CHAPTER III

LITERATURE REVIEWS

This chapter presents the literature reviews for dye-sensitized solar cell (DSSC)

3.1 Modification of TiO_2 electrode with mixed-metal oxides

To improve the performance of solar cells, one effective approach is the interfacial modification of nanoporous TiO_2 films with high band-gap semiconductor metal oxide coating layer such as SrO, $SrTiO_3$, $CaCO_3$, Nb_2O_5, MgO and Al_2O_3 between the TiO_2 and the dye interface has been attempted. MgO and Al_2O_3 have been studied as an insulating barrier given its high conduction band edge compared with TiO_2. Recently, many groups have proposed as follows;

Luo and coworkers (2008) studied, dye-sensitized TiO_2 electrodes were immersed into a solution of aluminum isopropoxide (Al_2O_3 over layer, Figure 3.1) using a "wet-chemical" method and after hydrolysis quasi-solid-state solar cell were fabricated. The cells with Al_2O_3 coating shown lower back current and better performance: under low light intensity illumination, the Voc increased by ~50mV, the Jsc decreased a little, and the overall efficiency was improved slightly; under 100mW·cm^{-2} AM 1.5, both the Voc and Jsc increased, resulting in a significant 28% improvement in overall efficiency. The Al_2O_3 coating also resulted in better stability of solar cells without encapsulation due to depression of the dye desorption and electrolyte degradation.

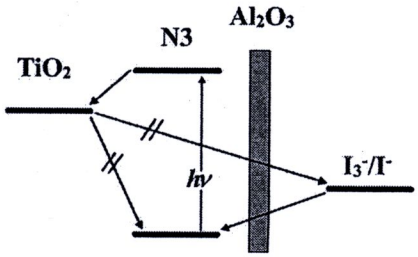

Figure 3.1 Illustration of the interfacial charge transfer processes occurring at the TiO_2|dye|electrolyte of a DSSC. Also shown is the Al_2O_3 overlayer as developed in this study. (Luo et al., 2008)

Bandara and coworkers (2008) investigated how the MgO coating on TiO_2 and SnO_2 affect of the flat-band (FB) potential levels. The results of coating of a thin insulating MgO layer on TiO_2 or SnO_2 particles to decreased a back-electron transfer reaction rate and can be assumed that the MgO coating on TiO_2 and SnO_2 may change the charge transfer and recombination kinetics which may in turn enhance the solar cell performance and photocatalytic activity.

Yang and coworkers (2002) preparation of nanoporous TiO_2 electrodes modified with an $MgTiO_3$ layer (represented as $TiO_2/MgTiO_3$) and its application in dye-sensitized solar cells (DSSC). The conduction band of $MgTiO_3$ stands higher than that of TiO_2, so the $MgTiO_3$ layer can be beneficial to the improvement of nanoporous TiO_2 electrodes. nanoporous TiO_2 films were prepared from colloids with particles of about 20 nm diameter. The surface modified $TiO_2/MgTiO_3$ electrode was fabricated by dipping a TiO_2 thin film in 0.2 $mol \cdot L^{-1}$ $MgCl_2$ and $TiCl_4$ mixture aqueous solution and sintered in air at 450°C for 30 minute. As a result, the photoelectrochemical properties of the modified electrodes were improved and the overall energy conversion efficiency η was increased from 6.12% to 8.75% under the illumination of a white light of 100 mW/cm^2.

Ganapathy and coworkers (2010) studied Alumina (Al_2O_3) shell formation on TiO_2 core nanoparticles by atomic layer deposition (ALD) to suppress the

recombination of charge carriers generated in a dye-sensitized solar cell (DSSC). ALD is an efficient process for controlling the nanostructure and layer thickness by regulating the number of deposition cycles. For a porous TiO_2 later prepared by applying a paste of TiO_2 nanoparticles (Ti Nanoxide T20) by means of a doctorblade on the FTO glass substrates and then annealing at 450°C for 30 minute. Then, the alumina coated TiO_2 electrodes and immediately immersed in solution of N3 dye. After the analyzed, a layer of Al_2O_3 on TiO_2 surface reduces the loss of electrons by suppressing their recombination, and this results in a significant increase in the short-circuit current and the overall power conversion efficiency.

César and coworkers (2010) preparation and characterization of core-shell electrodes for application in gel electrolyte-based dye-sensitized solar cells. The TiO_2 electrodes were prepared from TiO_2 powder (P25 Degussa) and coated with thin layers of Al_2O_3, MgO, Nb_2O_5 and $SrTiO_3$ prepared by the sol-gel method. The improvement in the solar cell energy conversion efficiency by the overcoat approach may be assigned to the following factors: (i) the wide band gap coating delays the electron back transfer to the electrolyte and minimizes charge recombination, (ii) the coating layer also enhances the dye adsorption onto the porous electrode and, as a consequence, the dye loading, increasing the photocurrent. The optimum performance was achieved by solar cells based on MgO/TiO_2 core-shell electrode: fill factor of ~0.60, short-circuit current density Jsc of 12 $mA{\cdot}cm^{-2}$, open-circuit voltage Voc of 0.78 V and overall energy conversion efficiency of ~5% (under illumination of 100 $mW{\cdot}cm^{-2}$).

Bihui and coworkers (2010) studied MgO/TiO_2 core shell film was obtained by using a simple chemical bath deposition method to coat a thin MgO film around TiO_2 nanoparticals. After 20 minute dipping of MgO, Jsc is increased by 19.6% from 7.36 $mA{\cdot}cm^{-2}$ to 8.80 $mA{\cdot}cm^{-2}$, and η is increased by 21.8% from 4.32% to 5.26%. The increase of the FF and η of the solar cell is due to the formed energy barrier by the thin MgO layer. Moreover, the MgO coating promotes the dye molecular adsorption ability of the electrodes, leading to the improvement of the Jsc.

However, the use of mixed metal oxide as an electrode was an alternative approach to enhance the efficiency of DSSC.

3.2 The structure of TiO_2 electrode of the dye-sensitized solar cell

Lee and coworkers (2009) investigated the improvement of the DSSC performance afforded by using multi-layered TiO_2 electrodes by light-scattering effect. Three types of TiO_2 electrode (shown in Fig 3.2) of the DSSC device were composed of TiO_2 particles of 9 nm, 20 nm, and 123 nm in the average diameter. The use of the light-scattering layers resulted in an increase of the Jsc value, thus the overall power conversion efficiency by 6.03% under illumination of simulated AM 1.5 solar light (100 $mW \cdot cm^{-2}$) was attained with a multi-layer structure using 123-nm-TiO_2 layer for the light-scattering layer and 9-nm-TiO_2 layer for the dense layer.

Xu and coworkers (2009) prepared bilayer-structured film with TiO_2 nanocrystals as underlayer and TiO_2 nanotubes as overlayer. The resultant double-layer TiO_2 film could significantly improve the efficiency of dye-sensitized solar cell owing to its synergic effects, i.e. effective dye adsorption mainly originated from TiO_2 nanocrystal layer and rapid electron transport in one-dimensional TiO_2 nanotube layer. The overall energy conversion efficiency of 6.15% was achieved by the formation of double layer TiO_2 film, with is 44.70% higher than that formed by pure nanocrystalline TiO_2 film. It is expected that the double layer film electrode can be extended to other composite film with different layer structures and morphologies for enhancing the efficiencies of DSSC.

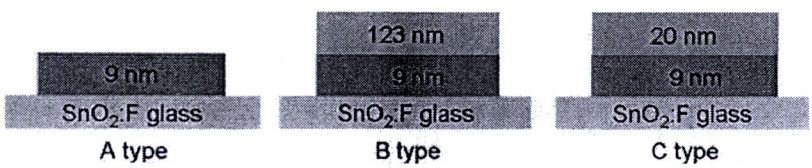

Figure 3.2 Three types of TiO_2 electrode onto SnO_2:F glass prepared for dye-sensitized solar cells. (From Lee et al., 2009)