Flexible transparent single-walled carbon nanotube electrodes: applications in electrochromic windows and dye solar cells

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Single-walled carbon nanotube (SWCNT) networks have emerged as very promising alternative to conventional transparent conducting oxides (TCO) for optically transparent electrodes, exhibiting comparable sheet resistance and optical transmittance but outperforming TCO in terms of mechanical and chemical robustness. Here the advantages of SWCNT films over conventional indium-tin oxide (ITO) on flexible polyethylene terephthalate (PET) as transparent electrodes will be illustrated for applications in two types of electrochemical devices, namely electrochromic windows and dye solar cells (DSC). Apart from their role as transparent conducting layer, the SWCNT film imparts additional functionality in both cases: electrocatalytic properties for the redox couple (as DSC counter electrode) and better resistance to flexure, improved adhesion and higher porosity for the electrochromic layer (in electrochromic films). SWCNTs were synthesized in a laminar flow aerosol reactor by a floating catalyst CVD method using carbon monoxide and ferrocene as carbon source and catalyst precursor respectively. SWCNT films were collected directly from the gas phase downstream of the reactor by filtering through nitrocellulose filters and transferred from the filter to PET by a simple room-temperature dry transfer process [1].

For applications in electrochromic windows, SWCNT-based electrodes act as a high surface area template for electrochemical deposition of the electrochromic material, resulting in nanostructured wire-like porous architectures that facilitate rapid ion uptake during the electrochromic switching. As a result, faster switching response, without sacrificing coloration and color contrast, has been attained for two types of electrochromic materials, a conjugated polymer and an inorganic oxide, electrodeposited on SWCNT/PET electrodes compared to films on TCO/PET. In addition to the improved electrochromic properties (higher coloration efficiency and faster switching time), the presence of the SWCNT skeleton imparts better adhesion of the electroactive layer to the plastic substrate, higher electrochemical/electrochromic stability and resistance to flexure when compared to films on TCO-based flexible electrodes [2].

For applications in photovoltaic devices, we demonstrate that very thin (~100 nm) SWCNT films on PET are very promising counter electrode in Pt-free flexible DSC, acting both as the conducting layer and catalyst toward the tri-iodide reduction reaction. The concept has been illustrated for low-intensity DSC applications, with a solar cell efficiency of 2.5% reached at 8 mW/cm^2 white light illumination [3]. Photocurrent generation of the cells was found to decrease when as-grown SWCNT films (containing iron catalyst particles from the synthesis) were used whereas electrochemical etching of the iron catalyst from the CNT films [4] stabilized the performance of the DSC. Further work is in progress to improve the catalytic properties and conductivity of the films and to reduce the residual iron content.

References

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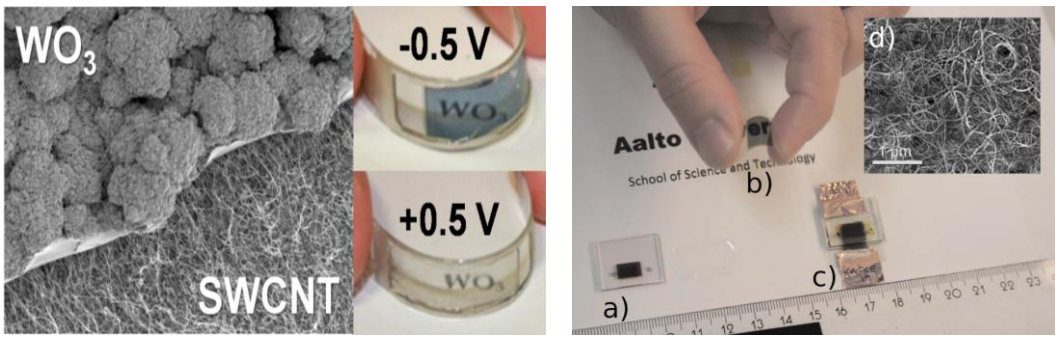
Figures



Left- Electrochromic films: SEM image and photograph in the colored and bleached states of a WO_3 on a SWCNT/PET electrode. Right- Photograph of the flexible, transparent SWCNT/PET counter electrode and other cell components: a) Photoelectrode, b) SWCNT film on PET counter electrode, c) Complete dye solar cell, d) SEM image of the SWCNT film.