Novel Photoelectrochemical Cell with Mesoscopic Electrodes Sensitized by Lead-halide Compounds (11)

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In the research of the dye-sensitized solar cell (DSSC), narrow band gap semiconductors have been investigated as novel visible light sensitizer for oxide semiconductor electrodes. Principally, quantum dot sized chalcogenide materials (CdS, CdSe, etc) have been researched. We have previously reported that lead-halide perovskite compound, $CH_3NH_3PbX_3$ (X=Br, I), works as a visible light sensitizer for TiO_2 electrode in a photoelectrochemical cell, showing over 2% energy conversion efficiency [1]. The stability of this system, however, is hardly adequate compared with the dye-sensitized system. One of the key techniques to enhance the stability of DSSC system is replacement of liquid type electrolyte with solid-state charge transport materials (p-type semiconductor, conductive polymer etc.). In this study, we attempted to fabricate a solid-state photovoltaic cell with polypyrrole-based conductive polymer material as charge transport layer for lead-halide compound sensitized photocell system.

Titania paste (Solaronix, SA) was spread on an F-doped SnO_2 (FTO) conductive glass by squeeze method and sintered at 500℃ for 1h in the air. The photoelectrode ($TiO_2/CH_3NH_3PbX_3$) was prepared with the precursor solution consisted of CH_3NH_3X and PbX_2 on nano-porous TiO_2 electrode. Polypyrrole (undoped) composite with carbon black (PPCB), supplied from Sigma - Aldrich Inc., was employed as conductive polymer material. FTO glass was used as counter-electrode. A solid-state cell was fabricated to sandwich the PPCB material between $TiO_2/CH_3NH_3PbX_3$ and counter-electrode. Photovoltaic performance was measured under 100 mW cm^{-2} irradiation using I-V measurement system (Peccell Technologies, Inc.). The effective area of solid-state cell was 0.238cm^2.

In the case of FTO/$CH_3NH_3PbX_3$-TiO_2/FTO system, photocurrent is hardly observed. On the other hand, photovoltaic characteristic was observed for the FTO/$CH_3NH_3PbX_3$-TiO_2/PPCB/FTO system. Fig.1 shows photocurrent-voltage characteristics of the solid-state cells and the photovoltaic performances are listed in Table.1. For the $TiO_2/CH_3NH_3PbBr_3$ system, the short-circuit photocurrent density (J_{sc}), open-circuit voltage (V_{oc}), fill factor (FF), and energy conversion efficiency (η) are 0.65mA cm^{-2}, 0.70V, 0.45, 0.21 %, and for the $TiO_2/CH_3NH_3PbI_3$ system, these are 1.39 mA cm^{-2}, 0.51 V, 0.52, and 0.37 %, respectively. The $TiO_2/CH_3NH_3PbI_3$ system showed higher photocurrent and energy conversion efficiency than $TiO_2/CH_3NH_3PbBr_3$ system. It is due to that $CH_3NH_3PbI_3$ have wide absorption region up to 800nm [2]. Comparing these results with those employing iodine/iodide liquid electrolyte, photovoltaic performance of the solid-state systems is lower than that of the liquid electrolyte system. It is considered that conductive polymer material was not sufficiently incorporated into the depth of TiO_2 moso-porous electrode in this system. Despite low conversion efficiency of the present stage of study, this is a rare example of solid-state DSSC driven by inorganic sensitizer, which exhibits a fairly high photocurrent and voltage. To improve the photovoltaic characteristics, other conductive polymer materials will be examined together with developing a suitable pore-filling method for porous electrode.

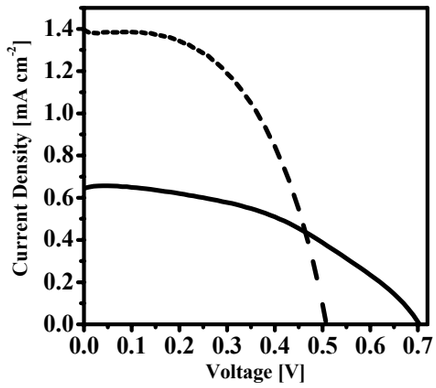

Fig.1 Current-voltage characteristics of polypyrrole based solid-state photocells using $CH_3NH_3PbBr_3$ (line) and $CH_3NH_3PbI_3$ (dot-line) as sensitizer for TiO_2 electrode .

Table.1 Photovoltaic performance of $CH_3NH_3PbX_3$ sensitized solid-state photocell with polypyrrole based conductive polymer as charge transport layer

sensitizer	J_{sc} (mA/cm^2)	V_{oc} (V)	*FF*	*Eff.* (%)
$CH_3NH_3PbBr_3$	*0.65*	*0.70*	*0.45*	*0.21*
$CH_3NH_3PbI_3$	*1.39*	*0.51*	*0.52*	*0.37*

1). A. Kojima, K. Teshima, Y. Shirai and T. Miyasaka, 210th ECS Meeting, Cancun, 2006.
2). A. Kojima, K. Teshima, Y. Shirai and T. Miyasaka, 212th ECS Meeting, Washington, 2007.