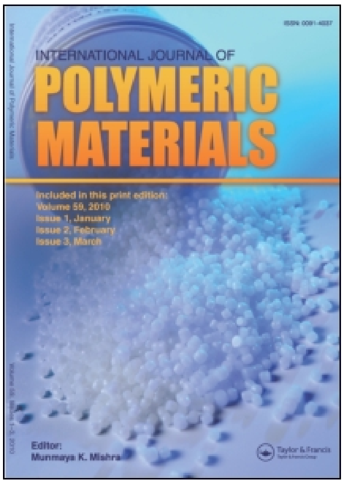

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# A New Photovoltaic Cell

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This study describes a photovoltaic cell whose design does not require any additional sources of electric power. The said cell comprises a charge carrier film of a polar polymer. Typically, useful polymers are poly(ethylene terephthalate), polyamide, penton (viz., poly-3,3-bis-(chloromethyl)oxethane), poly(vinyl butyral). The cell has, on both faces, conducting electrodes of metals whose electrochemical potentials differ by at least 0.8 V. The front electrode has a discrete coating, in the form of hemispheres, which is made of absorptive polymer material. In addition, the film charge carrier can be reinforced with a metallic grid whose electrochemical potential differs from those of the electrodes.

KEY WORDS Photovoltaic materials, polymers, films.

A photovoltaic device based on a semiconducting material was described earlier[1]; the front surface had a layer of at least one porphyrinic compound. This layer improved the absorptive characteristics of the device. The base of the device, however, was a rigid semiconducting plate which prevented making effective low weight photovoltaic devices with large areas to absorb radiation.

Another device to convert light energy to electric power contains a photo-sensitive layer covered with an insulating polymeric layer.[2] These layers provide spectral selection of radiation and enable photocurrents of up to $10^{-7}$ A/cm$^2$ to be obtained. In order to increase photocurrent, a photosensitive device can be used,[3] that comprises on each face of the layer electrodes an active zone in the form of a thin layer of a polymer compound. The charges are transferred across the interface as a result of the difference in the polymer's and electrodes' work functions. The designs mentioned above have a common disadvantage in that external electric voltage must be applied to the electrodes, and continuous coatings reduce the device's flexibility.

A photovoltaic cell[4] comprising an active zone of a semiconducting material covered on two faces with oxide layers (electrodes) in which holes are made is close to the present invention in its technical aspects and performance. In the holes of the front electrode surface there is a metallic contact, the holes themselves are the concentrators of radiation. The holes ensure higher efficiency of energy conversion, and make the device lighter. However, the semiconducting material used for the active zone makes the photovoltaic devices rather expensive and prevents these devices from being used in small large-area batteries. Small flexible batteries can be sources of energy for film antennae used in space technology or in apparatus operating in the upper atmospheric layers.

The purpose of the cell described in the present study is to widen functional possibilities and reduce the cost of photovoltaic cells.

This photovoltaic cell is based on a charge carrier film made of a polar polymeric material comprising conducting electrodes located on the carrier surfaces. These conducting electrodes are made of materials having unlike electrochemical potentials and the front electrode is coated. In accordance with the present invention, the electrodes are made of metals whose electrochemical potentials differ by at least 0.8 V. The front electrode is coated in a discrete mode in the form of hemispheres of a polymer material capable of absorbing radiation.

Additionally, an absorptive coating is applied onto the two electrodes, and the charge carrier film can be reinforced with a metallic grid; the electrochemical potentials of the electrode metals and of the grid are related through the following expressions:

$$\varphi_{e1} < \varphi_g \leq \varphi_{e2} \quad \text{or} \quad \varphi_{e1} \leq \varphi_g < \varphi_{e2}$$

where $\varphi_{e1}$ and $\varphi_{e2}$ are the electrodes' potentials, $\varphi_g$ is the grid potential.

The absorptive polymer coating in the form of hemispherical discrete particles attached to the surface of the front electrode increases the conversion efficiency of the incoming radiation while decreasing the area occupied by the absorptive coating. It improves the flexibility of the device because it uses scattered radiation incoming at small angles. The metals whose difference in electrochemical potentials is about 0.8 V increase the current characteristics of the device. The reinforcing material incorporated in the film has a different electrochemical potential from those of the external electrodes, thus increasing the possibilities of said batteries for use as solar cells under the conditions of two-side illumination.

The present authors are unaware of photovoltaic cells in which: 1) the difference of electrochemical potentials of the unlike electrodes located on a polar polymer film surface can be at least 0.8 V; 2) absorptive coating applied onto the electrode which is subject to radiation is of discrete hemispherical polymer material particles; and 3) the film charge carrier incorporates an additional reinforcing electrode made of material whose electrochemical potential differs from that of the external electrodes.

Figure 1 shows schematically the new photovoltaic device.

The film 1 made of a polar polymer, whose surface is covered with an upper (front) electrode 2 and a lower electrode 3, serves as a charge carrier film. The

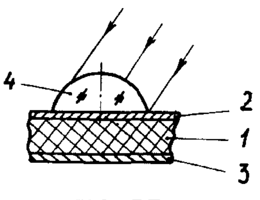

FIGURE 1

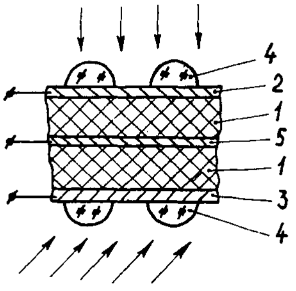

FIGURE 2

TABLE I

Accumulated Charge in Capacitor with Time for Model Cu-PET-Al when Illuminated on Copper Face

| Absorptive material | Voltage in capacitor (V) in time | | | |
|---|---|---|---|---|
| | 15 min | 30 min | 45 min | 60 min |
| Uncoated copper | 0.010 | 0.020 | 0.025 | 0.040 |
| Copper coated with soot | 0.041 | 0.068 | 0.087 | 0.105 |
| Copper coated in a discrete mode with P-EP-91(50% of copper area) | 0.160 | 0.245 | 0.320 | 0.350 |

front electrode surface is covered with an absorptive coating, made of polymeric material applied in the form of hemispherical particles 4 distributed over the contact surface and adhesively bonded to it.

A solar element with the film reinforced with the electrode 5 is shown in Figure 2. The electrodes 2 and 3 are covered with an absorptive coating 4 in the form of particles made of a polymeric material.

The device functions as follows. The incoming radiation is absorbed by the coating 4. Since the absorptive coating is made in the form of hemispherical spots of a polymer material, the radiation is collected from larger areas than that corresponding to the contact area between the particle and the substrate. Photons enable charge carriers to emit into the upper electrode; the carriers pass through the polymer film 1 and reach the electrode 3 surface. Thus, if the upper and the lower electrodes are linked to a measuring system, the electric field—resulting from the difference in the standard electrochemical potentials of the electrode materials—promotes the current to flow. Energy can be accumulated in such devices by means of a capacitor circuit.

If the film is reinforced with a material whose electrochemical potential differs from those of the upper and lower electrodes, the device functions if both the

TABLE II

Currents in the Model and Electrode Potential Differences for Contact Metals (Model:Metal 1-PET-Metal 2; Illumination with 88.3 W cm$^{-2}$)

| Contacts | | Difference of potentials, V | Current, A |
|---|---|---|---|
| Measuring | Illuminated | | |
| Aluminum | Aluminum | 0 | $0.40 \; 10^{-11}$ |
| | Magnesium | 0.70 | $0.51 \; 10^{-11}$ |
| | Nickel | 1.41 | $0.35 \; 10^{-8}$ |
| | Lead | 1.53 | $0.42 \; 10^{-8}$ |
| | Copper | 1.99 | $0.45 \; 10^{-10}$ |
| | Silver | 2.46 | $0.82 \; 10^{-11}$ |
| Aluminum | Aluminum | 0 | $0.09 \; 10^{-11}$ |
| Magnesium | | 0.70 | $0.20 \; 10^{-11}$ |
| Nickel | | 1.41 | $0.6 \; 10^{-11}$ |
| Lead | | 1.53 | $0.52 \; 10^{-11}$ |
| Copper | | 1.99 | $0.25 \; 10^{-11}$ |
| Silver | | 2.46 | $0.21 \; 10^{-11}$ |

upper and lower electrodes absorb radiation. In this case the upper and lower electrodes may be made of the same materials.

To examine the working capability of the device, we fabricated models the active zone of which was based on films of the following polymers: poly(ethylene terephthalate) (PET), polypropylene (PP), polyamide (PA), penton (PT), poly(vinyl butyral) (PVB). The film thickness was from 5 to 25 μm. The films were coated in vacuum with the following metals: aluminum, magnesium, nickel, lead, copper, and silver. The measuring plate electrodes of the electrometer V7-30 were connected to the upper and lower contacts. The solar cell was illuminated with a haloid lamp KG 220–1500 (TU 16-675.009-83) mounted 80 mm from the solar cell surface. The incoming radiation intensity can be varied from 18.4 to 101.2 W cm$^{-2}$ with the help of a voltage regulator. Hemispherical spots of the absorptive coating were applied following the procedure described elsewhere.[5]

It was established that the models prepared with polar polymers (PET, PI, PT, PVB) perform well. Typically, the cells current exceeded the dark current by 2 to 3 orders of magnitude.

The use of a polymeric material in the hemispherical form as an absorptive coating improved the performance of the device while the films remained flexible. Particularly, if 50% of the illuminated contact area was covered with such hemispheres, the charge accumulated by the capacitor circuit can be increased by an order of magnitude without reducing the flexibility of the device. A continuous coating of soot appeared to be technologically disadvantageous; a continuous coating of powder epoxy, paint P-EP-91 reduced the flexibility. Hemispherical spots of coating promote absorption of radiation incoming at different angles. For example, hemispherical spots occupying 50% of the illuminated area give the same result as a continuous coating applied to the whole illuminated area.

The fact that electrodes were made of unlike metals, and currents were measured when one of the electrodes was illuminated, allowed us to determine the potential difference range within which currents of the solar device are the highest (Table II). For this, data from Table II were used to determine the dependence of the current on the potential difference. The criterion that the current must exceed the minimum value by a factor of 2 was used to establish that higher currents are generated if the potential difference is at least 0.8 V.

Because the device is made of two polymer films with a reinforcing metallic electrode placed between them, and the external surfaces of the films are covered with metals whose electrochemical potentials differ from that of the reinforcing metal, a two-side illuminated model is possible. This further increases the current in the circuit.[6]

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