

### Electrochemical Properties of Nanocomposite Ion-gel Electrolytes for Dye-sensitized Solar Cells

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Dye-sensitized solar cells<sup>1</sup> (DSCs) are expected to be the next generation photovoltaic device because of low fabrication costs, simple manufacturing processes, and so on. Generally, DSCs employed an electrolyte solution composed of  $I/I_3^-$  redox couples dissolved in a volatile organic solvent, and evaporation of the solvent decreases long-term stability of devices. Replacing of the electrolyte to the non-volatile one has been attempted to avoid this problem. An ionic liquid or an ion-gel, which is a gelled ionic liquid, seems to be a suitable material for it. For example, performance of DSCs using the ion-gel electrolyte quasi-solidified by silica nano-particles was reported<sup>2</sup>. Recently, gelation of ionic liquid by dispersing single-walled carbon nanotubes into it was investigated<sup>3</sup>. We assembled DSCs used nanocomposite ion-gel electrolytes through the above mentioned gelation technique and showed the cell performance superior to that before gelation<sup>4</sup>. However, properties of the electrolyte brought the improvement of the cell output have been revealed yet. In this study, charge transport properties in the nanocomposite ion-gel electrolyte were investigated.

Nanocomposite ion-gel electrolytes were prepared from mixture of ionic liquid-based electrolytes and  $TiO_2$  nano-particles (e.g. P25). Ionic liquids used in this study were shown in Fig. 1. A suspension of nano-particles in the electrolyte solution was grinded and then an excess liquid phase was separated from a gel phase by centrifuging.

Fig. 2 presents a performance of the prepared nanocomposite ion-gel type DSCs. Short-circuit current, open-circuit voltage and fill factor parameters were improved, and the energy conversion efficiency was increased in comparison with that before gelation. The cyclic voltammetry measurement using Pt microelectrode was carried out to discuss a property of the electrolyte. Fig. 3 shows steady-state voltammograms corresponding to the redox reaction of  $I/I_3^-$  for the gel- and liquid-type electrolyte using various kinds of ionic liquids. In all cases, it was found that limiting currents ( $I_{lim}$ ) in these measurements were significantly enhanced by gelation. It means an acceleration of charge transport rate in the electrolyte. Apparent diffusion coefficients ( $D_{app}$ )<sup>5</sup> of this reaction were calculated.  $D_{app}$  values have doubled, especially, in the HMIm-I or EMIm-DCA system. In addition, it was also found that the equilibrium potential ( $E_{eq}$ ) of  $I/I_3^-$  in the nanocomposite ion-gel electrolyte shifted positively in compared with that of corresponding liquid state electrolytes, and widths of shift of  $E_{eq}$  showed good correlation with the changes of the open-circuit voltage of cells.

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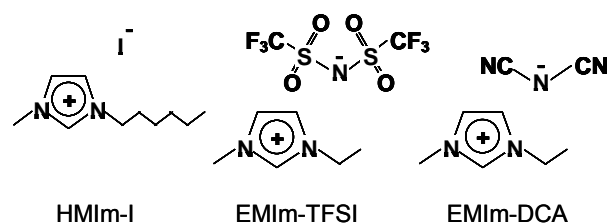


Fig. 1 Structure of ionic liquids used in this study.

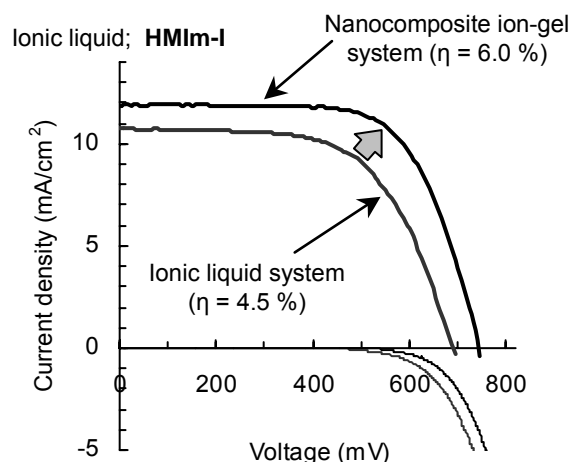


Fig. 2 I-V characteristics of cells using an ionic liquid system and nanocomposite ion-gel system. The ionic liquid (HMIm-I) was gelled by  $TiO_2$  nano-particles (P25). Photo-electrode area was 5 mm x 9 mm.

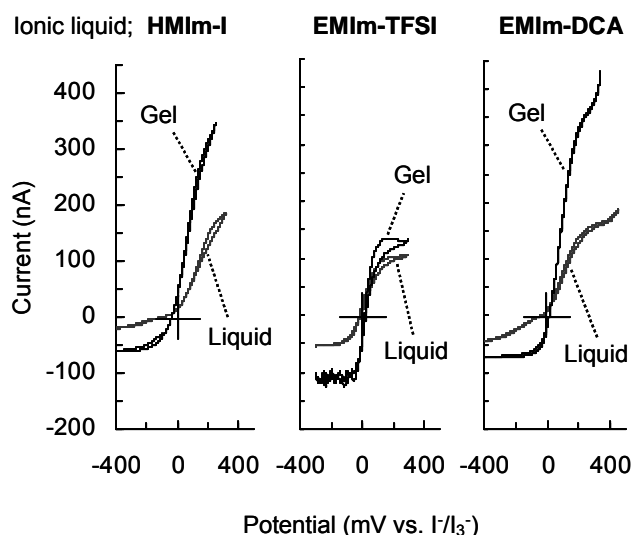


Fig. 3 Steady-stage voltammograms of nanocomposite ion-gel electrolytes at a Pt microelectrode with a 15  $\mu$ m diameter. Scan rate was 2 mV/s.

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