

Carrier Gas Driven Switching of Growth Site of Carbon Nanotubes

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Characterization of Precursor

Thermogravimetric Analysis:

Thermogravimetric analysis was carried out using a TA Instruments TGA Q50 analyzer. The precursor sample was heated upto 200 °C in a flowing nitrogen atmosphere at a constant heating rate of 10 °C/min. Two-step degradation of the precursor was observed. The first decomposition appearing between 111 °C and 114 °C, at 40% weight percentage, occurs due to acetanilide while the final decomposition at 176 °C is due to decomposition of camphor. No residue was obtained after the completion of the decomposition. The result suggests that the precursor is a mix of camphor and acetanilide in the ration of 40:60.

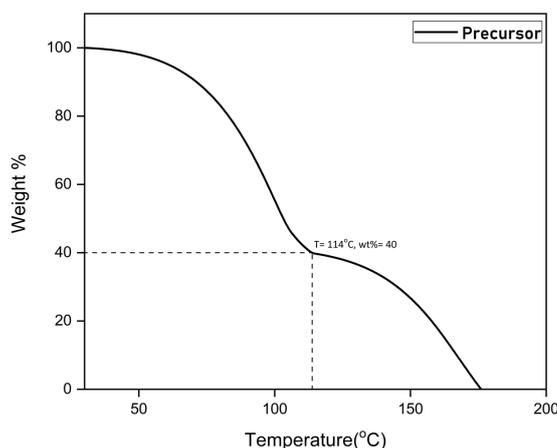


Figure S1. TG thermograph of precursor

Mass Spectrum Analysis:

Electrospray ionization mass spectral analysis of the precursor was done using a Quattro microTM API (Waters, Milford, MA, USA). MS analysis was done in positive ion mode in the scan range of 20–200 (m/z). The fragment observed at 152 corresponds to the M⁺ while the peak at 135 is assigned to the molecular fragment of acetanilide. The higher stability of acetanilide as compared to camphor could explain the weaker signal of acetanilide than that of camphor. The other major fragments are 109 (C₈H₁₃⁺), 95 (C₇H₁₁⁺), 85 (C₆H₁₁⁺), 70 (C₄H₅O) and 42 (C₃H₅⁺). The origin of base peak of 141 is yet to be identified.

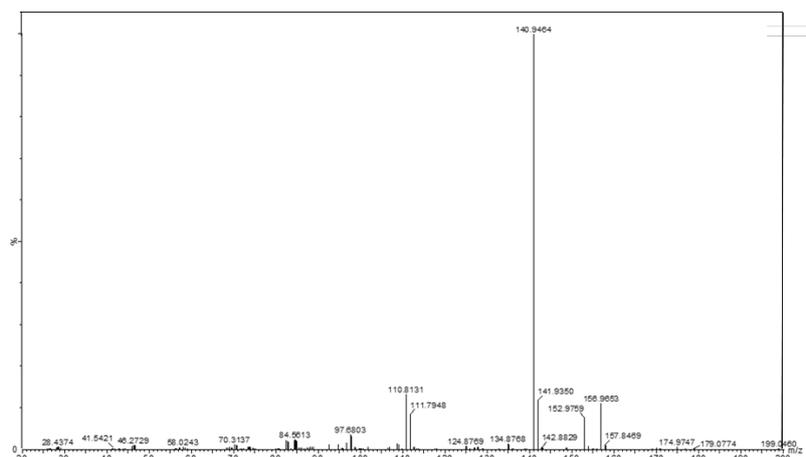


Figure S2. Mass spectrum of precursor

Fourier Transform Infrared Spectroscopy:

FTIR spectra of the precursor was recorded using a Thermo Scientific Nicolet 6700 FT- IR spectrometer (Fig 3). The region below 1500 cm^{-1} is known as the fingerprint region and shows strong prominent peak at around 1008 cm^{-1} , 1240 cm^{-1} , 1370 cm^{-1} and 1460 cm^{-1} which corresponds to camphor signals. The peak at 3300 cm^{-1} corresponds to terminal alkyne $\equiv\text{C-H}$ absorption.

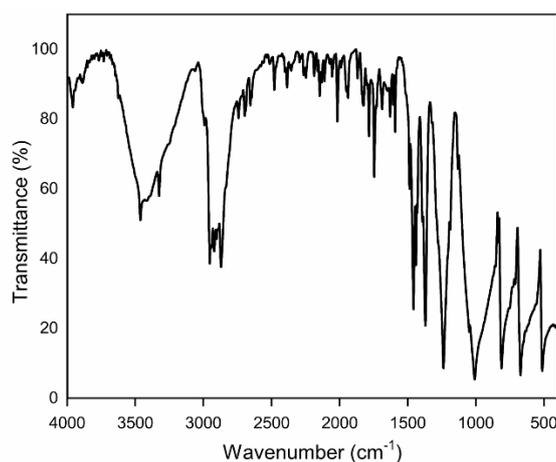


Figure S3. FTIR spectrum of the precursor.

Elemental Analysis of synthesized carbon nanotubes:

Elemental analysis of MWCNTs synthesized from ferrocene and camphor was conducted using Auger electron spectroscopy. The spectrum indicates the presence of nitrogen in the synthesized MWCNTs (Fig. S4). Presence of nitrogen in the as-synthesized MWCNTs is also observed by Energy dispersive X-ray spectroscopic analysis conducted in a FEI Tecnai G2 transmission electron microscope.

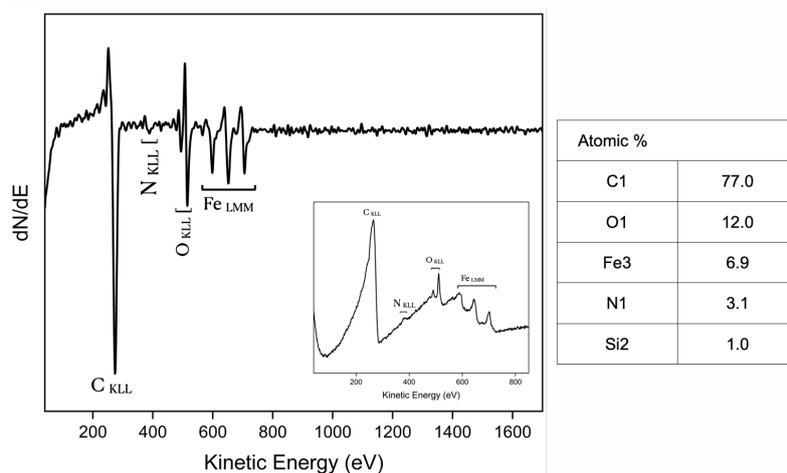


Figure S4: AES spectrum of as-synthesized MWCNTs confirming the presence of nitrogen in tube structure (inset: Magnified raw AES spectrum).

Characterization of MWCNTs synthesized from ferrocene alone (control experiment):

The as-synthesized MWCNTs using only ferrocene (as catalyst and camphor source) have a higher degree of metal filling as compared to tubes synthesized with camphor and ferrocene and the tubes do not exhibit intercalation (Fig. S5a) suggesting an absence of nitrogen in the tube structures. The synthesized MWCNTs are highly crystalline with well-graphitized tube walls (Fig. S5b) and exhibit a typical I_D/I_G ratio of 0.41 (Fig. S6). The higher quality of the tubes, as compared to the tubes synthesized from camphor and ferrocene, could be attributed to the higher structural integrity of the tubes owing to the lower carbon flux rate of this synthesis routine (and hence the lower growth rate) and the absence of intercalation of the tubes.

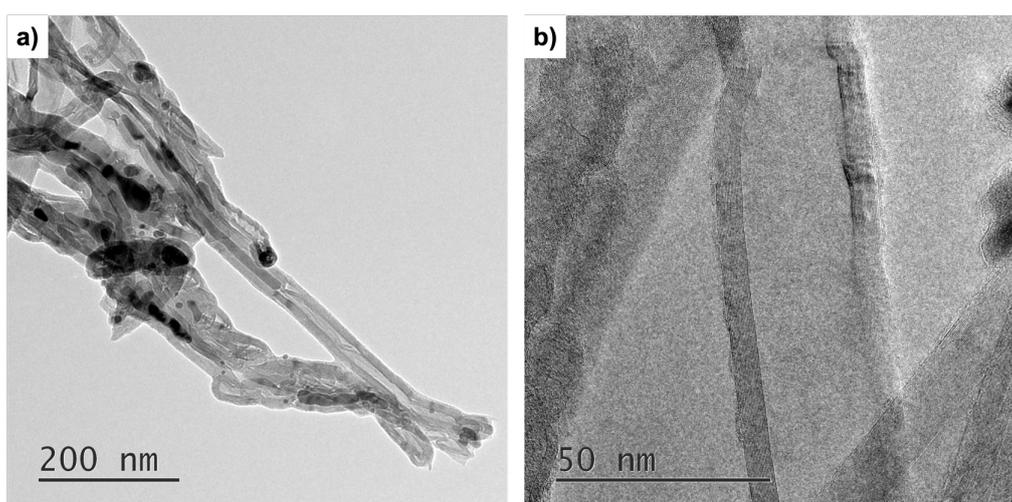


Figure S5: TEM micrograph of MWCNTs synthesized from ferrocene.

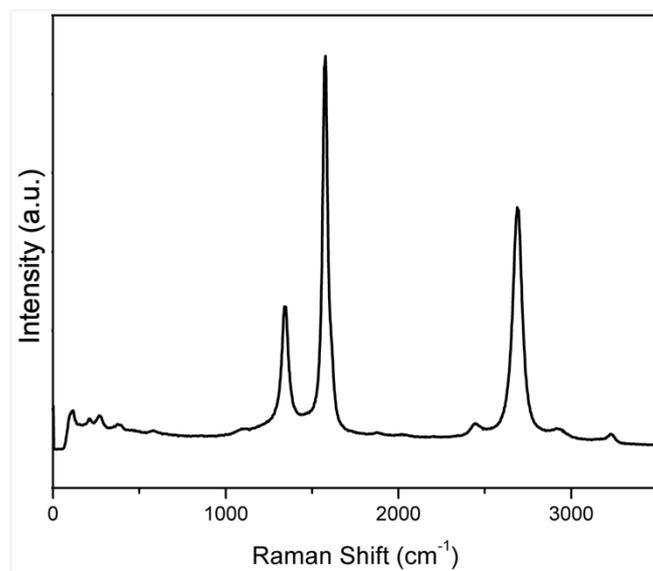


Figure S6: Raman Spectrum of MWCNTs synthesized from ferrocene.