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Photovoltaic properties and stability of I_2-doped polyacetylene

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Summary

Polyacetylene was doped with evaporated iodine (I_2). The characteristics of Al/cis-$[CHI_y]_x$/Au Schottky barrier solar cell was investigated. It is found that the maximum conversion efficiency is 2.6%. The solar cell parameters, such as open-circuit voltage (V_{oc}), short-circuit current (J_{sc}), fill factor (F.F.), and energy conversion efficiency (η), were measured under the various incident light intensity. The stability of the cell was also estimated by the variation of J-V curves in argon environment.

Introduction

Polyacetylene films can be synthesized by the method of Shirakawa et al [1, 2]. Polyacetylene, $(CH)_x$, has been very attractive, owing to its remarkable electrical and optical properties. The polyacetylene film can vary from insulator through semiconductor to metal by impurity doping [3-5]. Doping treatment with strong oxidizing and reducing agents leads to p- and n-type $(CH)_x$ films [6], which is analogous to the traditional inorganic semiconductors. From the viewpoint of ease of fabrication and potential low cost, it was interesting to choose the organic semiconductor as the sample of electronic devices.

In particular, semiconductive polyacetylene $(CH)_x$ have some advantages as high absorption coefficient ($\alpha > 10^5$/cm) and the band gap energy of $(CH)_x$ is about 1.5 eV at which the optimum solar energy conversion efficiency can be attained.

Solar cell devices using $(CH)_x$ have been reported by Shirakawa et al. [7] and Ozaki et al. [8], some of the fabricated devices have been combined with inorganic semiconductors. J. Tsukamoto et al.[9] have fabricated Schottky barrier solar cell using semiconductive $(CH)_x$, and obtained the conversion efficiency of 0.2%. Recently, we have been able to improve the conversion efficiency up to 2.6% relative to the transmitted light through electrode. However, the stability of Al/$[CHI_y]_x$/Au solar cell was not estimated. In this study, polyacetylene is doped with iodine in the vapor phase. The photovoltaic properties of I_2-doped $(CH)_x$ are described. The dependence of V_{oc} , J_{sc} , F.F., and η on incident light intensity and the stability of V_{oc} , J_{sc} , F.F., and η on the aging in argon environment, were also measured.

Experimental

Crystalline films of polyacetylene were obtained by polymerization using the Ziegler-Natta catalyst. The films were prepared at low temperature and therefore existed in the cis form. Trans—films can be obtained by heating the cis-films at 180°C for 30 min. All samples were stored in a Schlenk-type flask filled with argon gas. Because cis-$(CH)_x$ films are more flexible and tough than trans-$(CH)_x$ films, we choose the cis-$(CH)_x$ as sample of electronic devices in this study.

Doping was carried out by exposing the $(CH)_x$ films to evaporated iodine vapor. The vapor was initially trapped by liquid nitrogen in an ampoule, and pumping the vacuum line to below 10^{-3} torr, then the vapor was released to pass through a vessel containing $(CH)_x$ films at room temperature. The electrical conductivity of I_2-doped $(CH)_x$ was measured in accordance with the four-probe technique.

The characteristics are influenced significantly by the surface condition of the $(CH)_x$ films [10]. Because the shiny surface of $(CH)_x$ film has more trap density, Aluminum was evaporated on the dull surface of doped-$(CH)_x$ film to form Schottky barrier, and gold was coated on the shiny surface to make ohmic contact by vacuum deposition equipment VPC-260.

The sandwich type of Al/cis-$[CHI_y]_x$/Au cell was sealed by cylindrical flask which filled with argon gas. The Al electrode exposed to the incident light was about 4% transparent. The area of the cell is 0.25 cm^2 and the thickness of the $(CH)_x$ is about 100 μm. All the J-V characteristics of Schottky barrier solar cell were measured by using the HP 4140A PA METER/DC Voltage Source.

The performances of Schottky type solar cells were measured under the illumination of various light intensity and the stability of the cell is also investigated under the aging in argon environment. The light source to measure the characteristics of the solar cell was 125W lamp with AM1 equivalent spectrum. The light intensity was measured by a calibrated SPECTRA PR-1000. In order to prevent the oxidation of the films, all the measurements were taken with the Al/$[CHI_y]_x$/Au cell sealed into flask filled with argon gas.

Results and Discussion

The J-V characteristics of Al/$[CHI_y]_x$/Au Schottky barrier solar cell before and after illuminations are shown in Fig.1. It shows the rectifying property before illumination and the photovoltaic property after illumination. When the incident light intensity of 50 mW/cm^2 was applied to the cell, V_{OC}=300 mV, J_{SC}=400 $\mu A/cm^2$, F.F.=0.33, and η=1.98% were obtained.

Fig.2 illustrates the J-V characteristics of Al/$[CHI_y]_x$/Au solar cell under the illumination of various light intensity. It shows the V_{OC} increases less and the J_{SC} increases more at elevated illumination. The dependence of V_{OC}, J_{SC}, F.F., and η on the light intensity, are shown in Table 1 and Figs.3-5. Table 1 tabulates the measured results of the solar cell under various illumination conditions. It is noted that, for

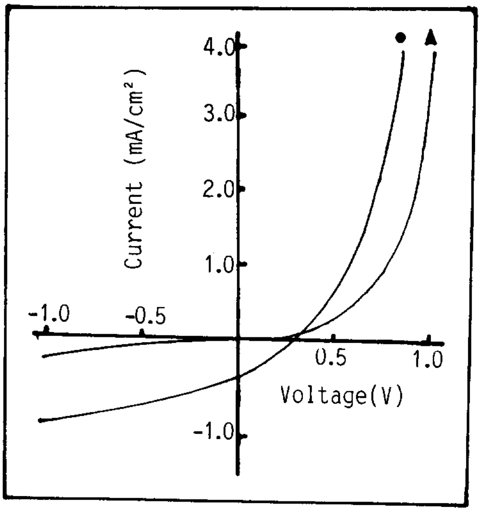

Fig.1 The J-V characteristics of Al/cis-$[CHI_y]_x$/Au solar cell

▲: before illumination;
●: after illumination.

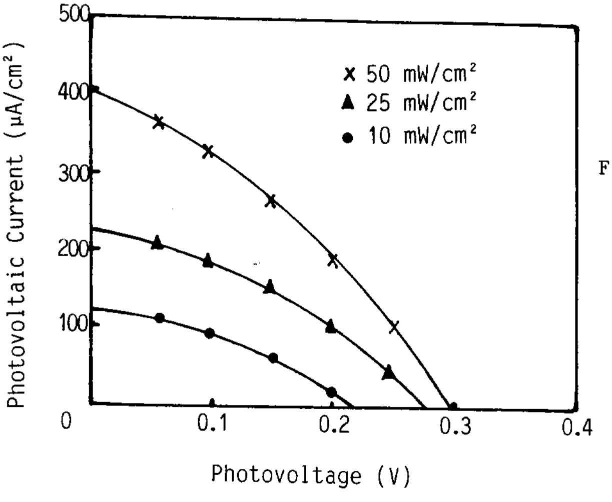

Fig.2 The photovoltaic properties of Al/ $[CHI_y]_x$/Au solar cell under various illuminations.

the illumination of light intensity of 10 mW/cm^2, V_{OC}=0.22V, J_{SC} =120 μA/cm^2, and F.F.=0.36 were obtained. Taking account of the transparency of the Al electrode (3.6%), the energy conversion efficiency is estimated to be 2.6%. In Fig.3, it shows that the value of V_{OC} increases rapidly at low-level illumination and slows down to approach a saturated value about 0.3V at elevated illumination. Fig.4 shows the short-circuit current is proportional to the light intensity. From these results, it is observed that the conversion efficiency of Al/$[CHI_y]_x$/Au cell increases with decreasing light energy. In Fig.5, it shows that the maximum conversion efficiency of the cell is 2.6% at 10 mW/cm^2, and then smoothly decreases to 2.2% at 50 mW/cm^2 incident light intensity.

Table 1 The dependence of V_{oc}, J_{sc}, F.F. and η of Al/[CHI_y]$_x$/Au solar cell on incident light itensity.

P_{in} (mW/cm²)	V_{oc} (V)	J_{sc} (μA/cm²)	F.F.	η(%)
10	0.22	120	0.36	2.6
25	0.28	220	0.34	2.3
50	0.30	400	0.33	2.2

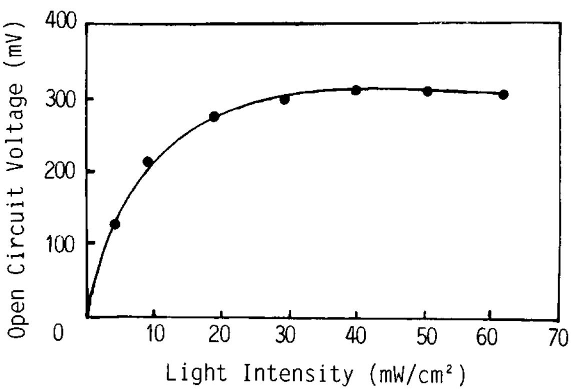

Fig.3 The dependence of the open-circuit voltage of Al/[CHI_y]$_x$/Au solar cell on incident light intensity.

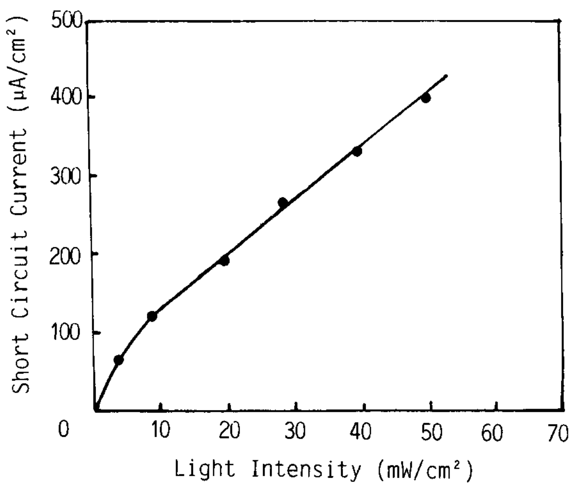

Fig.4 The dependence of the short-circuit current of Al/[CHI_y]$_x$/Au solar cell on incident light intensity.

The stability of Schottky barrier solar cell parameters, such as V_{oc}, J_{sc}, F.F., and η, on the aging in argon environment, are shown in Figs.6-8 and Table 2. Fig.6 illustrates the aging effect of Al/[CHI_y]$_x$/Au cell in argon environment under illumination of light intensity of

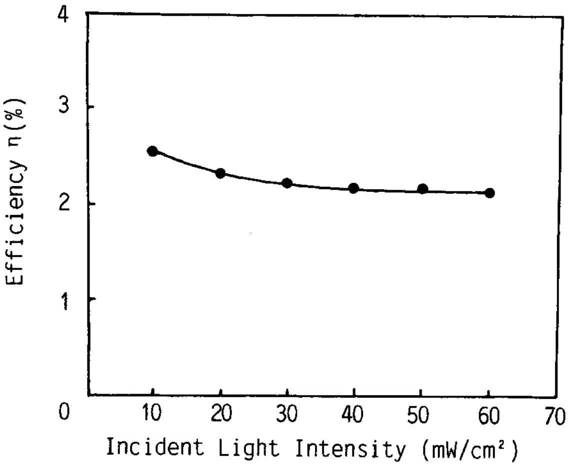

Fig.5 The dependence of the conversion efficiency of Al/$[CHI_y]_x$/Au solar cell on incident light intensity.

50 mW/cm². It shows the V_{oc} increases weakly with the aging time, but the J_{sc} decreases drastically to saturated value with the aging time in argon environment. Fig.7 shows the photovoltaic current decreases drastically at first and goes down to half of the initial value after five days. After that the current decreases gradually to 35 percent of the initial value eventually. Table 2 gives the aging of V_{oc}, J_{sc}, F.F. and η under 50 mW/cm² incident light intensity. It shows that the conversion efficiency decreases from 2.2% to 1.0% after four weeks. In Fig.8, it shows that the efficiency ratio decreases drastically to 0.6 after five days, and then decreases gradually to about 0.5 after four weeks. Obviously, it was suggested that careful encapsulation and elimination of oxygen in cell operation environment would gain a large improvement in cell stability.

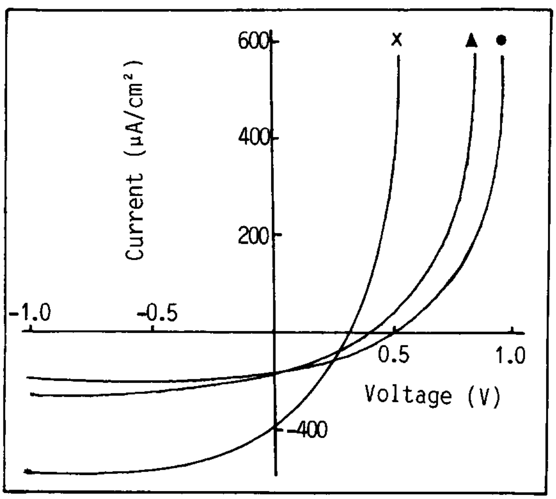

Fig.6 The J-V characteristics of Al/$[CHI_y]_x$/Au solar cell in argon environment under illumination of light intensity of 50 mW/cm².

x : 0 days;

▲ : 14 days;

● : 28 days.

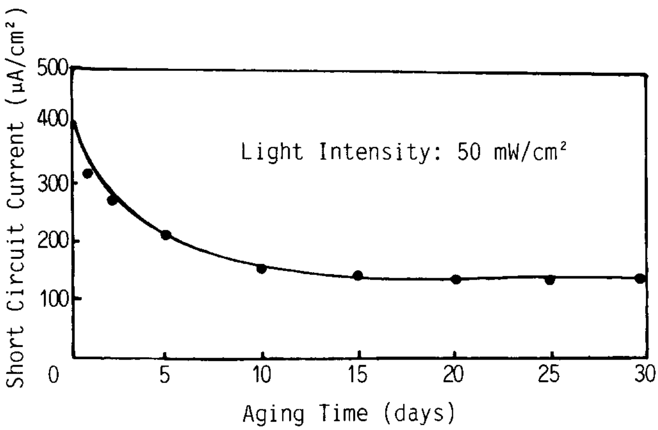

Fig.7 Aging of the short-circuit current of the solar cell in argon environment.

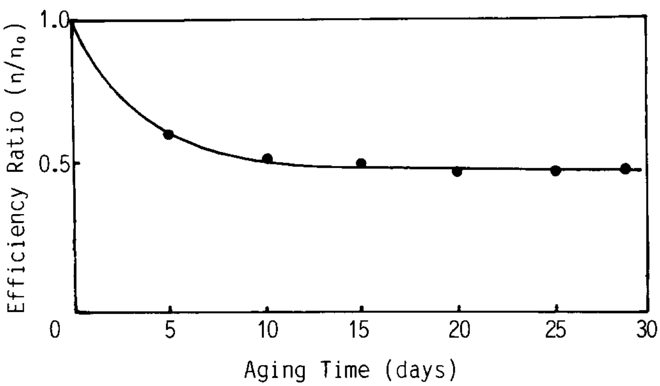

Fig.8 Aging of the conversion efficiency of the solar cell in argon environment.

Table 2 The stability of V_{oc}, J_{sc}, F.F. and η of Al/[CHI_y]$_x$ /Au solar cell in argon environment.

t(days)	V_{oc} (V)	J_{sc} (μA/cm²)	F.F.	η(%)
0	0.30	400	0.33	2.2
14	0.41	160	0.30	1.1
28	0.50	140	0.28	1.0

Conclusions

Using semiconductive polyacetylene, $(CH)_x$, we have fabricated Schottky barrier solar cell of the configuration of Al/cis-$[CHI_y]_x$/Au. The rectifying and photo-electric properties were investigated.

The dependence of V_{oc}, J_{sc}, F.F. and η on the incident light intensity were measured. It is observed that the conversion efficiency of Al/$[CHI_y]_x$/Au solar cell increases with decreasing light energy. The maximum conversion efficiency of the cell is 2.6% (V_{oc}=0.22V , J_{sc}=120 $\mu A/cm^2$, F.F.=0.36) relative to the transmitted light through the electrode under the illumination of light intensity of 10 mW/cm^2 . More higher efficiencies seem to be attained by more elaborate conditions of the polymerization of $(CH)_x$ films and fabrication technologies of the devices.

The stability of the Schottky barrier solar cell parameters, such as V_{oc}, J_{sc}, F.F. and η, on the aging in argon environment is also estimated. It shows the conversion efficiency decreases with aging. In order to improve the stability and conversion efficiency of Al/ $[CHI_y]_x$/Au Schottky barrier solar cell, the investigation of appropriate sealing technique, a good control of contact resistance, surface density, and crystallinity of the sample should be made.

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