Carbon nanotube thin films

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Indium is currently used as ITO (indium-tin oxide) to provide transparent conducting films (TCF) for a wide variety of consumer electronics devices, such as displays as well as touch screens of mobile phones and ipad-style portable computers. Polycrystalline silicon is the semiconductor material used in the thin film field effect transistors (TFT-FET) of the high quality display back planes. Recent introduction of bendable as well as flexible - and even stretchable – devices requires novel materials to replace both ITO and silicon, due to their rigid nature. In order to replace both indium and polycrystalline silicon, we have developed single-walled carbon nanotube (SWNT) thin films [1,2]. We introduce our industrial scale, ISO 9001:2008 certified direct dry printing (DPP) manufacturing of nanotube based TCFs, enabling the manufacturing of touch sensors with electrical properties on par with those of ITO-on-PET, and with optical properties better than those of ITO, metal nanowire and metal mesh. Similar dry deposition method has been used to manufacture TFT-FETs with properties comparable to those of polycrystalline silicon transistors [3,4].

We report recent studies on the synthesis of high quality single walled carbon nanotubes from CO with the ferrocene based floating catalyst chemical vapor deposition (FC-CVD) reactor and show that SWNT networks consisting of long, clean and highly individualized SWNTs exhibit substantially improved TCF performance. Interestingly, SWNT bundling has a strong effect on the tube growth rate. We introduce the novel FC-CVD reactor based on spark discharge catalyst generation to experimentally study the effect of bundling on the performance of TCF and TFT-FETs. The synthesis of SWCNTs relies on generation of iron catalyst particles in the diameter range of 4±3 nm with precisely tunable concentration into nitrogen carrier gas with a spark generator, allowing to grow individual and high-quality SWNTs from CO with well-defined diameter and length distributions. TCFs made from individual tubes with 4 micron mean length show 60 ohms/sq sheet resistance at 90 % transparency. TFT-FETs made of individual SWNT based thin films exhibit higher uniformity in terms of both mobility and ON/OFF ratio compared to the devices made with nanotube bundles. In addition, we compare TCFs made with direct dry deposition of the nanotubes using hydrocarbons as the carbon source [5] to those made from CO. Also, we discuss the conductive AFM-based studies on the SWNT network charge transport mechanisms [6].

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