

## A Comparative Study of Single- and Multi-Walled Carbon Nanotube Incorporation to Indium Tin Oxide Electrodes for Solar Cells

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**Abstract :** Alternative electrode materials for optoelectronic devices have been widely investigated in recent years. Since indium tin oxide (ITO) is the most preferred transparent conductive electrode, producing ITO films by simple and cost-effective solution-based techniques with enhanced optical and electrical properties has great importance. In this study, single- and multi-walled carbon nanotubes (SWCNT and MWCNT) incorporated into the ITO structure to increase electrical conductivity, mechanical strength, and chemical stability. Carbon nanotubes (CNTs) were firstly functionalized by acid treatment ( $\text{HNO}_3\text{:H}_2\text{SO}_4$ ), and the thermal resistance of CNTs after functionalization was determined by thermogravimetric analysis (TGA). Thin films were then prepared by spin coating technique and characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), four-point probe measurement system and UV-Vis spectrophotometer. The effects of process parameters were compared for ITO, MWCNT-ITO, and SWCNT-ITO films. Two factors including CNT concentration and annealing temperature were considered. The UV-Vis measurements demonstrated that the transmittance of ITO films was 83.58% at 550 nm, which was decreased depending on the concentration of CNT dopant. On the other hand, both CNT dopants provided an enhancement in the crystalline structure and electrical conductivity. Due to compatible diameter and better dispersibility of SWCNTs in the ITO solution, the best result in terms of electrical conductivity was obtained by SWCNT-ITO films with the 0.1 g/L SWCNT dopant concentration and heat-treatment at 550 °C for 1 hour.

**Keywords :** CNT incorporation, ITO electrode, spin coating, thin film

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