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Studies on the role of sulphur during FC-CVD synthesis of CNTs

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Abstract:

We present experimental studies on the effect of sulfur during the floating catalyst chemical vapor deposition (FC-CVD) synthesis of carbon nanotubes. We start with isopropanol as the carbon source, ferrocene as the catalyst precursor, thiophene as the sulfur precursor and nitrogen-hydrogen as the carrier gas using the liquid-feed FC-CVD reactor. Without adding thiophene, the synthesis yield is too low to allow thin film sample collection. With the thiophene dissolved to the isopropanol, thin films of single walled CNT (SWNTs) with the diameter around 1 nm and the semiconducting fraction over 90 % were directly collected at the reactor outlet, when operating the reactor at low ferrocene concentration regime. We discuss the mechanisms for increasing the semiconducting tube fraction based on the gas composition analysis at the reactor outlet [1]. We present both individual SWNT FETs as well as thin film TFT-FETs using the semiconducting SWNT enriched samples.

We present recent results on the effect of elemental sulfur during CNT synthesis from methane with ferrocene as the catalyst precursor and nitrogen-hydrogen mixture as the carrier gas [2]. Increasing the sulfur concentration while keeping the ferrocene as well as methane concentration conctant results in a linear yield increase and a transition from single-walled CNTs to DWCNTs without significantly affecting size distribution of catalyst particles. Highest DWCNTs proportion is 87% which was confirmed with high-resolution transmission electron. Electron diffraction (ED) patterns reveal a random (n,m) as well as chiral angle distribution of CNT, indicating minimal sulfur impact on the nanotube atomic structure [3]. We discuss the conducting transparent films with the sheet resistance down to 35 ohms/sqat 90 % transmittance made by DWNTs. When depositing DWNTs into the patterned structures, we can reduce the sheet resistance down to 5 ohms/sq at 90 % transmittance [4].

In addition, we present recent results on the effect of using several S sources, including elemental S, thiophene and CS2 and with ethanol as the carbon source and ferrocene as the catalyst precursor regarding the SWNT properties.

[1] P. Liu *et al*. Advanced ElectronicMaterials **9**, 2300196 (2023)
[2] Q. Zhang *et al.* Advanced Functional Materials **32**, 2103397 (2022).
[3] Z. Xu *et al*. Carbon, submitted (2024).
[4] Z. Xu *et al*. Nanotoday, accepted (2025).

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