1,123,035

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,123,035

Date of Application and filing Complete Specification: 22 June, 1967.

No. 28954/67.

Application made in United States of America (No. 559489) on 22 June, 1966.

Complete Specification Published: 7 Aug., 1968.

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Index at acceptance: —H1 K(1D3B, 2S1B, 2S20, 5A, 5C7, 5C8, 7A1); G3 T(A4B1, A5X); H2 H(8B, 8E3)

Int. Cl.: —H 01 l 15/04

COMPLETE SPECIFICATION

Photoelectric Conversion System

We, THE UNITED STATES TIME CORPORATION, a Corporation organized under the laws of the State of Connecticut, United States of America, of Waterbury, Connecticut, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a photoelectric converter and to circuits and instruments employing a photoelectric converter, and more particularly to controlling the output of a solar cell.

Semi-conductive solar cells have been available for some years. These cells convert light (actinic) energy into electrical energy. They are sometimes used to charge electrical storage batteries. Such cells include a specially produced semiconductive body, usually of silicon, having a p-n junction.

When a solar cell is used out of doors or in other locations in which the amount of light reaching the cell varies from darkness to brightness, the cells may be constructed so that they are not adversely affected by bright light. However, the electrical current output of the cell is directly proportional to the amount of light reaching its surface. If too much light reaches the cell, its electrical current output may rise to a sufficiently high level to injure the component to which it is connected, such as a storage batterv.

There have been a number of circuits proposed to avoid the problem of overcharging the battery with too high a rate of current. A widely used measure is to provide a current regulator, such as a semi-conductive Zener diode, in parallel with the battery. The regulator prevents an excess current from reaching the battery.

Another solution is to make the area of the solar cell so small that even in the brightest light its current output will not exceed the capacity of its connected load. However, this measure necessarily means that in subdued light there may not be sufficient power produced by the cell to operate the load, for example, to keep the battery charged.

It is the objective of the present invention to provide a solar cell device the electrical output of which is automatically limited. It is a further objective that the device be compact, not subject to mechanical or electrical breakdown, and relatively inexpensive.

In accordance with the present invention, a phototropic (photochromic) material is placed over the light sensitive surface of the solar cell. The term "solar cell", as used herein, refers broadly to all types of semi-conductivce devices for converting actinic energy into electrical energy. By the term "phototropic material" as used throughout the description and claims we mean a transparent or translucent material which darkens reversably in proportion to the intensity of the light incident upon it. As the amount of incident light increases, the phototropic material becomes darker and permits the passage of a decreasing percentage of the incident light through the material. In this way the amount of light reaching the solar cell is limited to a relatively constant level or a level below some predetermined maximum level. Since the quantity of light reaching the cell is limited, the cell's electrical output is also limited to a level below the current which would injure a rechargeable battery connected thereto.

Other objectives of the present invention will be apparent from the description of the preferred embodiment of the invention given below, which is taken in conjunction with the accompanying drawings, in which:—

[*Price 4s. 6d.*]

Figure 1 is a perspective view of an improved photoelectric converter of the present invention;

Figure 2 is a circuit diagram in block form of a circuit employing the photoelectric converter of the present invention; and

Figure 3 is a top plan view of an electric watch with its dial partly broken away to show its internal mechanism.

In Figure 1 the photoelectric converter 4 includes a semi-conductive solar cell shown as consisting of "p" layer 2 and "n" layer 3. The term "p" refers to the conduction primarily by holes which occurs in that semi-conductive layer. In the "n"-type layer 3 the conduction is mainly by electrons. The semi-conductive body, preferably of highly refined silicon, is doped with impurities to provide an excess or deficit of valence electrons which may be displaced by light (actinic radiation). The boundary between the p and n layers, i.e., the junction of layers 2 and 3, is a rectifying junction known as a p-n junction. Preferably the p-layer 2 is formed by the vapour diffusion of an electron acceptor impurity such as boron into the n-layer to form the extremely thin p-type layer 2. Layer 2 is sufficiently thin (about the diffusion length of the minority carriers) so that it is effectively transparent to incident light.

The solar cell is covered by a layer of phototropic material 1. Preferably layer 1 is joined to the other layers by a clear transparent thermosetting resin 14. Layer 1 darkens in direct proportion to the amount of light per unit volume impinging upon it over the range of the light's intensity. That is, its transmittal of light is inversely proportional to the intensity of light upon it. A suitable phototropic material is an amorphous silicate glass having a concentration of between .01% and .1% by volume of light sensitive crystals. Suitable crystals are silver chloride, silver bromide and silver iodide crystals of less than 100 Angstroms in diameter. The crystals are added to the glass when it is molten and the glass is cooled slowly. Further details of such glasses are obtainable from U.S.A. Patents Nos. 2,208,860 and 3,197,296, among other publications.

Preferably the spectral response of the solar cell is in direct inverse relation to the spectral response of the phototropic layer 1. For example, "Bestlite" photochromic glass, manufactured by Corning Glass, absorbs ultraviolet rays below 330 millimicrons, is darkened by near ultraviolet, and transmits throughout the remainder of the visible spectrum, i.e., transmittal of about 90 per cent for visible light above 450 millimicrons. It is darkened primarily by near ultraviolet. This glass is preferably used with a solar cell which produces electricity primarily in response to near ultraviolet radiation.

In Figure 2 the solar cell with its phototropic cover is shown as cell 4. It is connected to a semi-conductive diode 5. A rechargeable (secondary) battery 6 is in parallel with the series combination of the diode 5 and the solar cell 4. The function of diode 5 is to prevent the cell 4 from draining the battery 6 during dark periods. The solar cell 4, during darkness, acts as a passive load with low impedance.

The load 7 is placed in parallel with the solar cell 4 and the battery 5. Typical loads are small motors, lights, warning horns and electronic equipments such as amplifiers.

The battery 6 is preferably of the nickel-cadmium type. The electrodes are, initially, cadmium oxide or cadmium hydroxide and nickel. The electrolyte is an alkaline liquid. In the "Durac" (registered Trade Mark) type of nickel-cadmium battery the electrodes are of nickel carbonyl impregnated with nickel and cadmium salts. Nickel-cadmium batteries are damaged by too high a rate of charging. In the case of a single cell miniature battery having a rated capacity of 20 milliampere hours a charging rate in excess of 2 milliamperes per hour would be excessive and may damage the battery. For example, in the nickel-cadmium battery "Everready N22", (registered Trade Mark), a button cell manufactured by Union Carbide, the ten-hour rate is 2 milliamperes and the maximum recommended charge is also 2 milliamperes. If the recommended rate of charge is exceeded, oxygen may be evolved at the nickel electrode faster than it can be reacted at the cadmium electrode and sufficient pressure may develop to rupture the cell.

An alternative secondary battery is the silver oxide type. This type uses zinc and silver oxide as the electrodes and potassium hydroxide and zinc hydroxides as the electrolyte. The charging of this type of cell should be by constant current. Vinyl, in his book "Storage Batteries", at page 101 states, in regard to silver oxide batteries, "Charging may be done also by the modified constant-potential method from a d-c source of 2.2 to 2.5 volts with a series resistance in the circuit to limit the initial current to that corresponding to the 1-hour rate".

The phototropic layer 1 limits the rate of charging the battery 6; however, it does not protect the battery from overcharging due to an over-accumulation of charge over time.

In the specific embodiment of a watch as shown in Figure 3, the solar cell 4a, which is the cell of the present invention as shown in Figure 1, is the dial plate of the watch. It is protected from the atmosphere by the watch crystal 8. Alternatively, the dial is an uncovered solar cell, i.e., consisting of p-layer

2 and n-layer 3, and the watch crystal 8 is of a phototropic glass. The crystal is mounted in a bezel 9 of the watch case. The solar cell 4a is connected to a rechargeable miniature battery 10, for example, by a circuit as described in connection with Figure 2. The wire 11 from the battery leads to a miniature electric motor 12 mounted on a base plate within the watch case. The output shaft 13 of the motor drives the gear mechanism of the watch and ultimately the hands (not shown). A suitable circuit for driving a motor in a watch and a suitable motor is shown in U.S.A. Patent No. 3,046,460.

WHAT WE CLAIM IS:—

1. A photoelectric converter including a solar cell having an active face reactive to actinic energy, characterized in that the converter also includes a phototropic material mounted in an optically facing relationship to said active face between the cell and incident actinic energy.

2. A photoelectric converter as set forth in claim 1, wherein said photographic material darkens in substantially direct proportion to the amount of incident actinic energy over a range of incident actinic intensity, thereby providing a substantially constant amount of actinic energy to said cell over said range.

3. A photoelectric converter as set forth in claim 1 or claim 2, wherein said phototropic material is characterised in having a spectral response which is in direct inverse relation to the spectral response of said solar cell.

4. A photoelectric converter as set forth in any one of claims 1 to 3, wherein said solar cell is made of a semi-conductor material having a p-n junction.

5. A battery charging system comprising the photoelectric converter as set forth in any one of the preceding claims, and a rechargeable battery connected to said solar cell.

6. A battery charging system as set forth in claim 5 further including a diode in series with said solar cell.

7. A horological instrument comprising a case, a base plate within the case, gear mechanism, hands attached to the gear mechanism, motor means mounted on the plate to drive the gear mechanism, and a photoelectric converter as set forth in any one of claims 1 to 4 mounted within the case, a storage battery positioned on the plate and connected to said solar cell and said motor means, and the layer of phototropic material being positioned in the case over said solar cell.

8. An instrument as set forth in claim 7, further comprising a diode in series with said solar cell.

9. An instrument as set forth in claim 7 or claim 8 further including a crystal mounted on the said case, and in which the solar cell is a dial plate.

10. An instrument as set forth in claim 9 in which the crystal is a phototropic glass.

11. A photoelectric converter substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

12. A battery charging system substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

13. An electric watch substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

STEVENS, LANGNER, PARRY & ROLLINSON,
Chartered Patent Agents,
Agents for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1968.
Published by the Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

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2. A photoelectric converter as set forth in claim 1, wherein said photographic material darkens in substantially direct proportion to the amount of incident actinic energy over a range of incident actinic intensity, thereby providing a substantially constant amount of actinic energy to said cell over said range.

3. A photoelectric converter as set forth in claim 1 or claim 2, wherein said phototropic material is characterised in having a spectral response which is in direct inverse relation to the spectral response of said solar cell.

4. A photoelectric converter as set forth in any one of claims 1 to 3, wherein said solar cell is made of a semi-conductor material having a p-n junction.

5. A battery charging system comprising the photoelectric converter as set forth in any one of the preceding claims, and a rechargeable battery connected to said solar cell.

6. A battery charging system as set forth in claim 5 further including a diode in series with said solar cell.

7. A horological instrument comprising a case, a base plate within the case, gear mechanism, hands attached to the gear mechanism, motor means mounted on the plate to drive the gear mechanism, and a photoelectric converter as set forth in any one of claims 1 to 4 mounted within the case, a storage battery positioned on the plate and connected to said solar cell and said motor means, and the layer of phototropic material being positioned in the case over said solar cell.

8. An instrument as set forth in claim 7, further comprising a diode in series with said solar cell.

9. An instrument as set forth in claim 7 or claim 8 further including a crystal mounted on the said case, and in which the solar cell is a dial plate.

10. An instrument as set forth in claim 9 in which the crystal is a phototropic glass.

11. A photoelectric converter substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1968.
Published by the Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

