Tailoring electronic structure of SWCNTs for transparent and conductive film applications

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Single-walled carbon nanotubes (SWCNTs) are among the strongest candidates for the replacement of commonly used transparent and conductive films (TCFs) based on doped metal oxides, such as indium tin oxide (ITO). SWCNTs possess unique multifunctional nature, which is based on their outstanding combination of mechanical strength and flexibility, chemical stability, exceptional electrical conductivity and optical properties [1]. However, to fully utilize these properties in modern transparent electrode applications, SWCNT-based TCFs have to demonstrate the optoelectronic performance at the level of high-end ITO-based TCFs. This has not been achieved for SWCNT films yet and as a result limit their practical usage.

Using gold chloride as the most effective dopant for the SWCNTs (Table 1), we improve their optoelectrical characteristics by optimizing the doping solvent and conditions [2]. We examined various solvents to push the optoelectrical performance of the TFCs based on SWCNTs. As a result, we obtained the sheet resistance as low as 40 Ω/□ at the transmittance of 90% (at 550 nm) using 15 mM $HAuCl_4$ solution (Figure 1). This optoelectrical performance is better than that of ITO on PET substrates and satisfy most of the requirements for modern applications and relatively stable without additional protection over two years storing under ambient conditions.

Table 1. Work function of 80% and 65% transmittance SWCNT films before and after the doping by $AuCl_3$ and $HAuCl_4$ and measured by means of UPS technique.

Transmittance of the film at 550 nm (%)	Work function of pristine SWCNTs (eV)	Work function of $AuCl_3$-doped SWCNTs (eV)	Work function of $HAuCl_4$-doped SWCNTs (eV)
80	4.46	5.87	6.14
65	4.44	5.85	6.07

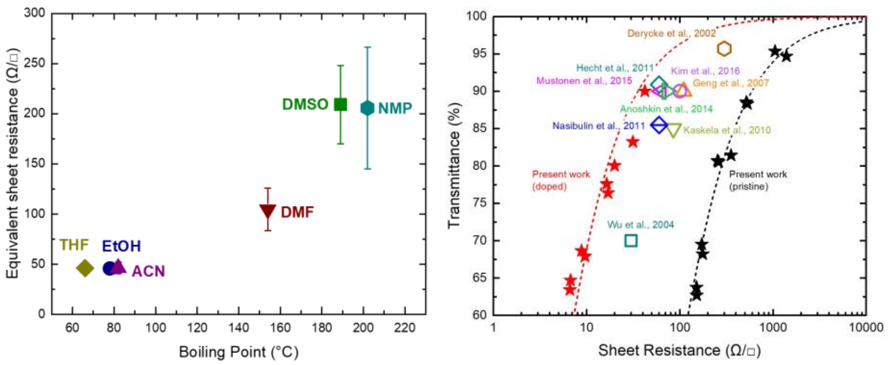

Figure 1. a) The resulting equivalent sheet resistance of the $HAuCl_4$-doped samples at RT plotted *vs.* the boiling temperature of the solvents. b) Comparison of the performance of SWCNT-based TCFs after p-type doping: sheet resistance *vs.* optical transparency at 550 nm. Dashed lines indicated theoretical relationship between transmittance and sheet resistance of pristine (black) and $HAuCl_4$-doped (using EtOH as a solvent) SWCNT films (red) obtained in this work.

Also, we examine the effect of ionic liquid gating on the electronic structure of the SWCNTs and their optical and electrical properties.

The effect of the presence of catalyst particles on the optoelectronic properties of the SWCNT films is also presented.

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