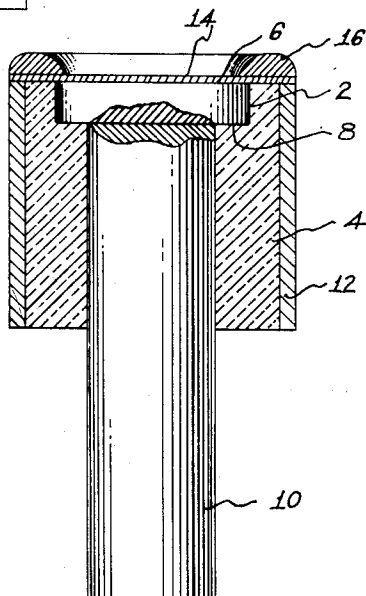


Fig. 4.

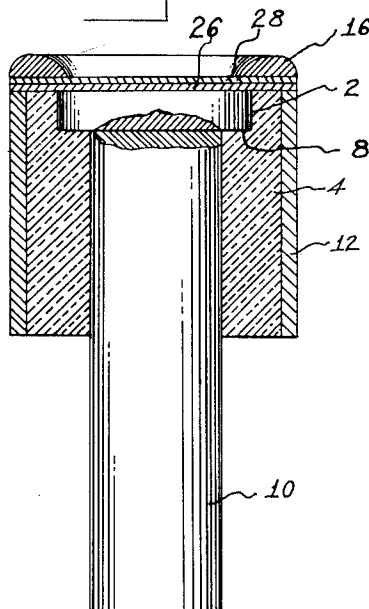


Fig. 2.

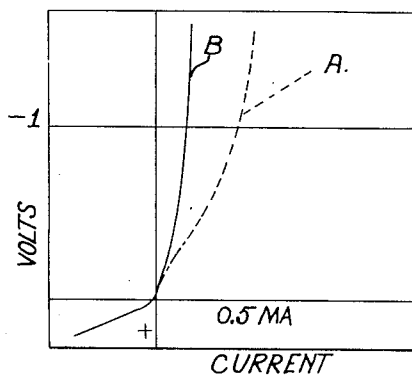
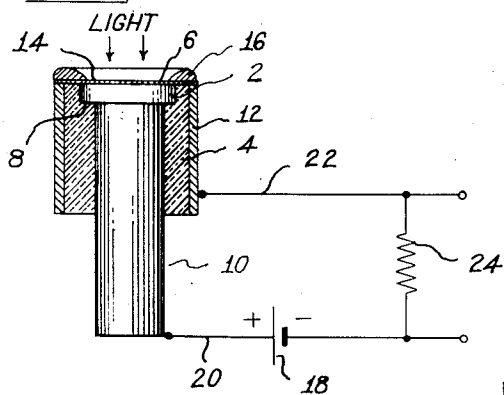


Fig. 3.

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2,669,663

SEMICONDUCTOR PHOTOCONDUCTING
DEVICE

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Application November 30, 1951, Serial No. 259,233

7 Claims. (Cl. 250-211)

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This invention relates to an improved device including a photocell of the type which comprises a body of semi-conducting material having a light-transmitting film of metal on a surface thereof. More particularly, the invention relates to a device including a photoconducting cell of this type.

It has been known that photovoltaic cells can be made by etching a surface of a body of a semi-conducting material such as highly purified germanium and depositing a thin, light-transmitting film of any one of a number of metals on the etched surface. The metals that have been found to give best results for the light-transmitting film are gold, copper, and nickel. These have previously been disclosed in a copending application of Jacques Pantchechnikoff, Serial No. 231,195, filed June 12, 1951.

It has now been found that a device having excellent photoconducting properties can be made by using films of antimony, bismuth, or beryllium and applying a bias voltage between the film and the body of semi-conducting material.

One object of the present invention is to provide an improved device which includes a photoconducting cell.

Another object of the invention is to provide a photoconducting device which is relatively simple in construction.

Another object of the invention is to provide an improved photoconducting device which is rugged in construction and stable in operational characteristics.

Another object of the invention is to provide an improved photodevice having photoconducting properties when a bias voltage is employed.

These and other objects will be more apparent and the invention will be more readily understood from the following detail description and the accompanying drawing of which:

Figure 1 is an elevation cross-section view of one form of photocell that can be used in the device of the present invention,

Figure 2 is a schematic diagram of a circuit arrangement used with a photocell such as shown in Figure 1 to make up a device in accordance with the present invention,

Figure 3 is a graph having curves to show comparison between currents in the dark and in the light, with different bias voltages applied, in a device of the present invention, and

Figure 4 is a view similar to that of Figure 1, of another embodiment of a photocell that can be used in the device of the present invention.

Referring now to Figures 1 and 2, a specific

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embodiment of a device constructed in accordance with the principles of the present invention comprises a photocell which includes a body 2 of germanium semi-conducting material embedded in a block 4 of material such as polystyrene or other good insulating material. The body of semi-conducting material is embedded in a manner such that one of its faces 6 is exposed. To another surface 8 of the semi-conducting body an electrode 10 is soldered. This electrode may be a nickel stud, for example.

A second electrode 12 is provided in the form of a metal cylinder surrounding and concentric with the semi-conductor body 2 and the stud 10. The inner walls of the cylinder are spaced from the semi-conductor body.

A thin, light-transmitting film of metal 14 is deposited on the exposed face 6 of the semi-conducting body and across the end of the block of insulating material to the cylindrically shaped electrode 12. In this case the metal should preferably be beryllium, antimony or bismuth for it has been found that when any of these metals is used, the cell acquires photoconducting properties in the presence of a biasing voltage. It has also been found that cells including any of these three metals as the light-transmitting film do not exhibit photovoltaic properties. The metal may be deposited by well known vapor deposition techniques in vacuo. The thickness of the metal coating may vary considerably but is preferably such that about 10 to 40% of the incident light is transmitted. Ohmic resistance of the film should preferably be about 500 ohms per square.

As previously disclosed in the aforementioned co-pending application Serial No. 231,195 it is advantageous to provide a contact electrode in order to provide a better electrical path between that part of the metal film 14 overlying the semi-conductor body 2 and the end of the cylindrical electrode 12. The contact electrode may comprise a ring 16 of silver paste deposited around the edge of the metal film 14 such that it overlaps both the semi-conductor body and the cylindrical electrode.

Before depositing the metal film on the exposed surface of the semi-conductor body, this surface should be ground smooth and etched. Etching may be carried out using any one of a number of conventional etching solutions which have now become well known for preparing germanium surfaces to be used in rectifiers or amplifiers. One example of such a solution comprises 4 parts by volume of hydrofluoric acid

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(48% reagent), 2 parts by volume concentrated nitric acid, 4 parts by volume distilled water, and 200 milligrams cupric nitrate per 10 cc. of solution. Etching may be carried out within a period of 1 or 2 minutes.

So called N- or P-type semi-conducting material may be used in the photocell which forms a part of the present invention. If germanium is used, the germanium must, of course, be highly purified such that it has considerably less than 1% residual impurities and may be made either N- or P-type by "doping" with the necessary elements in very small amounts. For example, to obtain N-type germanium, tin or arsenic may be added as a donor and, to obtain P-type germanium, aluminum may be used as the additive.

Referring to Figure 2, if N-type germanium is used, a source of D.-C. biasing voltage is connected across the electrodes 10 and 12 such that the surface film 14 is negative with respect to the semi-conductor body 2. The source of biasing voltage may comprise a low voltage battery 18.

The device may also include a pair of output leads 20 and 22 connected to electrodes 10 and 12 respectively. An output impedance 24 may be connected across these leads.

In order to utilize the device of the present invention, the output leads are connected to any suitable utilization circuit, such as a light-indicating meter, for example, and light is directed through the central portion of the light-transmitting film overlying the semi-conductor body, as indicated by the arrows of Figure 2. As shown in Figure 3, when using a typical cell prepared as described, as the biasing voltage is increased from about 0.1 of a volt to about 1.5 volts, current in the forward direction is considerably increased for the illuminated condition (curve A) as compared to the dark condition (curve B). Magnitude of forward current when light is applied depends upon the area illuminated and the internal resistance of the photocell.

Example

A cell of the type shown in Figure 1 was made up using a film of antimony on a body of N-type germanium semi-conducting material. The thickness of the antimony film was such that about 11% of the incident light was transmitted. Resistance of the film was 160 ohms per square. Using a 40 watt, 110 volt Mazda lamp the film was positioned so that it was 11 cm. from the center of the bulb. This cell delivered 0.3 milliamp. current per sq. mm. area of surface when the bias voltage was about 0.5 volt.

To provide increased sensitivity, the device of the present invention may be modified by using a slightly different type of photocell. Referring to Figure 4, the modified photocell may comprise the same general parts, i. e., a body 2 of semi-conducting germanium embedded in a block of synthetic resin 4, one electrode consisting of a nickel stud 10 soldered to one surface of the semi-conductor body, and second electrode 12 of cylindrical form surrounding but not touching the semi-conductor. In this case, however, the film 26 of antimony, bismuth, or beryllium is much thinner than in the first embodiment described. It may be made so thin as to transmit about 40-90% of incident light. The electrical conductivity of a film of this type is usually very poor, however. To increase the conductivity a film 28 of copper or nickel is deposited over the

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first film. This film may also be applied by deposition from metal vapor, the metal having been vaporized in vacuo. The combined film thickness is preferably such as to permit about 30-40% light transmission. This type of composite film has higher electrical conductivity than one of the same thickness composed entirely of antimony, bismuth, or beryllium.

Of the three elements antimony, bismuth, and beryllium, which have been found to produce photoconductive type cells when deposited on a barrier layer type semi-conductor such as germanium, antimony and bismuth are preferred. Photoconductivity is relatively weaker in the case of beryllium. By barrier layer type semi-conductor is meant a semi-conducting material capable of forming a barrier layer at a surface thereof.

Various modifications can be made in the devices which have been described without departing from the spirit of the invention. For example, any convenient arrangement of electrodes may be utilized, that illustrated being merely one form which has been found both simple and efficient.

Instead of germanium any other surface barrier layer forming semi-conductor, such as silicon, may be used.

In connecting up the photocell with the source of bias voltage, if P-type semi-conducting material is used, the metal film should be + with respect to the semi-conductor body.

Any good insulating material that can be molded readily can be used as the medium in which the semi-conductor is embedded. Examples of suitable materials are polystyrene, cellulose esters and ethers, vinyl resins and acrylic acid derivative resins. It is also possible to omit the embedding material entirely since it does not contribute to the photoelectric properties of the device. If the embedding material is omitted, the metal film is deposited on the prepared surface of the semi-conductor body and contact made to the film with a wire.

What is claimed is:

1. An electrical device comprising a body of semi-conducting material capable of forming a barrier layer at a surface thereof and having on said surface a semi-transparent film of a metal from the class consisting of antimony, bismuth, and beryllium, an electrode in contact with said body, another electrode in contact with said film, a source of bias voltage and means connecting said source across said electrodes.

2. A device according to claim 1 in which said semi-conducting material is germanium.

3. An electrical device comprising a body of N-type semi-conducting material having on a surface thereof a light transmitting film of a metal from the class consisting of antimony, bismuth, and beryllium, an electrode in contact with said body, another electrode in contact with said film, a source of bias voltage, and means connecting said source to said electrodes such that said film is negative with respect to said body.

4. An electrical device comprising a body of semi-conducting material capable of forming a barrier layer at a surface thereof, a light-transmitting film of a metal from the class consisting of antimony, bismuth, and beryllium on said surface of said material, and means for applying a bias voltage between said body and said film.

5. An electrical device comprising a body of semi-conducting material having on a surface

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thereof a first semi-transparent film of a metal from the class consisting of antimony, bismuth, and beryllium, a second semi-transparent film of a metal from the class consisting of nickel and copper superimposed on said first film, an electrode in contact with said body, and another electrode in contact with said second film.

6. A device according to claim 7 in which said semi-conducting material is germanium.

7. An electrical device comprising a body of semi-conducting material having on a surface thereof a first semi-transparent film of a metal from the class consisting of antimony, bismuth, and beryllium, a second semi-transparent film of

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a metal from the class consisting of nickel and copper superimposed on said first film, and means for applying a bias voltage between said body and said films.

JACQUES I. PANTCHECHNIKOFF.

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