The effect of TiO_2 surface coating by some metal oxides or acetates and improvement of open circuit voltage in the dye-sensitized solid-state solar cell

Akinori Konno,[†] Hiroaki Kida,[†] Hirotaka Kawasaki,[†] G. R. Asoka Kumara,[†] Masayuki Okuya,[†] Shoji Kaneko,[†] and Kirthi Tennakone[‡]

[†]Faculty of Engineering, Shizuoka University, 3-5-1 Johoku, Hamamatsu, 432-8561 Japan.

[‡]Institute of Fundamental Studies, Hantana road, Kandy, Sri Lanka.

The liquid electrolyte in the dye-sensitized solar cell (DSSC), leads to several technological problems such as: dye desorption, solvent evaporation and degradation, and seal imperfection, etc. Tennakone et al have developed a dye-sensitized solid-state cells (DSSSCs) using p-CuI as the hole-conductor.[1] In this paper, we demonstrate that a significant increase in the efficiency of dye-sensitized solid-state can be achieved by deposition of an ultra-thin shell of MgO on the TiO_2 nanocrystallites before the deposition of the dye[2] or by deposition of some acetates on the dyed TiO_2 nanocrystallites.

On increasing the MgO shell thickness Voc and η gradually increased with slow decrease in Isc and η reached an optimum when the MgO shell thickness is ~ 0.5 nm (Figure 1). An increase of the thickness of the shell beyond the optimum gave rapid decreased of Isc and η while Voc continues to increase up to a maximum of ~ 750 mV and again decreased on further increase of the shell thickness. Figure 2 shows the I-V characteristics of the cell at the optimum thickness corresponding to the cell parameters being η = 4.7%, Isc = 13.0 $mAcm^{-2}$, Voc = 620 mV and FF = 0.58. Shell thickness becomes crucial because too thick film of MgO would slow down the electron injection rate.

In the case of MgO coating, high temperature (400-500˚C) calcination treatment in order to make insulator metal oxides from magnesium acetate is drawback of this method. Dyes are always introduced after this calcination process and thus adsorption of dye proceeded mainly on the insulator coated on TiO_2. On the other hand, acetate coating method (the second issue of this paper) does not need a high temperature process and thus coating can be done after dying to TiO_2. This treatment is very simple i.e. just dip the dyed TiO_2 electrode into ethanol solution of acetate (1 mM) then dry it. The result was shown in figure 3. This simple acetate coating resulted in fairly good cell performance especially in the Voc. Although the detailed mechanism of Voc improvement is still unclear, suppression of charge recombination at the interface between TiO_2-dye and CuI is suggested.

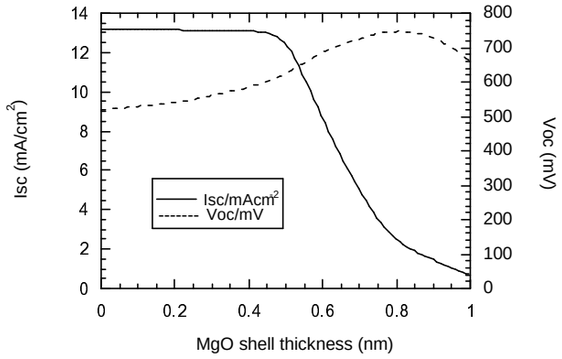

Figure 1. Variation of the short-circuit photocurrent (Isc) and the open-circuit voltage (Voc) of TiO_2-MgO/Dye/CuI cell with MgO shell thickness.

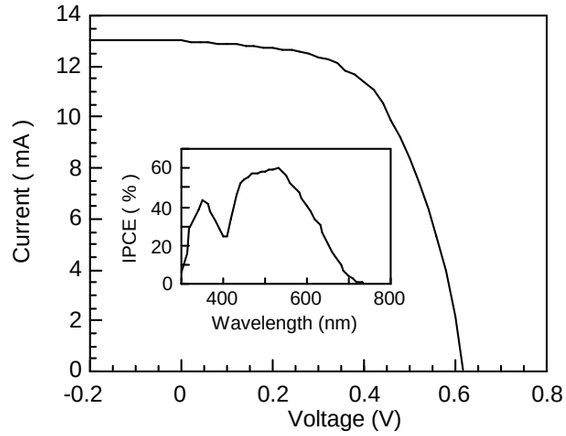

Figure 2. I-V Characteristics of the dye-sensitized solid-state solar cell made from MgO coated TiO_2. Inset: Photocurrent action spectrum of the cell (the peak at ~ 350 nm originate from carrier injection via band gap excitation of TiO_2, Illumination cell area; 0.25 cm^2).

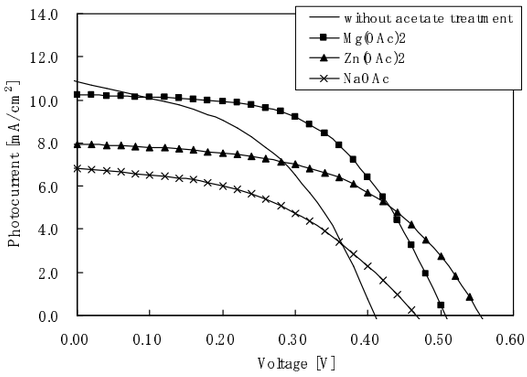

Figure 3. I-V characteristics of TiO_2/N3 dye/CuI cells with the treatment of the dyed TiO_2 surface by some acetate salts ($Mg(OAc)_2$, $Zn(OAc)_2$, Na(AcO)).

References

1. K.Tennakone, et al, *Semicond. Sci. Technol*. **1995**, *10*, 1689; *Semicond. Sci. Technol*. **1996**, *11*, 1737; *J. Phys. D: Appl. Phys*. **1998**, *31*, 1492.
2. G. R. A. Kumara, K. Murakami, S. Kaneko, M. Okuya, V. V. Jayaweera, and K. Tennakone, *J. Photochem. Photobiol*, A, **2004**, *164*, 183-185.