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PHOTOELECTRIC DEVICE

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Fig. 1

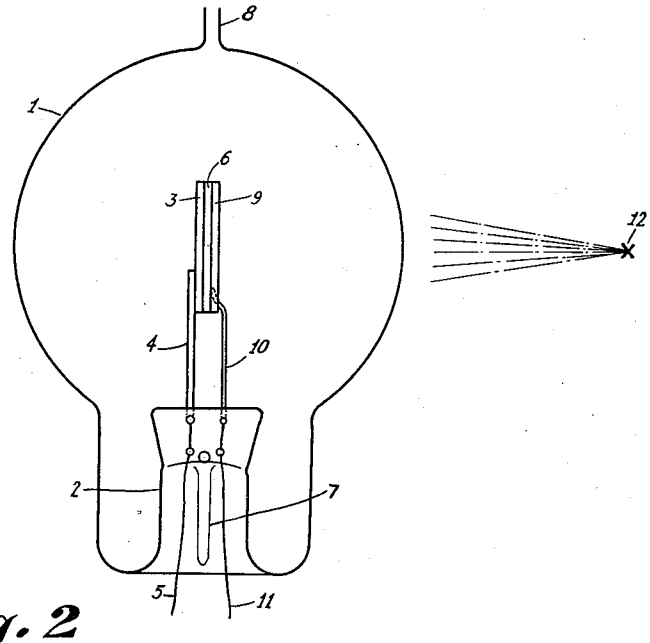
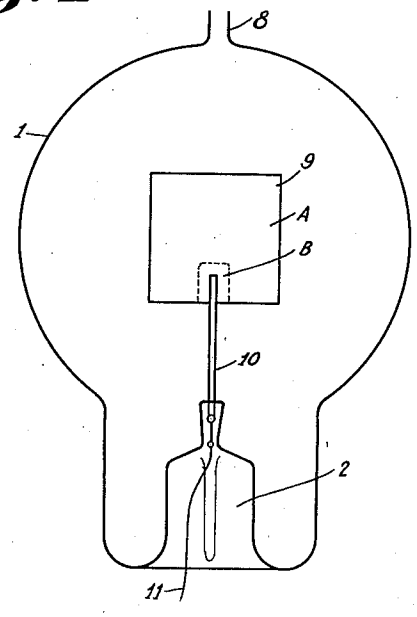


Fig. 2



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PHOTOELECTRIC DEVICE

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14 Claims. (Cl. 136—89)

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The invention relates to photoelectric devices, i. e., devices with the aid of which certain electrical phenomena can be obtained by means of rays of light.

A photoelectric device according to the invention comprises an electrode consisting, at least partly, of a photoelectric substance, and separated by a layer comprising one or more insulating solid substances from a second electrode consisting of electrically conducting material. By a photoelectric substance is meant hereinafter a substance which when irradiated by light rays emits electrons.

When the photoelectric electrode is irradiated, it appears that a potential difference is produced between the two electrodes of the device. If these electrodes are connected to one another via a galvanometer, this tension causes a current to flow through the said meter. The value of the tension set up and, therefore, of the current flowing through the galvanometer has been found to be dependent on the intensity of the light with which the photoelectric electrode is irradiated.

The photoelectric electrode is preferably made of one or more alkali—or alkaline—earth metals although good results can also be obtained for example with cadmium which, irradiated with ultra-violet rays, is photoelectric.

The separating layer can be formed between the two electrodes in different ways. In many cases the manufacture of the device can be simplified by causing the separating layer to consist of a chemical compound of the metal from which one of the electrodes is formed.

The sensitiveness of the device can be increased by causing the photoelectric substance, at least partly, to adsorb to the separating layer. In this case it is not absolutely necessary that the whole separating layer should consist of a substance which is a good adsorbent of the photoelectric substance. It is also possible to cause this layer to consist of such substance only at the surface which comes into contact with the photoelectric electrode.

In many cases the value of the potential difference set up between the electrodes due to the irradiation may be favourably influenced by making the photoelectric electrode so thin that it is transparent to light, so that the rays can penetrate as far as the boundary surface between the photoelectric electrode and the insulating substance. To this end the photoelectric electrode may conveniently consist of a mono-molecular layer of a photoelectric substance.

Sometimes it is desired to decrease the electric resistance of the separating layer. This can be advantageously effected by introducing into the separating layer particles of an electrically conducting substance. Care should of course, be taken not to introduce so many conducting particles into the layer that the electrodes of the device are short-circuited. The conducting particles may advantageously consist of particles of the photoelectric substance.

The invention will be more clearly understood by referring to the accompanying drawing which represents, by way of example, a photoelectric device according to the invention. In this drawing, Figures 1 and 2 represent two different elevations of the said device.

The device represented has a sealed vitreous envelope 1 consisting of glass, quartz or similar transparent material and having sealed to it a stem 2 on which are mounted the electrodes of the device. One of these electrodes is a metal plate 3, which may, for example, be zirconium, secured by means of a supporting wire 4 to the stem of the tube, said supporting wire being connected to a leading-in wire 5.

The electrode 3 is provided with a thin layer 6 of particles of insulating material. This layer 6 can be produced in a simple manner by oxidizing the zirconium plate 3, which may be effected prior to mounting the plate 3 inside the envelope 1. Owing to this oxidation the plate 3 is coated at its surface with a layer of particles of zirconium oxide, which, as is commonly known, is electrically insulating. This layer is preferably of a thickness of about 1 micron and at any rate considerably less than 1 mm.

After the electrode 3 with its layer 6 has been mounted inside the envelope, the latter is exhausted, which may be done with a vacuum pump connected to the stem tube 7. After the exhaustion some caesium is introduced into the envelope. The caesium vapor may be developed outside the envelope, for example, in a chamber communicating with the tube 8. It is also possible to produce the caesium in the envelope 1 itself with a caesium compound, for example, caesium chromate, and a reducing agent, for example zirconium, which is capable of liberating caesium from the caesium compound. The caesium vapor inside the envelope settles as a film of caesium on the zirconium oxide layer 6 and constitutes the photoelectric electrode 9 of the device. The current may be supplied to this electrode by a resilient lead wire 10 which is led out of the tube through the stem and which is

connected to the supply wire 11. After the formation of the photoelectric electrode, the envelope 1 may if desired be filled with an inert gas or vapor.

When the formed caesium film 9 is irradiated, for example, with the aid of a source of light 12, a potential difference is set up between the electrodes 3 and 9, which may cause a current to flow through a device connected between the wires 5 and 11. For example a galvonometer thus connected showed currents of some micro-amperes when the device was irradiated with a beam of light having an intensity of about 0.5 lumen/square cms. The potential difference set up is dependent on the intensity of the light, so that the device can be utilized for converting light variations into electric voltage or current variations. In contradistinction to the photoelectric cells known up to the present it is not absolutely necessary for the use of a device according to the invention to connect a separate source of voltage between the electrodes.

The polarity of the potential difference set up and, therefore, the direction of the current produced by this potential difference depends, inter alia, on the point of lighting and on the thickness of the zirconium oxide layer 6. This may be made clearer by describing some phenomena perceived with the above-described device. In one experiment the caesium electrode 9 was irradiated by a source of light whose rays could be concentrated on a small portion of the electrode 9. The beam of light striking this electrode had a cross-section of several square millimeters and the electrode was three centimetres in width and also in length. Moreover, the resilient lead wire 10 was bearing at the edge of the electrode system on a portion of the zirconium oxide layer which had a greater thickness than the other portion of this layer. This thicker portion of the oxide layer had a white colour and is denoted in Figure 2 by B whereas the thinner portion of the oxide layer, which had a green colour, is denoted by A. The whole film of zirconium oxide was covered by the caesium film 9.

If the beam of light struck the caesium layer covering the portions A of the zirconium oxide layer, there was produced between the electrodes 3 and 9 such a potential difference that after the wires 5 and 11 had been connected to a galvanometer, an electron current flowed from the photoelectric electrode 9 through the lead wire 10, the galvanometer, the support wire 4 to the electrode 3. For the external circuit the photoelectric electrode 9 and the electrode 3 consequently constituted the negative and the positive poles respectively.

If the beam of light struck the photoelectric substance covering the portion B of the zirconium oxide it was observed that with the same light intensity a heavier current flowed in the opposite direction. This current appeared to have a maximum intensity when irradiating with a wave length of about 6000 A°.

If the caesium covering the boundary zone between the portions A and B was lighted, no potential difference or electron current was perceived.

The photoelectric substance constituting the electrode 9 may be advantageously formed, not only from an alkaline metal such as caesium, but also from an alkaline earth metal. Good results can be obtained, for example, with barium applied to a layer 6 of barium oxide. The barium oxide, which constitutes in this case the intermediate layer of insulating material, is applied to the metal plate constituting the other electrode. In this case one may proceed as follows: On a metal plate, for example, of nickel, mounted in an exhausted envelope barium is precipitated from barium vapor, whereupon oxygen is admitted to oxidize the barium. Alternatively, the barium oxide may be directly applied to the nickel plate or be formed from compounds such as carbonates. After removal of the excessive oxygen some barium vapor is introduced again into the envelope or formed therein whereby there settles on the barium oxide a film of metallic barium which constitutes the photoelectric electrode. The oxidation of the barium to form the intermediate or separating layer, may also be effected by superficially oxidizing, before the precipitation of the barium, the electrode on which this barium is deposited. When this electrode is heated after or during the deposition of the barium, the latter will combine with the oxygen of the oxide formed at the surface of the electrode.

The intermediate or separating layer 6 may also be formed in other ways than in the manner above described and it need not always consist of a compound of the metal constituting one of the electrodes. Thus, for example, the intermediate layer of insulating material may consist of calcium fluoride, which may be applied by evaporation to a metal plate constituting one of the electrodes. If, subsequently, this calcium fluoride layer is brought into contact with caesium, the latter will adsorb as a thin film to the calcium fluoride. By removing the excessive caesium from the envelope inside of which the electrodes are arranged this adsorbed caesium film can even be made monomolecular, which may have a favourable influence on the sensitivity of the device.

Even when the intermediate layer consists of a substance whereby the photoelectric substance is adsorbed not at all or only to a slight extent, said substance may be caused to adsorb to the separating layer by first coating the substance essentially constituting the intermediate or separating layer with a thin layer of a substance which adsorbs the photoelectric substance quite well. Sometimes it is also possible to mix said well adsorbing substance with one or more other substances which constitute the intermediate layer. In the above-described device in which the separating layer consists of zirconium oxide said layer may be coated, for example, with a thin layer of caesium oxide. This oxide may be formed, for example, by depositing caesium on the zirconium oxide and by subsequently admitting oxygen. After removal of the excessive oxygen a new quantity of caesium may be introduced into the envelope whereby there is adsorbed to the caesium oxide layer a caesium film which constitutes the photoelectric electrode. The sensitivity of such a device, i. e. the potential difference produced with a given lighting, is very large.

Sometimes it is desired to decrease the electric resistance of the separating layer. This may advantageously be done by providing in the intermediate layer particles of an electrically conducting substance. In the case above set forth, in which the intermediate layer consists of calcium fluoride, it is possible, for example, to mix metal particles with the calcium fluoride. If this substance is deposited by evaporation, a metal, for example, tungsten, may be evaporated simultaneously with the calcium fluoride in which case one may proceed as follows: Inside the envelope

is mounted opposite the electrode 3 a filament coated with calcium fluoride and tungsten powder. After exhaustion of the envelope the filament is heated, whereupon the calcium fluoride reacts with the tungsten and forms metallic calcium and tungsten fluoride both of which evaporate and settle on the electrode 3. The calcium and the tungsten fluoride react again with one another so as to form calcium fluoride and tungsten, the latter being present in this case in the calcium fluoride in a finely divided state.

Conveniently, the conducting particles may be particles of the photo-active metal itself. For example, after caesium has been deposited on the intermediate layer consisting of calcium fluoride, the envelope and the electrode system may be heated, whereby part of the caesium penetrates into the intermediate layer and the electrical resistance of this layer decreases whilst, in addition, the value of the potential difference produced by the irradiation is favourably influenced.

What we claim is:

1. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal which has a work function no greater than two and one half volts and selected from the group including the alkali metals and cadmium, barium and calcium, a thin separating layer of solid insulating particles interposed between and in contact with substantially the entire areas of said electrodes, and electrical conductors respectively contacting and connected to said electrodes.

2. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of alkali metal, a thin separating layer of solid insulating particles interposed between and in contact with substantially the entire areas of said electrodes and intimately adjoined to said film, and electrical conductors respectively contacting and connected to said electrodes.

3. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer of particles of an insulating chemical compound of the metal of one of said electrodes interposed between and in contact with substantially the entire areas of said electrodes, said compound radical being chosen from a group including fluorine and oxygen, and electrical conductors respectively contacting and connected to said electrodes.

4. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer of solid insulating particles interposed between and in contact with substantially the entire areas of said electrodes and to which said film is at least partly adsorbed, and electrical conductors respectively contacting and connected to said electrodes.

5. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall, said photoelectric electrode being selected from the group including the alkali and the alkaline earth metals and comprising a monomolecular film of a metal which has a work function no greater than two and one half volts, a thin separating layer of solid insulating particles separating and in contact with substantially the entire areas of said electrodes, and electrical conductors respectively contacting and connected to said electrodes.

6. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer interposed between and in contact with substantially the entire areas of said electrodes and composed of solid insulating particles interspersed with conducting particles, and electrical conductors respectively contacting and connected to said electrodes.

7. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer interposed between and in contact with substantially the entire areas of said electrodes and composed of solid insulating particles with particles of the metal of said photoelectric electrode interspersed in said layer, and electrical conductors respectively contacting and connected to said electrodes.

8. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer of solid insulating particles interposed between and in contact with substantially the entire areas of said electrodes, a film of alkali metal oxide interposed between and adsorbed to said layer and to said photoelectric electrode, and electrical conductors respectively contacting and connected to said electrodes.

9. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer of solid particles of an insulating binary compound of an alkaline earth metal interposed between and in contact with substantially the entire areas of said electrodes, and electrical conductors respectively contacting and connected to said electrodes.

10. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a metal plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of caesium, a thin separating layer of particles of calcium fluoride interposed between and in contact with substantially the entire areas of

said electrodes, and electrical conductors respectively contacting and connected to said electrodes.

11. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a zirconium plate electrode, a cooperating photoelectric electrode exposed to said wall and comprising a film of a metal selected from the group including the alkali and the alkaline earth metals which has a work function no greater than two and one half volts, a thin separating layer of zirconium oxide on the surface of said plate electrode and located between and in contact with said electrodes, and electrical connections to said electrodes.

12. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a zirconium electrode having on its surface a layer a fraction of a millimeter thick of zirconium oxide, a cooperating photoelectric electrode exposed to said wall and comprising a film of alkali metal adjoining and supported by said layer, and electrical connections to said electrodes.

13. A photoelectric device comprising a sealed vessel with a transparent wall and enclosing a zirconium electrode having on its surface a layer a fraction of a millimeter thick of zirconium oxide, a transparent film of caesium on said layer, and electrical connections to said electrodes.

14. A photoelectric device comprising a sealed vessel with a transparent wall, a metal plate electrode therein, one entire face of which is oxidized, a layer of caesium in contact with all of the oxidized portion of the metal plate electrode and exposed to said transparent wall, and metallic conductors respectively contacting and connected to the metal plate electrode and the layer of caesium.

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