Quasi-Solid-State Dye-Sensitized Solar Cells with Ionic Gel Electrolytes

Wataru Kubo, Shingo Kambe, Takayuki Kitamura, Yuji Wada, and Shozo Yanagida
Material and Life Science, Graduate School of Engineering, Osaka University
2-1 Yamadaoka, Suita 565-0871, Japan.

Kenji Hanabusa
Graduate School of Science and Technology, Shinshu University, Ueda 386-8567, Japan.

Dye sensitized Solar cells (DSC) with ionic liquids, 1-alkyl-3-methylimidazolium iodide (alkyl: $C_3 – C_9$), and a low molecular weight gelator as a quasi solid state electrolyte was fabricated. The cell with 1-hexyl-3-methylimidazolium iodide (HMImI) showed a 5.0% conversion efficiency and high temperature stability. The value of conversion efficiency obtained from the cell with ionic gel electrolyte (IGE) was same as that with ionic liquid electrolyte (ILE), but about 2/3 of that with organic liquid electrolyte (OLE). To explain the difference of photocurrent-voltage properties between dye sensitized solar cells with OLE and ILE, four processes in DSC, (a) For charge transport in electrolyte viscosity of the electrolyte affects current density significantly. (b) In viscous ILE, concentration gradient of redox species, especially I_3^-, could be formed under high irradiation. To obtain photocurrent that of to OLE, higher concentration of I_3^- was required. However, I_3^- absorbs UV light with high absorption coefficient, and a tailing in this absorption extends into visible range. Then I_3^- deprives photons generating conduction band electrons, so the photocurrent density obtained from the cell decreases. (c) Charge recombination process between photoinjected electrons in metal oxide and I_3^- in the electrolyte play an important role in limiting device efficiency of DSC. The ILE contains high concentration of I_3^- about 10 times as much as organic solvent electrolyte. Here, the electron lifetime is related with probability to encounter holes, thus electron lifetime should be influenced by concentration of I_3^- in electrolyte. (d) The dynamics of electron transport in mesoporous TiO_2 films has been studied as electron diffusion with trapping events. The increase of diffusion coefficient with concentration of imidazolium cation was reported. ILE contains about 10 times as much imidazolium cation as OLE, then electron diffusion coefficient in ILE could show higher value than in OLE. In this report, we explained the difference between OLE and ILE through those four points of view.

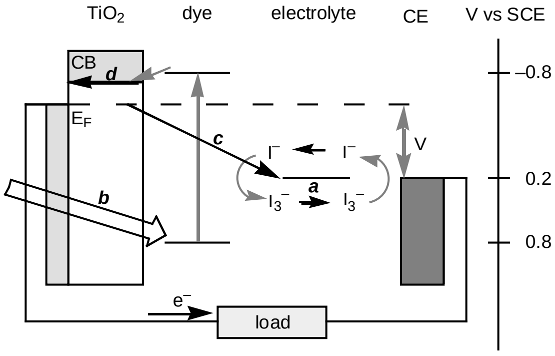
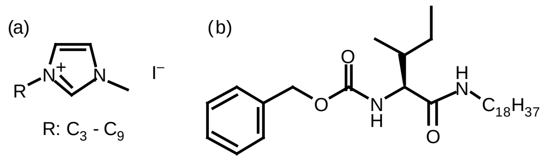


CHART 1: Chemical Structure of Ionic Liquids and Gelator



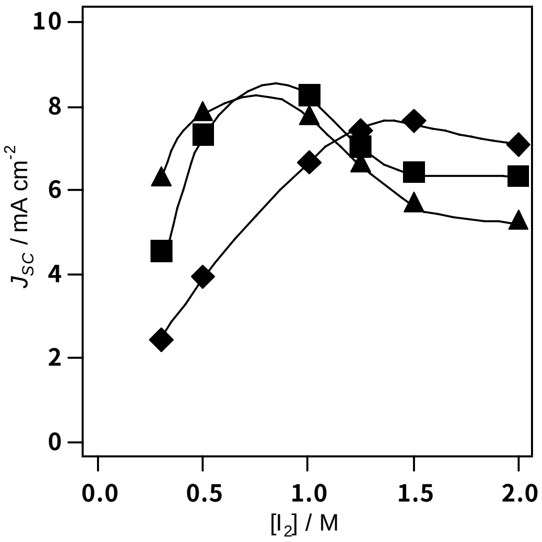


Figure 1. Effect of concentration of I_2 on short circuit current density, PMImI (triangle), HMImI (square), NMImI (diamond).

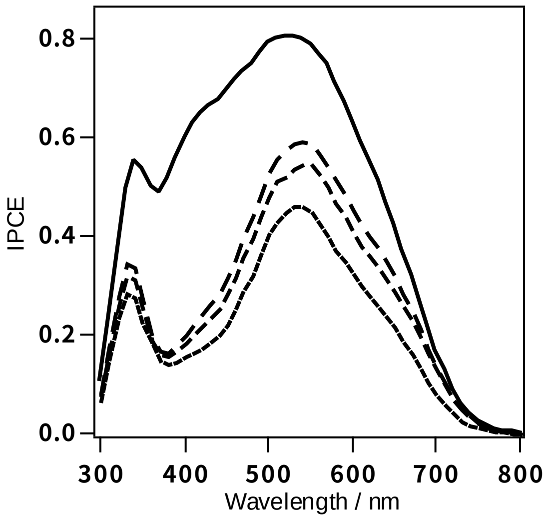


Figure 2. IPCE spectra of cells with OLE (solid curve) and ILE; PMImI (dotted), HMImI (short-dashed), and NMImI (long-dashed) with 1 M of I_2.

The difference of photocurrent-voltage properties of dye sensitized solar cells (DSC) with organic liquid electrolyte (OLE) and ionic liquid electrolyte (ILE) was well interpreted by the limit of mass transportation of iodide species in viscose electrolyte. Slow diffusion of I_3^- depressed the local concentration of I_3^- at counter electrode to limit the photocurrent density (J_{SC}). Optical absorption of due to the concentrated I_3^- was obvious in the wavelength range of < 600 nm, that reduced J_{SC} of 12% in ILE compare to that in OLE. The charge recombination between electron in conduction band of TiO_2 and I_3^- increased with increasing of I_3^- concentration in the electrolyte to decrease J_{SC} at high I_3^- concentration.