Quasi-Solid-State Dye-Sensitized Solar Cells Using Room-Temperature Molten Salts and Low Molecular Weight Gelator

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Dye-sensitized solar cells have attractive feature in high photon-to-current conversion efficiency and low production cost and energy. The electrolyte used in these cells that is usually composed of an I^-/I_3^- redox couple in organic solvents was sealed between two conducting glass substrates. Disadvantages of using liquid electrolytes are less long-term stability, difficulty in robust sealing and leakage of electrolyte in case of breaking of the glass substrates. Recently, dye-sensitized solar cells using gel electrolytes showed comparable efficiencies to the cell using liquid electrolyte and excellent stability in long-term stability test. For outdoor use, however, presence of organic solvents in the gel electrolytes will cause problems such as high-temperature instability and flammability. Here, we report on the fabrication, performance and high-temperature stability of quasi-solid-state dye-sensitized solar cells using neat room temperature molten salts, I_2, and gelator. The molten salts used as the high ionic strength iodide solution should enhance the electronic conduction in the electrolyte.

Photocurrent-voltage properties of the cells with imidazolium iodides (1-alkyl-3-methylimidazolium iodides; alkyl chain: C_3 - C_9) were also listed in Table 1. The short circuit photocurrent density (J_{SC}) increased with increasing alkyl length up to C_7. The open circuit voltage (V_{OC}) also showed a maximum at C_7. As the result, the electrolyte with 1-hexyl-3-methylimidazolium iodide gave the highest photoenergy conversion efficiency (η), and used as the component of gel electrolyte.

Fig. 1 shows photocurrent-voltage curves of the cell with molten salt electrolyte under AM 1.5 irradiation. V_{OC} , J_{SC} , fill factor (FF) and η of the cells were listed in Table 2. The curve obtained from the cell using gel electrolyte was similar to that the cell without gelator. The result implies that the gelator should build up a three-dimensional network structure, without inhibitation of the charge transport, even in molten salt electrolyte as in organic electrolyte solutions. The conversion efficiency obtained from the cell using gel molten salt electrolyte was c.a. 2/3 of that from the cell using organic liquid electrolyte. Dry heat test of the cells was carried out at 85 °C for 1000 h. Efficiency of the cells using organic solvent decreased immediately due to the solvent evaporation, but the cell using molten salt electrolyte kept 70% of the initial efficiency because there is no volatile solvent. The efficiency of the cell using molten salt gel electrolyte did not decrease at all.

Thus high-temperature stabilized and non-flammable electrolyte composed of room temperature molten salts and gelator provides a practical efficiency and stability of dye-sensitized solar cell.

Table 1 Photocurrent-voltage performance of dye-sensitized solar cells with imidazolium iodides.

C_n	A / cm^2	V_{OC} / V	J_{SC} / mA cm^{-2}	FF	η / %
3	0.23	0.59	6.0	0.59	2.1
4	0.21	0.60	6.6	0.61	2.4
5	0.22	0.65	7.2	0.68	3.0
6	0.24	0.67	7.4	0.66	3.3
7	0.21	0.70	7.4	0.63	3.3
8	0.23	0.69	6.7	0.62	2.8
9	0.21	0.68	6.6	0.60	2.7

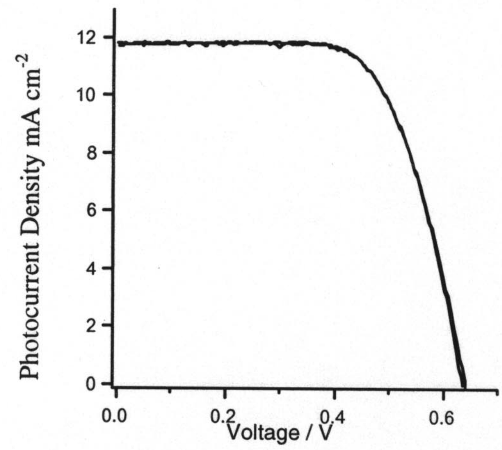

Figure 1. Photocurrent-voltage curves of the cells with 1-hexyl-3-methylimidazolium iodide containing 8.7 wt.% of I_2 under AM 1.5 irradiation; with (solid curve) and without (dashed curve) 40 g L^{-1} of gelator.

Table 2 Photocurrent-voltage performance of the dye-sensitized solar cells using molten salt electorolyte with (Gel) and without (Liq.) gelator.

	A / cm^2	V_{OC} / V	J_{SC} / mA cm^{-2}	FF	η / %
Gel	0.27	0.64	11.8	0.66	5.0
Liq.	0.27	0.64	11.8	0.67	5.0

Figure 2. Time-course change under dry heat test of the normalized photoconversion efficiency of the solar cells stored at 85°C; with molten salt gel electrolyte (solid line), molten salt electolyte (long dashed line), organic solvent gel electrolyte (short dashed line), and organic solvent electrolyte (dotted line).