Semiconducting Carbon Nanotube-based Stretchable Transistors

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ABSTRACT

Realizing stretchable electronics requires special materials with intrinsically elastic or durable properties. One of candidates is the semiconducting carbon nanotube due to its excellent mechanical property and ultra-high charge transport mobility.

1 INTRODUCTION

Recently, attempts have been made actively to apply displays to various form factors. For deformable displays, the transistors that control the light emitting devices must also be flexible. Unlike rigid electronics, stretchable devices have advantages of high surface coverage and deformability like skin. Realizing deformable and stretchable electronics requires special materials with intrinsically elastic or excellent mechanical properties. Among various semiconductors, one of candidates is the semiconducting carbon nanotube due to its network matrix and ultra-high charge transport mobility. Single-walled carbon nanotubes (SWNTs) is one of the actively researched nanoscale materials with one-dimensional (1D) structure due to its remarkable electrical, mechanical, and photophysical properties. However, none of synthetic methods for SWNTs cannot produce metallic and semiconducting tubes selectively as a mass scale at present technology level. To realize the high-performance electronic devices using the SWNTs, one of significant issues is separating the semiconducting SWNTs with an enough purity for active layer of transistors from the bare mixture. Among various methods for separation of the semiconducting SWNTs, the selective dispersion of s-SWNTs using conjugated polymers is considered most easy and scalable technique.

Here, we report a process for selective dispersion of semiconducting SWNTs by poly(9,9-di-n-dodecylfluorene (PFDD) and a fabrication of transitors. The stretchable transistor is composed of sorted SWNTs semiconductor and insulating elastomer, SEBS. We demonstrate that this device can show the less-changed mobility by low-band gap of SWNTs under even high strain-rate.

2 EXPERIMENT

To sort semiconducting carbon nanotubes (CNTs) from a bare mixture (RN-220, Nanointegris Inc.), PFDD polymers were added into 20 mL of toluene to 1 mg/Ml, and then 5 mg single-walled CNTs were added into the polymer solution, and then dispersed for 1 h by a probe sonicator (Sonics & Materials Inc., VCX-130, 130 W) with a cool bath. During sonication, polymers selectively dispersed semiconducting CNTs. To extract only semiconducting CNTs from the suspension, the solution was centrifuged at a relative centrifugal force (RCF) of 85000g for 1 h (Hanil Scientific Inc., Supra 50K), leaving metallic CNTs and impurities as sediment, whereas dispersed semiconducting CNTs and excess unwrapping PFDD polymers remained within the solution. A filtration was conducted with a 0.20 μ m MCE membrane to remove the excess polymers. And Semiconducting CNTs embedded in the membrane were redispersed in 5 mL of toluene by bath sonication for 1 min on mild condition.

To fabricate CNT-based transitors, the bare CNTs mixture was coated on the SEBS substrate by spray coating for source and drain electrodes with shadow mask. And then, CYTOP was spin-coated on top of electrodes for active layer patterning. the semiconducting CNTs ink was droped within CYTOP guide layer. After short baking, CYTOP layer was removed by fluorinated solvent. And then, SEBS solution was coated on CNTs active layer. Finally, the bare CNTs mixture was coated on insulator layer as the gate electrode.

Transistor transfer and output characteristics at room temperature in the nitrogen-filled glovebox were measured using a semiconductor parameter analyzer (Keithley 4200-SCS). UV−vis−NIR absorbance spectra were measured using a spectrophotometer (JASCO V-770).

3 RESULTS

Commercially available Plasma torch SWNTs were dispersed by using PFDD polymers in toluene solvent and the suspension were extracted after centrifugation (85,000g). The absorption spectra of the supernatants were measured by ultraviolet/visible/near infrared (UV/Vis/NIR) spectroscopy to confirm the relative amounts, yields and purities of dispersed s-SWNTs in the solution. Sorted CNTs shows three absorption peaks in the regions of 1400-1900 nm for the first semiconducting exitonic transition (S_{11}), 700-1100 nm for the second semiconducting exitonic transition (S_{22}) and 450-550 nm for the third semiconducting exitonic

transition (S_{33}). These NIR peaks indicated that PFDD was able to sort and disperse semiconducting CNTs. (Figure 1)

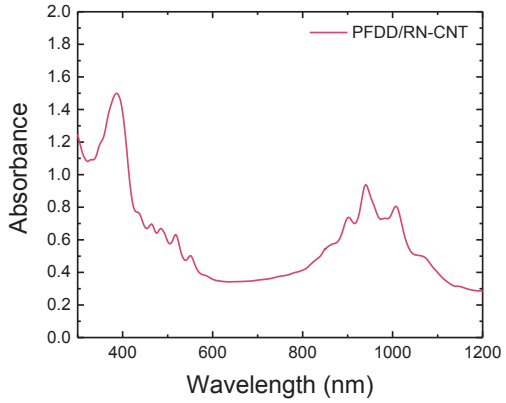

Figure 1. Absorption spectra of dispersed SWNTs by PFDD after enrichment by filtration.

To realize semiconducting layer for FETs by using IDT-BT/s-SWNT, the s-SWNT network has been spin-coated 3 times from the solution (8.8 μg/ml) that s-SWNT was enriched and excess polymer was removed. On a rigid glass substrate, P-type mobility was average 7.3 cm2/V·s (maximum 10.5 cm2/V·s) in the saturation and ON/OFF ratio of the p-type region was approximately 10^2. (Figure 2)

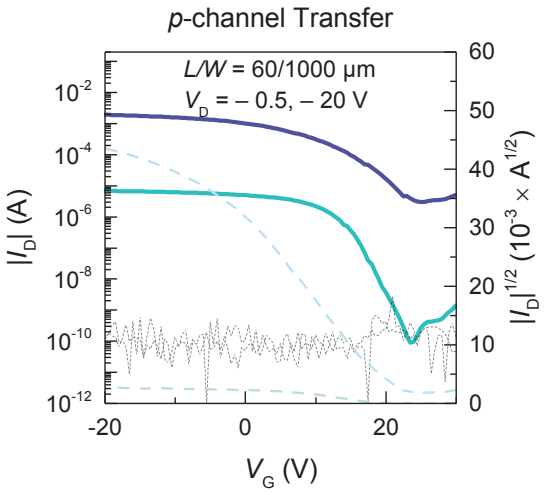

Figure 2. p-channel transfer curve of bottom-gated bottom contact structured SWNT transistor on a rigid substrate.

A fabrication of stretchable transistor is on processing.

4 DISCUSSION

Sorting semiconducting SWNTs was and conducted successfully and its purity was confirmed by absorption spectra.

A discussion about the stretchable transistor is on processing.

5 CONCLUSIONS

The semiconducting SWNTs were selectively sorted and dispersed by wrapping of PFDD polymer. And, the SWNT-FETs showed high hole mobility with high ON/OFF ratio.

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