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/SiO_2 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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Precursor-dependent reversible diameter modulation of vertically aligned single-walled carbon nanotubes

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We synthesized vertically aligned single-walled carbon nanotubes (SWNTs) with a mean diameter of approximately 1 nm by chemical vapor deposition (CVD) of an acetonitrile-ethanol mixture [1]. The addition of no more than five volume percent acetonitrile in ethanol results in a dramatic reduction of the mean SWNT diameter. In the absence of acetonitrile, the mean diameter returns to the ~2 nm typical of ethanol-grown vertically aligned SWNTs. We also show the diameter can be modulated on the fly by the addition or absence of acetonitrile in the feedstock, and this diameter change is both reversible and repeatable [2].

We examined the interface between small- and large-diameter SWNTs by scanning electron microscopy (SEM) and high-resolution transmission electron microscopy (HR-TEM). Layers having different diameter can be separated from one another, but the separation is not always clear-cut. Further examination by HR-TEM revealed some of the SWNT junctions are actually continuous, whereas most are discontinuous across the interface [2]. Based on these findings, we propose that acetonitrile changes the growth mode from tangential to perpendicular [3], causing a marked reduction in SWNT diameter.

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