Micro-Honeycomb Network Structure of Single-Walled Carbon Nanotubes for Heterojunction Solar Cell

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We propose a self-organized micro-honeycomb network structure of single-walled carbon nanotubes (SWNTs) obtained by water vapor treatment of as-synthesized vertically aligned SWNTs (VA-SWNTs) [1] for SWNT/n-Si heterojunction solar cell [2-6]. Dependence of photovoltaic conversion efficiency (PCE) on the nanotube network structure was examined.

The VA-SWNTs was synthesized by the standard alcohol-catalytic CVD method with Co/Mo dip-coated on Si/SiO_2 substrate [1]. The fabrication process of the micro-honeycomb structured film involved only two steps. First, an as-synthesized VA-SWNTs film was exposed to water vapor by hanging over heated water. Then, the film was dried by simply turning over the film upwards. By carefully controlling the temperature and pressure of water vaporization, different morphologies of SWNT film as shown in Fig. 1 were obtained. Fig. 1 (a) shows a quasi-regular honeycomb structure made from 5 μm thick VA-SWNT film. By the vapor treatment, collapsed spaghetti-like SWNTs make contact to the substrate in the middle of each honeycomb cell. Cell walls consist of vertically aligned SWNTs with heavily bundled top part as shown in Fig. 1 (d). The cell walls are less pronounced for morphologies in Fig. 1 (b) and (c) made from shorter VA-SWNTs; 3 μm and 2 μm thick VA-SWNTs, respectively.

The schematic of SWNT/n-Si heterojunction solar cell built with the SWNT thin film is shown in Fig. 2. The micro-honeycomb SWNTs network film was placed on top of the substrate which has a 3 mm × 3 mm bare n-type silicon contact window in the center. The contact window is surrounded by SiO_2 as insulating layer and Pd as electrode. By using the hot water technique [7], the removal of micro-honeycomb SWNTs network was easier than as-grown VA-SWNTs.

Figure 3 shows current density and voltage (J-V) characteristic of the SWNT-Si heterojunction solar cell using SWNT films shown in Fig. 1. The optimal photovoltaic conversion efficiency (PCE) under AM1.5 is 5.1% (from the network structure shown in Fig. 1(b)), with the fill factor of 46%. The open-circuit voltage and short-circuit current are 0.54V and 20.72 mA/cm^2, respectively. This showed a substantial improvement compared with previous reported result (PCE = 8.4% [3], 2.4% [4], 1.7% [5], 1.53% [6]). The improvement should be attributed to the self-organizing micro-honeycomb network, in which the spaghetti-like SWNTs in good contact with the Si serve as the charge carrier separation interface, and the artery-like condensed SWNTs serve as the holes collector and transport high-way to the electrode.

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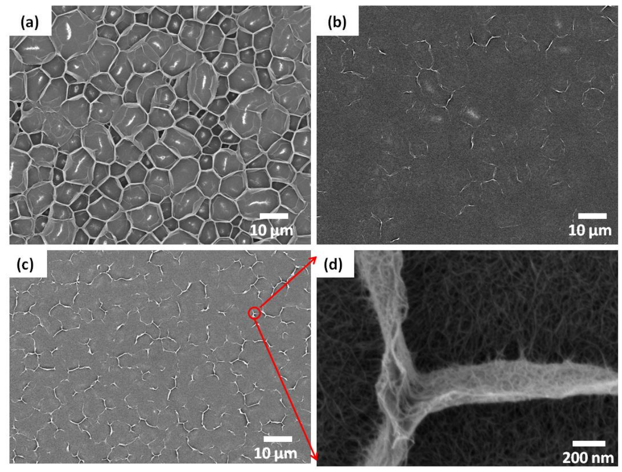

Fig. 1 (a, b, c) SEM images of different self-organizing micro-honeycomb network of SWNTs; (d) enlarged image of condensed SWNTs bundles from (c).

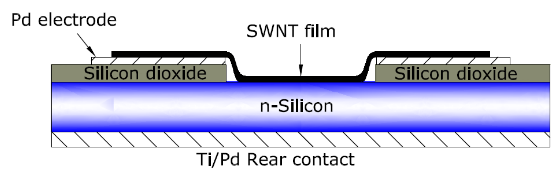

Fig. 2 Schematic of SWNT/n-Si heterojunction solar cell.

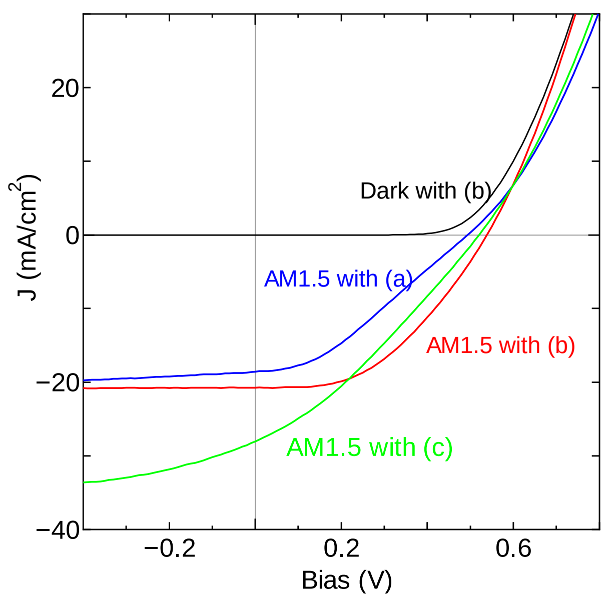

Fig. 3 Solar cell J-V characteristics of cells by SWNTs morphologies (a), (b) and (c) in Fig. 1 under AM1.5 illumination and morphology (b) in dark.

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