Carbon Nanotubes and Graphene for Perovskite Solar Cells

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Single-walled carbon nanotubes (SWNT), graphene, and fullerene (C_{60} and PCBM) would be very efficiently used in lead halide Perovskite solar cells. A film of SWNTs or graphene can be flexible and stretchable transparent-conductive layer. At the same time, this film can be carrier-selective layers, i.e., electron-blocking-layers or hole-blocking-layers, by using adequate polymer-doping. Based on our experiences of using nanotube films for CNT-Si solar cells and organic polymer solar cells [1,2], we have extended the application of SWNT films for organic-inorganic Perovskite solar cells. We have demonstrated the replacement of ITO in inverted-type perovskite solar cells, SWNTs/PEDOT:PSS/$CH_3NH_3PbI_3$/PCBM/Al [3]. The flexible application on polyethylene terephthalate (PET) is also demonstrated [3]. Replacement of electron-blocking-layer and metal electrode in normal-type perovskite solar cells is demonstrated as well. They show high power conversion efficiency (PCE), cost-efficiency, and higher stability. Those devices can have comparable PCE as the conventional design with organic electron-blocking layer and top metal electrode. The normal-type perovskite solar cell, composed of ITO/C_{60}/$CH_3NH_3PbI_3$/SWNTs, can achieve a PCE of 17 % with spiro-MeOTAD as dopant to SWNTs [4]. This structure with a perovskite layer sandwiched by C_{60} and SWNTs can lead to the solar cells without hysteresis and with much improved air-stability [4]. The effective passivation of the degradation of perovskite material by moisture can be achieved with C_{60} and SWNTs [4]. More recent configuration is using a film of SWNTs for both anode and cathode electrode [5]. With adequate polymer-doping, we can fabricate Perovskite solar cells without ITO and metal electrode. Finally, SWNT film and graphene are compared as flexible transparent electrode of inverted Perovskite solar cells [6].

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