



## UNITED STATES PATENT OFFICE

2,089,830

## LIGHT SENSITIVE APPARATUS

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Original application January 23, 1928, Serial No. 248,852, now Patent No. 1,970,135, dated August 13, 1934. Divided and this application February 10, 1934, Serial No. 710,744

7 Claims. (Cl. 250—41.5)

Our invention relates to light sensitive apparatus, that is, to apparatus which responds to variations in intensity of light, and it also relates to methods of using such apparatus.

We will describe several forms of apparatus and several methods embodying our invention, and will then point out the novel features thereof in claims.

The present application is a division of our copending application Serial No. 248,852, filed January 23, 1928, for Light sensitive apparatus which became Patent No. 1,970,135 on August 13, 1934.

In the accompanying drawing, Fig. 1 is a view, partly diagrammatic, showing one form of apparatus embodying our invention. Figs. 2 and 3 are views showing modifications of the apparatus illustrated in Fig. 1 and also embodying our invention. Fig. 4 is a view showing in section another modified form of apparatus embodying our invention. Fig. 5 is a top plan view of the apparatus shown in Fig. 4.

Similar reference characters refer to similar parts in each of the three views.

Referring first to Fig. 1, the reference character A designates a rectifier comprising four rectifying units A<sup>1</sup>, A<sup>2</sup>, A<sup>3</sup> and A<sup>4</sup>, each comprising a member of metal with a compound of the metal formed thereon. As here shown each of these units comprises a member 1 of copper with a coating 2 of cuprous oxide formed directly thereon. The rectifying units are disc-shaped and are provided at their centers with holes to receive a bolt 10 from which each of the units is insulated by a sleeve 11. Contact plates 4 are arranged between each two adjacent units and adjacent the outside surface of each end unit for the purpose of making connections with outside circuits. A washer 3 of soft conducting material such as tin foil or lead foil is interposed between each unit and the adjacent contact plate 4 to insure good electrical contact. The various parts are assembled in proper relation and clamped together by a nut 12 threaded on bolt 10. It will be noticed from the drawing that units A<sup>1</sup> and A<sup>2</sup> are assembled with the oxide coating 2 toward the left, whereas units A<sup>3</sup> and A<sup>4</sup> are assembled with the oxide coating 2 toward the right. The units A<sup>1</sup>, A<sup>2</sup>, A<sup>3</sup> and A<sup>4</sup> have the property of offering a comparatively high resistance to electrical currents flowing from the copper to the oxide, and a comparatively low resistance to currents flowing in the opposition direction, that is, from the oxide to the copper.

A source of alternating current, here shown

as a secondary winding 7 of a transformer T, has one terminal connected with the contact plate 4 between units A<sup>1</sup> and A<sup>2</sup>, and the other terminal connected with the contact plate 4 between units A<sup>3</sup> and A<sup>4</sup>. Primary 5 of transformer T is constantly supplied with alternating current from a source not shown in the drawing. A relay B has one terminal connected with plate 4 between units A<sup>2</sup> and A<sup>3</sup>, and the other terminal connected with bolt 10. Since bolt 10 is connected with the outside faces of units A<sup>1</sup> and A<sup>4</sup>, it will be seen that the device comprises a double wave rectifier which changes the alternating current supplied by secondary 7 of transformer T into direct current which is supplied to relay B.

We have discovered that, when the alternating current input remains constant, and the current supplied to the rectifier is small with relation to its capacity, the output of rectifier A varies between wide limits in response to variations in the intensity of the light incident thereupon; the greater the intensity of light the lower the direct current output of the rectifier. This variation is apparently due entirely, or almost entirely, to an electromotive force which is generated within each rectifier unit at or very close to the junction of the copper and the cuprous oxide, which electromotive force is in such direction as to oppose the unidirectional output current of the rectifier. As the intensity of the light increases, the electromotive force generated in the rectifier increases, so that the greater the intensity of the light, the lower is the direct current output of the rectifier. We have found that the rate of variation of the rectifier output is much greater than that which would be due solely to the change in the resistance of cuprous oxide in response to change in the intensity of light.

In the apparatus shown in Fig. 1 we make use of this characteristic of the rectifier to control an electro-responsive device, such as an electric lamp C, in accordance with the intensity of the illumination of rectifier A. For this purpose we provide lamp C with a circuit including a source of energy, such as a secondary 6 on transformer T, and an impedance 9. The parts are so proportioned that the current through this circuit is sufficient to light lamp C to only a fraction of its normal brilliancy. When relay B is deenergized, however, a low resistance path is closed around impedance 9, shunting current around this impedance and lighting lamp C to its full brilliancy.

Our invention is well adapted for the control of the signal lamps in a railway signaling sys-

tem when it is desirable that the lamps should be more brilliantly lighted during daylight than at night. For this purpose rectifier A is exposed to the light of the sun. During the day time when the rectifier is illuminated the direct current output is considerably less than at night when the rectifier is not illuminated. The parts are so proportioned that in daylight relay B is de-energized, thus closing the shunt around impedance 9 and lighting lamp C to full brilliancy. At night, however, no light will fall upon rectifier A and the output of the rectifier will be increased. Relay B will then become energized, opening the shunt around impedance 9 and decreasing the brilliancy of lamp C.

Referring now to Fig. 2, a rectifier unit A<sup>5</sup>, similar to one of the units illustrated in Fig. 1, is connected in series with a battery K and a relay B, the connections being such that the current from battery K flows freely through rectifier unit A<sup>5</sup>. Inasmuch as the phenomenon referred to in the present application takes place only at relatively low energization of the rectifier, it is necessary to apply a lower potential than even the potential delivered by one cell of battery. For this reason a resistance 17 is connected across the terminals of battery K, and the terminals of the circuit for rectifier A<sup>5</sup> and relay B are connected with two points on this resistance. When the rectifier A<sup>5</sup> is not illuminated, current flows through this rectifier in the low resistance direction to energize relay B. When the rectifier is illuminated, however, the electromotive force produced in the rectifier in the high resistance direction partially neutralizes the current in the low resistance direction due to the battery, and relay B then opens. Relay B may be used for any suitable purpose; as here shown, a back contact of this relay controls a circuit including a lamp C and a battery L, so that this circuit is closed only when relay B is open.

Referring now to Fig. 3, the apparatus shown in this view is the same as that shown in Fig. 2, except that the battery K is omitted. When the rectifier A<sup>5</sup> is not illuminated, no current flows through relay B. When the rectifier is illuminated, the electromotive force produced in the rectifier creates a current which energizes relay B. It follows that in this view the relay is energized when the rectifier is illuminated, whereas with the apparatus shown in Fig. 2, the relay is energized when the rectifier is dark.

Referring now to Figs. 4 and 5, the apparatus illustrated in these views comprises a metal disc 18 having formed thereon a compound of the metal as indicated at 18<sup>a</sup>. For example, the disc 18 may be of copper and the compound 18<sup>a</sup> may be cuprous oxide. The free surface of the cuprous oxide 18<sup>a</sup> is exposed to the source of light to which the device is to respond. An electrode 19 is placed in electrical contact with the compound 18<sup>a</sup> in such manner as to absorb only a portion of the light which falls on the device. As here shown, the electrode 19 is a spiral of wire. The electrode 19 and the compound 18<sup>a</sup> are preferably protected by a glass plate 20, and the parts are securely held together by a bolt 13 and a nut 14. One terminal 15 is connected with the electrode 19 and another terminal 16 is connected with the metal disc 18, the function of these terminals being to connect the electrode in an electric circuit.

We have found that when light falls on the compound 18<sup>a</sup>, a difference of potential is created

between the terminals 15 and 16, and that when the intensity of the light is varied, the difference of potential varies. The variations in the difference of potential may be amplified, if necessary, and used to operate any suitable electro-responsive device. For example, if the illumination is made to vary in accordance with a train of sound waves, the electromotive force produced across the terminals 15 and 16 can be amplified and the sound waves can thereby be reproduced.

One feature of our invention is that little fatigue is noticeable even after constant illumination for a considerable number of hours. No saturation value of the light electromotive force is reached up to several thousand foot candles, and so the devices can be designed to be affected only by very strong illumination. There is little, if any, time lag between a change of illumination and the resulting change of electromotive force; when a sector disc is rotated between the device and a source of light at a speed to give over 150 breaks per second, there is no noticeable time lag.

Although we have herein shown and described only a few forms of apparatus and methods embodying our invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of our invention.

Having thus described our invention, what we claim is:

1. In combination, a photo-electric generator comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of generating an electric current at the junction between said copper and oxide in response to light incident thereupon, an electro-responsive device, and means for connecting said device with said copper and oxide to cause the device to respond selectively in accordance with the illumination of said generator.

2. In combination, a photo-electric generator comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of generating an electric current at the junction between said copper and oxide in response to light incident thereupon, an electro-responsive device, and a circuit connecting said device across said copper and oxide and including means for supplying to the circuit an electromotive force in opposition to said generated current.

3. In combination, a photo-electric generator comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of generating at the junction between said copper and oxide in response to incident light an electromotive force which causes the said copper to be electropositive with respect to said oxide, a source of current for applying to said generator a potential difference in opposition to said electromotive force, and an electroresponsive device connected with said generator and responsive to the resultant of said electromotive force and said potential difference.

4. In combination, a device comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of offering higher resistance to current flowing from the oxide to the copper than to current flowing from the copper to the oxide and also having the characteristic of generating at the junction between the copper and oxide in response to incident light an electromotive force the magnitude of which va-

ries with the intensity of said light and the polarity of which is such as to make the copper electropositive with respect to the oxide, a source of alternating current, and an electroresponsive device connected in series with said source across said device and receiving direct current which is the resultant of the rectified current from said source and the current due to said electromotive force.

5. In combination, a device comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of offering higher resistance to current flowing from the oxide to the copper than to current flowing from the copper to the oxide and also having the characteristic of generating at the junction between the copper and oxide in response to incident light an electromotive force the magnitude of which varies with the intensity of said light and the polarity of which is such as to make the copper electropositive with respect to the oxide, means for supplying an alternating current small with respect to the normal capacity of said device in the low resistance direction, and an electroresponsive device connected in series with said means across said device and receiving direct current which is the resultant of the rectified current from said source and the current due to said electromotive force.

6. In combination, a rectifier made up of a plurality of units connected in a bridge having input and output terminals and each unit comprising copper having a layer of cuprous oxide

formed thereon and having the characteristic of offering higher resistance to current flowing from the oxide to the copper than to current flowing from the copper to the oxide and also having the characteristic of generating at the junction between the copper and oxide in response to incident light an electromotive force the magnitude of which varies with the intensity of said light and the polarity of which is such as to make the copper electropositive with respect to the oxide, means for supplying to said input terminals alternating current of a magnitude small with respect to the normal capacity of the rectifier, and an electroresponsive device connected with the output terminals of said rectifier and receiving direct current which is the resultant of the rectified current from said source and the current due to said electromotive force.

7. In combination, a photo-electric generator comprising copper having a layer of cuprous oxide formed thereon and having the characteristic of generating an electric current at the junction between said copper and oxide in response to light incident thereupon, an electroresponsive device, and a circuit connecting said device across said copper and oxide and including means for supplying to the circuit an exciting current in opposition to said generated current and small with respect to the normal capacity of said generator to conduct current in the direction from said oxide to said copper.

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