Controlled CVD Growth and Solar Cell Applications of Single-Walled Carbon Nanotubes

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We have modulated the diameters and morphologies of SWNTs for the applications of SWNT/Si solar cells [1, 2], organic bulk heterojunction solar cells, dye-sensitized solar cells and perovskite-type solar cells. Highly transparent-conductive SWNT films from controlled bundle-diameter and long bundle length were synthesized by floating catalyst CVD. The SWNT films with a sheet resistance of 134 Ω/sq. at the 81.5% transparency were dry-transferred onto Si substrate to form a diode. The power conversion efficiency (PCE) of the solar cell is 11% and is stable after 1 year, which is attributed to the high purity pristine SWNTs. Moreover, the solar cell performance under different light intensities is investigated to evaluate both the series and shunt resistance of the device. The interfacial oxide layer between the SWNT film and the Si substrate is also discussed [1].

In order to further improve the performance of the solar cell, we investigated the effect of the SWNT morphology. Using the vertical-aligned SWNT arrays synthesized by alcohol catalyst CVD method, we have obtained a hierarchical 3D honeycomb-like architecture of SWNTs using the breath figure technique, where water vapor condenses on the surface of vertical-aligned SWNT and forms hexagonal pattern. The micro-honeycomb network consists of vertical aggregated SWNT walls and a buckypaper bottom. This hierarchical structure exhibits lower sheet resistance and higher optical transmittance compared with the buckypaper. The honeycomb networked SWNT film was transferred onto the 3 mm by 3 mm n-type silicon substrate by hot water thermocapillary method. The pristine SWNT-Si solar cell shows a record-high fill factor of 72% as well as a PCE of 6%. The PCE remains stable for months in ambient condition. A PCE exceeding 10% is achieved in the dry state after dilute nitric acid treatment. Through modeling, the honeycomb-networked SWNT film shows much smaller series resistance than random-oriented SWNT film [2].

By using cobalt-copper binary metallic catalysts, we have reduced the diameter of the VA-SWNT from 2 nm to less than 1 nm, with the E_{11} of SWNTs increasing from 0.5 eV to 1.2 eV. The effect of the diameter change on the solar cell performance will be discussed. Moreover, we fabricated both bulk heterojunction solar cells and dye-sensitized solar cells using the SWNT films to replace the ITO layer, with little degradation in performance. The application of SWNT films as hole-collector in the perovskite-type solar cells is also promising.

References:

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