Optoelectronic Probes of Suspended Carbon Nanotube Transistors

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**Abstract:**  
Suspended carbon nanotube transistors are used as nanoscale optoelectronic probes to investigate the electrical and optical processes in biological systems due to their high sensitivity, robust electrochemical stability, and high surface to volume ratio. Taking advantage of dual-optical trapping technique and scanning photocurrent microscopy, we are able to study the interface between carbon nanotubes and biomolecules such as DNA at the single-molecule level.

**Research Summary:**  
Carbon nanotube-biomolecular hybrids have emerged as one of the most promising materials for biological and biomedical applications, such as biosensors, drug delivery, and imaging. Recently, carbon nanotubes (CNTs) have shown the ability to protect bound single-stranded deoxyribonucleic acid (ssDNA) cargos from enzymatic cleavage both during and after delivery into cells. This ability may result from the interaction between CNTs and ssDNA, which makes ssDNA unrecognizable to enzyme binding pockets. Furthermore, it is important to know whether ssDNA can be separated from CNTs in the presence of target complementary ssDNA. Therefore, we are interested in studying the interaction between CNTs and DNA.

Figure 1 shows the cross view of a CNT transistor. We etched a 7 µm wide and deep trench into a 170 µm thick fused silica substrate by the Oxford PlasmaLab 80+ RIE system. The source and drain electrodes (2 nm Ti, 40 nm Pt) were put beside the trench and separated by 9 µm. On the top of metal electrodes were the catalyst pads (10 nm of Al2O3, 0.2 nm of Fe) deposited by the evaporator.

Using a “fast heating” chemical vapor deposition method, we then grew the carbon nanotube which connects the source and drain. A 100 by 60 µm microfluidic poly(dimethylsiloxane) (PDMS) channel was sealed over the CNT, and a gold wire in a reservoir on the end of the channel was used to set the electrochemical potential of the solution [1].

Figure 2 illustrates the manipulation of DNA in our experiment. The ssDNA is attached to a microbead, which can be moved to different positions by optical trapping [2]. When the microbead is close to the CNT, the ssDNA forms a stable complex with individual CNTs by means of the aromatic interactions between nucleotide bases and CNT sidewalls (Figure 2, Left). After the ssDNA is attached to the CNT, we can separate them via the optical trap and directly measure the binding energy between them. If we label ssDNA, we can simultaneously study electrical transport and the fluorescence resonance energy transfer between CNTs and ssDNA. We can also introduce complementary ssDNA in the system, observe DNA hybridization process (Figure 2, Right) and study competitive binding of ssDNA with complementary ssDNA and ssDNA with CNTs. These experiments will not only extend the understanding of the interactions between DNA and CNTs, but also provide a new platform to probe in real-time and thus understand biomolecular interactions.

**References:**  
Figure 1: Left, cross view of an electrolyte-gated suspended CNT transistor inside a PDMS microfluidic channel. Right, SEM image of a CNT suspended cross a trench and connected with two electrodes.

Figure 2: Left, schematic diagram of ssDNA wrapped around a suspended CNT transistor. Right, schematic diagram of a biological CNT sensor to detect DNA hybridization.