Polymeric Acid-doped Carbon Nanotube-based Indium-free Organic Solar Cells that show Excellent Stability and Doping Durability

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Transparent electrodes are vital components for touch panels, displays, and photovoltaic cells. Widely used indium tin oxide (ITO) transparent electrodes are not suitable for use in flexible electronics because of their brittleness, high cost, and diffusion of impurities within devices. Carbon nanotube (CNT) has shown considerable promise as replacements for ITO-based electrodes, but they fall short in terms of conductivity. To offset this weakness, dopants are used to increase the conductivity by increasing the concentration of free carriers and reducing the resistance. As reported by Lee and colleagues, trifluoromethanesulfonic acid (TFMS) displayed nearly ideal durability when used to dope graphene in organic light emitting diodes. However, TFMS nonetheless does not exhibit permanent durability and has an issue regarding handling safety when used as a dopant in carbon electrodes.

We investigated the use of high molecular weight polymeric dopant in transparent conductive CNT films. We expected that entanglement of the CNT network and the long chains of the polymeric acid would stabilise the donated protons, which in turn would provide an exceptionally durable doping effect. The polymeric acid doped CNT films satisfied other key requirements for transparent carbon electrode, including transparency, smooth morphology, and safety of handling. In this work, various analyses were conducted to compare the polymeric acid with the established acid dopants HNO_3 and TFMS. This study showed that the polymeric acid had similar doping effectiveness but superior durability in comparison with the other dopants. Accordingly, we revealed that the polymeric acid dopant has nearly permanent (1 year) doping durability. Organic solar cells (OSCs) were fabricated using this polymeric acid-doped CNT films and a mixture of PBTZT-stat-BDTT and $PC_{71}BM$. The *p*-type polymeric acid-doped CNT-based OSCs initially produced a PCE of 8.0%, which was retained for more than 60 days, while the ITO-based OSCs had an initial PCE of 9.1%, which dropped below 8.0%, because of suspected degradation of ITO by poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS) and metal diffusion. The devices using the polymeric acid dopant were the most durable when compared with the devices using other dopants.

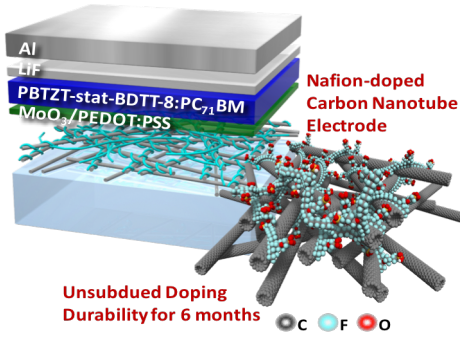

Figure 1. Illustration of polymeric-acid doped CNT-based indium-free organic solar cell.