The Solution to Cost and Stability in Perovskite Solar Cells by All-Carbon Approach

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Since Miyasaka and colleagues adopted perovskite semiconductors into photovoltaic devices,[1] Perovskite solar cells (PSCs) have received much attention in recent years, on account of high power conversion efficiency (PCE) and solution-processability.[2–4] Their reported PCEs have soared rapidly in the last five years, and now some of the certified efficiencies exceed 20%.[5,6] However, there remains several shortcomings, namely high-cost and stability that need to be addressed. Numerous research groups around the world have been working on these issues.

One of the promising methods, which can resolve both the issues, is using carbon nanotube (CNT) materials. CNTs have shown to be effective in replacing metal electrodes and enhancing the stability of PSCs in air. Li et al.,[8] and Aitola et al.,[9] used aerosol-produced single-walled CNTs as top electrodes to replace expensive metals and hole-conductors, but their PCEs and stability fell short due to high severe hysteresis. Also, Snaith and colleagues,[10] and Matsuda and colleagues[11] demonstrated hydrophobic nature of CNTs can function as an effective passivation. Nevertheless, they still rely on an expensive gold electrode, and high-temperature annealed TiO_2, which translate to high-cost and high hysteresis, respectively.

Here, we report PSCs in which lead perovskite layer is sandwiched by C60 and single-walled CNTs to maximize stability. Room temperature and air-processed PSCs with a configuration of $ITO/C_{60}/CH_3NH_3PbI_3/CNT$ produced a PCE of 13.2% with a cost down of 50% compared to the reference devices. Upon addition of a HTM onto CNT, it enhanced PCE and stability significantly. Addition of spiro-OMeTAD increased PCE to 17%, which was comparable to the gold-based reference devices (18%), but the cost remained relatively high. Application of polymeric HTMs, improved the stability even further at the expense of PCE. In this regard, application of P3HT demonstrated much better stability than PTAA due to its more compact packing and better interaction with CNTs. Therefore, to assess the full stability potential of our all-carbon approach, we employed glass encapsulation the devices and demonstrated unsubsided stability up to 1000 hours under constant illumination of one sun in ambient condition.

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