

DYE-SENSITIZED TiO₂ PHOTOELECTROCHEMICAL CELLS INCORPORATING PMMA-BASED GEL POLYMER ELECTROLYTES

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Introduction

Dye-sensitized TiO₂ photoelectrochemical cells have shown the impressive power conversion performance and are promising candidates for low-cost photovoltaic devices [1]. Such solar cells were fabricated with dye-sensitized porous nanocrystalline TiO₂ electrodes, to which characterize the high surface area allowing long-range light absorbed dye molecules attached while maintaining contact with the electrolytes. The electrolytes typically used in these cells are usually containing I⁻/I₃⁻ redox couple in organic solvents such as acetonitrile or propylene carbonate. The use of liquid electrolytes in practical devices, however, results in the degradation in the long-term stability and performance due to the difficulties of complete sealing of the devices. In order to overcome the leakage problem of liquid electrolytes, several types of solid-state cells have been proposed to replace the liquid phase. They include the use of p-type semiconductors [2,3], organic hole transport materials [4,5], and ionic conducting polymers [6-9]. In this work, the feasibility of quasi-solid state dye-sensitized TiO₂ solar cells with gel polymer electrolytes is demonstrated.

Experimental

TiO₂ thin films were prepared by sol-gel method. The sol-gel precursor was made by adding titanium isopropoxide, Ti[OCH(CH₃)₂]₄, to 0.1 M nitric acid solution under vigorous stirring. The solution was then heated at 80 °C for 10 h for peptization. The sol was added with polyethylene glycol (PEG, molecular weight of 20,000) and was used for preparing TiO₂ thin films by dip coating or spin-coating on fluorine-doped SnO₂-coated conducting glass substrate (FTO). The films were sintered at 450 °C for 30 min after air-drying. The sintered films were immersed overnight in an ethanol solution of ruthenium dye (cis-bis(isothiocyanato)bis(2,2'-bipyridyl-4,4'-dicarboxylato)-ruthenium (•)).

For preparation of the polymer electrolytes, PMMA, ethylene carbonate (EC), propylene carbonate (PC), •-butyrolactone (•BL) and I₂ were used. The amount of the iodide, XI (X was lithium or tetrabutylammonium), added was calculated so that the molar ratio of [I₂]/[X] is 0.1. Appropriate amounts of iodide salts, EC, PC, •BL, and PMMA were firstly mixed and heated for gelification. Iodine was added after the solution was cooled to room temperature to avoid loss due to evaporation. The gel electrolyte was then placed on the dye-adsorbed TiO₂ thin films and pressed against the platinized FTO counter electrode. The cells were sealed by epoxy glue. The configuration of the cell is shown schematically in Fig. 1.

Results and Discussions

The mechanisms of photocurrent generation for the dye-sensitized TiO₂ photoelectro-chemical cells can be explained as follows. The photoexcited dye molecules adsorbed at the TiO₂ surface inject electrons into the conduction band of TiO₂ and become dye cations. The oxidized dye molecules would be reduced by I⁻ in the electrolyte to recover their uncharged ground state. At the Pt electrode, I₃⁻ would accept electrons and complete the circuit.

The power conversion efficiency (\bullet) of the solar cell is given by

$$\eta(\%) = \frac{(I \times V)_{\max}}{P_{\text{Light}}} \times 100$$

where $(I \times V)_{\max}$ is the maximum output power of the solar cell and P_{Light} is the incident light intensity. In addition to \bullet , the fill factor (FF) that indicates the extent of departure from the ideal I-V behavior of the solar cell is defined as

$$FF = \frac{(I \times V)_{\max}}{I_{\text{SC}} \times V_{\text{OC}}}$$

Fig. 2 shows the current-voltage characteristics of the solar cells containing different iodide salts. For an incident light intensity of 10 mW/cm² (1/10 sun), the efficiencies of the solar cells with tetrabutylammonium iodide (TBAI) and lithium iodide (LiI) are 4.79 % and 1.48 % respectively. The photocurrent and efficiency of the solar cell with TBAI are much higher than those with LiI. It is inferred that the mobility of the anion (I⁻ in the present case) depends on the extent of interaction of cation with the polymer. The larger cation interacts more strongly with the polymer because of the viscous forces. Therefore the enhancement of I⁻ mobility in polymer with the immobilization of TBA⁺ facilitates the charge scavenging on dye cation and higher efficiency can be obtained.

Fig. 3 shows the current-voltage characteristics of the solar cells cells with electrolytes containing different plasticizer compositions. The efficiencies of the solar cells with (EC+PC), (\bullet BL+EC) and (\bullet BL+PC) are 4.79 %, 4.96 % and 4.41% respectively. The results are consistent with the order of the ionic conductivities for these mixed plasticizers. Again this indicates that the iodide has the highest mobility in (\bullet BL+EC) mixed plasticizers and favorable for recovering the oxidized dye molecules.

Acknowledgments

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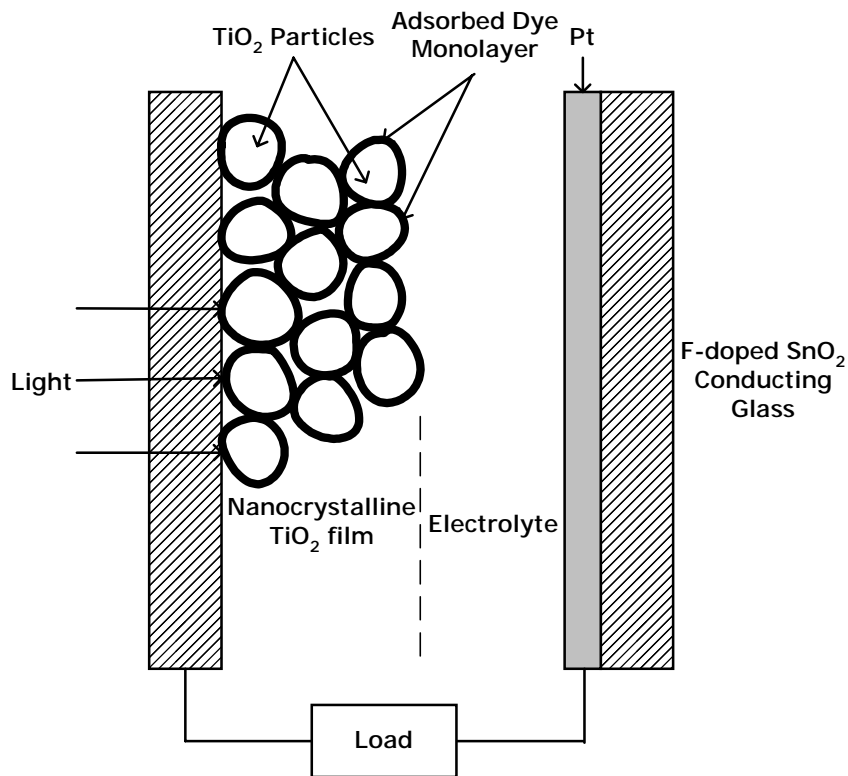


Fig. 1. Schematic configuration of the dye-sensitized TiO_2 photoelectrochemical cell.

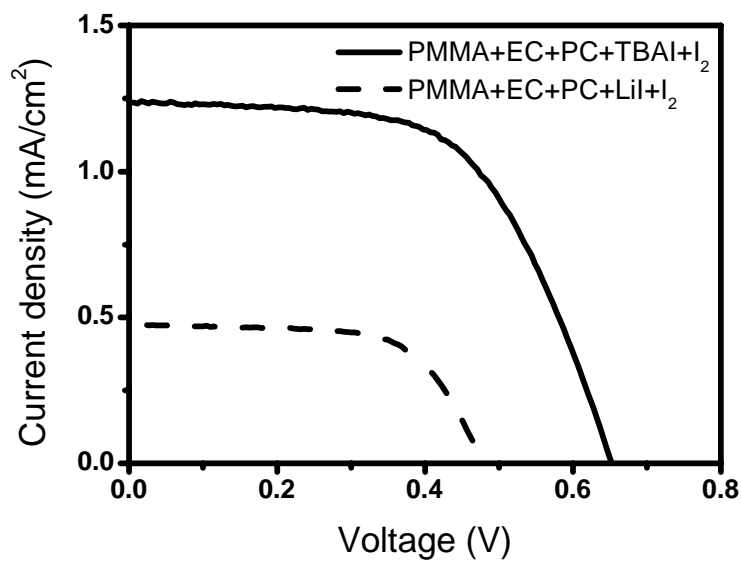


Fig. 2. Current-voltage curves of solar cells with electrolytes containing different iodide salts under 10 mW/cm^2 incident light intensity. The curves were obtained at a scan rate of 5 mV/s .

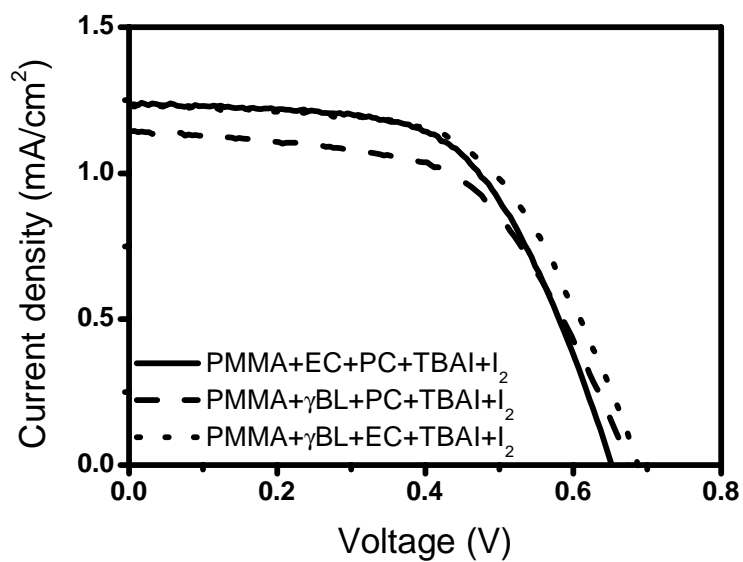


Fig. 3. Current-voltage curves of solar cells with electrolytes containing different plasticizer compositions under 10 mW/cm² incident light intensity. The curves were obtained at a scan rate of 5 mV/s.