A high-performance flexible transparent conductive film of carbon-welded single-wall carbon nanotubes

With the support of the National Natural Science Foundation of China, a research team led by Prof. Cheng HuiMing (成会明) and Liu Chang (刘畅) from Shenyang National Laboratory of Materials Science, Institute of Metal Research, Chinese Academy of Sciences, recently reported a high-performance, flexible transparent conductive film (TCF) composed of carbon-welded single-wall carbon nanotubes (SWCNTs) in *Science Advances* (2018, 4: eaap9264).

TCFs are an important component of touch screens, smart windows, liquid crystal displays, organic light-emitting diodes, and organic photovoltaic cells. Indium tin oxide (ITO) has been the most widely used transparent conductive material; however, the limited reserves of indium and the brittle nature of ITO hinder its sustainable application in flexible electronics. SWCNT films show excellent flexibility, desirable optical properties and good electrical conductivity, and therefore, is a promising candidate for making flexible TCFs. However, the optoelectronic performance of SWCNT TCFs so far reported is far away from those of ITO TCFs. It is well-proven that the intertube junction resistance and bundling effect are key issues limiting the transparent electrical properties of SWCNT TCFs.

Profs. Cheng and Liu's group and collaborators have recently synthesized a SWCNT thin film composed of isolated SWCNTs with carbon-welded joints for TCFs by an injection floating catalyst chemical vapor deposition method. By tuning the nucleation and growth concentration of SWCNTs, 85% the SWCNTs are isolated; by controlling the content of carbon source, a "carbon welding" structure is formed at tube-tube junctions. It is demonstrated that the carbon-welded joints convert Schottky contacts between metallic and semiconducting SWCNTs into near-ohmic ones, which significantly lowers the intertube junction resistance. Due to their unique structure, the pristine SWCNT films show a record low sheet resistance of 41 ohm $\square^{-1}$ at 90% transmittance for 550-nm light. And after HNO_3 treatment, the sheet resistance further decreases to 25 ohm $\square^{-1}$, better than that of ITO on a flexible substrate. These high-performance SWCNT TCFs with good flexibility show great potential for use in various flexible electronic and photoelectronic devices as a transparent electrode.

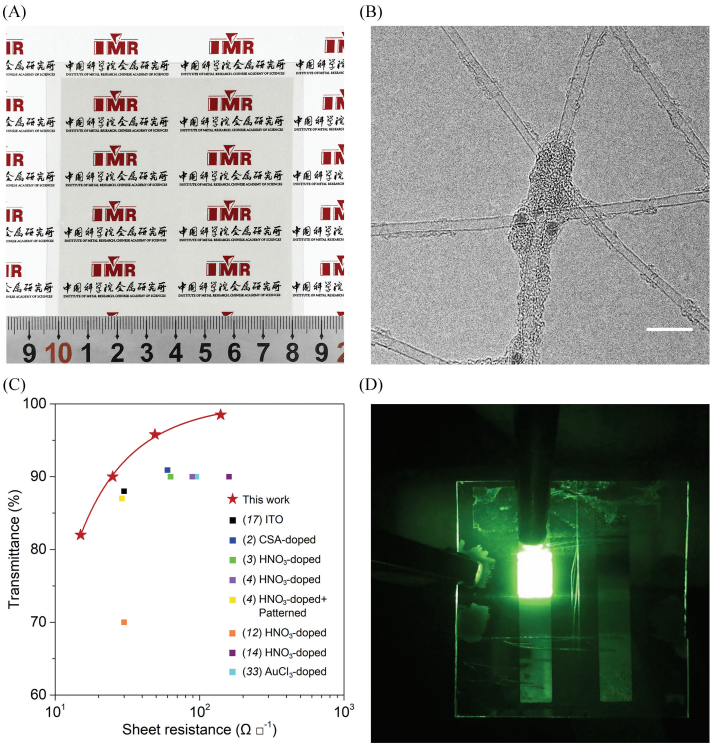

Figure (A) Optical image of an 80 mm×80 mm SWCNT TCF. (B) TEM image of an isolated SWCNT network with carbon-welded joints. (C) Transparent conductive property of the SWCNT TCFs. (D) Optical image of a lit OLED using the SWCNT TCF as transparent electrode.