Solid-state Dye-sensitized Solar Cell Made from a Nanocrystalline Film of TiO_2 Coated with MgO.

G.R.A. Kumara,[†] K. Tennakone,[‡] M. Okuya,[†] S. Kaneko.[†]
[†] Department of Material Science, Shizuoka University,
3-5-1 Johoku, Hamamatsu, 432-8561, Japan.
[‡] Institute of Fundamental Studies,
Hantana road, Kandy, Sri Lanka.

Dye-sensitized (DS) solid-state cells in principle are stable systems. However, the devices of this type reported so far have efficiencies smaller(1-5) than DS photoelectrochemical cells (PECs)(6,7). The reason seems to be the higher rate of recombination in the DS solid-state cells, compared to the DS PECs. Here the surface recombination are expected to very high because of the large area of the n-type semiconductor/dye/p-type semiconductor heterojunction interface. Moreover, the formation of voids in the dye layer cannot be completely avoided and direct contact of n-type and p-type semiconductor promote recombination. We have found that surface recombination in DS solid-state can be greatly suppressed by coating of an ultra-thin layer of MgO on the nanocrystalline TiO_2 film. This coating is made by boiling the TiO_2 coated plate in a solution of magnesium acetate, rinsing with ethanol and sintering. The thickness of the MgO shell estimated from a knowledge of the quantity of MgO in the film and its surface area is ~ 0.5 nm. The presence of MgO shell on TiO_2 crystallites was not visible to SEM or TEM. However EDX clearly demonstrated the distribution of Mg on the film surface. Naturally the characterization of ultra-thin shells on nanocrystallites is exceedingly difficult.

RuN3 dye is coated by the usual method and CuI is deposited from a solution of CuI in acetonitrile containing a small quantity of a CuI crystal growth inhibitor. The crystal growth inhibitor we used earlier was 1-methyl-3-ethyl-imidazolium thiocyanate. Recently we found that triethyl ammonium thiocyanate gives equally good or even better results.

Dye molecules adsorbed on the outer MgO shell injects electrons into the conduction band of TiO_2, concomitantly releasing a hole to CuI. The dye coated insulating MgO barrier suppresses the recombination, As a result, the open circuit voltage, fill factor and the efficiency are increased (Fig. 1 andTable.1). The slight decrease in the photocurrent could be due to a decrease in the injection efficiency originating from MgO barrier or increase in the internal resistance of the film by interposition of a MgO layer between TiO_2 crystallites. We believe that the efficiency of DS solid-state cells based on this idea can be further increase if methods are found for deposition of unbroken ultra-thin films of dye adsorbing insulators on TiO_2.

References

1. K. Tennakone, G.R.R.A. Kumara, A.R. Kumarasinghe, K.G.U. Wijayantha, P.M. Sirimanne. Semicond. Sci. Technol, **10**, 1689 (1995).
2. B. O'Regan, D.T. Schwartz, Chem. Mater, **7**, 1349 (1995).
3. B. O'Regan, D.T. Schwartz, Chem. Mater, **10**, 1501 (1998).
4. K. Tennakone, G.R.R.A. Kumara, I.R.M. Kottegoda, K.G.U. Wijayantha, V.P.S. Perera. J. Appl. Phys, **31**, 1492 (1998).
5. G.R.R.A. Kumara, A. Konno, G.K.R. Senadeera, P.V.V. Jayaweera, D.B.R.A. De. Silva, K. Tennakone. Sol. Energy. Mater. Sol. Cells, **69**, 195 (2001).
6. B. O'regan, M. Grätzel. Nature, **335**, 737 (1991).
7. M.K. Nazeeruddin, A. Kay, I. Rodicio, R. Humphry-Baker, E. Muller, P. Liska, N. Vlachopoulos, M. Grätzel. J. Am. Chem. Soc., **115**, 6382 (1993).

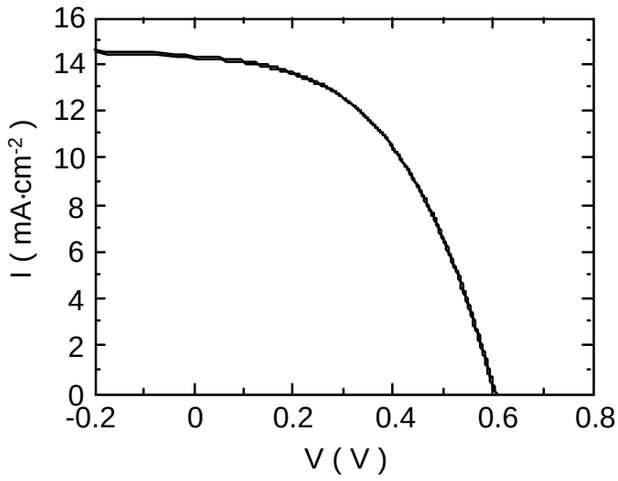

Fig. 1 I-V characteristics of the TiO_2/MgO/dye/CuI cell (AM 1.5 1000W· m^{-2} simulated sunlight)

Table. 1 Short-circuit photocurrent (I_{SC}), Open-circuit voltage (V_{OC}), Fill-factor (FF) and Efficiency (η) of the TiO_2/dye/CuI and TiO_2/MgO/dye/CuI cells. (AM 1.5 1000 W· m^{-2} simulated sunlight).

	I_{SC}(mA· cm^{-2})	V_{OC}(V)	FF	η(%)
TiO_2/Dye/CuI	14.7	0.52	0.44	3.2
TiO_2/MgO/Dye/CuI	14.0	0.62	0.56	4.1