Ordered Carbon Nanotube Deposition by Electrophoresis-Enhanced Self-assembly

Huifeng Li[1], Hung-Jue Sue[2,3] and Xing Cheng[1,3]

[1]Department of Electrical and Computer Engineering, Texas A&M University, College station, TX 77843

[2]Department of Mechanical Engineering, Texas A&M University, College station, TX 77843

[3]Polymer Technology Center, Texas A&M University, College station, TX 77843

Carbon nanotubes (CNTs) attracted huge research effort due to its unique structure and properties. CNTs are considered as promising building blocks for a wide range of material and device applications, including nanoelectronics, sensors, photovoltaics and biomedicines. One of the most fundamental and challenging problem existing with CNTs research is the high-speed, high-accuracy and low-cost placement and alignment of CNTs. Previous efforts to align CNTs focused on the mechanical approaches such as mechanical stretching of a nanotube composite and gas/liquid flow induced alignment. Other approaches include alignment by using magnetic and electric fields[1]. Current approaches have limited accuracy and scaling capability and their controllability is far from ideal. Easy-to-process and highly effective CNTs alignment technique is still of paramount importance to realize the potentials of CNTs.

In previous effort, we showed an approach to align SWNTs using guided electrostatic self-assembly by the combination of nanolithography and self-assembly processes[2]. However, this approach is still limited by the low processing rate and low CNTs loading ratio. As shown in Fig. 1, by externally applying an electric field and utilizing electrophoresis[3], we have extended the guided self-assembly technique to a high-speed, low-cost and highly controllable process to accurately place and align CNTs. A silicon substrate is first patterned with submicron gratings using nanoimprinted PMMA and treated with RIE to remove the residual polymer. A (3-aminopropyl)-triethoxysilane (APTES) monolayer is grown to improve the adhesion between CNTs and silicon surface. The substrate is connected to a voltage source and merged into well dispersed single-walled CNTs (SWNTs) aqueous suspension to serve as the anode. A metal cathode is also merged into the solution and connected to the source meter. The charged CNTs are forced to move towards the anode when a voltage is applied. Due to the geometric confinement of the PMMA grating, the CNTs are placed and aligned along the trench area on the substrate.

The SEM image of the aligned CNTs on a silicon substrate is shown in Fig. 2. This is a simple, rapid and cost-effective approach. The proposed process can be finished within a couple of minutes, much less than the generic self-assembly of CNTs. Using simple equipment, the process can place and align CNTs on large silicon and flexible substrates and can be easily scaled up for volume production. The density and process rate can be controlled by the voltage and time used for the electrophoretic process. The experimental characteristics such as the functionalization of the substrate surface, the design of the nanotube suspension, the deposition time, and the electric field strength will be discussed. The simplicity and flexibility of this process will lead to significant impact on device applications using CNTs.

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

[2] Huifeng Li, and X. Cheng, "Single-Walled Carbon Nanotube Alignment by Grating-Guided Electrostatic Self-assembly," submitted to Journal of Vacuum Science and Technology B, 2009.

[3] Aldo R. Boccaccini, Johann Cho, Judith A. Roethe, Boris J.C. Thomas, E. Jane Minay and Milo S.P. Shaffer, *Carbon*, 2006. Vol. 44, No. 15: p. 3149.

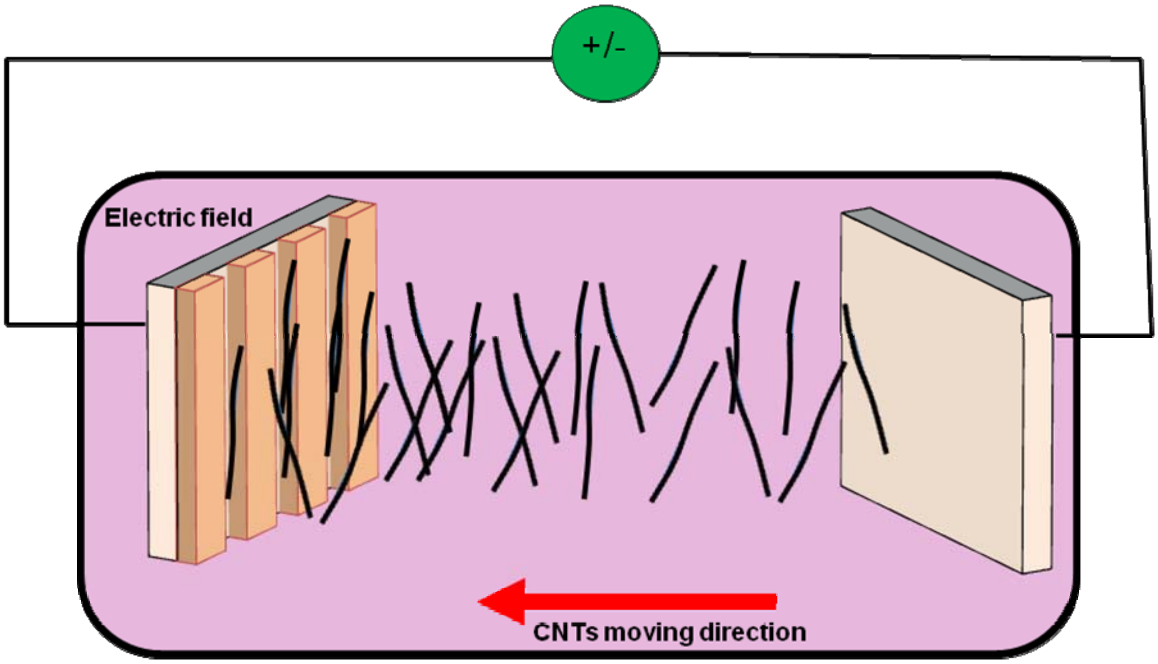

Figure 1. A schematic of the directed self-assembly process enhanced by electrophoresis for CNTs placement and alignment.

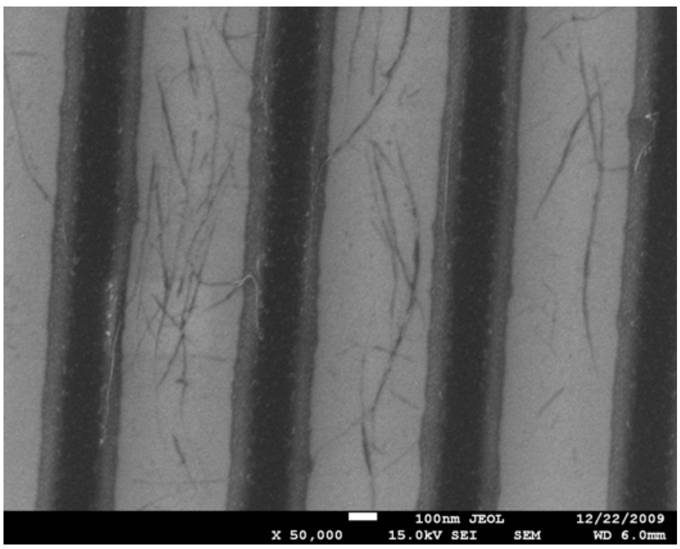

Figure 2. An SEM micrograph showing aligned SWNTs on a patterned silicon substrate.