Structural modification of TiO_2 nanorod films with an influence on the photovoltaic efficiency of a dye-sensitized solar cell (DSSC).

L.J. Meng[1,2], C. Li[3] and M.P. dos Santos[4]

1 Departamento de Física, Instituto Superior de Engenharia do Porto, Rua Dr. António Bernardino de Almeida 431, 4200-072 Porto- Portugal

2 GRF- Functional Coatings Group, Physics Centre, University of Minho, Campus de Azurém, 4800 Guimarães- Portugal

3 State Key Laboratory of Catalysis, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, 457 Zhongshan Road, Dalian 116023,China.

4 CeFITec, Universidade Nova de Lisboa/Departamento de Física, Universidade de Évora, Portugal

ABSTRACT

TiO_2 nanorod films have been deposited on ITO substrates by dc reactive magnetron sputtering technique. The structures of these nanorod films were modified by the variation of the oxygen pressure during the sputtering process. Although all these TiO_2 nanorod films deposited at different oxygen pressures show an anatase structure, the orientation of the nanorod films varies with the oxygen pressure. Only a very weak (101) diffraction peak can be observed for the TiO_2 nanorod film prepared at low oxygen pressure. However, as the oxygen pressure is increased, the (220) diffraction peak appears and the intensity of this diffraction peak is increased with the oxygen pressure. The results of the SEM show that these TiO_2 nanorods are perpendicular to the ITO substrate. At low oxygen pressure, these sputtered TiO_2 nanorods stick together and have a dense structure. As the oxygen pressure is increased, these sputtered TiO_2 nanorods get separated gradually and have a porous structure. The optical transmittance of these TiO_2 nanorod films has been measured and then fitted by OJL model. The porosities of the TiO_2 nanorod films have been calculated. The TiO_2 nanorod film prepared at high oxygen pressure shows a high porosity. The dye-sensitized solar cells (DSSCs) have been assembled using these TiO_2 nanorod films prepared at different oxygen pressures as photoelectrode. The optimum performance was achieved for the DSSC using the TiO_2 nanorod film with the highest (220) diffraction peak and the highest porosity.

Introduction

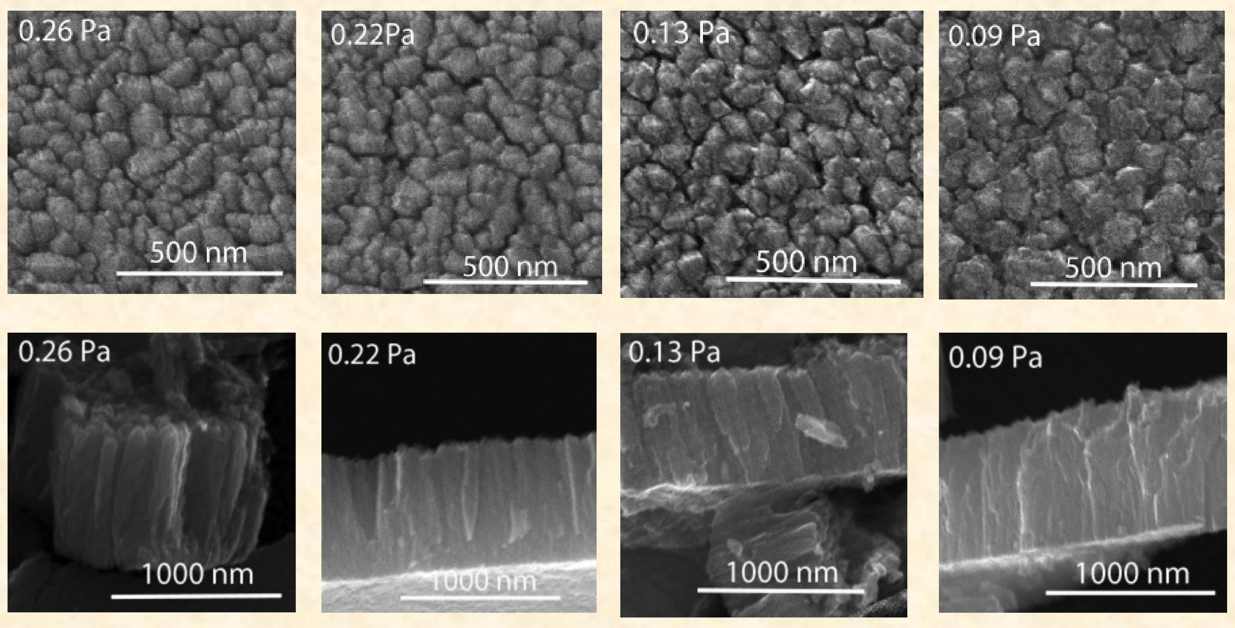
Most of the nanostructured TiO_2 films were made by chemical methods which are not easy to reproduce and have some limitations for industrial production. The sputtering technique is a very promising method because it is reproducible and suitable for industry. Although the conversion efficiency still needs to be improved, DSSC using TiO_2 films prepared by sputtering technique as photoelectrode have been reported. In this study, the TiO_2 nanorod films with different structures have been made and the effect of the structures of these nanorod films on the efficiency of DSSC has been studied.

Experimental

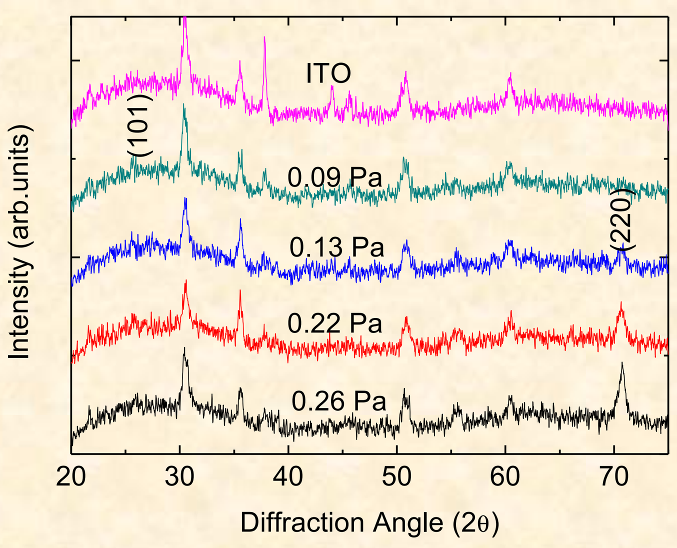
The TiO_2 nanorod films were prepared on commercial ITO substrates (sheet resistance of 20 Ω per square and thickness of 100 nm) by dc reactive magnetron sputtering technique. The TiO_2 films were sensitized with N719 dye by soaking the films in an ethanolic solution of N719 dye (0.5 mM) for 24 hours at room temperature. The counter-electrode was made by sputtering Pt on an FTO glass and the electrolyte is composed of 0.1 M I2, 0.1 M LiI, 0.6 M 1-hexyl-3-methylimidazolium iodide, and 0.5 M 4-tert-butylpyridine in 3-methoxypropionitrile. The photocurrent-voltage measurements were carried out with a Princeton 2273 Applied Research electrochemical system, a 500 W Xenon lamp under AM 1.5G illumination with a water filter was used. The light intensity was adjusted to 100 mW/cm^2. Cells with an active area of 0.15 cm^2 were tested.

Table 1. Cell Performance

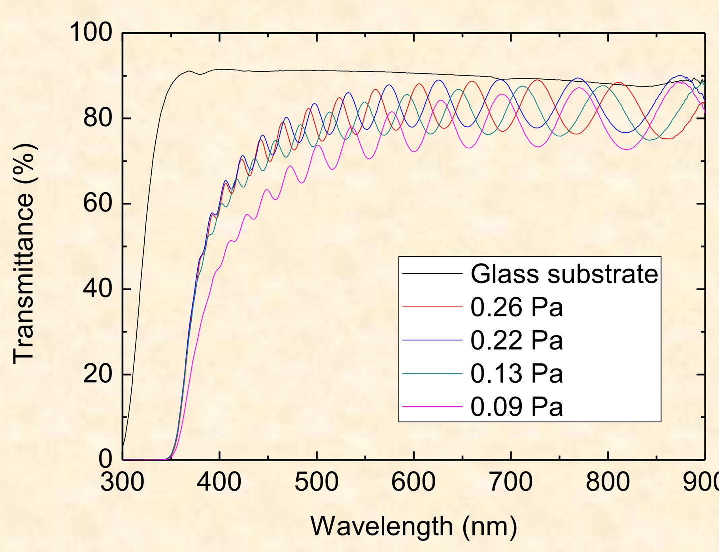
Sample	1	2	3	4
Oxygen pressure (Pa)	0.09	0.13	0.22	0.26
Jsc (mA/cm^2)	1.32	2.35	2.86	3.32
Voc (V)	0.54	0.62	0.64	0.64
FF (%)	0.59	0.69	0.72	0.65
Conversion efficiency (%)	0.42	1.01	1.32	1.38
Porosity (%)	8	22	25	27



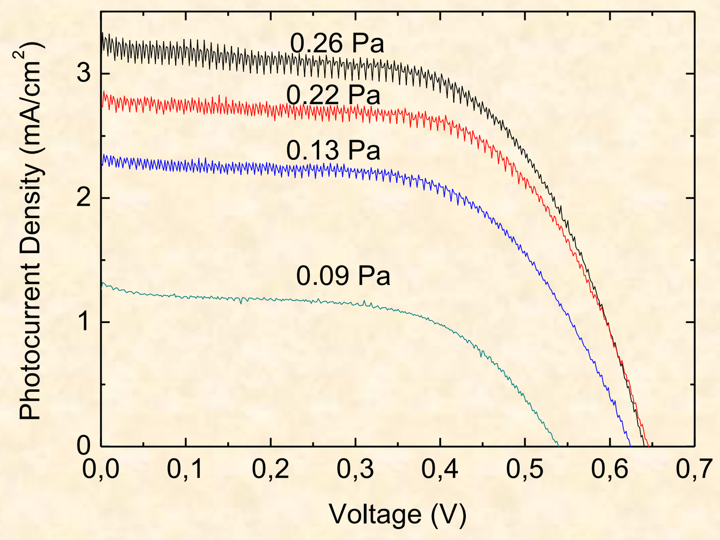
FE-SEM images for TiO_2 nanorod films made by dc reactive sputtering at different oxygen partial pressures.



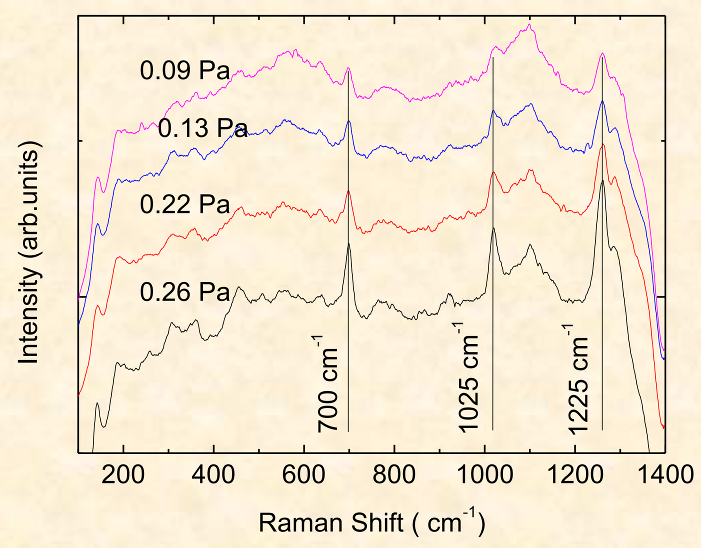
XRD patterns for the TiO2 nanorod films made by dc reactive sputtering at different oxygen partial pressures.



Specular transmittance spectra of TiO2 nanorod films made by dc reactive sputtering at different oxygen partial pressures.



Photocurrent-voltage plots of DSSC assembled with TiO2 nanorod films made by dc reactive sputtering at different oxygen partial pressures.



Raman spectra of TiO2 nanorod films made by dc reactive sputtering at different oxygen partial pressures after dye-sensitized.

CONCLUSIONS

TiO2 nanorods have been prepared both on ITO and glass substrates by dc reactive magnetron sputtering. The structure of these nanorods can be modified by changing the oxygen partial pressure during the preparation processes. The TiO2 nanorods prepared at oxygen partial pressures lower than 0.09 Pa show an orientation along the [101] direction and those prepared at the oxygen partial pressures higher than 0.09 Pa show an orientation along the [220] direction. The DSSCs have been assembled using these nanorods and the [220] orientation is more favorable for the electron transportation. The Raman scattering spectroscopy can be used to qualitatively characterize the dye adsorption.