(11)

PATENT SPECIFICATION (11) 1 553 356

1 553 356

(21) Application No. 53680/77 (22) Filed 23 Dec. 1977
(31) Convention Application No. 51/158878
(32) Filed 27 Dec. 1976
(31) Convention Application No. 52/007412
(32) Filed 26 Jan. 1977 in
(33) Japan (JP)
(44) Complete Specification published 26 Sept. 1979
(51) INT CL² H01L 27/14 21/72
(52) Index at acceptance
H1K 11B3 11C1A 11C4 11D1 11D 1EB 5B2 9N3 9R2 ECA

(19)

(54) SOLAR BATTERY

(71) We, KABUSHIKI KAISHA HAMAZAWA KOGYO a Japanese company of 5—11, 2-chome, Kogan-dori, Suwa-shi, Nagano-ken, Japan and KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company of 3—4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, 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:—

This invention relates to solar batteries.

Solar batteries have been developed as power sources for electric wristwatches and pocket calculators. For this purpose, a P-N junction solar battery is popular, such a battery employing a semiconductor material such as silicon or gallium arsenide as a substrate. The voltage obtained from such a solar battery is dependent upon the gap between the valence and conduction bands of the semiconductor material. A silicon solar battery produces a voltage of about 0.5 V and a gallium arsenide solar battery produces a voltage of about 0.9 V. Electronic wristwatches need a power source producing about 2 V and pocket electronic calculators a power source producing about 4 V, so that a plurality of solar batteries connected in series have to be used. For example, 5 solar batteries connected in series may be required to power an electronic timepiece and ten solar batteries connected in series to power an electronic pocket calculator. In the past solar batteries have been connected in series by first attaching them to an electrically insulating substrate and then electrically connecting them by a wire bonding technique. Alternatively, it has been known to connect a plurality of solar batteries in series using lead frames and a face-down bonding technique or to use a tape carrier technique. These methods have various disadvantages such as complicated mounting, high costs and low reliability. Nowadays, when solar batteries are being put to everyday practical use and being mass produced, there is a demand for a monolithic solar battery comprising a plurality of solar cells mounted on one substrate.

According to the present invention, there is provided a solar battery of monolithic construction comprising: a plurality of P-N junction solar cells formed in a substrate and electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, each solar cell having a diffusion layer which is integral with and of the same conductivity type as the or one of the adjacent barrier diffusion layers and forms a P-N photovoltaic junction with the substrate.

In one embodiment electrical conduction means electrically connecting the solar cells are formed on a surface of the substrate opposite to a light receiving surface thereof. The electrical conduction means may connect the solar cells in series. The electrical conduction means may be deposited on the substrate. The electrical conduction means may be formed of aluminium.

The substrate may be an N-type substrate.

The substrate may be a single crystal of silicon.

According to a further aspect of the present invention there is provided an electronic timepiece or electronic calculator having a solar battery as recited above.

According to a further aspect of the present invention there is provided a method of making a solar battery of monolithic construction consisting of a plurality of P-N junction solar cells, in a substrate, electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, comprising first forming said barrier layer or layers and then forming a diffusion layer which is integral with and of the same conductivity type as the or one of

the adjacent barrier diffusion layers and forms with the substrate a photovoltaic P-N junction.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1, consisting of Figures 1(a) to 1(e) illustrates schematically one method of making a solar battery according to the present invention,

Figure 2, consisting of Figures 2(a) to 2(e), illustrates another method of making a solar battery according to the present invention.

Referring first to Figure 1 there is illustrated one method of making a solar battery according to the present invention. A substrate 1 of N-type semiconductor material is between 100 and 150 μm in thickness. The semiconductor material may be a single crystal of silicon. First, thin layers 2 of silicon dioxide are formed on opposite surfaces of the substrate by a wet oxidation technique and then unwanted parts of the layers are removed by a photo-etching technique. The exposed parts of the substrate define areas for diffusion layers which electrically insulate each solar cell from its neighbour in the completed solar battery. When the diffusion layers are formed from both surfaces of the substrate at once, the time required for diffusion can be reduced by half. Therefore, the removal of the layer 2 from both surfaces must be aligned precisely so that the required diffusion layers are formed.

Next, P-type impurities are diffused onto both surfaces of the substrate 1 for half an hour at 1100°C and then, after light-etching, the P-type impurities are diffused through the substrate by heating it at 1200°C in an atmosphere including 10% oxygen. P^- barrier diffusion layers 3 shown in Figure 1(b) are thus formed.

Further parts of the layer 2 are removed by a photo etching technique and the P-type impurities are diffused into the substrate so that a P^+ diffusion layer 42 μm in depth is formed. The diffusion layer 4 is formed over the barrier diffusion layers 3, so as to be integral therewith. The diffusion layer 4 and the barrier diffusion layer 3 are covered with a layer 2' of silicon dioxide by a wet oxidation technique and an N^+ diffusion layer 5 for ohmic contact between the substrate 1 and the electrodes is formed.

Next, after etching the whole surface of the substrate with hydrogen fluoride, a thin layer of silicon dioxide, 1500 Å in thickness is formed on the whole surface, and the layer is photo-etched in areas where electrodes are to be positioned. Subsequently an aluminium layer is formed on the silicon dioxide layer and unwanted parts are removed by photo-etching so that wiring 6 between the solar cells and electrodes are formed. In this way, a monolithic solar battery is achieved.

Referring now to Figure 2, there is illustrated another method of making a solar battery according to the present invention.

A substrate 10, of N-type semiconductor material is between 100 and 150 μm in thickness and consists of a single crystal of silicon. First a thin layer 12 of silicon dioxide is formed on opposite surfaces of the substrate 10 by a wet oxidation technique and then unwanted parts of the layer are removed by a photo-etching technique. Exposed parts of the substrate define areas for barrier diffusion layers which electrically insulate each solar cell from its neighbour in the completed solar battery. The time required for the formation of the barrier diffuson layers can be reduced by half by performing the diffusion simultaneously from both opposite surfaces of the substrate. To this end, the exposed parts of the substrate on the two opposite surfaces are aligned.

P-type impurities are then diffused onto both the opposite surfaces of the substrate for thirty minutes at 1100°C and resulting P^+ diffusion layers are lightly etched. The P-type impurities are subsequently diffused through the substrate by heating it to 1200°C in an atmosphere of nitrogen including 10% of oxygen to form P^- diffusion layers 13 (Figure 2b).

The layers 12 are then removed and both opposite surfaces of the substrate are covered again with new thin layers 12' of silicon dioxide. Selected portions of the new thin layers of silicon dioxide between the diffusion layers 13 on both opposite surfaces are removed by an etching technique. P-type impurities are then diffused into the substrate so that a P^+ diffusion layer 14, which is 2 μm in depth is formed on a light receiving surface of the substrate and P^+ diffusion layer 14' is formed on a non-light receiving surface, the diffusion layer 14' being, in the completed solar battery, in ohmic contact with electrodes.

After the electrode has been subjected to a wet oxidation treatment on both opposite surfaces, an N^+ diffusion layer 15 is formed in the substrate in areas designed for contact with the electrodes by removing selected portions of the thin layer 12' of silicon dioxide on the non-light receiving surface of the substrate. This is shown in Figure 2(d).

The diffusion layer 14 is formed integral with the diffusion layers 13 which separate the individual solar cells.

Both surfaces of the substrate are etched with hydrogen fluoride, and thin layers of silicon dioxide of 1500 Å in thickness are formed over both opposite surfaces. The

non-light receiving surface is subjected to a contact photo etching technique. An aluminium film is formed on the non-light receiving surface by a metalizing technique and then photoetched to form electrodes and wiring 16 of the individual solar cells.

The effective photovoltaic area of the solar battery of Figure 2 is about 20% greater than that of a conventional solar battery of the same size with electrodes on the light receiving surface, and a high photoelectric current can be produced. Therefore, the solar battery of Figure 2 can be made smaller for a given output current than the conventional solar battery. If the wiring and electrodes are placed on the light receiving surface of the solar battery, relatively more space is occupied thereby when the solar battery is miniaturised. The provision of electrodes and wiring on the non-light receiving surface of the solar battery of Figure 2 is thus of great merit.

The above described solar batteries are P-N junction solar batteries employing N-type semiconductor material as a substrate. The invention is, however, applicable to N-P junction solar batteries employing P-type semiconductor material as a substrate. While in the embodiments illustrated the substrate is silicon, the invention is applicable to homojunction solar batteries employing gallium arsenide or gallium phosphide as a substrate.

The solar batteries according to the present invention and described above, are extremely simple to manufacture since the individual solar cells are electrically connected at the same time as the electrodes are formed. The diffusion layers which electrically separate each solar cell are simply formed in large quantities by photo-etching and diffusion techniques which are popular in the art of semiconductor manufacture.

Thus, since the individual solar cells are formed on one substrate the solar battery can be mounted in and used to power, for example, an electronic watch, a pocket electronic calculator or the like to great advantage and in particular costs are reduced. Moreover, the solar batteries have a great reliability since they are only connected to the circuitry being driven by two external electrical connectors.

WHAT WE CLAIM IS:—

1. A solar battery of monolithic construction comprising: a plurality of P-N junction solar cells formed in a substrate and electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, each solar cell having diffusion layer which is integral with and of the same conductivity type as the or one of the adjacent barrier diffusion layers and forms a PN photovoltaic junction with the substrate.

2. A solar battery as claimed in claim 1 in which electrical conduction means electrically connecting the solar cells are formed on a surface of the substrate opposite to a light receiving surface thereof.

3. A solar battery as claimed in claim 2 in which the electrical conduction means connect the solar cells in series.

4. A solar battery as claimed in claim 2 or 3 in which the electrical conduction means are deposited on the substrate.

5. A solar battery as claimed in any of claims 2 to 4 in which the electrical conduction means are formed of aluminium.

6. A solar battery as claimed in any preceding claim in which the substrate is an N-type substrate.

7. A solar battery as claimed in claim 6 in which the substrate is a single crystal of silicon.

8. A solar battery substantially as herein described with reference to and as shown in the accompanying drawings.

9. An electronic timepiece or electronic calculator having a solar battery as claimed in any preceding claim.

10. A method of making a solar battery of monolithic construction consisting of a plurality of P-N junction solar cells, in a substrate, electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, comprising first forming said barrier layer or layers and then forming a diffusion layer which is integral with and of the same conductivity type as the or one of the adjacent barrier diffusion layers and forms with the substrate a photovoltaic P-N junction.

11. A method as claimed in claim 10 and substantially as herein described with reference to the accompanying drawings.

J. MILLER & CO.,
Agents for the Applicants,
Chartered Patent Agents,
Lincoln House,
296—302 High Holborn,
London, WC1V 7JH.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1979
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

non-light receiving surface is subjected to a contact photo etching technique. An aluminium film is formed on the non-light receiving surface by a metalizing technique and then photoetched to form electrodes and wiring 16 of the individual solar cells.

The effective photovoltaic area of the solar battery of Figure 2 is about 20% greater than that of a conventional solar battery of the same size with electrodes on the light receiving surface, and a high photoelectric current can be produced. Therefore, the solar battery of Figure 2 can be made smaller for a given output current than the conventional solar battery. If the wiring and electrodes are placed on the light receiving surface of the solar battery, relatively more space is occupied thereby when the solar battery is miniaturised. The provision of electrodes and wiring on the non-light receiving surface of the solar battery of Figure 2 is thus of great merit.

The above described solar batteries are P-N junction solar batteries employing N-type semiconductor material as a substrate. The invention is, however, applicable to N-P junction solar batteries employing P-type semiconductor material as a substrate. While in the embodiments illustrated the substrate is silicon, the invention is applicable to homojunction solar batteries employing gallium arsenide or gallium phosphide as a substrate.

The solar batteries according to the present invention and described above, are extremely simple to manufacture since the individual solar cells are electrically connected at the same time as the electrodes are formed. The diffusion layers which electrically separate each solar cell are simply formed in large quantities by photo-etching and diffusion techniques which are popular in the art of semiconductor manufacture.

Thus, since the individual solar cells are formed on one substrate the solar battery can be mounted in and used to power, for example, an electronic watch, a pocket electronic calculator or the like to great advantage and in particular costs are reduced. Moreover, the solar batteries have a great reliability since they are only connected to the circuitry being driven by two external electrical connectors.

WHAT WE CLAIM IS:—

1. A solar battery of monolithic construction comprising: a plurality of P-N junction solar cells formed in a substrate and electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, each solar cell having diffusion layer which is integral with and of the same conductivity type as the or one of the adjacent barrier diffusion layers and forms a PN photovoltaic junction with the substrate.

2. A solar battery as claimed in claim 1 in which electrical conduction means electrically connecting the solar cells are formed on a surface of the substrate opposite to a light receiving surface thereof.

3. A solar battery as claimed in claim 2 in which the electrical conduction means connect the solar cells in series.

4. A solar battery as claimed in claim 2 or 3 in which the electrical conduction means are deposited on the substrate.

5. A solar battery as claimed in any of claims 2 to 4 in which the electrical conduction means are formed of aluminium.

6. A solar battery as claimed in any preceding claim in which the substrate is an N-type substrate.

7. A solar battery as claimed in claim 6 in which the substrate is a single crystal of silicon.

8. A solar battery substantially as herein described with reference to and as shown in the accompanying drawings.

9. An electronic timepiece or electronic calculator having a solar battery as claimed in any preceding claim.

10. A method of making a solar battery of monolithic construction consisting of a plurality of P-N junction solar cells, in a substrate, electrically separated from one another by a barrier diffusion layer or layers of a conductivity type different from that of the substrate, comprising first forming said barrier layer or layers and then forming a diffusion layer which is integral with and of the same conductivity type as the or one of the adjacent barrier diffusion layers and forms with the substrate a photovoltaic P-N junction.

11. A method as claimed in claim 10 and substantially as herein described with reference to the accompanying drawings.

J. MILLER & CO.,
Agents for the Applicants,
Chartered Patent Agents,
Lincoln House,
296—302 High Holborn,
London, WC1V 7JH.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1979
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.