Self-assembled micro-honeycomb network of single-walled carbon nanotubes for heterojunction solar cells

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The gap between the outstanding electrical and optical properties of an individual single-walled carbon nanotube (SWNT) and inferior performance of macro-scale SWNT devices is hindering its widespread applications. The smart assembly is necessary to play SWNT to its full potential. Here, we propose a self-assembled micro-honeycomb network (μ-HN) of SWNTs obtained by water or ethanol vapor treatment of as-synthesized vertically aligned SWNTs (VA-SWNTs) for heterojunction solar cells with higher performance.

The VA-SWNTs was synthesized by the standard alcohol-catalytic CVD method with Co/Mo dip-coated on Si/SiO2 substrate [1]. The fabrication process of the micro-honeycomb structured film was obtained by exposing the as-synthesized VASWNT to water vapor and drying under ambient environment afterwards. Each micro-honeycomb cell consists of capillary-aggregated walls and randomly oriented bottom that contacts the Si substrate. The SWNT film was transferred on top of the substrate which has a 3 mm × 3 mm bare n-type silicon contact window in the center using hot water transfer technique. By the vapor treatment, collapsed spaghetti-like SWNTs contact to the substrate in the middle of each honeycomb cell. Cell walls consist of cross-linked heavily bundled SWNTs. The pristine SWNT-Si heterojunction solar cell fabricated with μ-HN shows a stable fill factor of 72%, which is the highest fill factor reported to date [2, 3]. The improvement is attributed to the hierarchical structure of micro-honeycomb network. A PCE beyond 10% is achieved in the dry state after dilute nitric acid treatment.

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Thermoelectric modules made of p- and n-type single walled carbon nanotube composite films

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Single walled carbon nanotube (SWCNT) networks, composed of semiconducting and metallic nanotubes forming free standing mats (buckypaper) are known for high electrical conductivity and a reasonable value of the Seebeck coefficient. SWNT composites with polymers still show a high electrical conductivity, whereas their thermal conductivity is low due to blocked heat flow across the composite structure. We prepared and characterized thermoelectric materials based on thin films of SWCNT composites with polyvinylalcohol. Pristine SWCNTs incorporated in polymer matrix generated positive value of the thermopower and were used as a p-doped thermoelectric material. Polyethyleneimine (PEI) was studied as an n-type dopant for SWCNTs. Simultaneous change of majority charge carriers from holes to electrons upon addition of PEI caused the Seebeck coefficient to change sign from positive to negative providing an n-type thermoelectric material. A single p/n couple made of two composite strips containing 20 wt% of SWCNTs - pristine p-type and n-type PEI doped nanotubes - generated a TEP voltage of 92 μV per 1 K temperature gradient. By comparison, a single p/n couple made of two films made of polyvinylidene fluoride with 95 or 20 wt % of multi-walled carbon nanotubs conducting layers produced ~15 μV per 1 K temperature gradient, as recently reported for the multilayered carbon nanotube/polymer composite based thermoelectric fabrics [1]. In our study, the thermoelectric voltage generated by a single p/n polymer couple per 1 K was improved by factor of 6 through chemical functionalization of SWCNTs loaded to 20 wt%. A module composed of 5 electrically connected p/n junctions demonstrated a 25 mV voltage output by a temperature gradient of 50 K. The module generated 4.5 nW power, when a load resistance matched the internal module resistance of 30 kΩ.

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