

Energy-storable dye-sensitized solar cell with a polypyrrole electrode

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Dye-sensitized solar cells (DSSCs) have attracted much attention because of the low production cost, the relatively high performance, and the application to the colorful and/or flexible solar cells. In this study, we developed a novel type of solar-rechargeable battery, an "energy-storable dye-sensitized solar cell (ES-DSSC)," by hybridizing a typical Grätzel cell and a conducting polymer storage cell. The ES-DSSC can store energy by photo-charging under visible-light irradiation and output the electrical power even in the dark.

The configuration of the ES-DSSC is a bridging three-electrode system with a charge-storage electrode (Fig. 1). Compartment A is a part of the DSSC, and compartment B is a part of the charge-storage electrode. As a photoelectrode, N3dye adsorbed meso-porous TiO₂ prepared on an FTO-glass electrode was used. The counter electrode was a Pt-mesh electrode (1cm×1cm, 100mesh). The electrolyte solution of compartment A was 0.5M LiI and 0.05M I₂ dissolved in propylene carbonate (PC). In compartment B, polypyrrole (PPy) on ITO prepared under galvanostatical conditions at 50μA/cm² from a 0.1M pyrrole and 0.1M LiClO₄ PC solution was used as a charge-storage material in 0.5M lithium perchlorate (LiClO₄) PC solution. The polymerization volume of pyrrole was regulated by electropolymerization charges of 50, 100 and 200 mC/cm². The PPy film showed a reversible voltammogram (Fig.2) with sharp peaks at about -0.35V vs. SCE, indicating a reversible doping/undoping reaction, which is the suitable electrochemical behavior for the charge storage from the conduction band of the TiO₂. Compartment A and B were separated by a low-resistance cation-exchange membrane, Selemion (Asahi glass Co., Ltd.).

Under AM1.5 irradiation, the photocurrent-voltage curve of the ES-DSSC was nearly identical to that of the DSSC without a charge-storage electrode. The open circuit voltage (V_{oc}) of the ES-DSSC was 700-800mV. It was confirmed that the ES-DSSC had comparable performance to the conventional DSSC. Under photoirradiation without an external load, the photoexcited N3 dye injected the electron to the conduction band of TiO₂, and the photogenerated electron was transferred and stored by the PPy in compartment B. On the other side, the oxidized N3 dye received the electron from I⁻ in compartment A, and then I⁻ was oxidized to I₃⁻. After the sufficient photoirradiation, the PPy film was completely de-doped and the charge was balanced to the oxidation of I⁻ to I₃⁻. In a sufficiently photo-charged cell, the output current was obtained between the counter electrode and the charge-storage electrode even in the dark. The output current was due to the electrochemical doping process of undoped PPy film, which can electrochemically be oxidized by I₃⁻. When A-B was open, the output was also obtained. After the photo-charging of the ES-DSSC, V_{oc} was kept at more than a few hundred mV in the dark. According to the photo-charging time, V_{oc} was kept at higher voltage and

the keeping period of V_{oc} was elongated, indicating the accumulation of the electron. Figure 3 shows the charged electricity estimated from the discharge current in the dark as a function of the photo-charging times for various polymerization volumes of PPy. The stored charge of the ES-DSSC increased with the increase in the photo-charging time. Additionally, the charged electricity of the ES-DSSC increased with the increase in the polymerization volume of PPy.

Acknowledgments

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Reference

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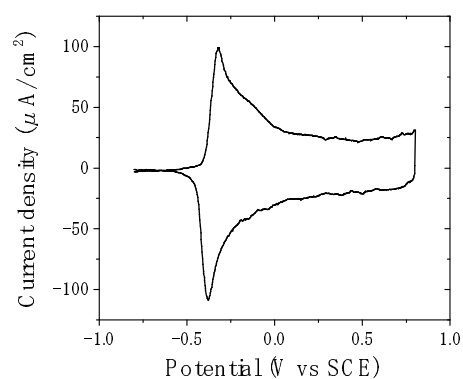
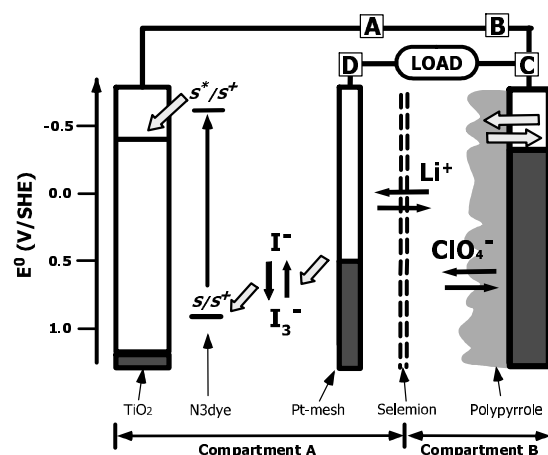


Fig.2 Cyclic voltammogram of PPy film on an ITO electrode in 0.5M LiClO₄/PC. The scan rate is 5mV/s.

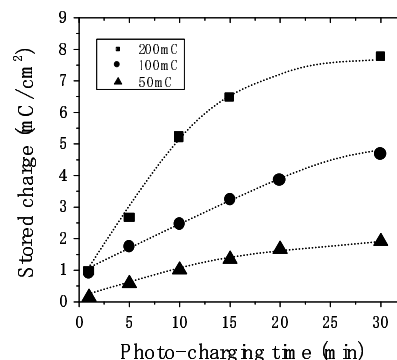


Fig.3 Stored charge by various periods of photo-charging on PPy films. The charge depends on the polymerization electricity (▲: 50mC, ●: 100mC, and ■: 200mC).