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The Formation of Tin Chalcogenide Nanomaterials

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ACS Chemistry for Life®

Volcano Vista High School Hawks

AML Advanced Materials Laboratory

STAR PROGRAM

AMERICAN CHEMICAL SOCIETY PROJECT SEED

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Safety In The Lab

Sandia National Laboratories

Glove Box

Schlenk Line

Goggles

Lab Coat

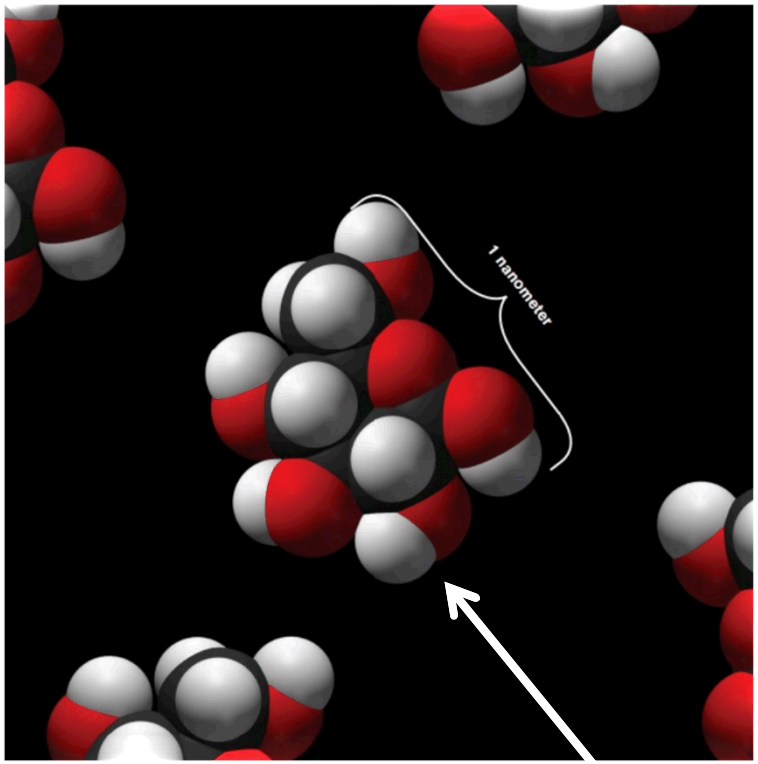
Gloves

Safety Training Courses

- New Employee Orientation
- Chemical Safety Training
- Site -Specific Chemical Safety Training
- Cryogen Safety
- Pressure Safety Orientation
- Neo200
- ES&H Awareness
- Hazardous Waste & Environment Management Training.

What is Nano?

One nanometer is a BILLIONTH of a meter.



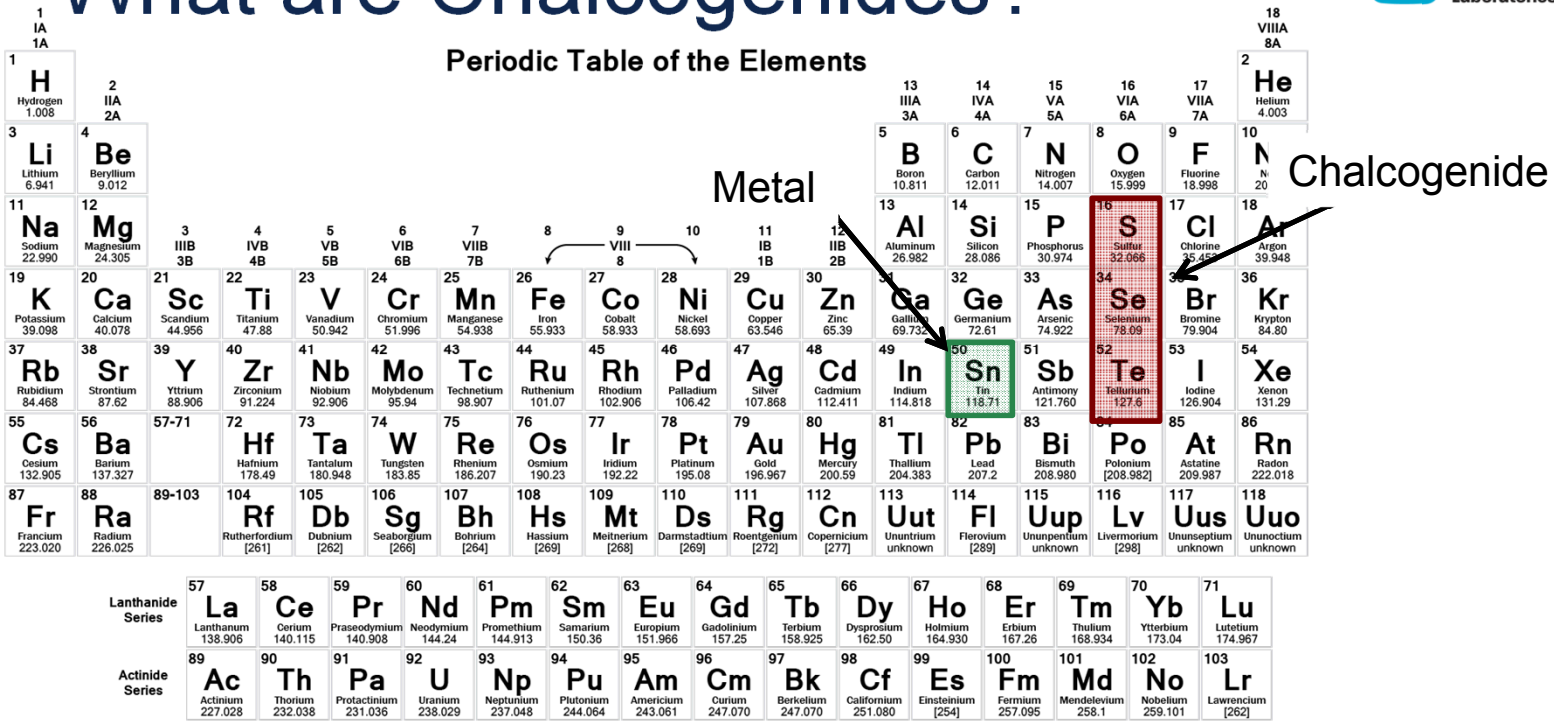
$$1 \times 10^{-9} \text{ of a meter} = \frac{1}{1{,}000{,}000{,}000}$$

A sugar molecule is about 1 nanometer wide.

http://www.nano.gov/sites/default/files/pub_resource/nanotechnology_bigthingsfromatinyworld-print.pdf

What are Chalcogenides?

They are located in group 6A

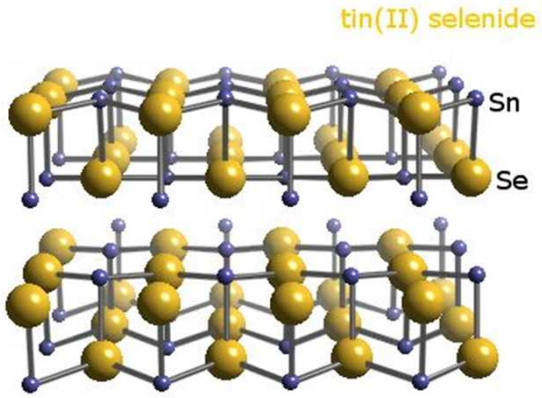


- Group 16 elements are Chalcogens.
- Metal + Oxygen = Metal Oxide (Oxygen is categorized differently)
- I am working with Sulfur, Selenium & Tellurium are Chalcogenides.
- Metal + Chalcogen = Metal Chalcogenide

Tin Chalcogenides

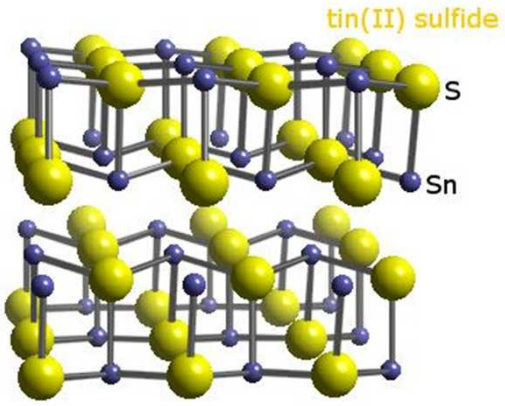
Tin Selenide

- E_g = 0.2eV (Bulk)
- Narrow band gap semiconductor
- Orthorhombic
- CELL: a=4.313Å b=11.703Å
  c= 4.313 Å <90.0 x 90.0 x 90.0>
- Vo l= 217.7
- Density(c) = 6.03



Tin Sulfide

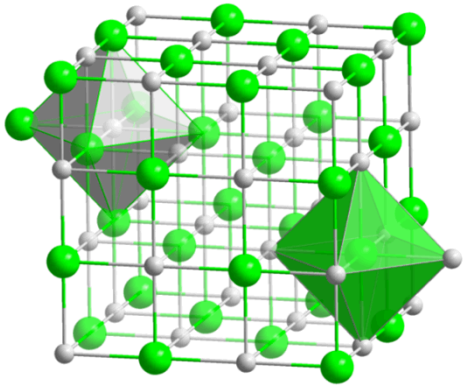
- E_g = 1.0-2.3 eV (Bulk)
- Semiconductor
- Orthorhombic
- CELL: a=4.175Å c=11.42Å
  c=4.125Å <90.0 x90.0 x90.0>
- Vol = 253.3
- Density(c) = 6.46



NaCl Crystal Structure

Tin Telluride

- E_g = 0.18eV (Bulk)
- Narrow band gap semiconductor
- Cubic
- CELL: a=6.327Å b=6.327 Å
  c=6.32751Å <90.0x90.0x90.0>
- Vol = 196.7
- Density(c) = 5.064



Applications

**E= Se, S, Te*

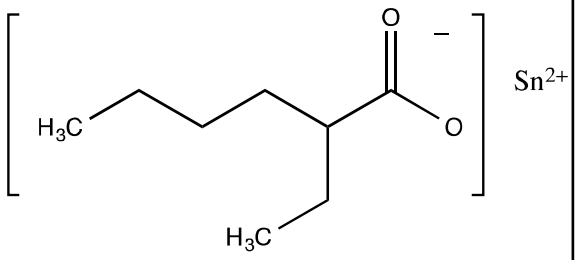
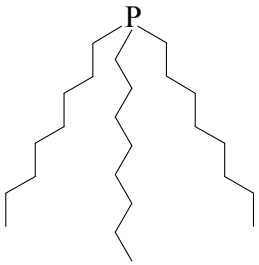
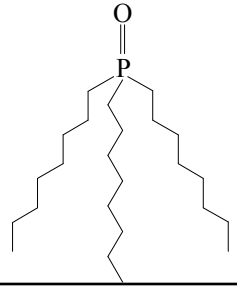
SnE is a potential product that can be use for…

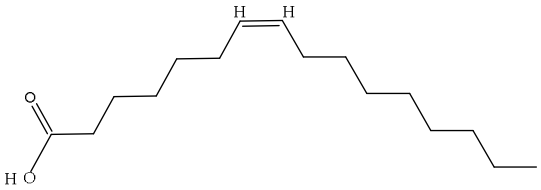
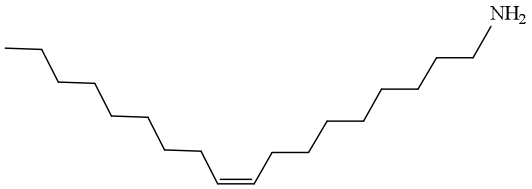
Thermoelectrics

Solar Panels

Infrared

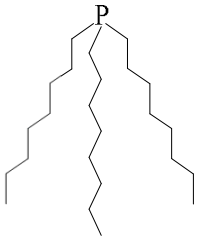
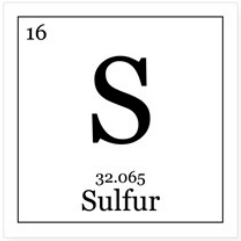
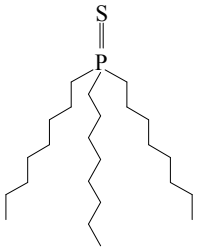
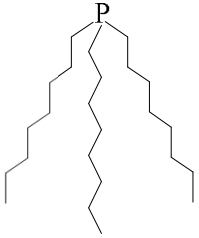
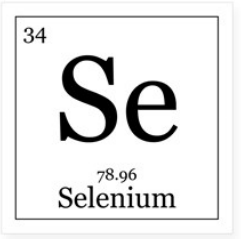
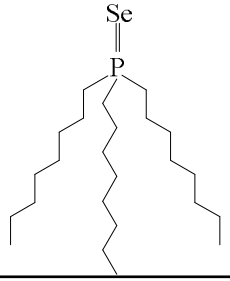
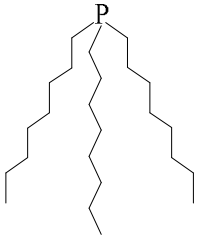
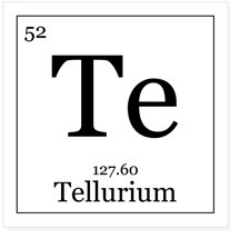
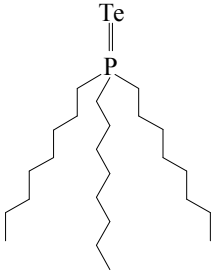
Precursors

Tin(II) Ethylheaxanoate	Trioctylphosphine (TOP)	Trioctylphosphine Oxide
		

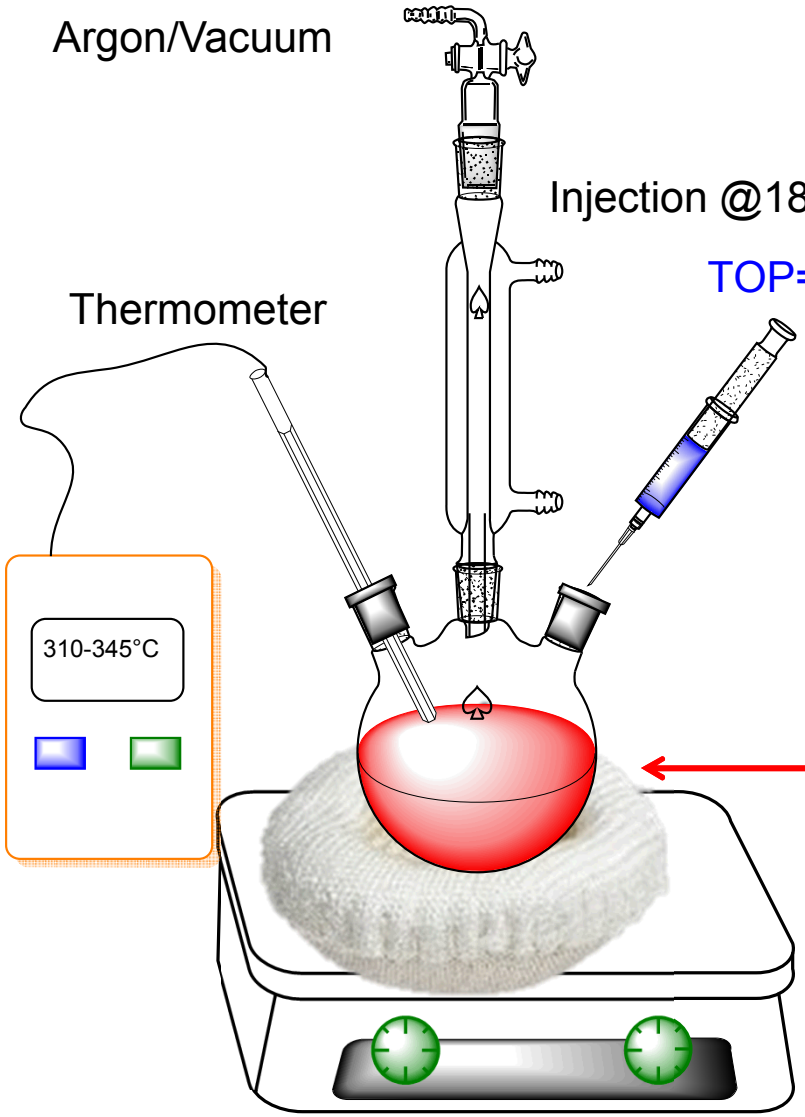
Coordinating Solvents:	**NON-Coordinating Solvent:**
Oleic Acid 	Octadecene 
Oleylamine 	Precursors explored for shape control

Preparation of TOP=E Precursors

TOP + E ⟶ TOP=E

Trioctylphosphine 	**Sulfur** 	**Trioctylphosphine Sulfide** 
Trioctylphosphine 	**Selenium** 	**Trioctylphosphine Selenide** 
Trioctylphosphine 	**Tellurium** 	**Trioctylphosphine Telluride** 

How To Synthesize SnE Nanomaterials



*E= Se, S, Te

Variables

- Time
- Temperature
- Solvent
- Precursor

$Sn(EtHEx)_2$ + Solvent

Time/Temperature

- Injection at 180 °C with TOP=E
- Max Temps between 340−350 °C
- Total Time (1hr 30 minutes)

Characterization

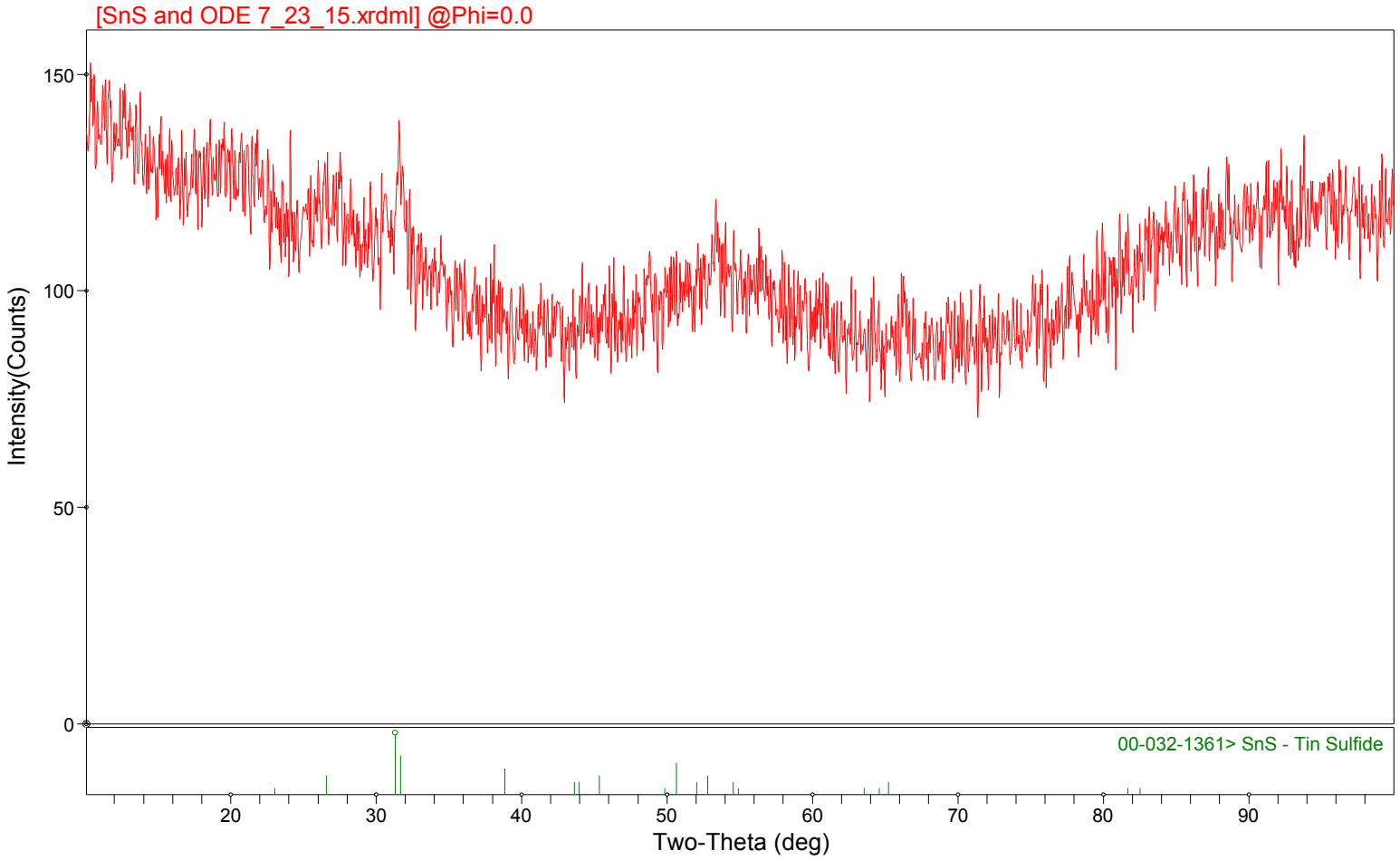
PXRD (Powder X-ray Diffraction): Identifies crystal structure & phase

TEM (Transmission Electron Microscopy): Shows nanoparticle size & shape

SnE Reactions

Tin Precursor	Chalcogen Precursor	Reaction Time	Solvents	Max. Temp. (°C)	XRD Phase	TEM
$Sn(EtHex)_2$	TOP=Se	1 hr. 30 min.	OA	315	SnSe	Mixed Morph. (Sheets, organic) ✓
$Sn(EtHex)_2$ (Temporal Study)	TOP=Se	1 hr. 30 min.	OA	331	SnSe	--- ✓
$Sn(EtHex)_2$	TOP=Te	1 hr. 5 min.	OA	270	SnTe	Organic Shape ✓
$Sn(EtHex)_2$ (Temporal Study)	TOP=Te	1 hr. 35 min.	OA	338	SnTe	--- ✓
$Sn(EtHex)_2$	TOP=S	1 hr. 30 min.	OA	345	Mixed SnS	---
$Sn(EtHex)_2$	ODE + S	60 min.	OA	330	Amorphous	---

Tin Sulfide Reaction with Octadecene



Tin Telluride Morphology

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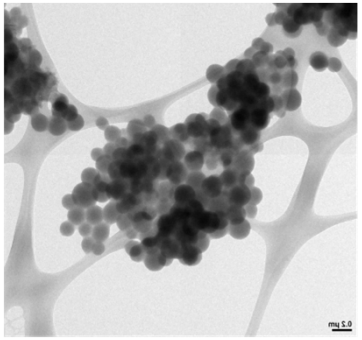
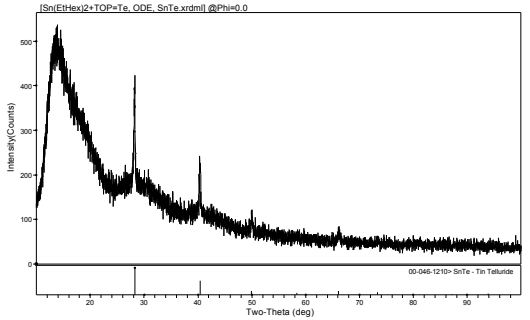
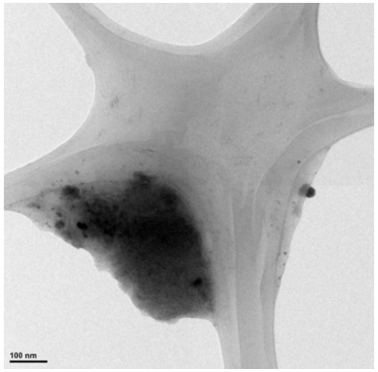
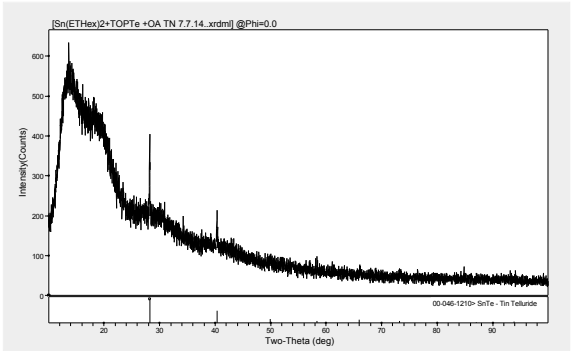
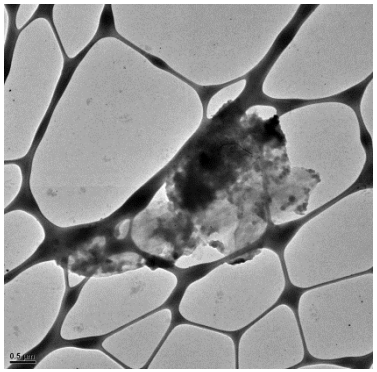
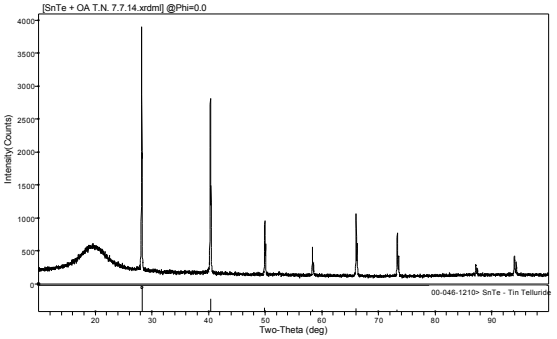
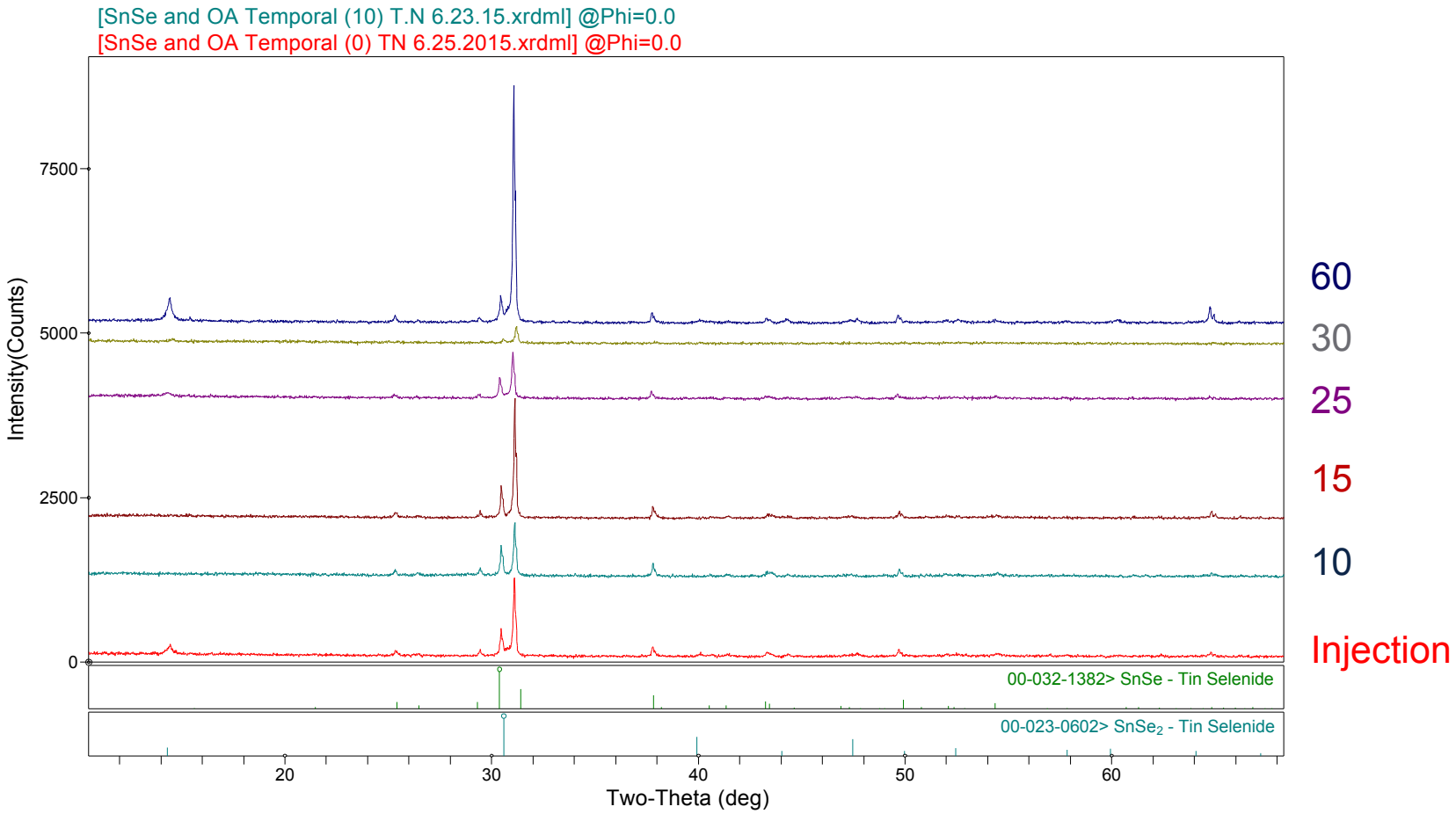
Octadecene		
Oleylamine		
Oleic Acid		

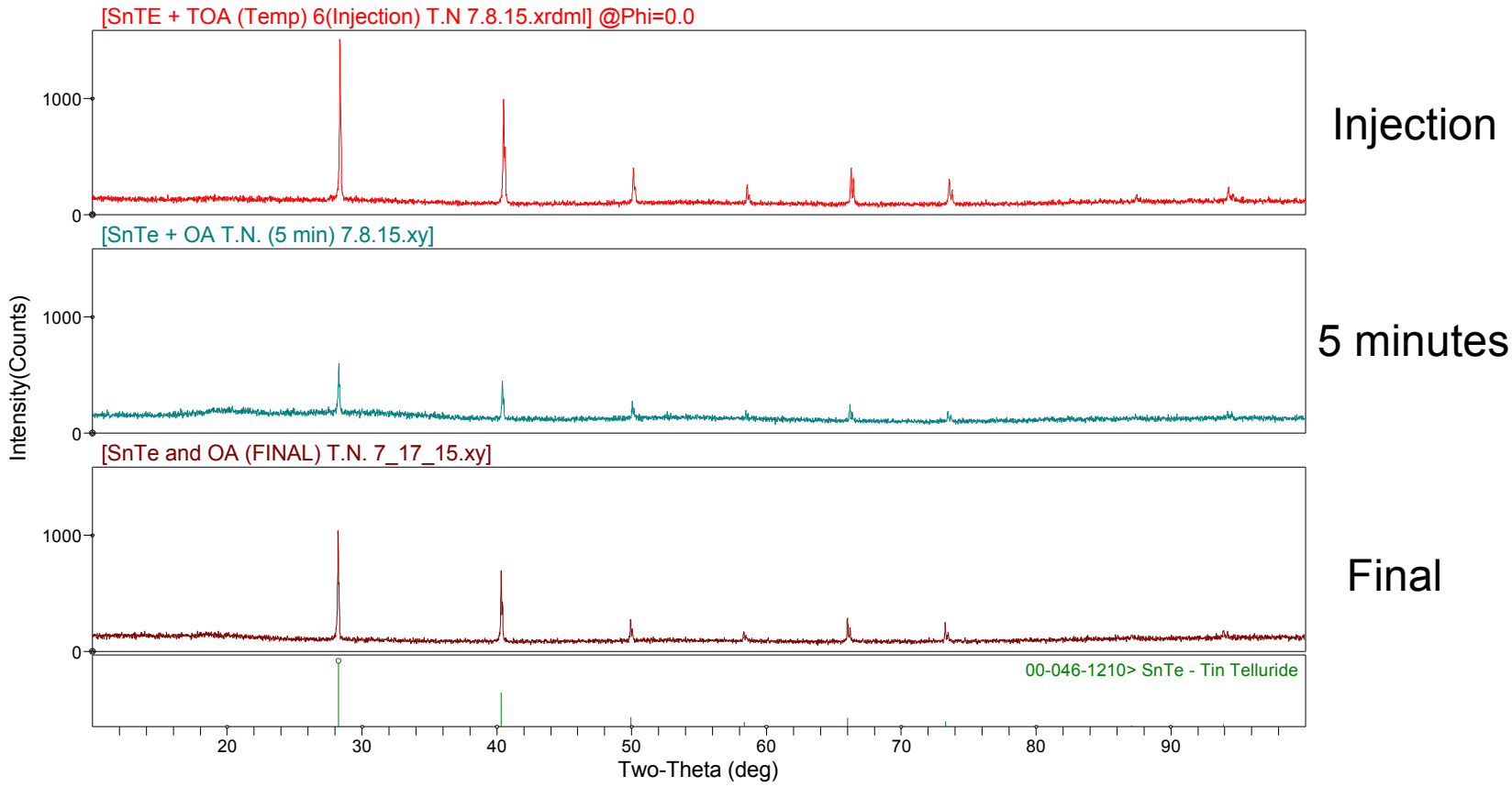
Temporal Study

$$Sn(EtHex)_2 + TOP{=}Se \xrightarrow[\Delta\ 305°C,\ 1hr\ 30\ min]{OA} SnSe$$



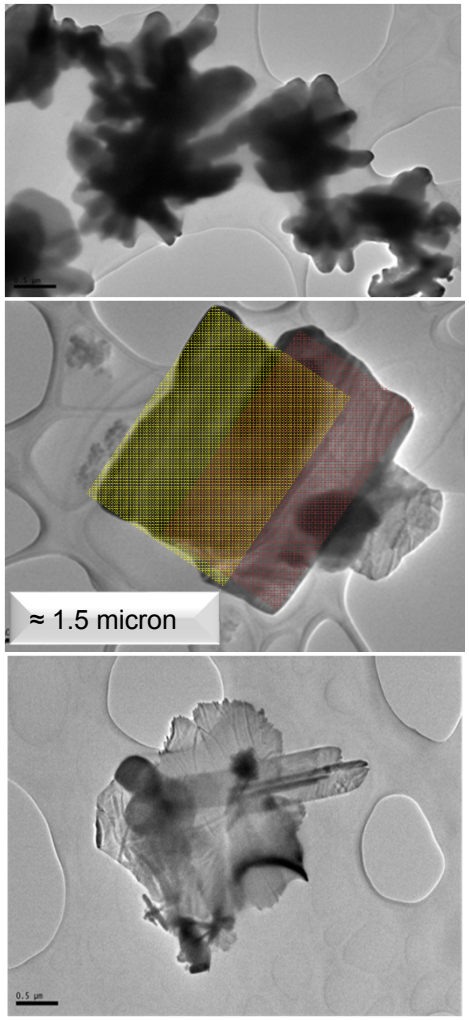
Temporal Study

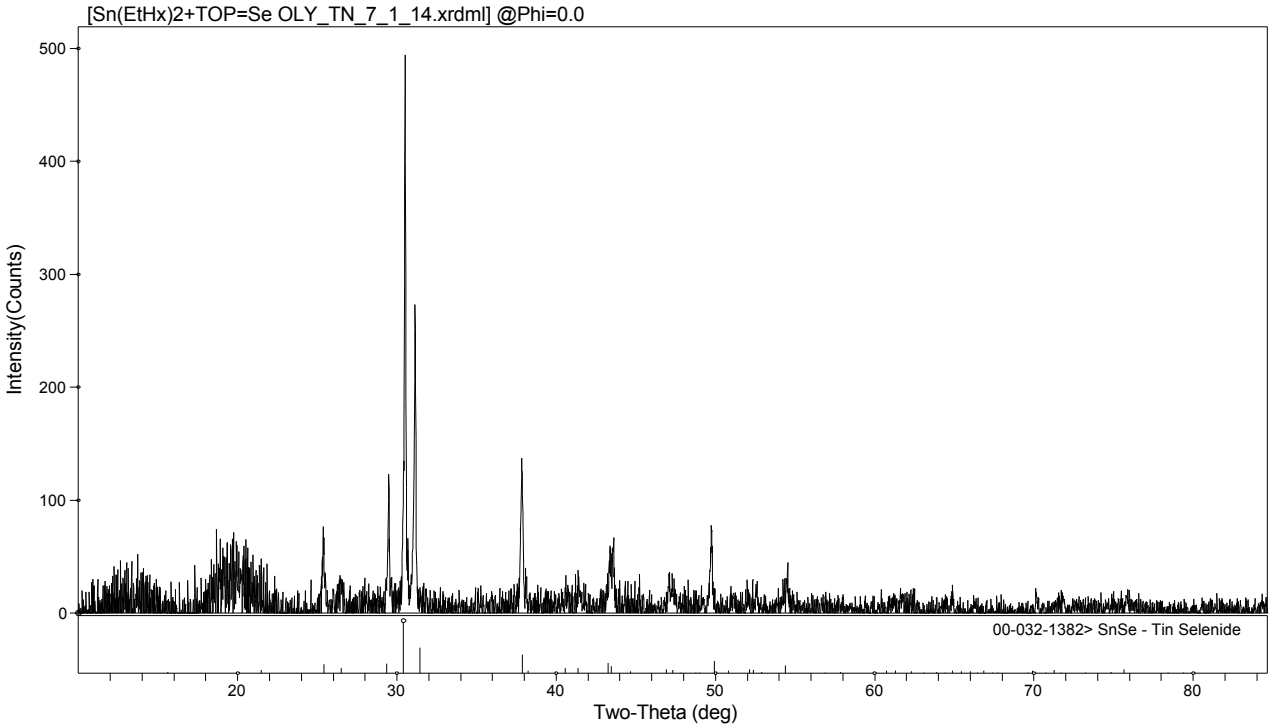
$$Sn(EtHex)_2 + TOP{=}Te \xrightarrow[\Delta\ 305°C,\ 1hr\ 30\ min]{OA} SnTe$$



XRD and TEM

Different morphologies observed for the Same Rxn Condition, SnSe





$$Sn(EtHex)_2 + TOP{=}Se \xrightarrow{OLY} SnSe$$

Δ 305°C, 1hr

What I Learned

- Bulk tin chalcogenide nanomaterial have a band gap of 0.2-2.3 eV and the products can be used as thin film coating for the panel for antireflection.
- Tin Telluride temporal study revealed that product formed right when the chalcogenide was injected.
- Different morphologies can be seen for the same product.