

## WO<sub>3</sub> electrochromic film deposited on flexible CNT-on-PET substrate

D. A. Castañón-Cisneros,\* H. Esparza-Ponce,\* A. Rosas-Aburto,\*\* W. Antúnez-Flores,\* A. Aguilar-Elguézabal,\* and M. Román-Aguirre \*

\* Centro de Investigación en Materiales Avanzados S.C. Chihuahua, Chih. Méx., 31109

\*\* Centro de Investigación y Desarrollo, DESC, Lerma, State of México, Méx.

Electrochromic materials have been widely studied [1-2] due to their potential applications on energy saving devices like smart windows. Other possible devices that can be build with electrochromic materials are flexible displays. Such devices require transparent conductive films. Oxides of tin and indium (ITO) are the typical materials used for this purpose. Nevertheless ITO forms rigid structures that are not suitable for flexible devices. Carbon nanotubes (CNT) are good candidates for making flexible conductive [3] transparent films because of their large aspect ratio that make them flexible conducting fiber. On the present work we deposited a film of CNT on poly(ethylene terephthalate) (PET) transparent substrates and then we deposited WO<sub>3</sub> electrochromic films on CNT-on-PET substrates. Morphology and electrochromic properties of WO<sub>3</sub>-CNT-PET films were characterized.

PET substrates were washed with distilled water and isopropyl alcohol, then immersed in a KOH 3 M bath at 70 °C, substrates were then washed with distilled water and isopropyl alcohol, dried, and finally exposed to UV light for 20 min in order to clean and activate the substrate surface. CNT's were exposed to an acid treatment by refluxing with a solution of nitric acid 9 M for one day. After the acid treatment, CNT's were filtered, washed with distilled water and dried at 110 °C for overnight in an oven at 110-115 °C. CNT's suspension was prepared with 0.05 g of dried CNT's dispersed in a solution containing 0.1 g of sodium dodecil sulfate and 100 mL of distilled water treated in an ultrasonic bath for 1 h. The dispersion was passed across a 300 mesh filter and the material trapped on the mesh was discarded. Thus obtained CNT's suspension was used to make the transparent conductive film. Previously activated PET substrates were heated to 70-80 °C on a hot plate and a layer of the CNT dispersion was applied during 5 min using an airbrush. Finally, WO<sub>3</sub> film was deposited on the CNT-PET by sputtering in an Intercovamex equipment using a WO<sub>3</sub> sputter target, under Ar flow of 40 sccm at a work pressure of  $5 \times 10^{-2}$  torr, pulsed power was 200 W, and deposition time was 60 min. The morphology of WO<sub>3</sub>-CNT-PET samples was characterized by field emission scanning electron microscopy (FESEM) in a JEOL 7401F microscopy. In order to measure the electrochromic performance of the sample, an electrochemical cell was mounted on a quartz container using the sample as the working electrode placed in perpendicular position to the light path, a platinum wire as the counter electrode and a 1M solution of LiClO<sub>4</sub> in propylene carbonate was used as the electrolyte. Spectra were collected while no voltage was applied to the cell, then at a potential of -2 V and finally at a potential of 2 volt. The measurement was made in a Perkin Elmer Lambda 10 Uv-Vis spectrometer.

Morphology of the samples is shown on Figure 1a and 1b. Micrograph shows that the carbon nanotubes were successfully coated with a uniform layer of WO<sub>3</sub> having a grain size about of 10 nm. Grain size and porosity are related electrochromic properties of the film [4] since a high porosity favors the diffusional process of Li<sup>+</sup> ions in to the WO<sub>3</sub> structure. Other works [5] report that for lower distance between particles the highest electrochromic change can be obtained. Reversible

electrochromic behavior was observed on the  $\text{WO}_3$ -CNT-PET samples as shown on Figure 2, since the bleached states (no potential or positive potential) has a light transmittance of about 60 % while dark state (negative potential) has a transmittance of about 30 %.

### References

- [1] Arno Seeboth, et-al., *Solar Energy Materials & Solar Cells* 60 (2000) 263
- [2] C.G. Granqvist. *Solar Energy Materials & Solar Cells* 92 (2008) 203
- [3] Yoshiyuki Show, et-al, *Diamond & Related Materials* 17 (2008) 602
- [4] Yung-Sen Lin, et-al, *Solid State Ionics* 180 (2009) 99
- [5] A. Antonaia et-al, *Electrochimica Acta* 46 (2001) 2221
- [4] The authors thank to SOFI de Chih. S.C. Specially to M. Olivas, and to The National Laboratory of Nanotechnology at CIMAV especially to K. Campos, and M. Orozco for their invaluable collaboration on the present study. Finally authors acknowledge to the National Council of Science and Technology of Mexico for the grant given to D.A. Castañon during the present research.

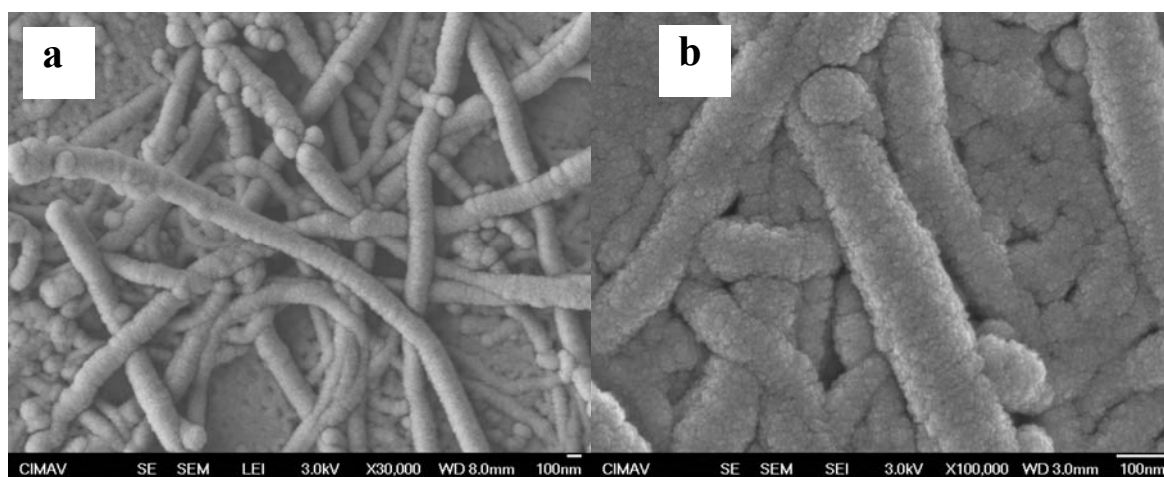


FIG. 1. FESEM micrographs of  $\text{WO}_3$  sputtered on CNT-PET substrates. At a) 30000 X and b) 100000 X.  $\text{WO}_3$  was homogeneously deposited on the CNT's.

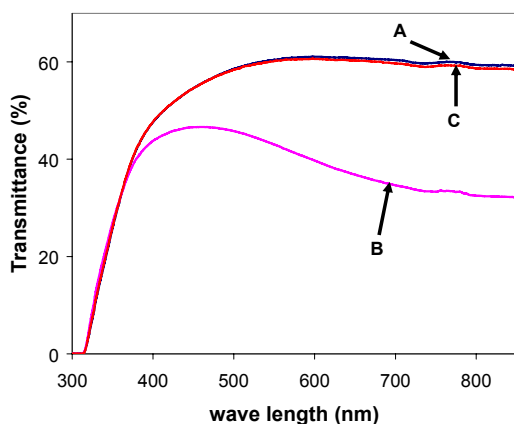


FIG. 2. UV-Vis spectra of  $\text{WO}_3$  deposited on CNT-PET when a potential of A) 0V, B) -2 V and C) 2 V is applied