Single-Walled Carbon Nanotube Alignment by Grating-Guided Electrostatic Self-assembly

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Single-walled carbon nanotubes (SWNTs) are regarded as promising building blocks for applications in electronics and sensors because of their unique and supreme electrical properties. Most electronic applications require SWNT alignment and precise placement. Due to the importance of the CNT alignment, many approaches have been explored to achieve this goal, including mechanical stretching of a nanotube composite, gas flow induced alignment during CNT growth, alignment by magnetic and electric fields, flowing CNT suspension through microfluidic channels and many others[1]. Although a plethora of techniques have been developed, current process controllability is far from ideal and a good SWNT alignment technique remains elusive. Easy-to-process and highly effective SWNT alignment technique is still of primary interest and of paramount importance for realizing the potentials of the SWNTs in electronic devices.

In this work, we present a simple yet effective CNT alignment technique based on grating-guided electrostatic self-assembly (ESA). SWNTs are first debundled and dispersed in water. The CNT suspension is stabilized by polyionic surfactant (polystyrene sulfonate), which also yields negative charges on individual SWNT for ESA. PMMA grating with sub-micron width is created on a silicon oxide substrate by nanoimprint and oxygen plasma etching. A (3-aminopropyl)- triethoxysilane (APTES) monolayer is grown on the oxide surface to promote the adhesion of SWNTs on oxide substrate. The substrate is then alternatively immersed in the SWNT dispersion and a polyvinyl alcohol solution to grow bilayers of ESA. Since the grating width is much narrower than the length of the SWNTs, SWNTs will be aligned in the trench area of the PMMA grating during ESA deposition. After ESA growth, a lift-off process is performed to remove the polymer grating template and aligned-CNT stripes are left on the substrates.

The SEM image of 5-bilayer aligned-CNT stripes is shown in Fig. 1. Due to the simplicity of the technique, uniform aligned-CNT stripes can be deposited over a large area with a high yield. Polarized Raman spectra taken from the aligned-CNT stripes indicate very efficient SWNT alignment (Fig.2). When the polarization direction of the probe laser is parallel (0^o) to the stripes, the Raman signal of the D and G bands of SWNTs reaches a maximum, while the signal is at the minimum if the probe laser is polarized perpendicular to the longitudinal direction of the SWNT stripes (90^o). The large contrast in Raman signals among different laser polarizations indicate that a high level alignment of the SWNTs is achieved. The details of this alignment technique and the discussions on its potential impact will be presented.

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[1] Yehai Yan, Mary B. Chan-Park, and Qing Zhang, *Samll,* 2007. Vol. 3, No. 1: p.24.

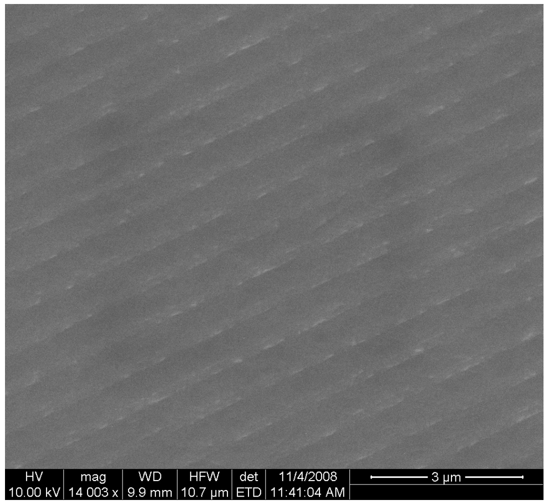

Figure 1. An SEM micrograph of aligned-CNT stripes on a silicon oxide substrate.

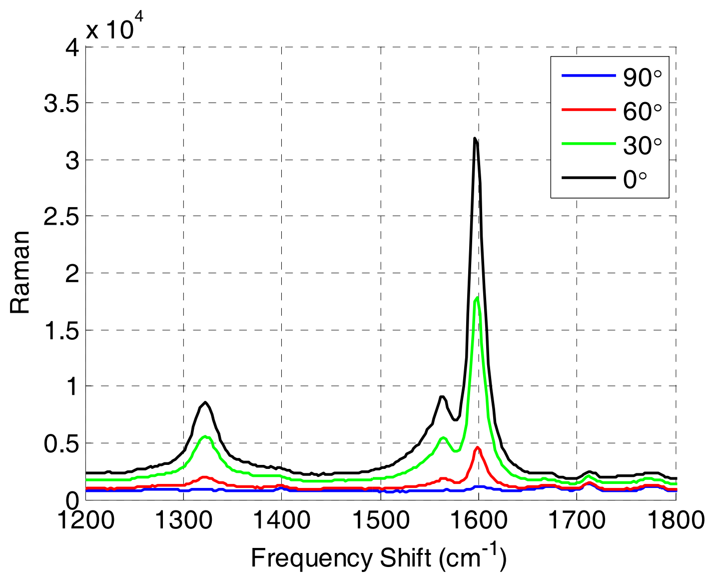

Figure 2. Raman signals of aligned-CNT stripes with different probe laser polarization directions. The numbers indicate the angles between the polarization directions of the incident laser light and the longitudinal direction of the deposited CNT stripes.