Development of novel room temperature molten salts and the application to the solid-state dye-sensitized photovoltaic cells

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Room temperature molten salts constitute promising systems with the potential of practical applications in a diverse variety of technological disciplines.[1] Organic electrochemical applications of these materials have intensively been studied especially for environmentally friendly alternative to the conventional organic electrolytic medium, i.e. supporting electrolyte and organic solvent. A class of room temperature molten salt that has been widely studied are the salts formed from imidazolium derivatives and inorganic or organic acids. An interesting observation we made was the peculiar behaviour of the thiocyanate ion. Almost all thiocyanates of inorganic and organic bases have melting points well below that of their halide counter parts. Some alkylammonium thiocyanates were also reported to show quite low melting points.[2] Motivated by the above observations, we examined thiocyanates of a number of organic cations. On the other hand, we have reported successful application of one of these thiocyanates, i.e. 1-ethyl-3-methylimidazolium thiocyanate (EMISCN), to the dye-sensitized solid-state solar cell which has a triple layered structure (TiO_2/dye/CuI, Figure 1), as an additive and a crystal growth inhibitor for CuI layer preparation.[3] In this paper, development of novel room temperature molten salts and the application to the solid-state dye-sensitized photovoltaic cells are presented.

Several kinds of thiocyanates were prepared by the reaction of a corresponding halide with AgSCN or by the reaction of an alkyl amine with NH_4SCN. Some of them resulted in the formation of room temperature molten salts. Figure 2 shows the conductivity of the typical thiocyante molten salt, i.e. Et_3NHSCN which have a melting point of 7 °C. The reason why the thiocyanates generally have melting points lower than the corresponding halides could be partly understood as originating from more delocalization of the charge on the SCN^- compared to the halide ions. This would make the anion (SCN^-) and cation electrostatic interaction weaker, reducing the lattice binding energy.

Table 1 shows the results of addition of several 1-ethyl-3-methylimidazolium (EMI) salts to the CuI layer of TiO_2/Dye/CuI cell and the effect of their counter anions on the performance of the cell are described. We improved the performance and stability of the solid-state dye-sensitized solar cell using CuI with EMISCN which is also a room temperature molten salt.

References

1. T. Welton, *Chem. Rev.*, **1999**, *99*, 2071.
2. M.E. Coddens, K.G. Furton , C.F. Poole, *J. Chromatogr.*, **1986**, *356*, 59.
3. G. R. A. Kumara, A. Konno, K. Shiratsuchi, J. Tsukahara, K. Tennakone, *Chem. Mater.*, **2002**, *14*, 954.

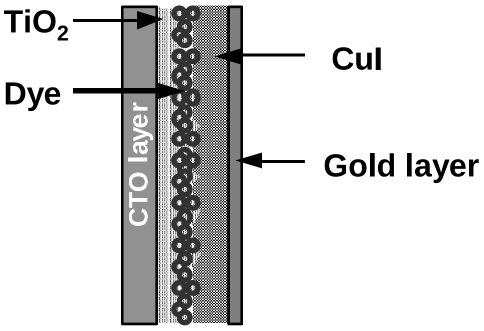

Figure 1. Schematic structure of TiO_2/Dye/CuI cell.

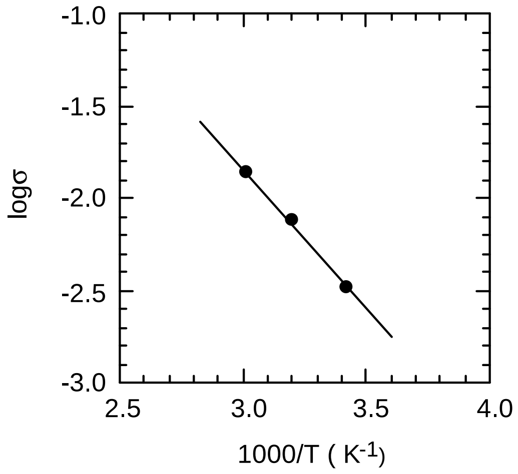

Figure 2. Temperature variation of the conductivity of Et_3NHSCN.

Table 1 Solar cell performances of cells using CuI as a hole conductor with or without an 1-ethyl-3-methylimidazolium (EMI) salt.

Anion of EMI salt	Isc/mAcm^{-2}	Voc/mV	FF$^{a)}$	η$^{b)}$/%
SCN^-	9.8	565	0.49	2.7
I^-	9.5	505	0.45	2.2
Cl^-	3.1	505	0.52	0.8
CF_3COO^-	3.5	390	0.40	0.5
without EMI salt	3.1	430	0.40	0.5

a) Fill factor.
b) Energy conversion efficiency of the cell under illumination of AM 1.5 simulated sunlight.