Proceedings of the 4th International Conference on Nanostructures (ICNS4)
12-14 March, 2012, Kish Island, I.R. Iran

Mesoporous TiO_2 electrodes with different thickness for dye sensitized solar cell application

M. Abdi Jalebi, A.M. Bakhshayesh, M.R. Mohammadi *

[a] Department of Materials Science and Engineering, Sharif University of Technology, Tehran, Iran
* E-mail: mohammadi@sharif.ir

Abstract: Mesoporous TiO_2 films with different thicknesses were prepared for dye sensitized solar cell application using dip coating method. The crystal structure and morphology of the films were studied by scanning electron microscope and X-ray diffraction. The optical properties of the films were investigated through UV–Vis absorption. With increasing film thickness from 3.1 to 13.9 μm, the efficiency increases from 0.81 to 3.09 %.

Keywords: TiO_2; Dye sensitized solar cell; Dip coating method

Introduction

Dye sensitized solar cell (DSSC) that was proposed by O'Regan and Grätzel [1] has attracted considerable interest since 1991 due to their low production cost and low environmental impact during fabrication [2]. The semiconductor photoelectrode is a key component of a DSSC, whose properties determine the photogenerated electron transport and dye adsorption.

Jiu et al. presented a process (including a mixed template method) for fabricating a crack-free porous TiO_2 electrode film of any thickness [3]. Richards et al. produced a highly porous TiO_2 electrode film using APCVD [4].

In this study, mesoporous and nanocrystalline TiO_2 films with different thicknesses were prepared for dye sensitized solar cell application using dip coating method. Titanium dioxide nano-powders were prepared by the hydrolysis of titanium tetra-isopropoxide by sol-gel method in an acidic solution.

Experimental

Titanium isopropoxide was mixed with ethanol and the distilled water was added drop by drop under vigorous stirring for 1 hour. This solution was peptized by nitric acid and refluxed for 8 hours. The conductive glass substrates were coated by prepared sol using dip coating method. The thickness of the film was increased by repeating the coating process. The coated TiO_2 films were sintered at 400℃ for 2 hr.
The thickness of TiO_2 film coated 5 times was 3.1 μm. This product denoted as NP05. In order to study the effect of thickness, parallel experiments were carried out at different conditions, as presented in Table 1.

Table 1. The samples prepared with various thicknesses by sol-gel method

Sample	Coating times	Thickness (μm)
NP05	05	3.1
NP10	10	7.7
NP15	15	10.2
NP20	20	13.9

TiO_2 electrodes were soaked in 0.3 mM ruthenium (II) dye (Ruthenium 535- bisTBA dye, or N719, Solaronix) solution for 20 h. The electrodes were washed once with acetonitrile, dried, and then immediately used for photovoltaic measurements. The redox electrolyte was composed of 0.6 M dimethylpropylimidazolium iodide, 0.1 M LiI, 0.05 M I_2, and 0.5 M 4-tertbutylpyridine in acetonitrile. A Pt-coated FTO was used as a counter electrode [6].
TiO_2 electrodes were characterized by X-ray diffraction diffractometer (XRD) using a Philips X'pert PW3020, Cu-K_α and field emission scanning electron microscope (FE-SEM) using a JEOL 6340 and Ultraviolet–Visible (UV–Vis) spectroscopy using a 6705 JENWAY spectrometer.

Results and Discussion

Figure 1 shows the XRD patterns of the NP05 sintered at 400℃.

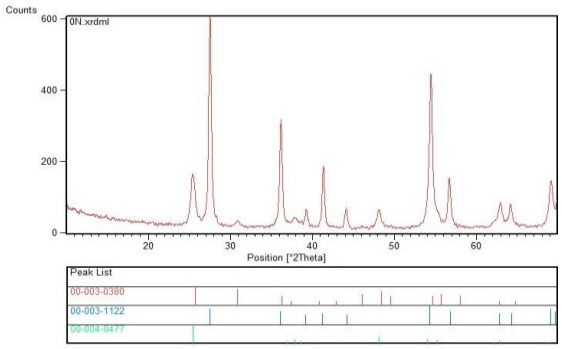

Figure 1. XRD patterns of NP05 sintered at 400℃ for 2 hr.

It can be observed that this sample consisted of the mixture of anatase, brookite and rutile and were matched with JCPDS card numbers 00-04-0477, 00-003-0380 and 00-003-1122, respectively.
The particle morphologies of the NP05 sintered at 400℃ were observed by FE-SEM, as shown in figure 2.

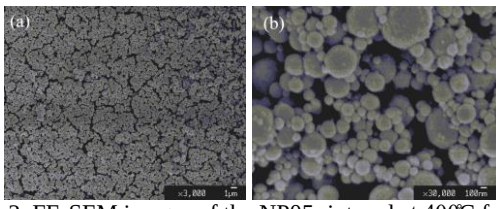

Figure 2. FE-SEM images of the NP05 sintered at 400℃ for 2 hr: (a) X3,000; (b) X30,000.

Figure 3 shows the UV-Vis spectra of the NP05 in the wavelength range of 200 nm to 900 nm. It is known that, bulk TiO_2 has large band gap energy of about 3.26 eV corresponding to the wavelength 385.5 nm [7]. The absorption spectra of NP05 showed an adsorption edge at 278 nm. According to the relation between the band gap energy and the absorption edge, the calculated band gap of NP05 is 4.46 eV.

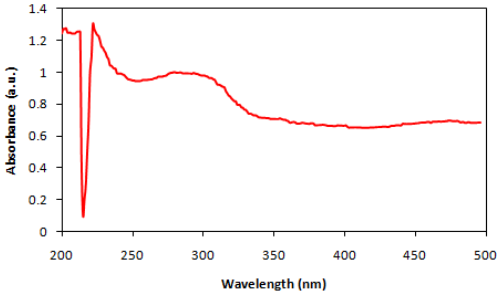

Figure 3. UV–Vis spectra of NP05.

Table 1 shows the thickness of TiO_2 films at various coating times. The thickness of the TiO_2 film coated 5 times (NP05) was 3.1 µm. As the coating time increased to 20 times, the thickness of TiO_2 film increased to 13.9 µm.

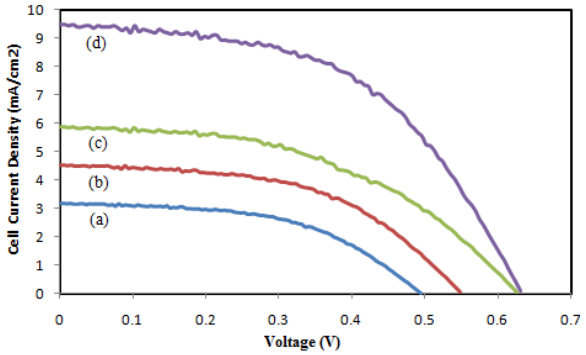

Figure 4. photocurrent-voltage characteristics of samples: (a) NP05; (b) NP10; (c) NP15; (d) NP20.

Figure 4 shows the photocurrent-voltage characteristics of samples. Table 2 lists the photoelectric data of the DSSCs in Figure 3. With increasing film thickness from 3.1 to 13.9 µm, the J_{sc} increases by 185%, V_{oc} increases by 31% and FF indicates almost the same values at all thicknesses.

Table 2. photoelectric data of the DSSCs

Sample	Thickness (µm)	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	Efficiency (%)
NP05	3.1	3.32	0.49	0.47	0.81
NP10	7.7	4.59	0.54	0.51	1.28
NP15	10.2	5.92	0.63	0.55	1.92
NP20	13.9	9.45	0.64	0.61	3.09

Conclusions

A TiO_2 sol was prepared by the sol-gel method and the films were coated using dip-coating method. The dependence of the thickness of mesoporous TiO_2 film was studied on *J-V* characteristics.

The optimum efficiency of TiO_2 solar cell was attained around 13.9 µm thickness.

References

[1] B. O'Regan, M. Grätzel, "A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO_2 films", *Nature*, 353 (1991) 737–740.

[2] A. Hagfeldt, M. Grätzel, "Light-Induced Redox Reactions in Nanocrystalline Systems", *Chem.* 95 (1995) 49-68.

[3] J. Jiu, F.Wang, M. Sakamoto, J. Takao, M. Adachi, "Preparation of nanocrystalline TiO_2 with mixed template and its application for dye-sensitized solar cells", *Journal of the Electrochemical Society*, 151 (2004) A1653-A1658.

[4] B.S. Richards, N.T.P. Huong, A. Crosky, Highly "porous nanocluster TiO_2 films deposited using APCVD in an excess of water vapor", *Journal of the Electrochemical Society*, 152 (2005) F71-F74.

[5] H. Han, X. Zhao, J. Liu, "Enhancement in photoelectric conversion properties of the dye-sensitized nanocrystalline solar cells based on the hybrid TiO_2 electrode", *Journal of the Electrochemical Society*, 152 (2005) A164-A166.

[6] Y.S. Jin, K.H. Kim, H. Choi, "Properties of TiO_2 Films Prepared for Use in Dye-sensitized Solar Cells by Using the Sol-gel Method at Different Catalyst Concentrations", *Journal of the Korean Physical Society*, 57 (2010) 1049-1053.

[7] X. Chen, "Titanium Dioxid Nanomaterials and Their Energy Applications", *Chinese Journal of Catalysis*, 30(8) (2009) 839-851.