Fabrication and characterization of optoelectronic device using CdSe nanocrystal quantum dots/single-walled carbon nanotubes heterostructure

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ABSTRACT

The ability to transport extracted carriers from the development of NQDs (nanocrystal quantum dots) based optoelectronic sensors have drawn considerable attention due to NQDs' unique optical properties. Coupling of NQDs to 1-D nanostructures such as SWNTs (single-walled carbon nanotubes) is expected to produce a composite material which facilitated selective wave length absorption, charge transfer to 1-D nanostructures, and efficient electron transport. In this paper, we fabricated the optoelectric device based on cadmium selenide (CdSe) nanocrystal quantum dots (NQDs)/single-walled carbon nanotubes (SWNTs) heterostructure using dieletrophoretic force. The efficient charge transfer phenomena from CdSe to SWNT make CdSe-Pyridine (*py*)-SWNT unique heterostructures for novel optoelectric device. We monitored the electrical signatures from NQDs decorated SWNTs upon excitation and were able to elucidate the carrier transfer mechanism. The conductivity of CdSe-*py*-SWNT was increased when it was exposed at ultra violet (UV) lamp, and showed a function of wavelength of incident light.

Keywords: Nanocrystal quantum dot (NQD), single-walled carbon nanotube (SWNT), charge transfer

1 INRODUCTION

NQDs (nanocrystal quantum dots) have been attracted considerable attention due to their semiconducting properties [1]. In addition, the band-gap energy of NQDs can be tuned using varying their size. These unique properties of NQDs make them have wide applications including bio-medical applications, electronic and optical devices [2,3]. Especially, in optical component based on NQDs, it is very important that how to detect electronically the carriers from NQDs when they were photo-excited. In this work, the novel typed optical sensor was fabricated using hybrid nano-materials which were comprised of NQDs and SWNTs (single-walled carbon nanotubes) that transport the carriers from the NQDs. The SWNTs can be the best candidate for the transport materials because of their nano-scaled size and ballistic transport properties [4].

2 RESULTS AND DISCUSSIONS

Fig. 1 shows the schematic diagram of device fabrication procedure. First, the CdSe (cadmium selenide) as the NQDs having average size of 2.8 nm were synthesized by conventional method [5], and covered with pyridine ligand instead of surfactant for non-covalent coupling with single-walled carbon nanotubes. As shown in TEM (transmission electron microscope) image of **Fig. 2(a)**, we can check the CdSe were coupled well with SWNTs using pyridine linking. Next, the CdSe-*py*(pyridine)-SWNTs nano hybrid materials were aligned between Cr/Au microelectrodes using AC (alternative current) dielectrophoretic force as shown in Fig. 1, and we also confirm the aligned CdSe-*py*-SWNTs between microelectrodes through the FESEM (field emission scanning electron microscope) image of **Fig. 2(b)**.

The 100 mV of bias voltage was applied to the optical sensor, and the UV (ultra-violet) lamp having wavelength of 365 nm and power of ~5 mW was used for the light source. The change of resistance value was monitored by Ohm meter (Fluke 189) in a real time (See **Fig. 3**). The conductance of optical device was increased when they exposed at UV lamp was on as shown in *Fig. 4*. However, the conductance was decreased and reached at their original resistance value when the UV lamp was off. The position of conduction band on CdSe (~3.5 eV) is higher than that of SWNTs (~4.8 eV), the electrons can be transferred thermo-kinetically from the CdSe to SWNTs when they were photo-excited. For this reason, the conductance of optical device can be changed based on the transferred carriers from NQDs to SWNTs. Moreover, the more carriers can be generated using excitation frequency with higher energy. Therefore, the change in resistance values with an excitation frequency of 490 nm is much higher than when the optical sensor was excited with wavelength of 550 nm. In this typed of optical device that composed of CdSe and SWNTs, the detection of selective wavelength is possible due to tunable band gap energy of CdSe. Furthermore the speed of device can be enhanced by using 1-D (one-dimensional) structure of SWNTs that transport the carriers with theoretically no loss.

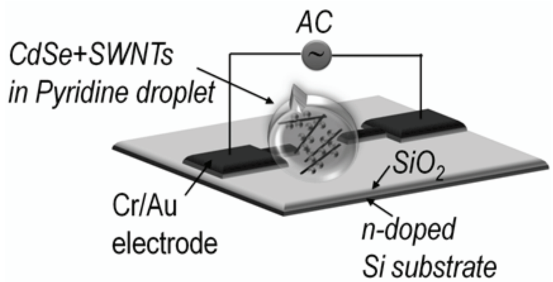

Fig. 1 Schematics of the dielectrophoretic assembly of CdSe-*py*-SWNT optoelectronic devices

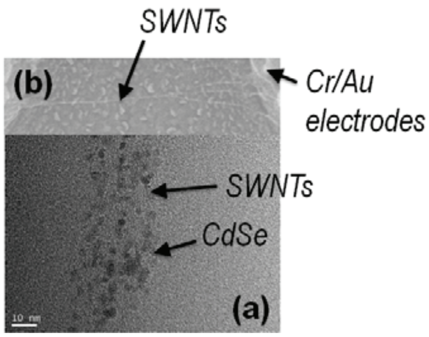

Fig. 2 (a) TEM image of CdSe-*py*-SWNTs, (b) FESEM image of CdSe-*py*-SWNTs between microelectrodes

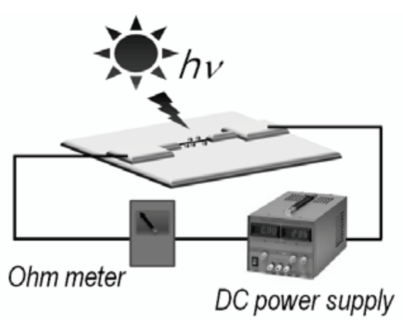

Fig. 3 Schematics of the measurement on CdSe-*py*-SWNT optoelectronic devices with ohm meter

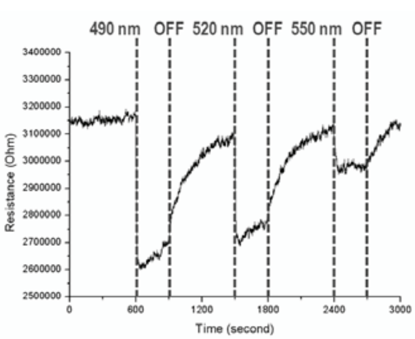

Fig. 4 The changes in resistance *vs* time of CdSe-*py*-SWNT optoelectronic device *via* different wave length illumination.

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