Synthesis and Characterization of Transition Metal Dichalcogenide and Carbon Nanotube Coaxial Heterostructures

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Abstract

Carbon nanotubes (CNTs) have many fascinating electronic and mechanical properties, such as high electrical conductivity, high tensile strength, and high thermal conductivity. Transition metal dichalcogenides (TMDs) can be grown in a similar tube structure, but exhibit different electronic and mechanical properties. Depending on their elemental composition, these TMD nanotubes can be semiconducting, metallic, or insulating, resulting in tunable properties.[1] Coaxial heterostructure composites of a TMD nanotube grown around a CNT would exhibit a unique combination of CNT and TMD properties. Therefore, synthetic approaches of TMD/CNT heterostructure growth via chemical vapor deposition (CVD) are being explored. Raman, scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are being used to determine ideal growth conditions for consistent and uniform coaxial heterostructure growth, and to reduce production of non-tubular structures. When these heterostructures can be controllably grown, new transport properties can be explored for potential use in electronics, such as smaller and more efficient battery and solar cells.[2]

Background

TMD Properties

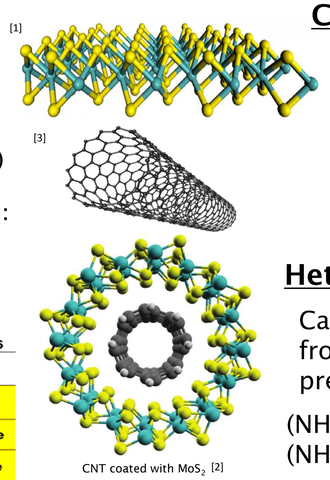
- Semiconducting (group 6)
- Metallic (group 5)
- Insulating (group 4)

Follows the MX_2 pattern:

M: Transitional Metal

X: Chalcogenides

4	5	6	7	10	16
					O
Ti	V	Cr	Mn	Ni	S
Zr	Nb	Mo	Tc	Pd	Se
Hf	Ta	W	Re	Pt	Te



CNT coated with MoS_2 [2]

CNT Properties

- High Electrical Conductivity
- High Tensile Strength
- Highly Flexible

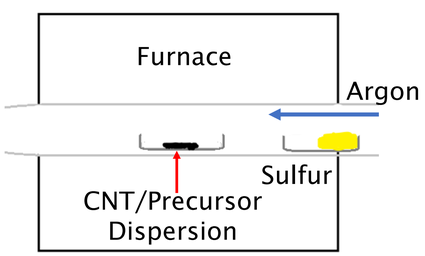
TMD/CNT Heterostructures

Can be synthesized from the following precursors:

$(NH_4)_2WS_4$	WO_3
$(NH_4)_2MoS_4$	MoO_3

Synthesis Method and Characterization

Growth By Chemical Vapor Deposition



Scanning Electron Microscopy (SEM)

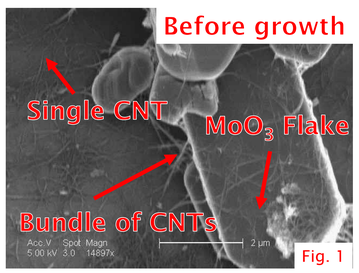
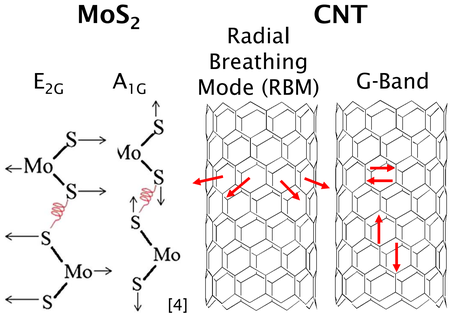
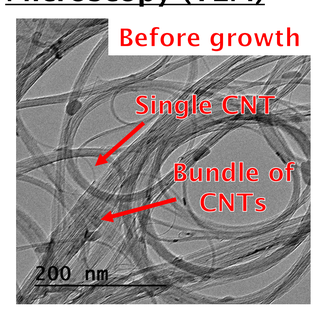


Fig. 1

Raman modes



Transmission Electron Microscopy (TEM)



Results

Raman for MoS_2 /CNT composites after growth

(MoO_3+CNTs in isopropyl alcohol dispersion at 800 ˚ C)

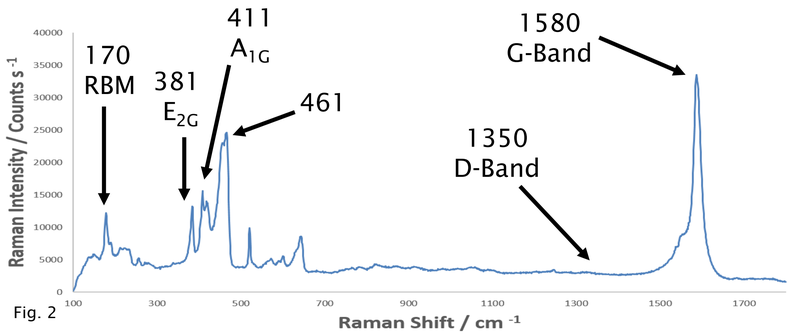


Fig. 2

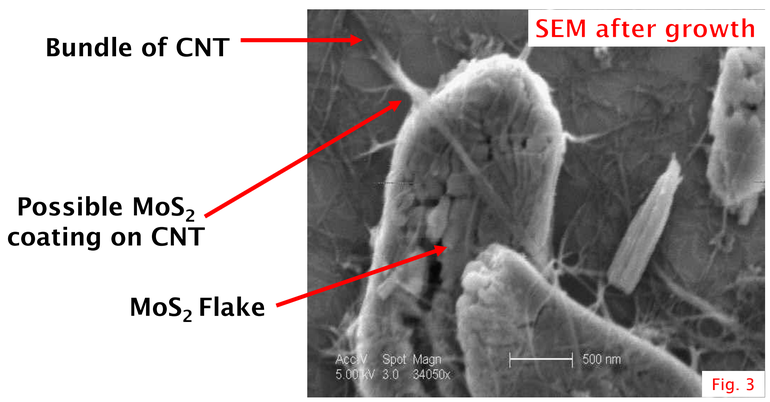


Fig. 3

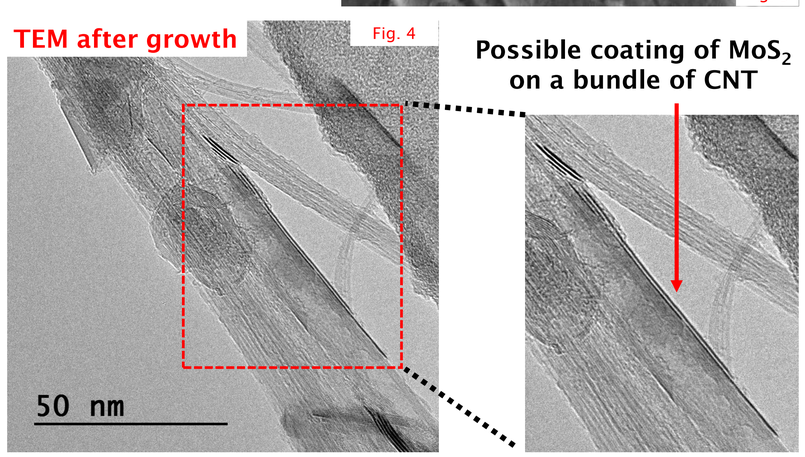


Fig. 4

Discussion

- As shown in Fig. 2, Raman signal shows MoS_2 growth from MoO_3 precursor, along with CNT signal, indicating existence of TMD and CNT composites.
- SEM images show TMD growth highly associated with CNTs.
- As seen in Fig. 1, CNT bundles are found surrounding precursor particles pre-growth and TMD flakes post-growth in Fig. 3.
- Shown in Fig. 4, there is possible evidence of TMD growth on a CNT bundle.

Future Work

- Reduce precursor particle size to encourage better mixing with CNTs and suspend more easily
- Explore additional growth parameters such as furnace temperatures and reaction times

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Support Information
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