Physical Vapor Deposition of Thin Films Tungsten Diselenide (WSe_2)

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Abstract

The interest of a better semiconductor for highly specialized electronic devices, such as photo couplers, gas sensors, solar cells, e-papers, non-volatile memory, etc., has recently shifted to a group of Transitional Metal Dichalcogenides (TMDCs), specifically Tungsten Diselenide (WSe_2), because of its unique characteristics in the monolayer form. Finding a standardized method to synthesize high quality monolayer WSe_2 should push the study forward and promote the application of such material.

Monolayer Tungsten Diselenide (WSe_2)

- Transitional Metal Dichalcogenides (TMD/TMDCs)
- Monolayer "sandwich" structure:
  - Se / W / Se
  - Trigonal Prismatic geometry
- Thickness of one layer: **~0.9 nm** (Zhang [1])

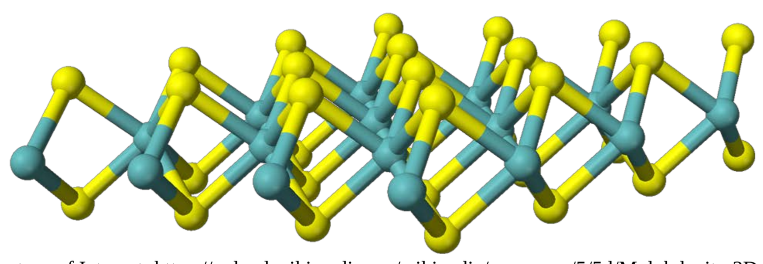
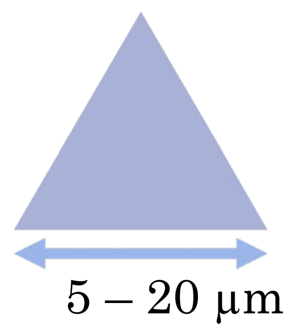


Image courtesy of Internet, https://upload.wikimedia.org/wikipedia/commons/5/5d/Molybdenite-3D-balls.png

- A **direct band gap** makes monolayer WSe_2 a promisingly good semiconductor for LEDs, optoelectronics, touchscreen, etc.

Bulk	→	Monolayer
~1.2 eV (Si: 1.1 eV)		~1.6 eV
Indirect Band Gap		Direct Band Gap



Motivation

- The need of a **reliable, consistent** and **low-cost** synthetic method that is **compatible** with the current literature of monolayer WSe_2

Project Objectives

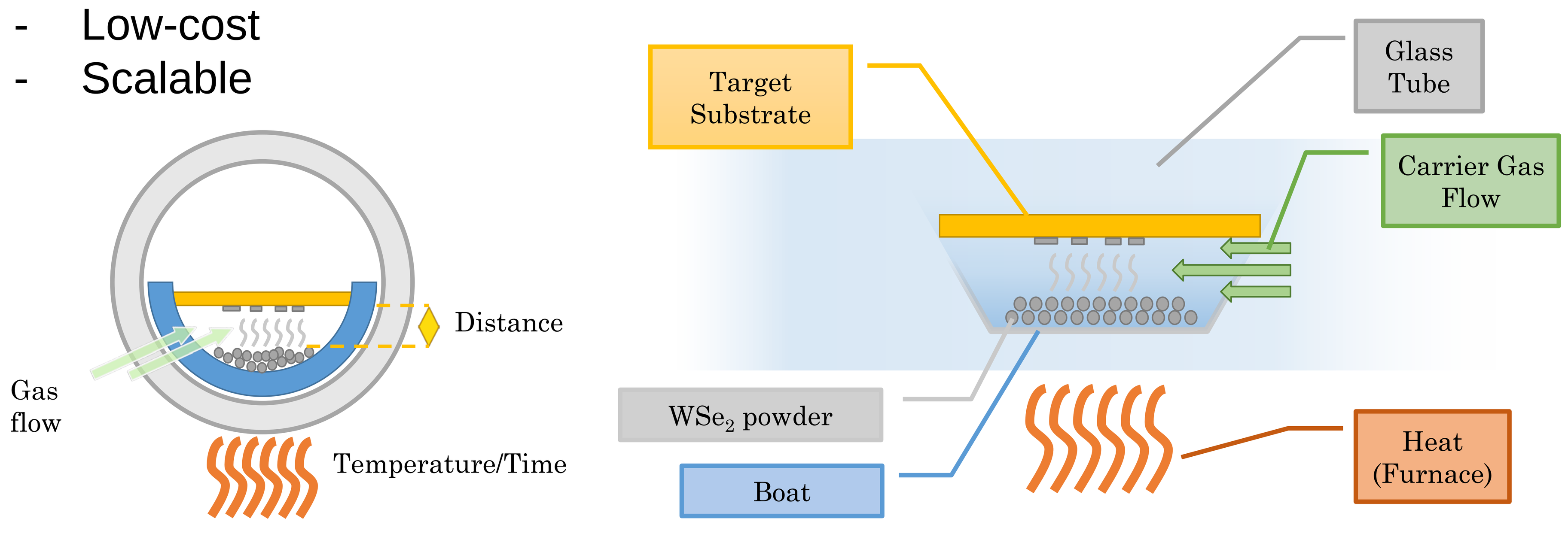
- Use Physical Vapor Deposition (PVD) method to synthesize monolayer WSe_2
- Study how the input parameters affect the growth
- Find an optimal set of parameters that give consistent results

Physical Vapor Deposition (PVD)

Solid Source → (Vaporization) → Vapor → (Deposit) → Solid

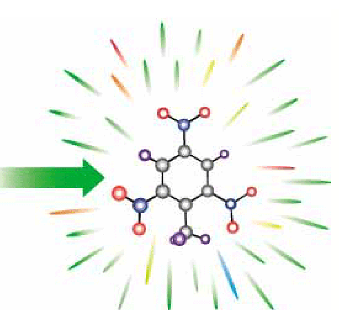
Advantages of **Physical Vapor Deposition**:

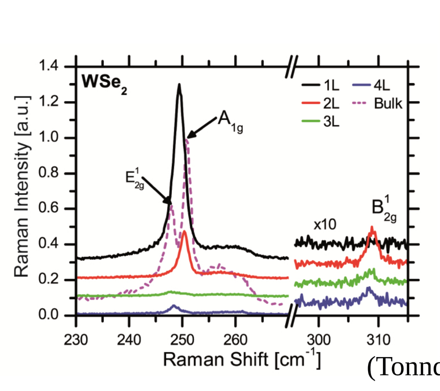
- Ability to produce **high quality** thin WSe_2 films in **large quantity**
- Straight-forward, simple experiment setup
- Low-cost
- Scalable

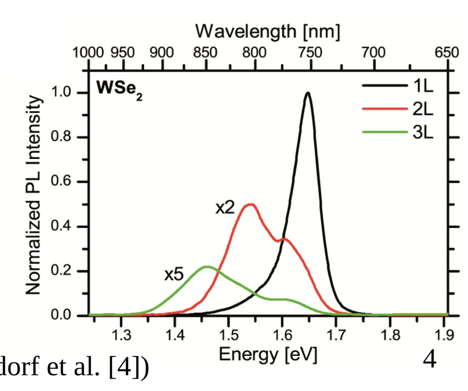


Characterization

Raman Micro-scope







(Tonndorf et al. [4])

Optical Microscope - Up to 100x

Raman Spectroscopy:

- Detects the vibrational, rotational, low-energy modes
- Gives a unique "footprint" for each different materials

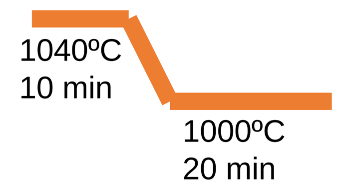
Photoluminescence (PL):

- Observes light emission after photon excitation
- Detects band gaps

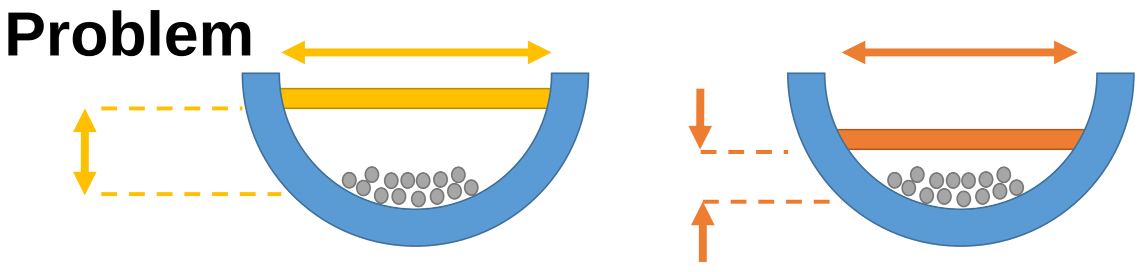
Experimental Data

Good Parameters

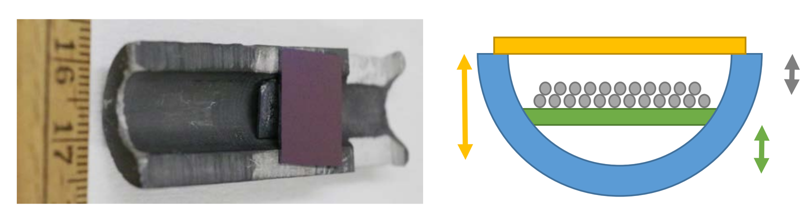
150 scc/m Ar
0.05 g WSe_2

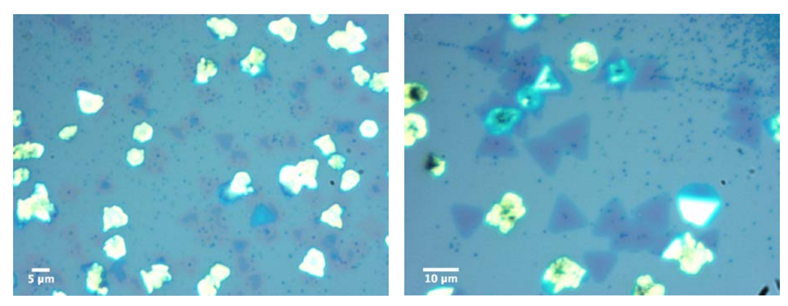


Problem



Distance Control Approach #1





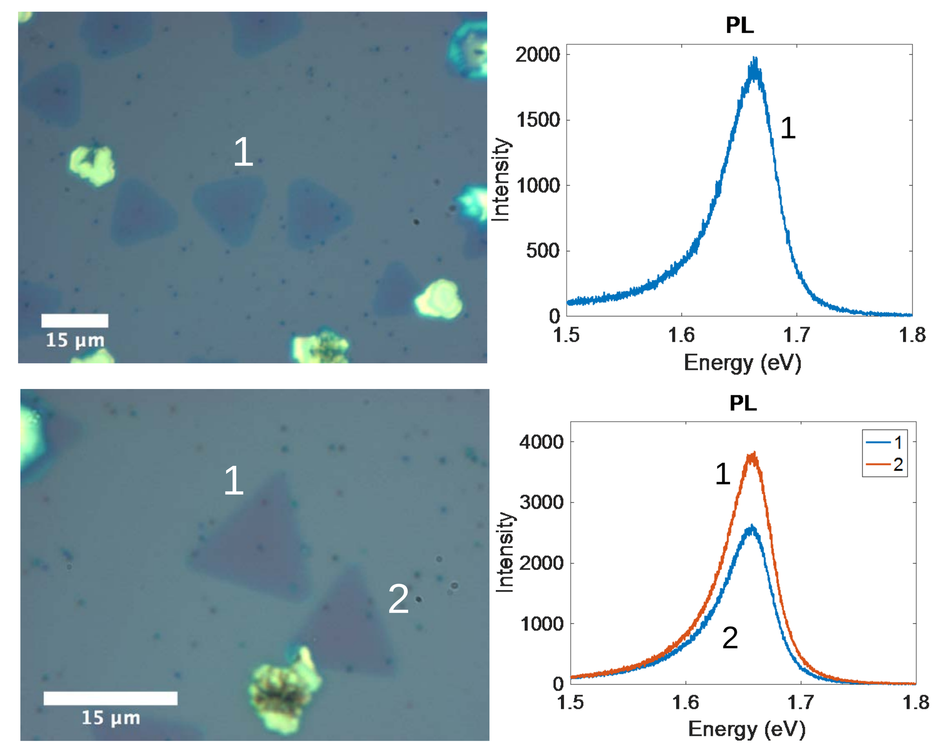
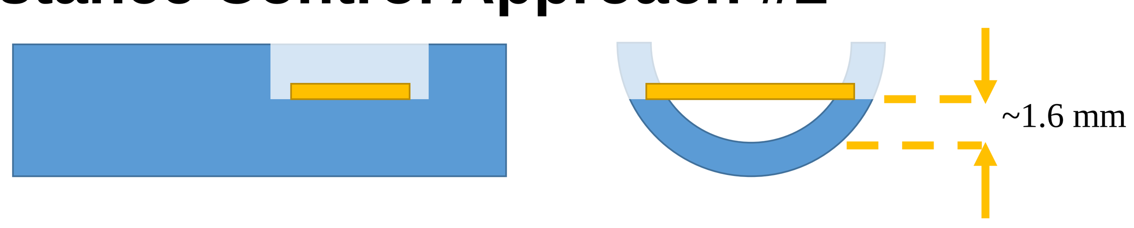


Figure 1a, 1b. Two different experiments with the same parameters and same distance control ▲
Figure 2a, 2b. Optical Image and Photoluminescence (PL) spectra of the results ▸

Distance Control Approach #2



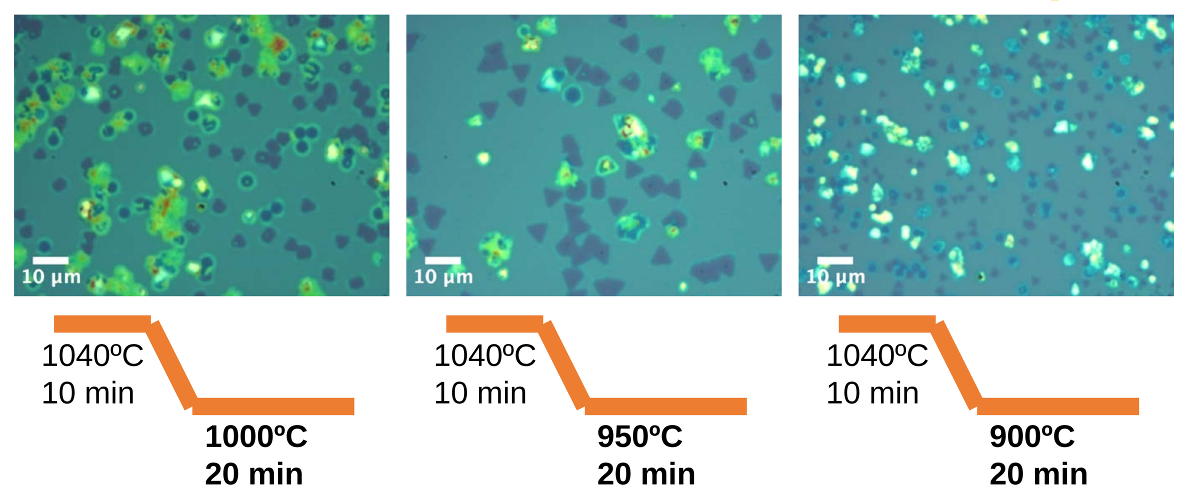


Figure 3a, 3b, 3c. The results of three experiments with three different temperatures

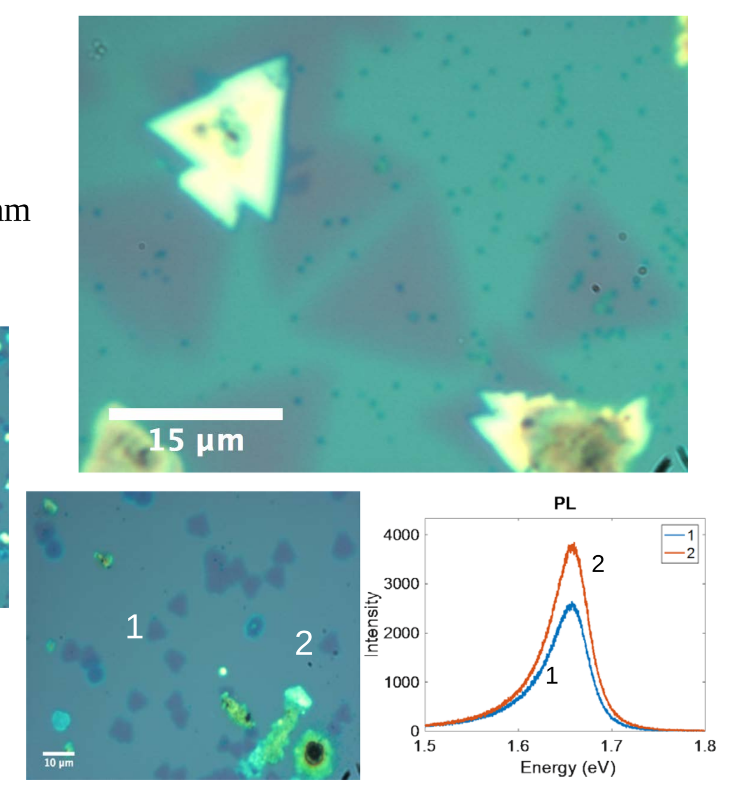
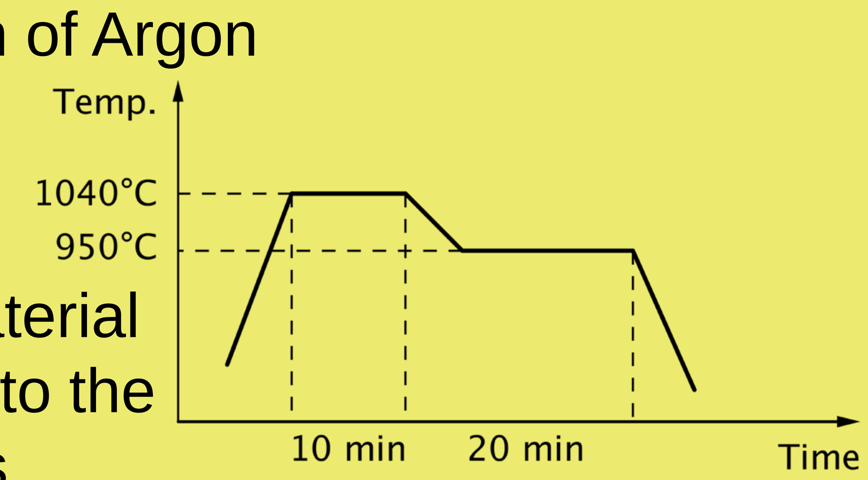


Figure 4a, 4b, 4c. Optical image and Photoluminescence (PL) spectra of the 1040ºC/950ºC result

Project Results

- The **distance** between the source material and the target substrate is **critical** to the growth of WSe_2
- The following **parameters** should result in good growth (thin flakes in dense population):
  - Temperature profile: 1040ºC/950ºC
  - Time: 10/20 minutes (respectively)
  - Gas flow: 150 standard cm^3/min of Argon
  - Distance: 1.6 mm



Further Study

- Deeper characterization of the material
- Application of the thin films WSe_2 to the next generation electronic devices

References

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Support Information

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