Mesoporous TiO_2 Thin Films for Photovoltaic Applications

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Introduction

Thin films of nanocrystalline, mesostructured titanium dioxide are very promising materials to build low cost and efficient photovoltaic devices. TiO_2 present a high chemical stability and electronic properties such as photo-induced electronic transfer properties associated with the anatase phase. [1,2,3]

For many applications, highly porous nanostructured thin films with accessible pores are preferable to dense ones. Indeed, high accessible porosity leads to high surface area increasing the electron transfer surface.[1,3,4]

How it works?

As showed in **Fig.1**, an electric current is produced when the dye molecules, adsorbed on the TiO_2 thin film, are excited by absorption of photons and inject electrons in the TiO_2 conducting band. The electrons migrate through the mesoporous thin film to a collecting electrode and are transferred to the external circuit. The dye is regenerated by an electronic transfer from the electrolyte. Finally, the electrolyte is regenerated by trapping an electron from the counter-electrode.[1,5] This photovoltaic cell is known as "Dye Sensitized Solar Cell".

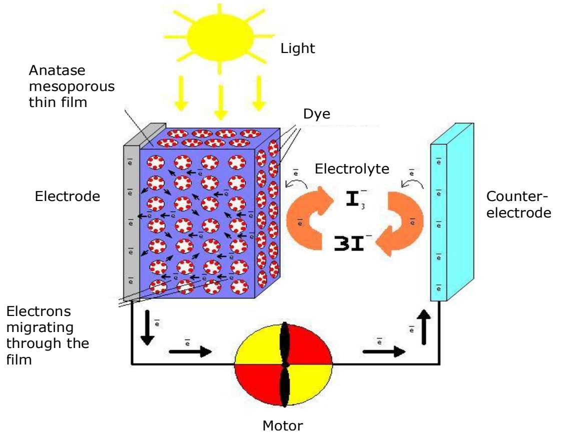

Fig.1: Schematic diagram of a dye-sensitized solar cell.

Results and discussion

Relative humidity

As displayed in **Fig.2** , TEM analysis show that higher relative humidity (RH) leads to a better organization of the mesostructure. For 12% RH during the dip-coating and after deposition we have obtained a wormlike mesostructure whereas a gridlike structure is obtained for 30% RH during the dip-coating and 60% after deposition. The films studied have just been stabilized at 120°C.

Thermal treatment

The thermal treatment is a critical parameter. It has to cristallize the film in form of active anatase while avoiding the mesostructure collapse. Too high temperatures or too long treatments lead to the mesoporous network destruction (**Fig.3**).

Electrochemical impedance spectroscopy (EIS)

A voltage U is applied to testing cells. It leads to an electrical sinusoidal disturbance and the current variation induced is measured for different frequencies. The U/I values correspond to the impedance for each frequency. For constant module and phase tending towards 0°, we measure an electrical resistance equal the Y-axis intercept point. For module inversely proportional to the frequency and phase tending towards 90°, we measure an electrical capacity equal the inverse value of the slope. In **Fig.4 a)**, the TiO_2 film acts as a resistance and the TiO_2/electrolyte and the conducting glass electrode/electrolyte interfaces as capacities. For high frequencies extrapolation (>100 kHz), we can determine the conducting glass resistance. In **Fig.4 b)**, we observe the same effect but the resistive behavior of the TiO_2 film is preponderant.

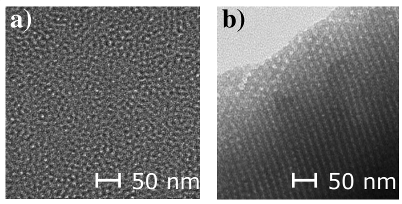

Fig.2: TEM analysis for films obtained in a) 12% RH (wormlike mesostructure), in b) 30%-60% RH (gridlike mesostructure).

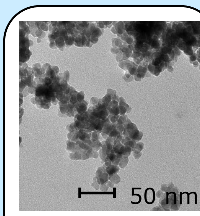

Fig.3: TEM picture of a film collapsed.

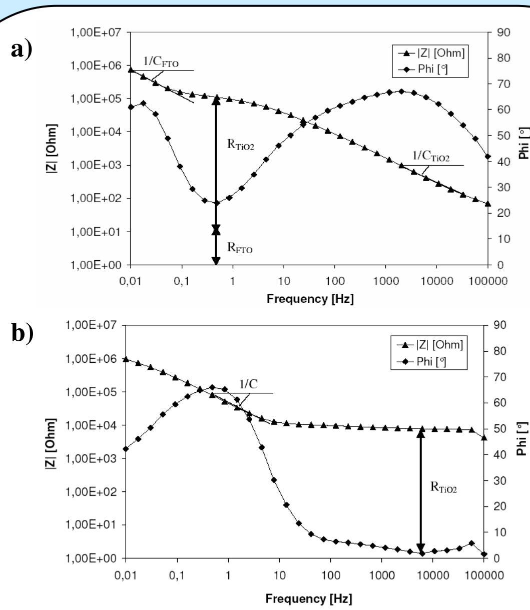

Fig.3: EIS measurements for a) a gridlike mesoporous thin film, b) a dense film

Conclusions

As showed by TEM, experimental parameters such as relative humidity and thermal treatment influence the mesostructure. The thermal treatment had to be accurately adjusted in order to maximise the crystallisation of the inorganic network while avoiding the collapse of the porous mesostructure.

By EIS, we can observe differences between mesoporous films and dense ones. Dense films present a predominant resistive behavior. This effect limit the photovoltaic performance for dense films, mesoporous films are then more interesting for photovoltaic applications.

References

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