Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

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Version of record first published: 18 Oct 2010

To cite this article: Jung Kim, In Chung, Young Kim, Jai Kim & Jae-Woong Yu (2004): Dye Sensitized Solar Cell with P(VDF-CO-HFP) Gel Electrolyte, Molecular Crystals and Liquid Crystals, 424:1, 241-244

To link to this article: http://dx.doi.org/10.1080/15421400490506243

Mol. Cryst. Liq. Cryst., Vol. 424, pp. 241–244, 2004

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400490506243

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DYE SENSITIZED SOLAR CELL WITH P(VDF-CO-HFP) GEL ELECTROLYTE

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A solid-state solar cell was fabricated with perylene acid-sensitized nanostructural tin oxide electrode and poly(vinylidene fluoride-co-hexafluoropropylene)-based gel electrolyte. The effect of ionic conductivity on the device performance was investigated by varying the weight ratio of propylene carbonate acting as a plasticizer in the gel polymer electrolyte (GPE). At a proper composition of GPE, a short circuit photocurrent density of 2.5 mA/cm^2, an open circuit photovoltage of 0.28 V, and a fill factor of 0.51 were obtained under illumination of white Xe light with an intensity of 100 mW/cm^2.

Keywords: perylene acid; polymer electrolyte; solar cell

INTRODUCTION

Polymer electrolytes [1] composed of low lattice energy salts dissolved in polymers containing polar group such as oxygen, nitrogen, sulfur and fluorine, have been investigated as electrolyte systems for the devices such as lithium rechargeable battery [2], supercapacitor [3], electrochromic device [4] and photovoltaic cell [5]. The driving force for these trends seems to be

Received 1 October 2003; accepted 26 December 2003.
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from the intention to improve stability, flexibility and processability. In this study, we deal with a dye sensitized solar cell (DSSC) composed of perylene acid-sensitized nanostructural SnO_2electrode and poly(vinylidene fluoride-co-hexafluoropropylene) [P(VdF-co-HFP)]-based gel electrolyte with a superior film-forming property.

EXPERIMENTAL

15% tin(IV) oxide, as a colloidal dispersion of 15 nm particles in water, was purchased from Alfa/Aesar. P(VdF-co-HFP) (MW = 477 kg/mol) was supplied by ELF-Atochem. Co. Perylene-3,4,9,10-tetracarboxylic acid(PTCA) was synthesized as described elsewhere [6]. The molecular weight of PTCA according to Mass spectra (Agilent Tech.) was 428.051763. PTCA-sensitized SnO_2 electrode was prepared according to the Gregg's procedure without any significant modification [6]. GPE was formed directly on the PTCA-sensitized electrode and a platinized counter electrode was laminated. The intensity of irradiation light (Xe 300 W lamp, ThermoOriel) was fixed at 100 mW/cm^2. Current-voltage behavior was measured with a Keithley 2400 source measure unit. Impedance data were obtained using a frequency response analyzer (FRA, Solartron SI 2400).

RESULTS AND DISCUSSION

The chemical structure of PTCA is shown in Figure 1(a). PTCA is a promising dye for solar cell application since it has quite high molar absorptivity coefficient ($\varepsilon \sim 10^5\,M^{-1}cm^{-1}$) in visible range [6]. The orbital energy level

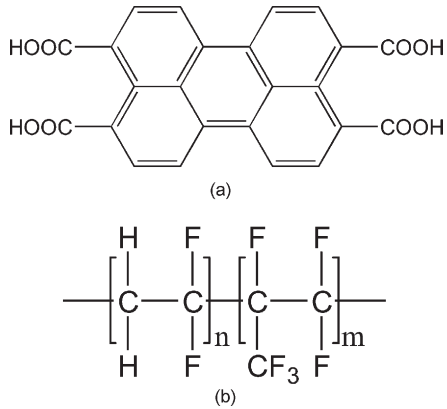

FIGURE 1 Chemical structures of (a) PTCA and (b) P(VdF-co-HFP).

of PTCA was elucidated using electrochemical methods [7]. Based on the results of cyclic voltammogram (CV), the lowest unoccupied molecular orbital (LUMO) was -3.98 eV vs. vacuum energy level using the reduction half-wave potential ($E_{1/2}$). The highest occupied molecular orbital (HOMO $= -6.01$ eV) was estimated from LUMO information combined with the optical band gap ($E_{g,opt} = 2.03\,\text{eV} = 610\,\text{nm}$) obtained from the band edge of absorption spectrum.

P(VdF-co-HFP) was incorporated as a component of GPE for the PTCA-sensitized DSSC application (see Fig. 1(b)). This copolymer can absorb a large amount of plasticizer such as propylene carbonate (PC) without losing its dimensional stability. In the special composition of GPE, P(VdF-co-HFP): PC: NaI: $I_2 = 1$: 3: 1.07: 0.07 (weight ratio), the measured ionic conductivity using FRA was 2.34×10^{-3} S/cm when prepared in the glove box under argon atmosphere.

The DSSC with an ITO/SnO_2(PTCA)/GPE/Pt structure was fabricated. When light with energy larger than $E_{g,opt}$ of PTCA is illuminated on the cell, the photovoltaic process is considered to occur as follows,

$$\text{PTCA} + (\text{CB}) \xrightarrow{h\nu} \text{PTCA}^* + (\text{CB}) \rightarrow \text{PTCA}^{\bullet+} + \text{e(CB)} \tag{1}$$

$$\text{PTCA}^{\bullet+} + (3/2)\text{I}^- \rightarrow \text{PTCA} + (1/2)\text{I}_3^- \tag{2}$$

$$\text{I}_3^- + 2\text{e} \rightarrow 3\text{I}^- \tag{3}$$

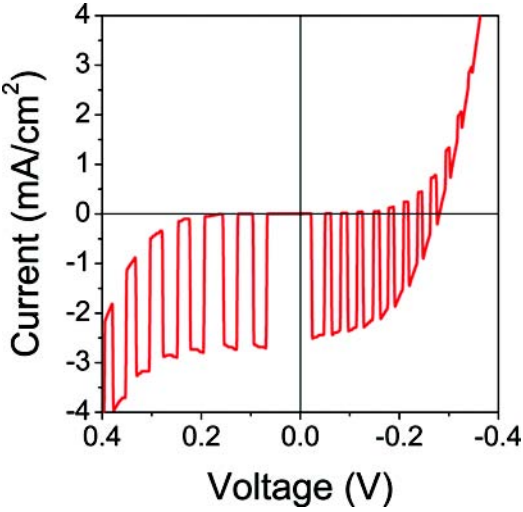

FIGURE 2 Current-voltage curve for the DSSC under white Xe light of 100 mW/cm^2.

By the absorption of light, PTCA comes to be an excited species (PTCA*), which contains the electron-hole pairs. These pairs usually are separated at the hetero-interface (SnO_2/PTCA/GPE), and free charges are formed. The separated electrons are transferred to the conduction band of SnO_2 for occupying more stable state, and the external redox couples scavenge the holes. As shown in Figure 2, a short circuit photocurrent density of 2.5 mA/cm^2, an open circuit photovoltage of 0.28 V and a fill factor of 0.51 were obtained under illumination of white Xe light with an intensity of 100 mW/cm^2.

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