Encapsulation of Quasi-One-Dimensional Transition Metal Trichalcogenides

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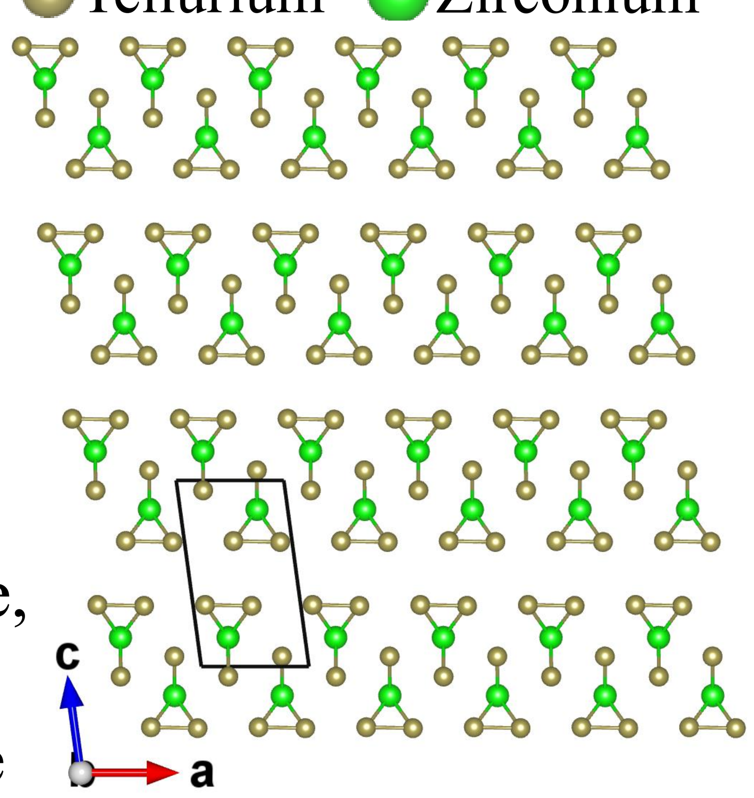
Abstract: Transition metal trichalcogenides (TMTs) offer a rich group of quasi-one-dimensional materials to study for their interesting physical properties. The TMT structure is comprised of trigonal prismatic chains held together by van der Waals bonding. Altering the crystal dimensions, thereby altering the van der Waals bonding between chains, should affect the TMT physical properties. Here, we report one approach to isolating TMTs down to the quasi-one-dimensional limit as a first-step to exploring the physical property relation to dimensionality.

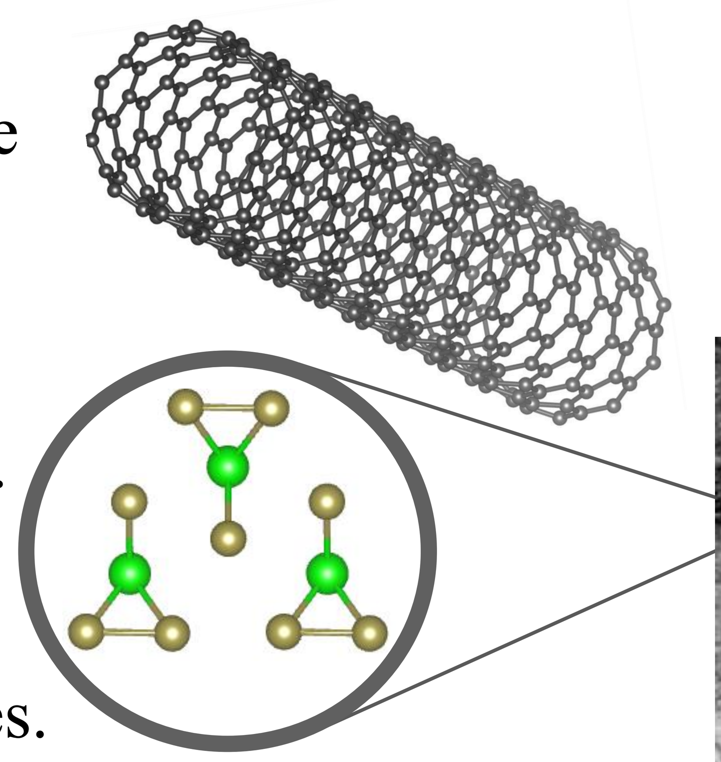
$ZrTe_3$ Properties

- Layered material, made of trigonal prismatic chains.
- Extensive Te-Te interaction perpendicular to chain direction.
- Physical properties should exhibit dependence on crystal dimensionality.
- Van der Waals interactions dictate: optical properties, charge density wave, and superconducting phases in 3D crystals, which could distinctly change in isolation.



Encapsulation Principle

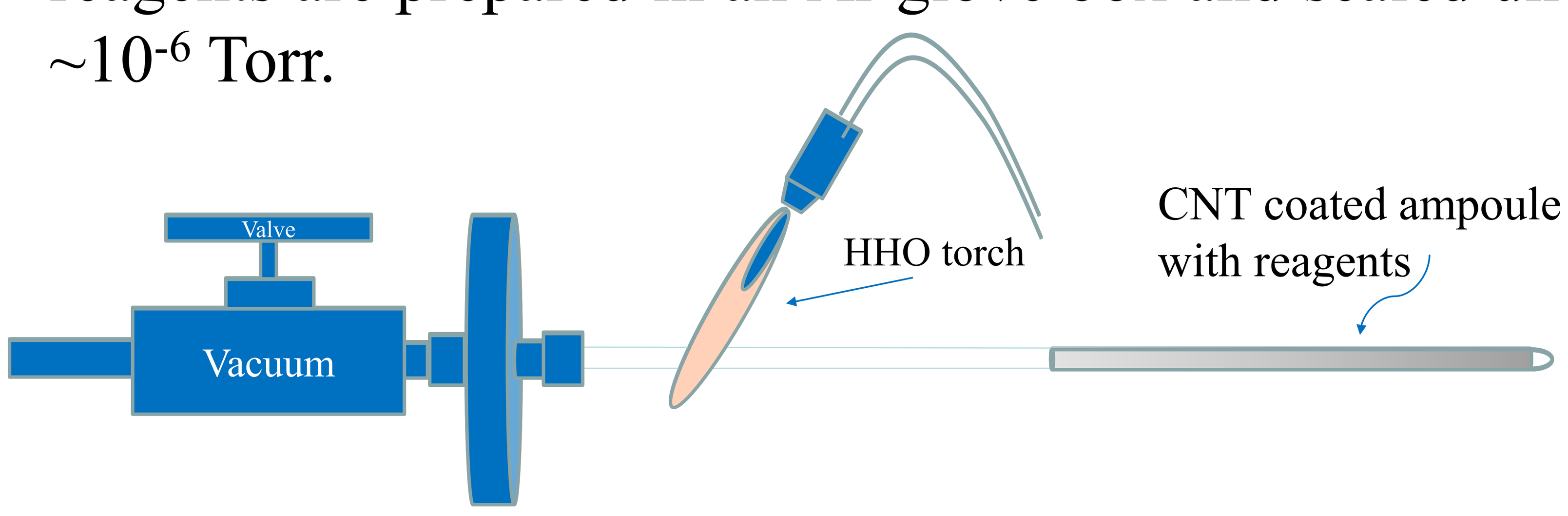
- Carbon nanotubes (CNT) are a robust nanomaterial in which TMT chains can be isolated.
- Inner dimension of the CNT will dictate how many chains of TMT can grow, resulting in few- to single-chain isolation.
- CNT provide chemical and physical stabilization of the chains, allowing for more thorough characterization techniques.



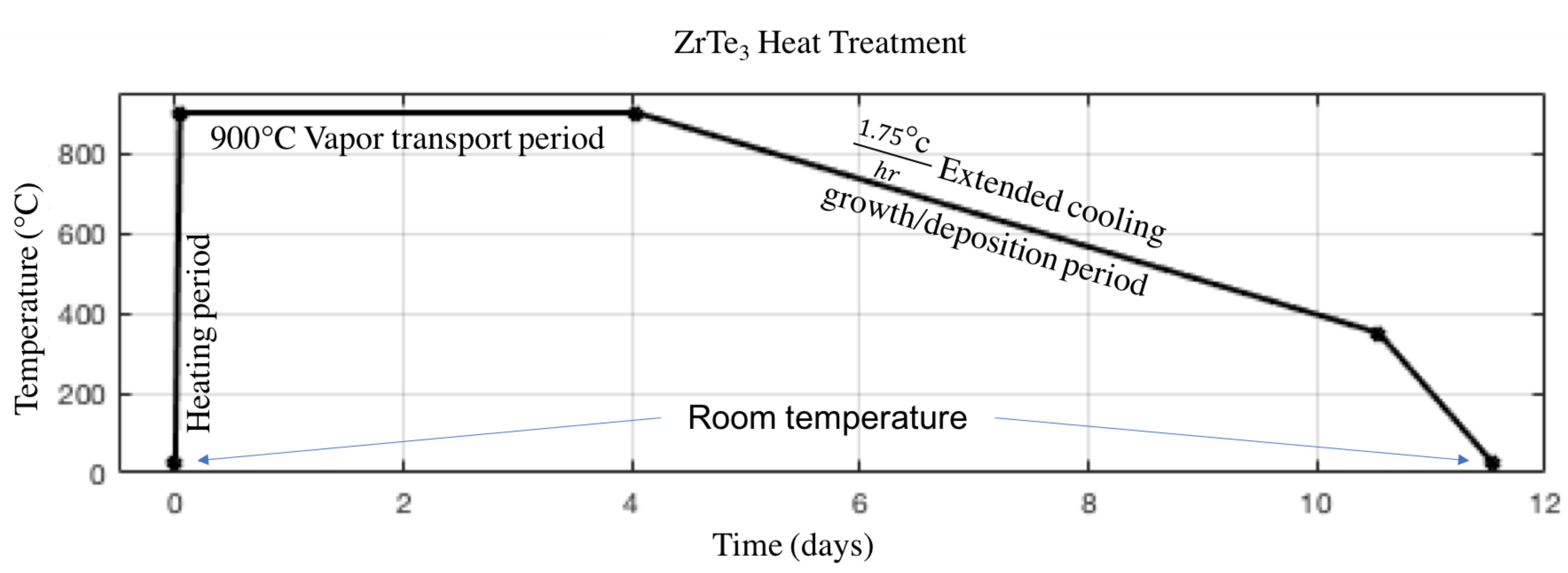
Method for Encapsulation

Vapor transport technique used to facilitate filling of CNT.

- CNT coated ampoules of stoichiometric amounts of reagents are prepared in an Ar glove box and sealed under ~10^{-6} Torr.

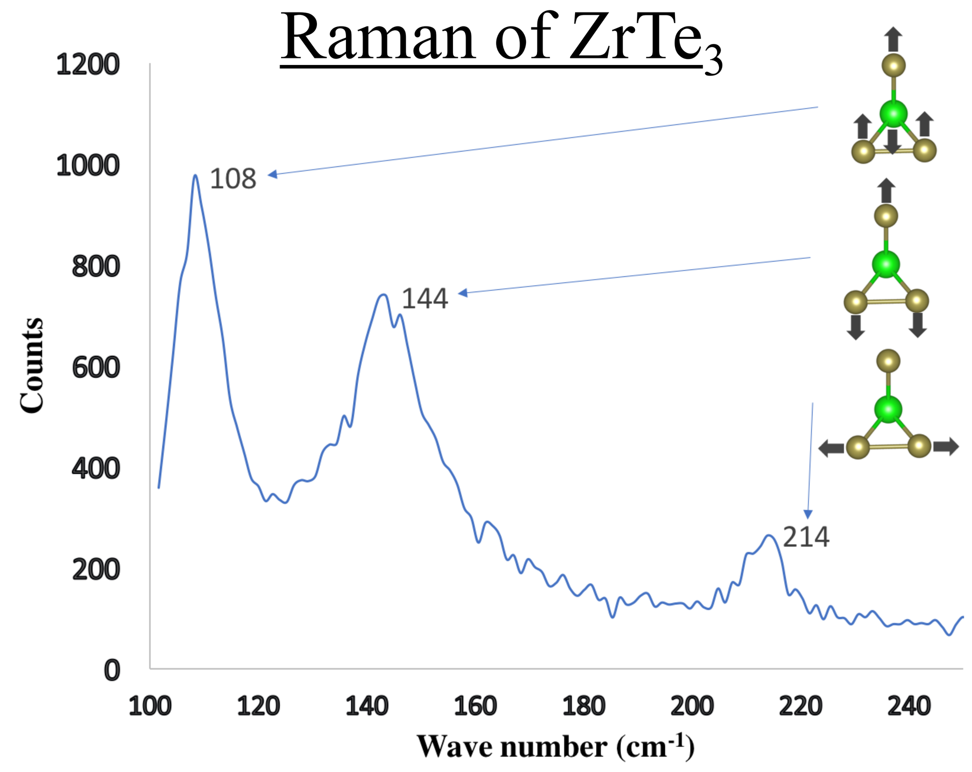


•Heat treated with extended cooling protocol.

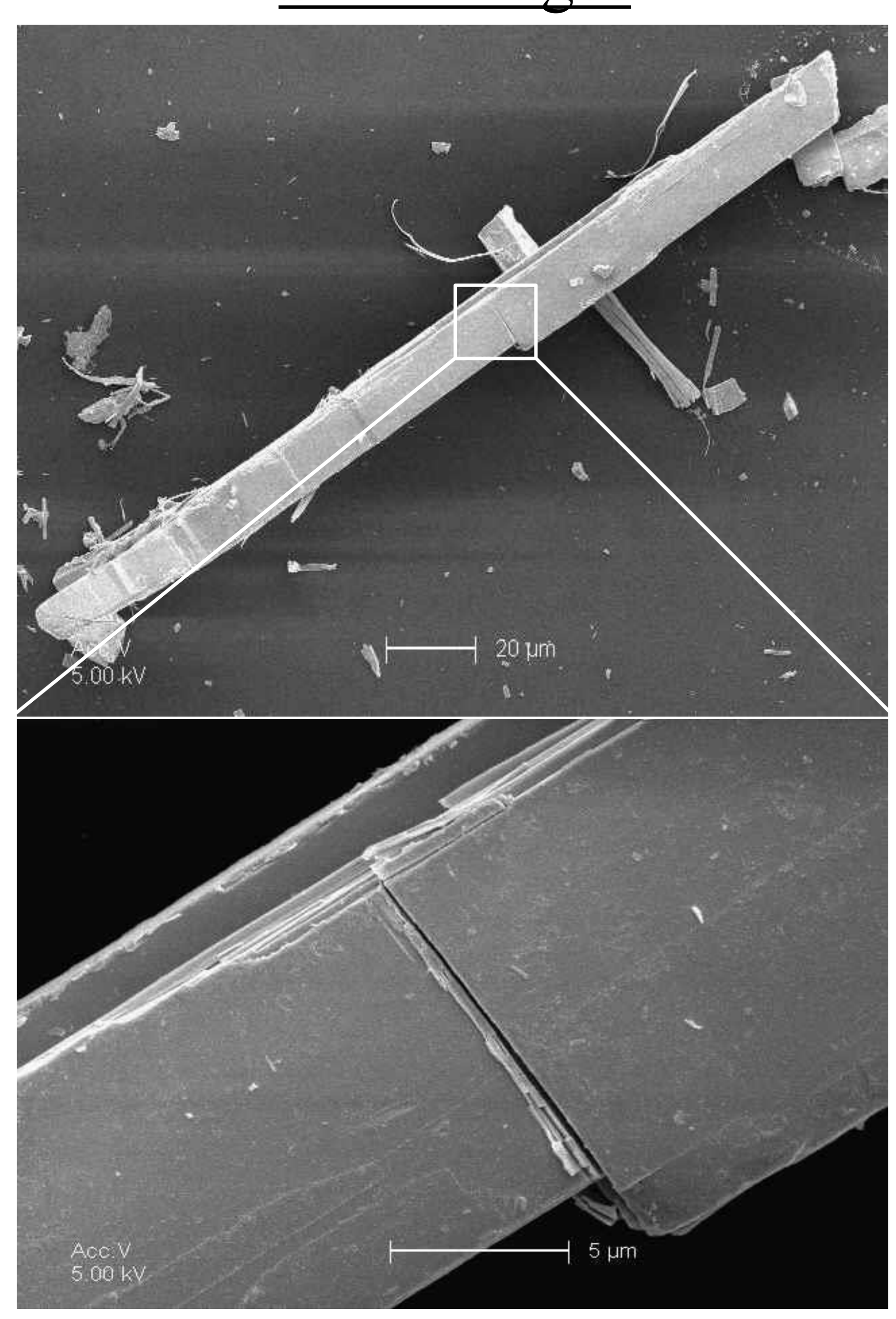


Results

Raman of $ZrTe_3$

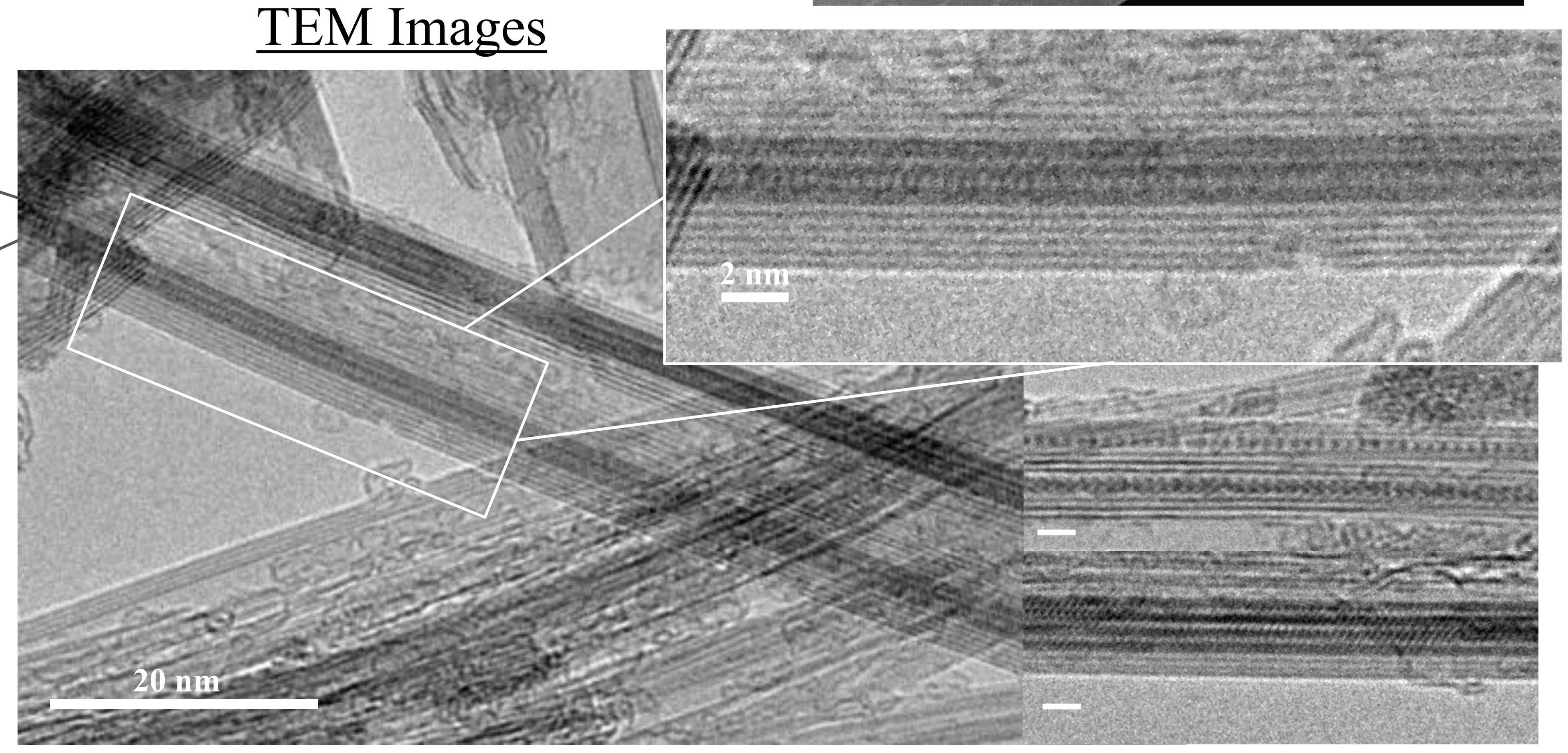


SEM Images



- Scanning electron microscope (SEM) images and Raman spectrum show conditions were favorable to $ZrTe_3$ growth.
- Transmission electron microscope (TEM) images show filling of CNT.

TEM Images



Future Work

- Prove stoichiometry of encapsulated crystals using energy-dispersive x-ray spectroscopy.
- Experimentally study the physical properties of the encapsulated chains and compare to the bulk (3D) crystal

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References

Felser, C.; Finckh, E. W.; Kleinke, H. Electronic Properties of ZrTe3. *Journal of Materials Chemistry* **1998**, 1787-1798.

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