

A New Ionic Liquid for Redox Electrolyte of Dye-Sensitized Solar Cells

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Various air-stable molten salts have been extensively used as essential sources for I_3/I^- redox couple electrolytes in dye-sensitized TiO_2 solar cells (DSSCs). Recently, some papers reported on using room temperature molten salts as both iodide sources and solvents in redox electrolytes for long-term stability and non-volatility of DSSCs.^{1,2}

In this study, an air stable molten salt, containing vinyl group instead of methyl or ethyl group at the C(1) position of imidazole ring has been designed. The molten salt, vinyl-contained imidazolium iodide, can be a good monomer to make polymer electrolyte contained poly iodide. We report on synthesis and characterization of a new molten salt, 1-vinyl-3-heptylimidazolium iodide (VHpII). Photovoltaic performance of VHpII-contained dye-sensitized solar cells is investigated.

VHpII was synthesized by thermal reaction between 1-vinylimidazole and heptyl iodide in trichloroethylene at 70 °C for 3 hours under Ar atmosphere.³ The synthesized products were confirmed by 1H NMR (300MHz Bruker DRX300). Thermogravimetric property of the synthesized VHpII was investigated using a SDT 2960 simultaneous DSC-TGA (TA Instrument) at a heating rate of 5 °C/min in air.

TiO_2 colloidal solution prepared by a sol-gel method was coated by doctor blade on FTO glass (Libbey-Owens-Ford). The resulting films were annealed at 500 °C for 30 min in air. The thickness of TiO_2 film was about 9 μm . The films were immersed in 3×10^{-4} M $Ru(II)L_2(NCS)_2$ ethanol solution for 24 h at room temperature. The redox electrolytes were prepared by dissolving iodine in VHpII with the mole ratio of $[VHpII]/[I_2] = 20$, where 4-tert-butylpyridine (0.125 M) and lithium iodide (0, 0.2, 0.4 and 0.6 M) were added. Pt electrode was used as a counter electrode.

$J-V$ curves were measured using a Keithley 2400 source meter. The incident photon-to-current conversion efficiency (IPCE) was measured at the low chopping speed of 5 Hz using a system by PV Measurement Inc.

The synthesized VHpII was found to be stable for thermal stress upto 250 °C and non volatile at 150 °C (Figure 1). The newly prepared molten salt was applied as an electrolyte for dye-sensitized solar cell. Figure 2 shows $J-V$ characteristics for the dye-sensitized solar cells. The solar cell contained the redox couple of VHpII and iodine showed the conversion efficiency of 2.63% under 1 sun light intensity at AM 1.5, which was much improved by about 40% when adding 0.4 M LiI, resulting in the conversion efficiency of 3.63%. The increased conversion efficiency was ascribed to an increase in external quantum efficiency. Addition of small Li^+ cation in VHpII can cause the band edges to shift to more positive potential because the Li^+ cations adsorbed on the TiO_2 surface are likely to induce the potential drop across the Helmholtz layer. As a result, V_{oc} is expected to decrease. The increase in J_{sc} can also be related to conduction band edge movement. The positive shift of the TiO_2 conduction band

by Li^+ cations allows low lying excited states of the adsorbed dye to inject electrons, resulting in an enhanced photocurrent.

Conclusively, we synthesized an imidazolium iodide-based molten salt contained vinyl group. The conversion efficiency of VHpII-based DSSC seems to be not as good as organic liquid-based DSSCs, however, the former is more beneficial in practical point of view because of thermal stability. It is better than the reported ionic liquids in the absence of organic solvent.

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References

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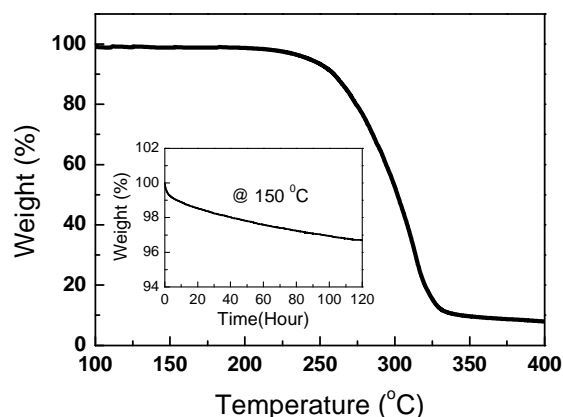


Figure 1. TGA curve of VHpII measured at a heating rate of 5 °C/min in air. Inset shows a plot of weight loss of VHpII at 150 °C as a function of time.

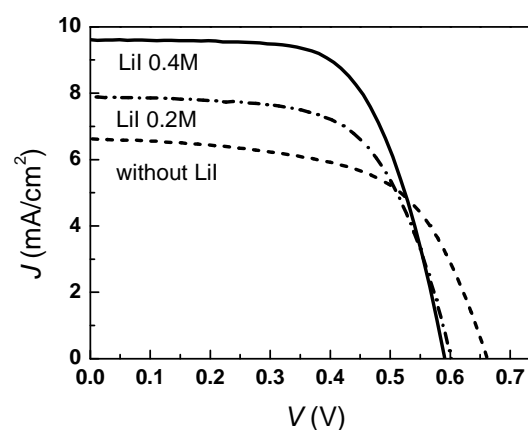


Figure 2. $J-V$ curves of dye-sensitized solar cells contained VHpII ionic liquids with and without LiI at AM 1.5 (100 mW/cm^2).