NQD-SWNT FETs Assembled using Dielectrophoresise

Sohee Jeong, Hyung Cheoul Shim†, Soohyun Kim†, Chang-Soo Han**

**Nanomechanical Systems Research Division, Korea Institute of Machinery and Materials 171 Jang-dong, Yuseong-gu, Daejon 305-343, Korea*
†Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology Guseong-dong, Yuseong-gu, Daejeon 305-343, Korea
sjeong@kimm.re.kr

Semiconductor nanocrystal quantum dots (NQDs) have attracted considerable interest for use in photovoltaics and optoelectric sensor applications. The ability to transport extracted carriers from the NQDs is essential for the development of NQD incorporated device applications. Coupling of NQDs to one-dimensional nanostructures such as single wall carbon nanotubes (SWNTs) is expected to produce a composite material which facilitates selective wavelength absorption, charge transfer to 1-D nanostructures, and efficient carrier transport. Both covalent and non-covalent routes to assemble NQDs to SWNTs have been reported.

In this paper, we actively assembled CdSe/ZnS nanocrystal quantum dots on CNTs using AC electric fields. Photoluminescence coming from NQDs allowed us to monitor the assembled structures on CNTs aligned in between the electrodes. We further fabricated FETs using NQD/SWNT hybrid nanostructures using dielectrophores to monitor the carrier transfer behavior upon photoexcitation.

Assembly of NQDs on SWNTs using Dielectrophoresis

DEP is the electrokinetic motion of dielectrically polarized materials in non-uniform electric fields and is currently an active area of research for manipulation of biological materials such as cells, bacteria and DNA. [2] The polarized material is driven towards (positive DEP) or away from (negative DEP) the high field region depending on the complex dielectric permittivity of the particle and its surrounding medium.

Generally for the particles smaller than 500 nm, the dielectophoretic force is negligible compared to the Brownian motion due to their small size. When CNT is used as an electrode, independent of the position along the CNTs, dielectric force F_{DEP} can be described as followed;

$$\nabla(Erms^2) \approx -2[V_{rms}/\{\ln(4h/d)\}]2(r^{-3})\boldsymbol{r} \quad [2]$$

For the positive DEP force, AC sinusoidal wave was applied and NQDs were assembled on the aligned CNTs on Pt electrode with 2 μm gap. Resulting assembly was viewed under the confocal microscope where the excitation wavelength was 458 nm and photoluminescence (PL) emitting at the maximum wavelength of 550 nm was collected. (Fig. 2, middle) Decrease in PL intensity was observed due to the photobleaching of NQDs. Around after 4 minutes, no observable PL signal was obtained. (Fig. 2, right)

Optical/Electrical Characterizations of NQD/SWNT Hybrid Nanostructures

Further to verify the charge transfer mechanism of the NQD-CNT hybrid nanostructures, we assembled the NQDs to SWNTs first then assemble the FET device using dielectrophoresis. Attaching NQDs to SWNTs were performed via non-covalent attachment where both NQD and SWNTs retain their electronic structures before and after the attachment. [3, 4] PL intensity measurements expect us to the extent of charge transfer in core and core/shell NQDs to SWNTs. More efficient charge transfer is expected in core NQD-SWNTs system.

The assembled CdSe-SWNTs which resulted in photoluminescence quenching confirmed optically was fabricated into the FET using dielectrophoresis. We used n-doped silicon substrate as back gate, and the aligned the CdSe-SWNTs hybrid nanostructures between microelectrodes function as a channel in FET structure. We then packaged CdSe-SWNT device into conventional chip using wire bonding for the convenience of measurement of electrical properties. With the fabricated FET device, we measured the resistance between source and drain with gate voltage of 100 mV using digital multimeter (Fulke, 189) in real-time. The resistance starts to decrease when the light was on and increase when the light was off.

In this paper, we assembled prepared CdSe (core and core/shell with ZnS) semiconductor nanocrystal quantum dots on single walled carbon nanotubes using dielectrophoresis (DEP). Confocal imaging confirmed the assembled hybrid nanostructures. To further characterize the charge transfer from photoexcited NQDs to SWNTs, FETs were fabricated. We monitored the electrical signatures from NQD decorated SWNTs upon photoexcitation and were able to elucidate the carrier transfer mechanism.

References:

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[3] S. Banerjee, and S. S. Wong, *JACS*, 125 (2003) 10342
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Figures:

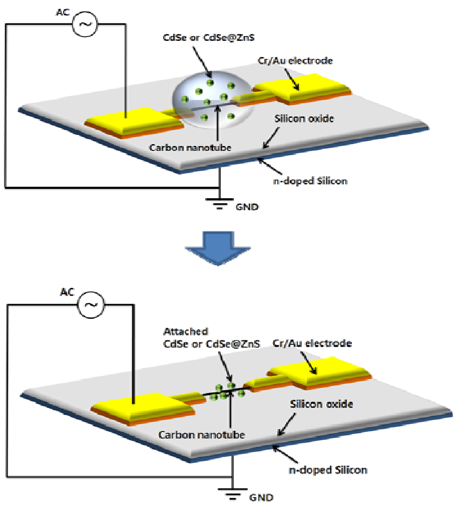

Figure 1 DEP assembly of NQDs on CNTs

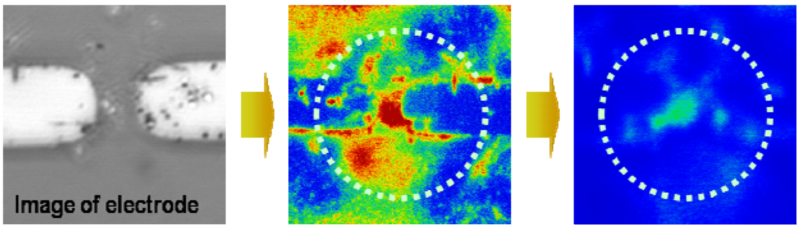

Figure 2 Microcope images of nanocrystal quantum dot s assembled on carbon nanotubes (left: transmission image of electrode, middle 550 nm emitting dots assembled on carbon nanotubes aligned in between the electrodes, right: PL from the NQDs were photo-bleached)