Growth Mechanism of Well Aligned Semiconducting Single-walled Carbon Nanotubes on Quartz Substrate

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Even though the devices made from individual nanotubes have shown outstanding performances such as high mobility, high current, high thermal conductivity, good chemical and mechanical stability, the high hope for the next generation of carbon nanotube based electronics is hampered by several major problems. Among them are the lack of reliable methods to control the alignment and position of nanotubes as well as and perhaps most problematically, the simultaneous growth of nanotubes with different chiralities, yielding random mixtures of metallic and semiconducting nanotubes. Even though the post-growth separation of metallic from semiconducting SWNTs have made good progress, the alignment and assembly of the separated nanotubes into devices are still challenging and not suitable for large scale fabrication. Consequently, a method that can directly produce well aligned arrays of pure semiconducting nanotubes is thought to be the ideal choice for large scale fabrication of nanotubes FETs. In this talk, we show that such a method is not a dream. Recently we have successfully synthesized high-density, horizontally aligned SWNTs on quartz wafers, and the thin-film transistors (TFTs) based on this SWNT array show high on-driving current density (up to ~220 μA/μm). Additionally, through systematic studies, we proposed and confirmed the high growth selectivity originates from the etching effect and chemical reactivity difference of metallic and semiconducting nanotubes. Three important rules were summarized for achieving a high selectivity in growing semiconducting nanotubes by systematically investigating the relationship among water concentration, carbon feeding rate and the percentage of semiconducting nanotubes in the produced SWNT arrays. Furthermore, these three rules can also be applied to the growth of random SWNT networks on silicon wafers. This understanding will help us to develop better method to solve the most difficult problem which limited applications of carbon nanotubes in nanoelectronics – the coexistence of metallic and semiconducting nanotubes in samples produced by most, if not all, growth methods. Based on these results, the alignment and density will no longer be the bottlenecks for the surface growth of SWNTs anymore.

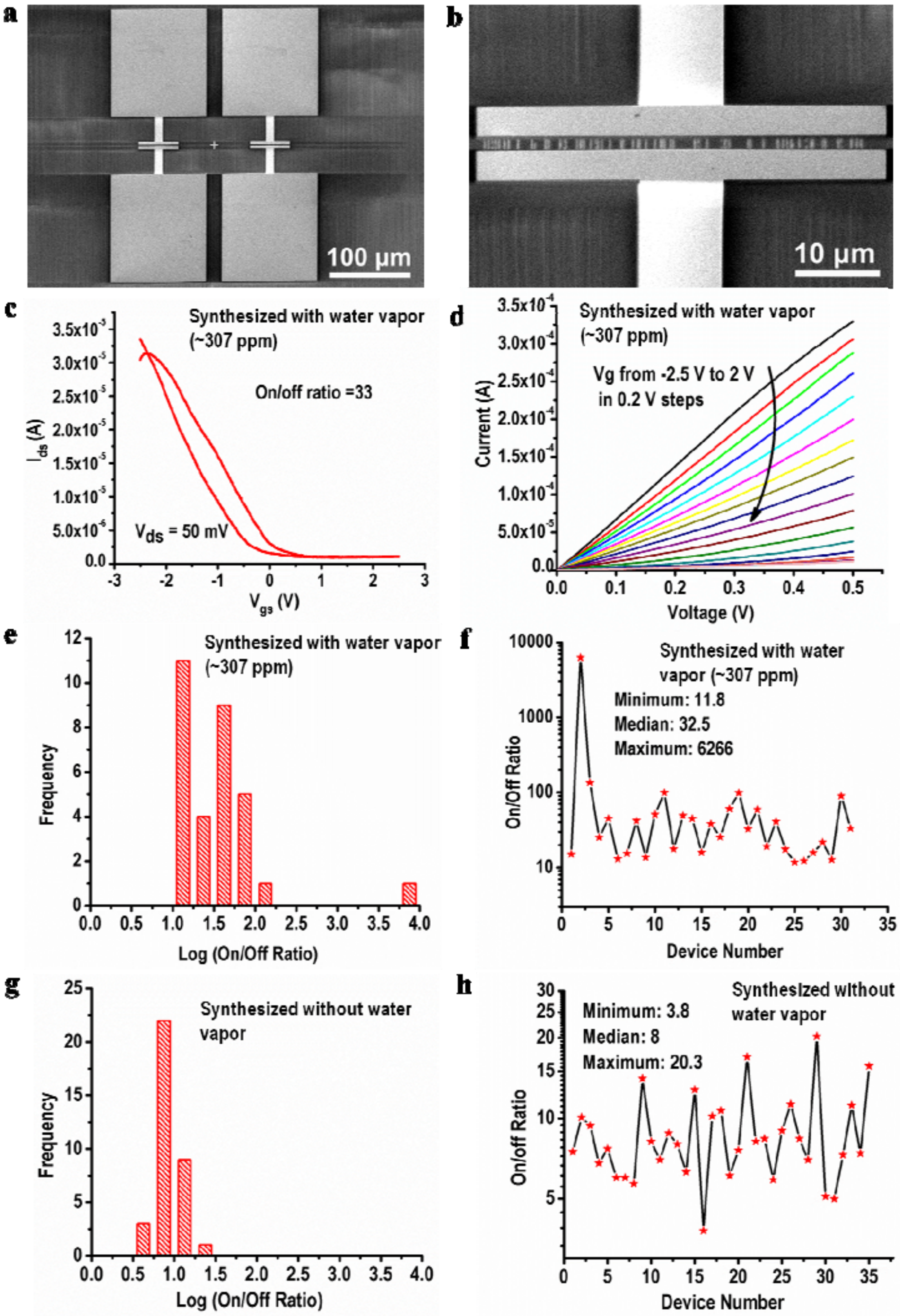

Figure 1. On/off ratio measurement results of the SWNT array samples synthesized with and without water vapor, respectively. a-d, SEM images (**a, b**), transfer (**c**) and output characteristics (**d**) of a representative device fabricated on SWNT array sample synthesized with water vapor. **e, g,** Histograms of on/off ratio distributions of the TFT devices based on the SWNT array samples synthesized with (**e**) and without water vapor (**g**). **f, h,** Display of on/off ratios of all TFT devices based on the SWNT array samples synthesized with (**f**) and without water vapor (**h**).