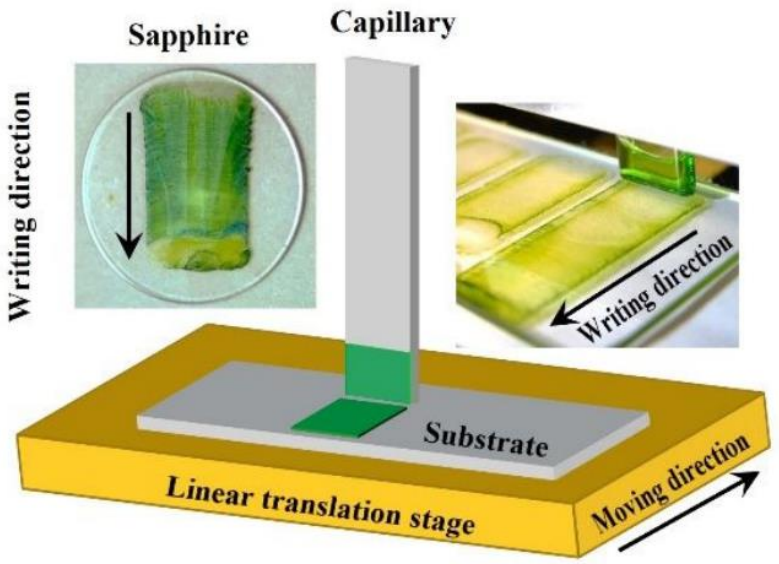
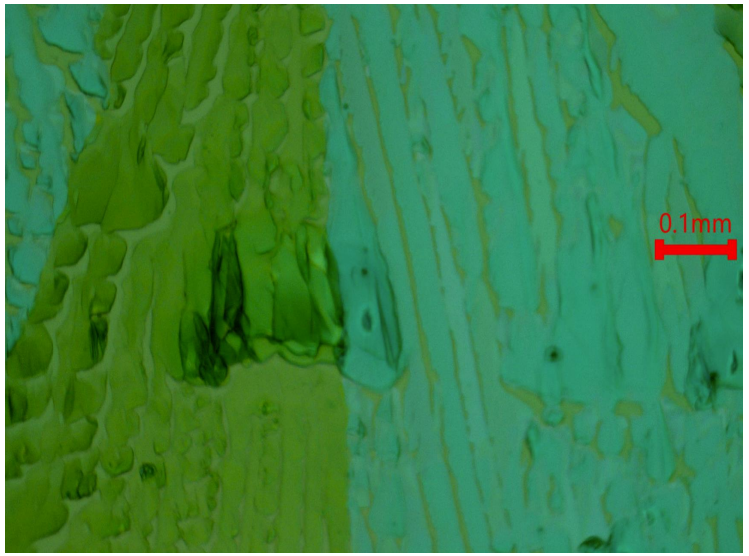
Linear Dichroism (LD) & Absorption Characterization of Solution-Cast Organic Semiconductor Thin Films



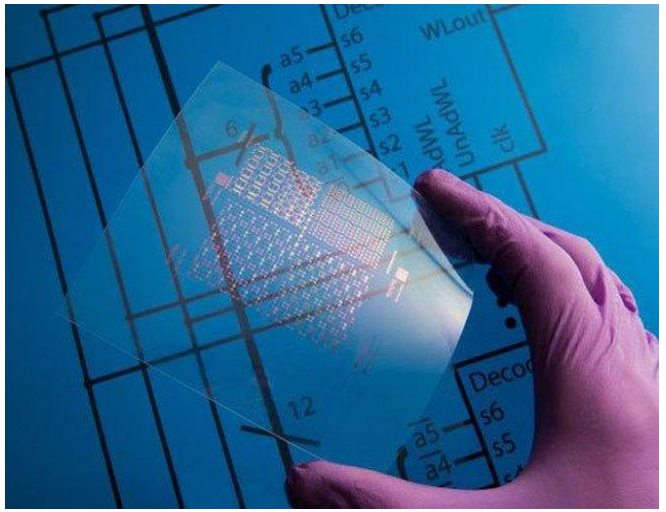


Presenting : Hilbi Akbar
Research Group: Dr. Furis Group (Condensed Matter Physics)
hilbi.akbar-1@ou.edu
Homer L. Dodge Physics & Astronomy Department
Center for Quantum Research Technologies
University of Oklahoma

Motivation

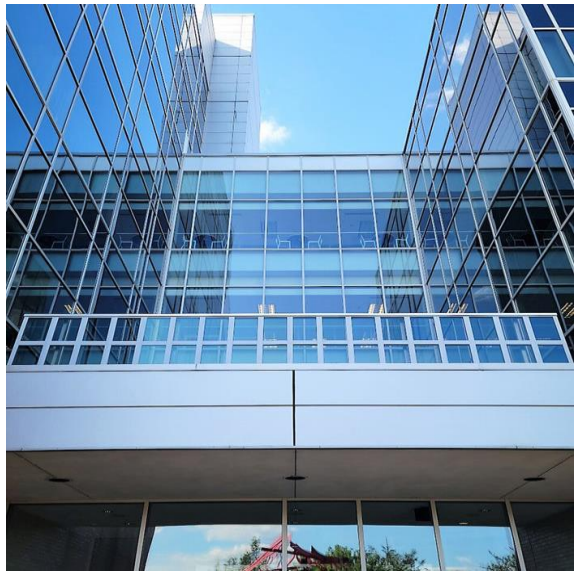
Organic Semiconductors have many advantages over inorganic semiconductors including:

- **Flexibility**
- **Low-Cost manufacturing**
- **Environmentally friendly**

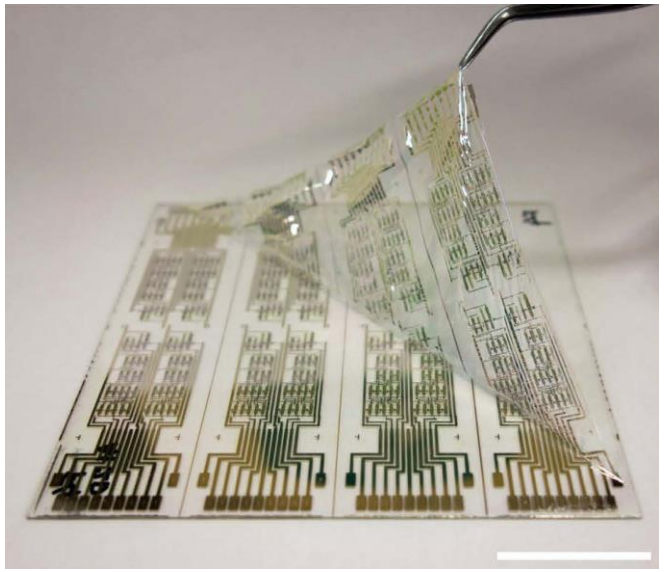


Applications of Organic Semiconductors

Flexible Organic display



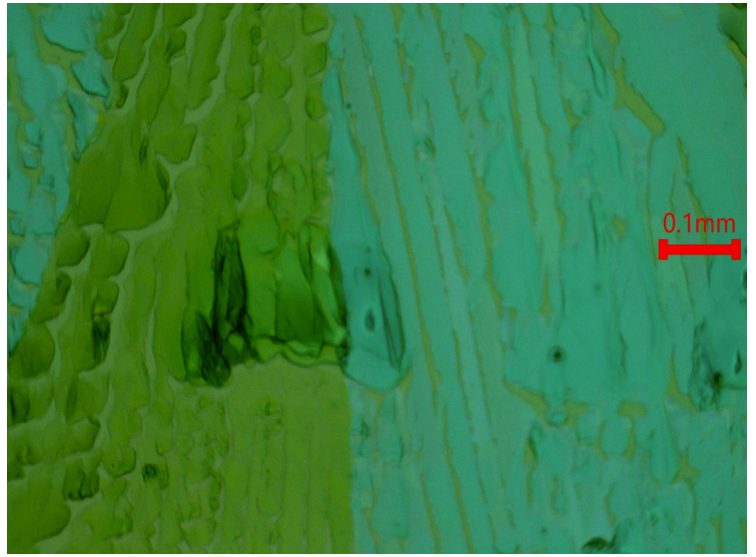
Biomedical & Physical Sciences Building Michigan State University

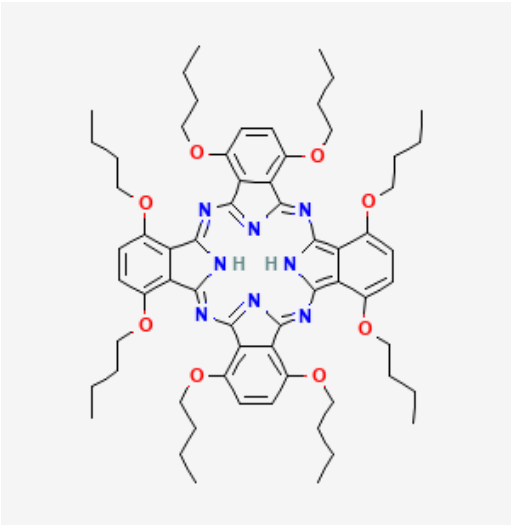


Organic Field-Effect Transistor (OFET)

My REU Project

How do the optical properties of organic thin films evolve when the morphology of the film changes?

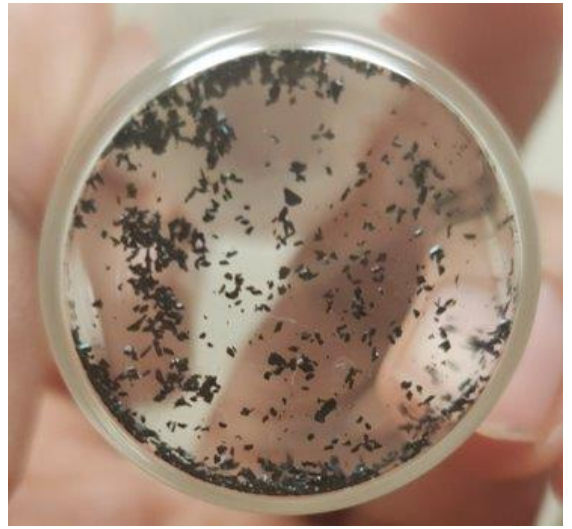




Phthalocyanine ($H_2$0BPc)

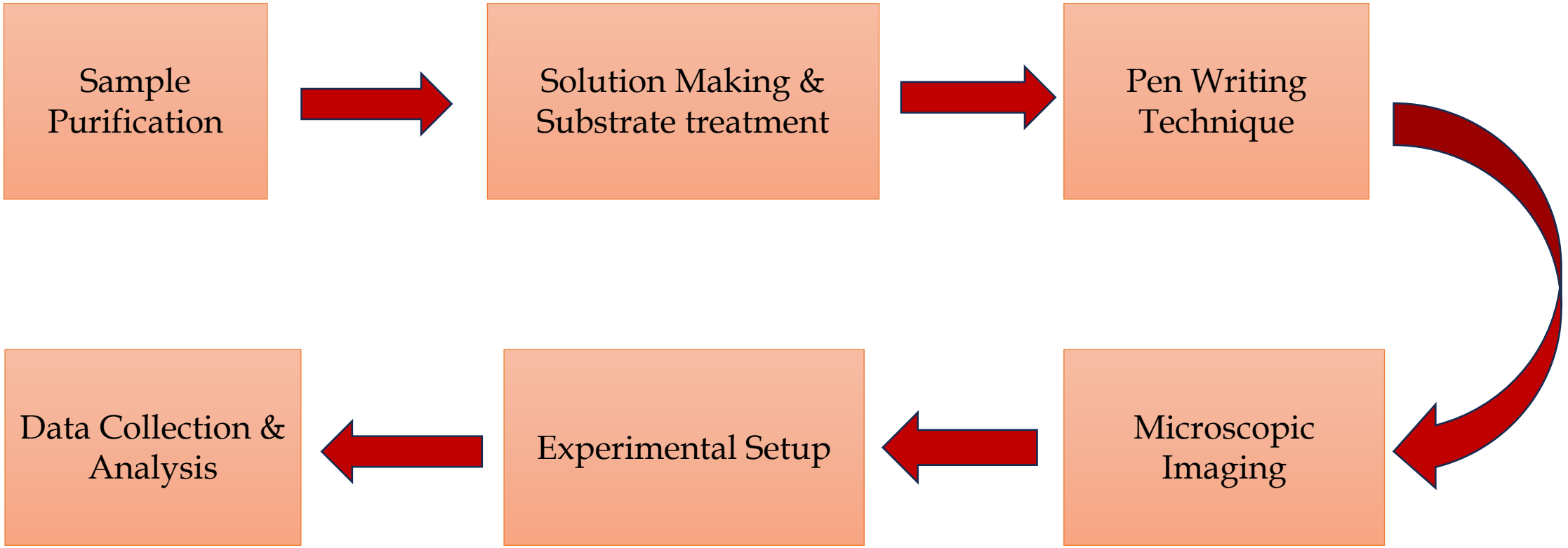
Leaves (Chlorophyll)

Solution & recrystallization



Purified $H_2$0BPc Crystals

Outline


Sample Purification
Solution Making & Substrate treatment
Pen Writing Technique
Microscopic Imaging
Experimental Setup
Data Collection & Analysis

Important Concepts

- **Linear Polarization:**

The direction of electric field vector does not vary with time or position

- **Absorption & Transmission:**

How much light is absorbed Vs how much passes through the sample. $I = I_0 e^{-\alpha d}$ → A

- **Linear Dichroism (LD):**

The effect of causing different polarizations to be absorbed by different amounts.

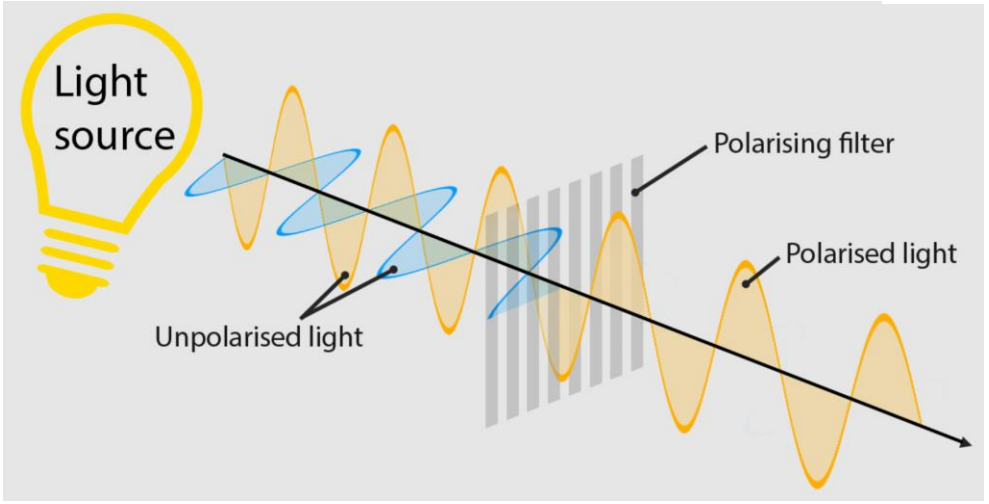
$$LD = A_x - A_y$$

$$OR$$

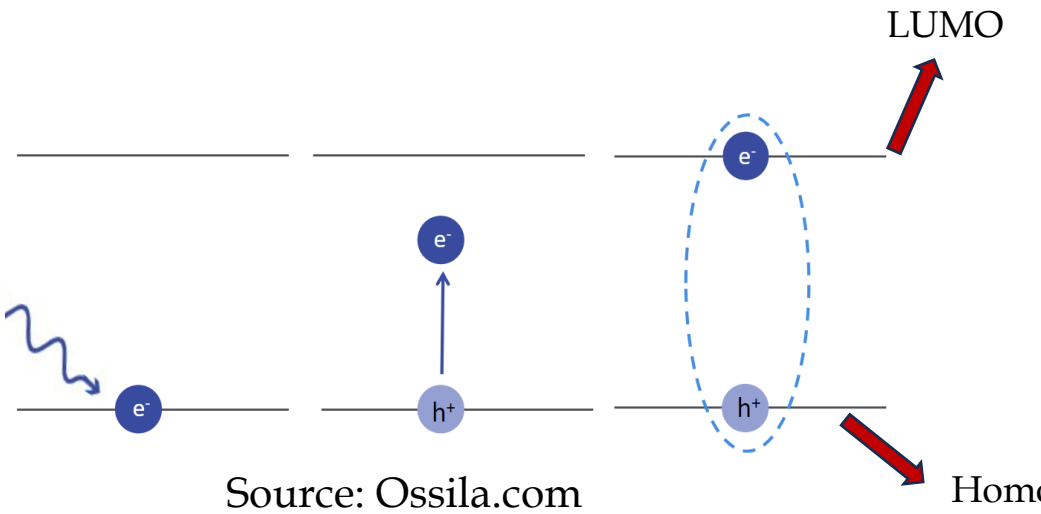
$$LD = A_{||} - A_{\perp}$$

- **Exciton:**

The combination of negatively charged electron and positively charged electron hole which interact through the electrostatic Coulomb Force (Transition Dipole).



Source: Physics Stack Exchange



Source: Ossila.com

How do we make our samples?

1. Purification & Solution Making process

I. Column Chromatography & Rotary Evaporation

II. Concentration (Pc in Toluene): $\boldsymbol{C = \frac{m}{V} \times 100\%}$

2. Substrate Treatment:

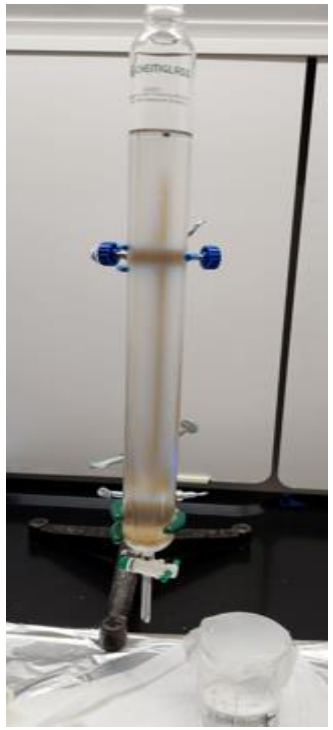
I. Cleaning with soap and water

II. Sonication in Toluene

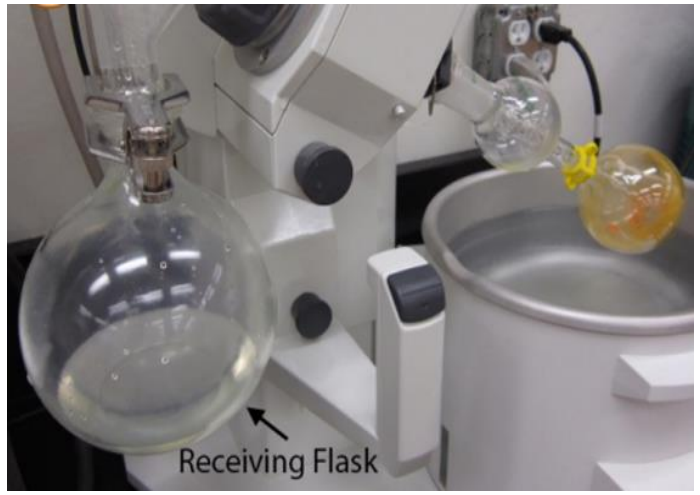
III. Dry cleaning with Nitrogen

IV. Ozone cleaning

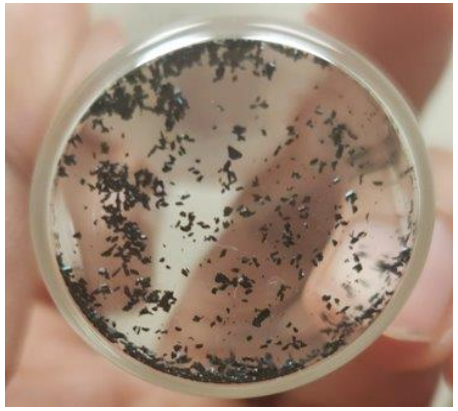
A. Column Chromatography



B. Rotary Evaporation

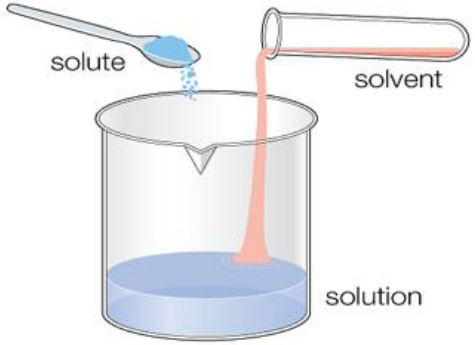


C. Recrystallization



Purified H_2OBPc Crystals

D. Solution Making



E. ITO Treatment

Pen Writing vs Spin Coating

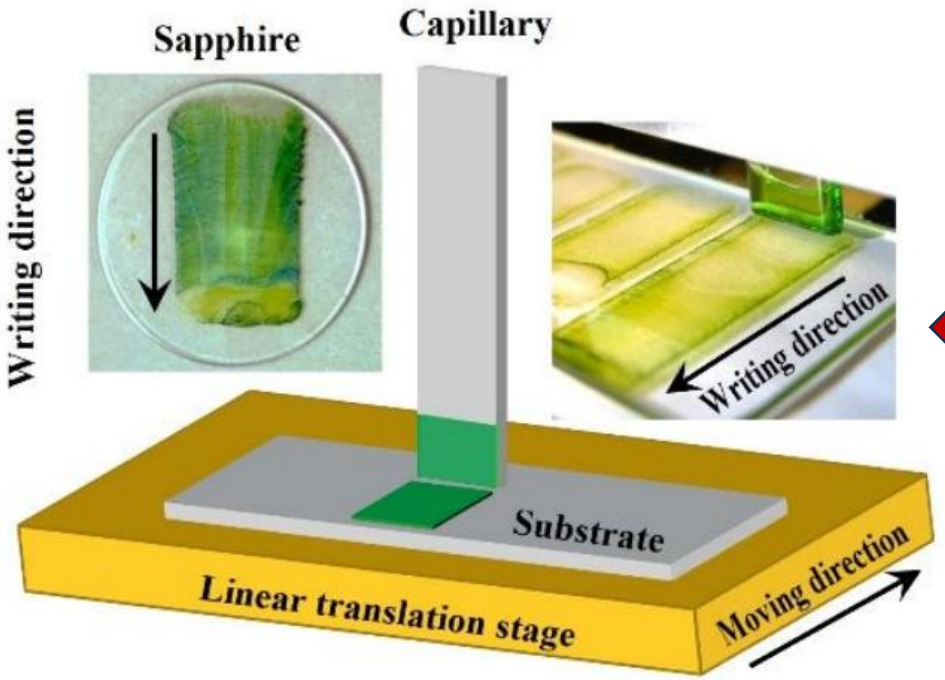
3. Put the solution carefully into the capillary tube using a pipette.

Different parameters:

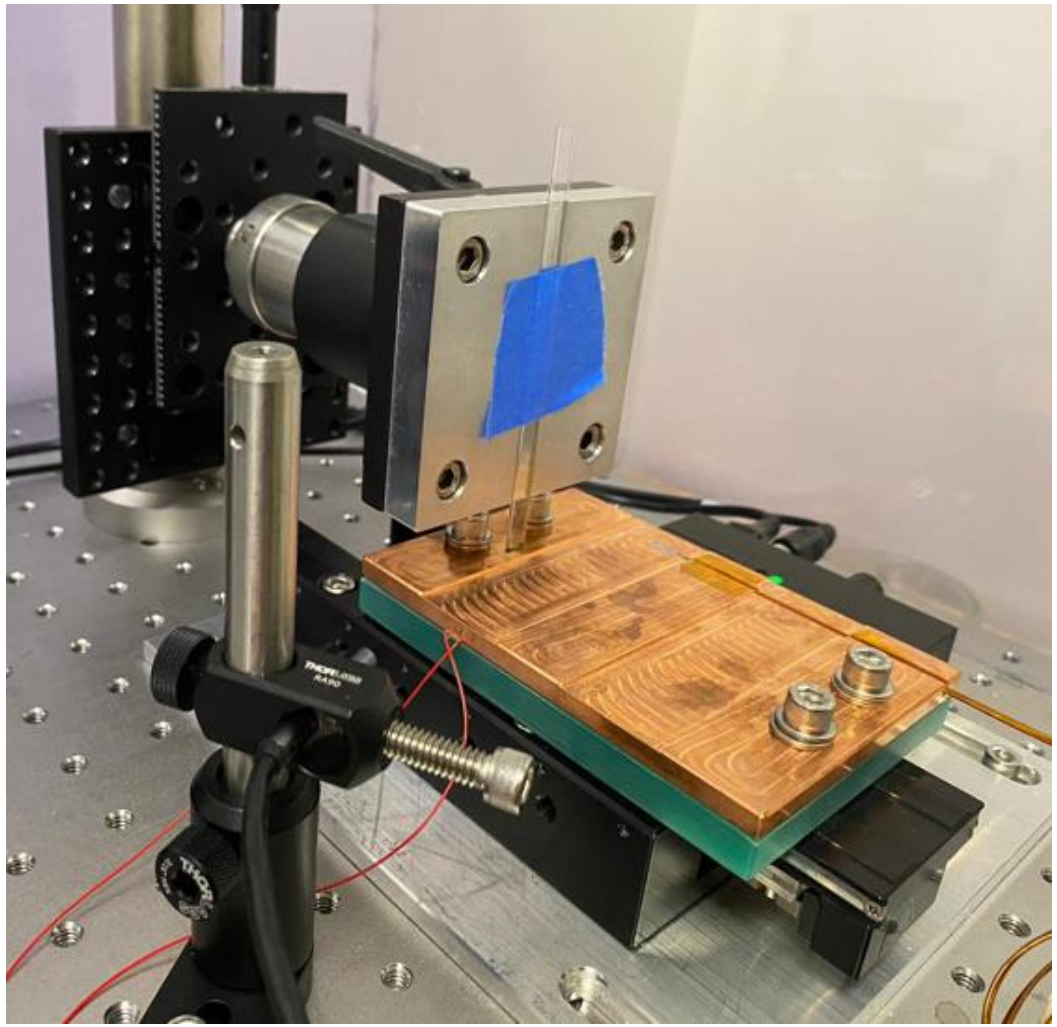
I. **Concentration (Pc in Toluene) :** 0.1% & 0.5% : $\boldsymbol{C = \frac{m}{V} \times 100\%}$

II. **Substrate Temperature:** 25 ℃ *to* 60 ℃

III. **Pen-Writing Speeds:** 18 µm/s to 700 µm/s



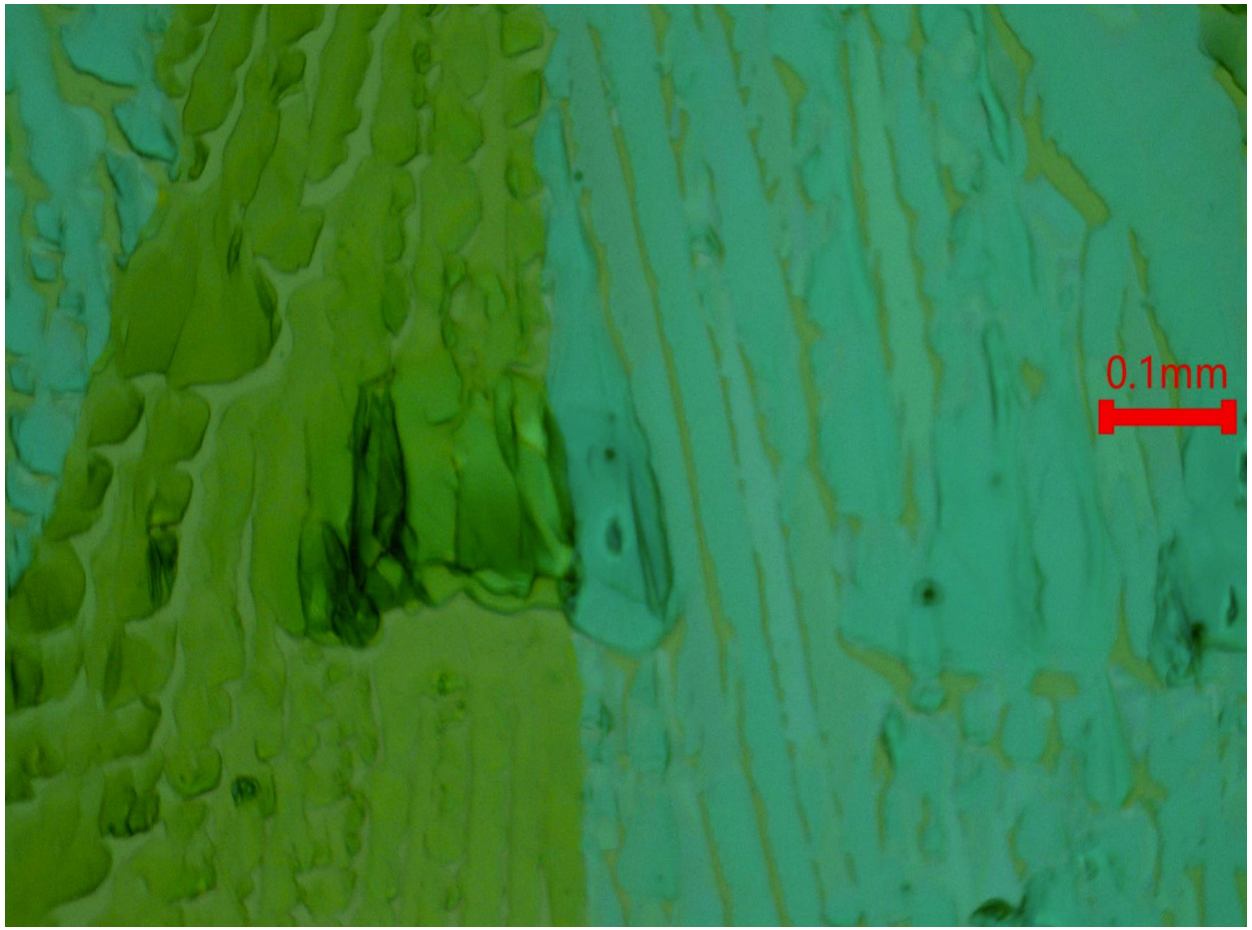
Thin Film Making



Pen Writing Stage

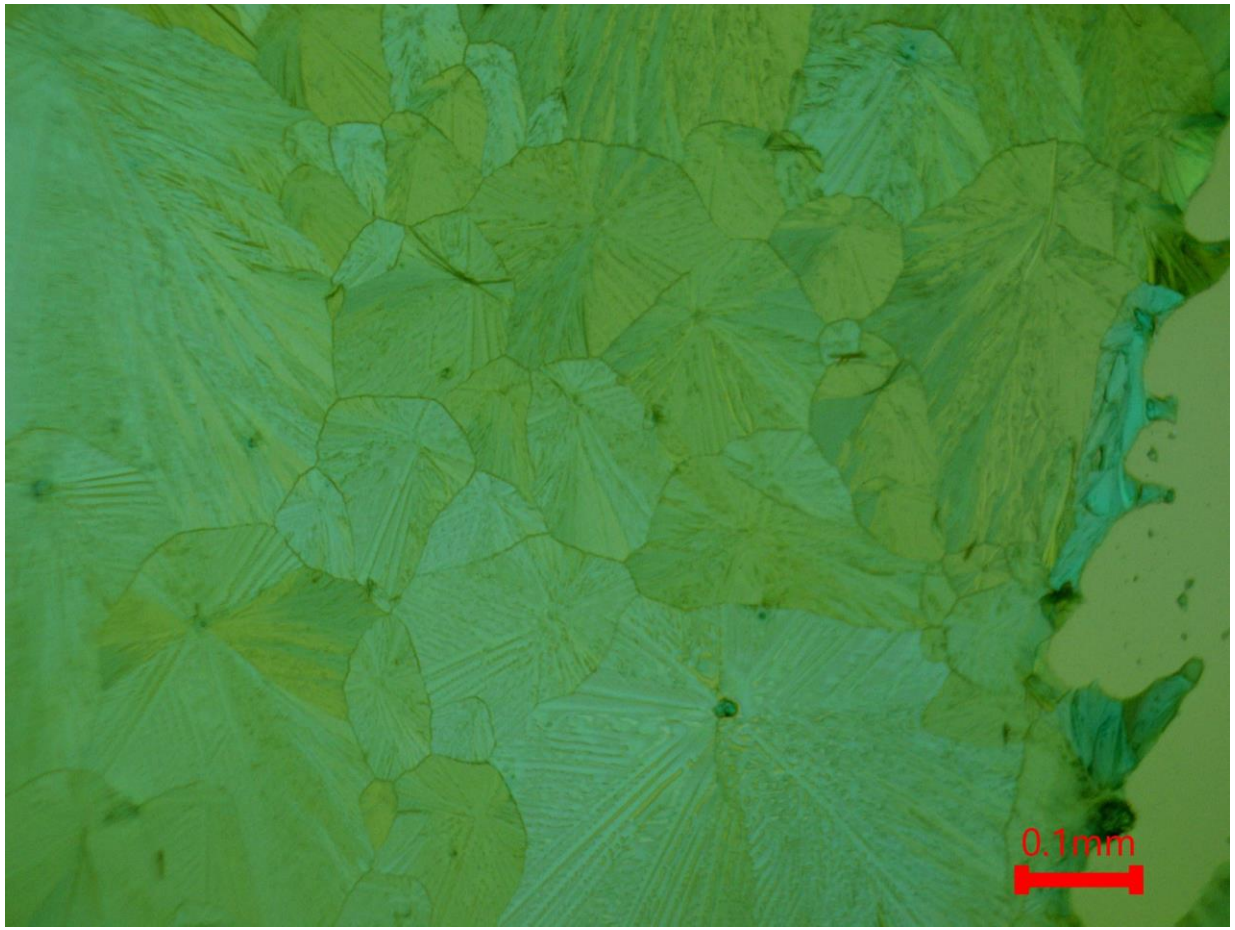
Microscopic Imaging: 0.5%, 25°C

Grain Like structures



16 $\mu m/s$

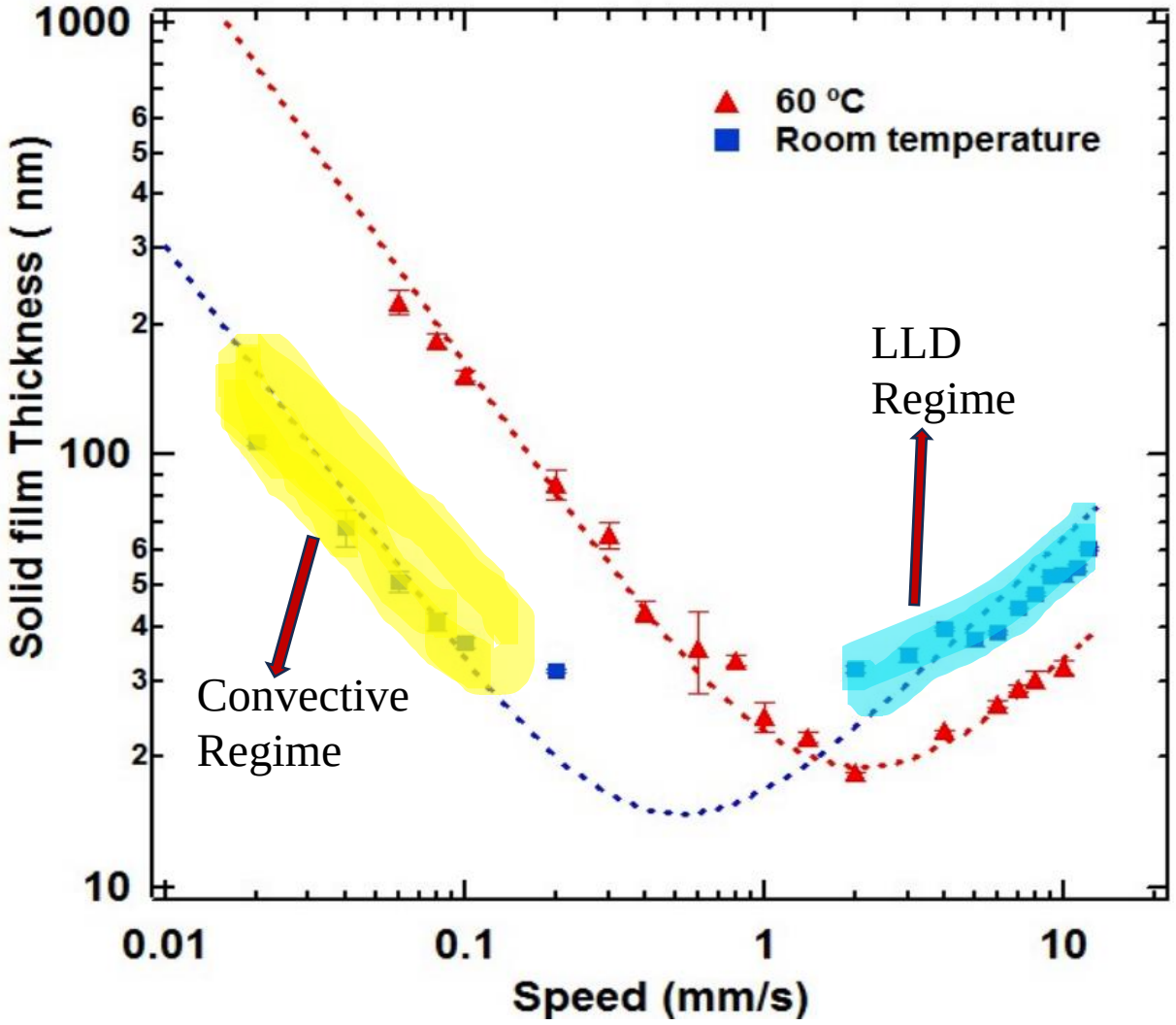
Fan Like structures



40 $\mu m/s$

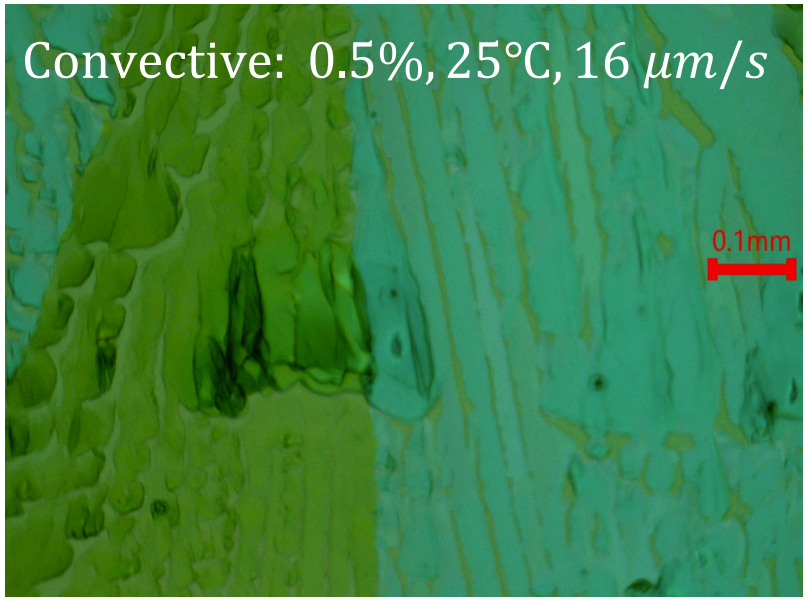
Convective & LLD regime

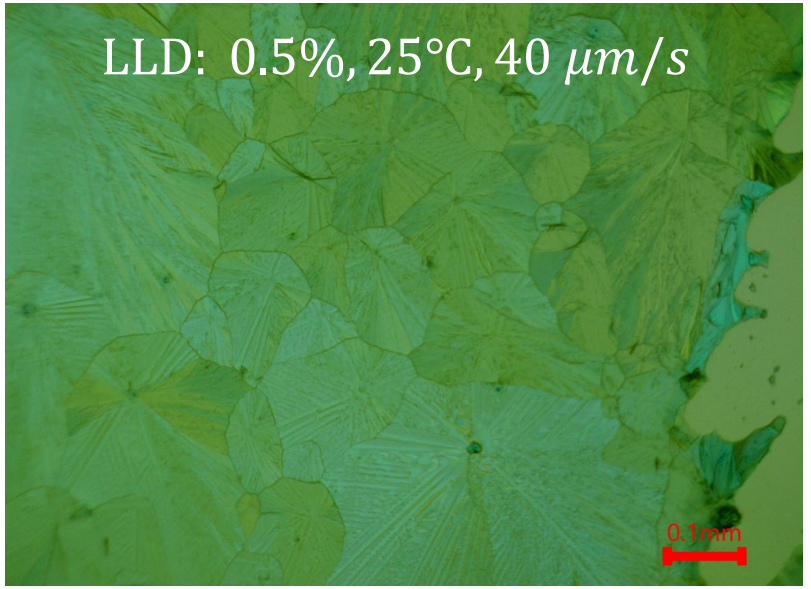
TIPS Pentacene



$h \sim v^{-1}$

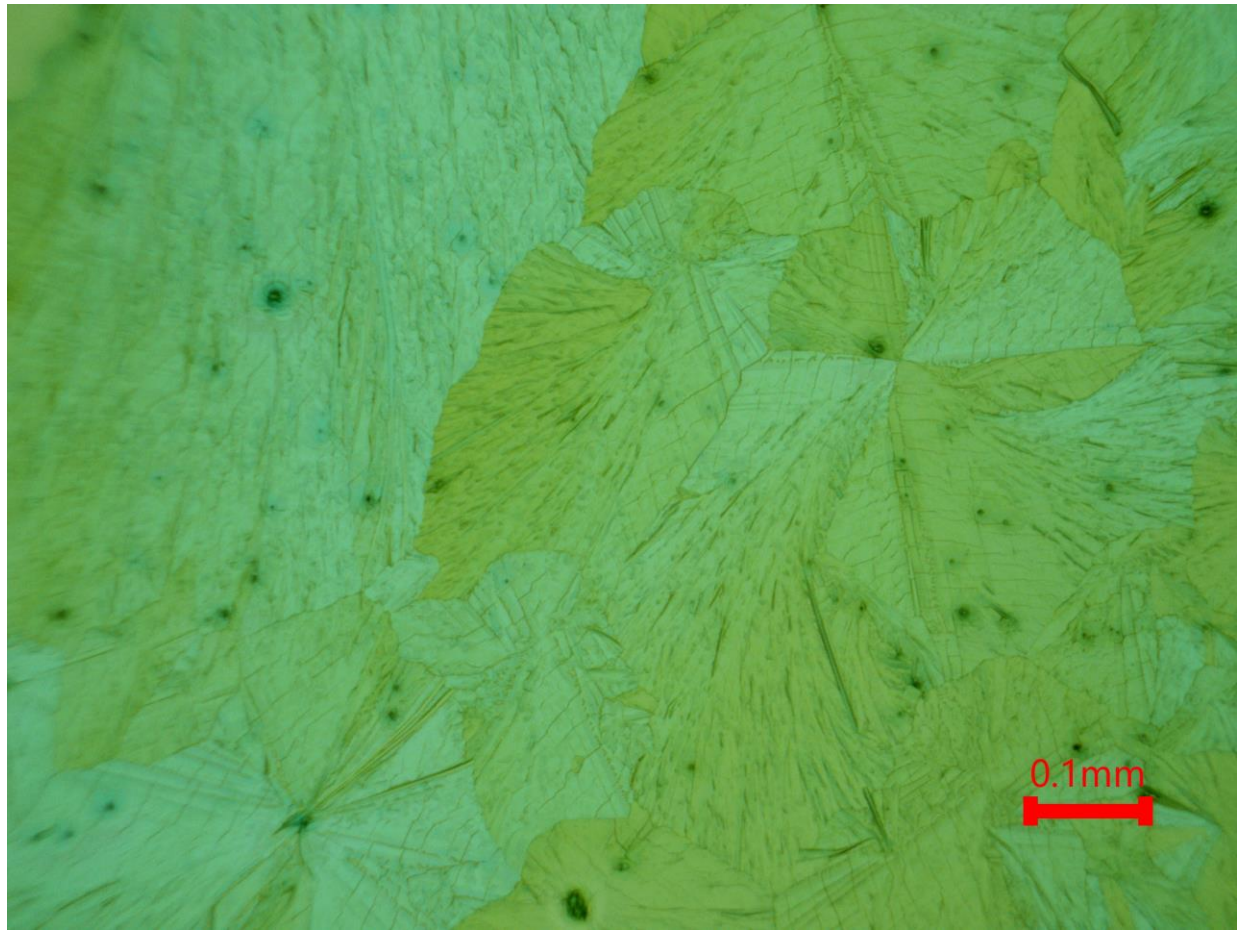
$h \sim v^{2/3}$



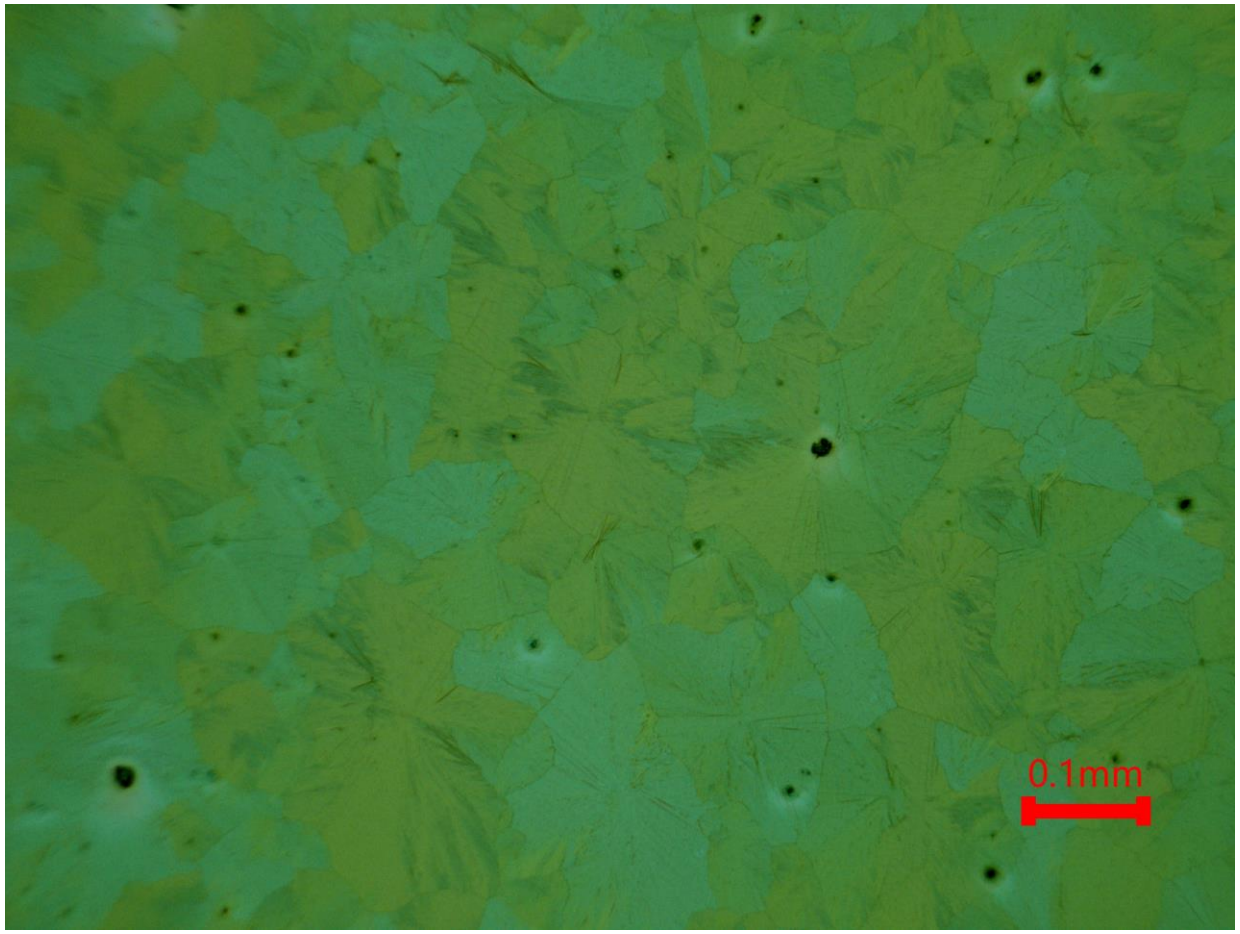


Landau-Levich-Derjaguin; Ishviene Cour;Randall L. Headrick et al **"Origin of stress and enhanced carrier transport in solution-cast organic semiconductor films"** ***Journal of Applied Physics*** **114, 093501 (2013)**

Samples Continued: 0.5%, 60°C

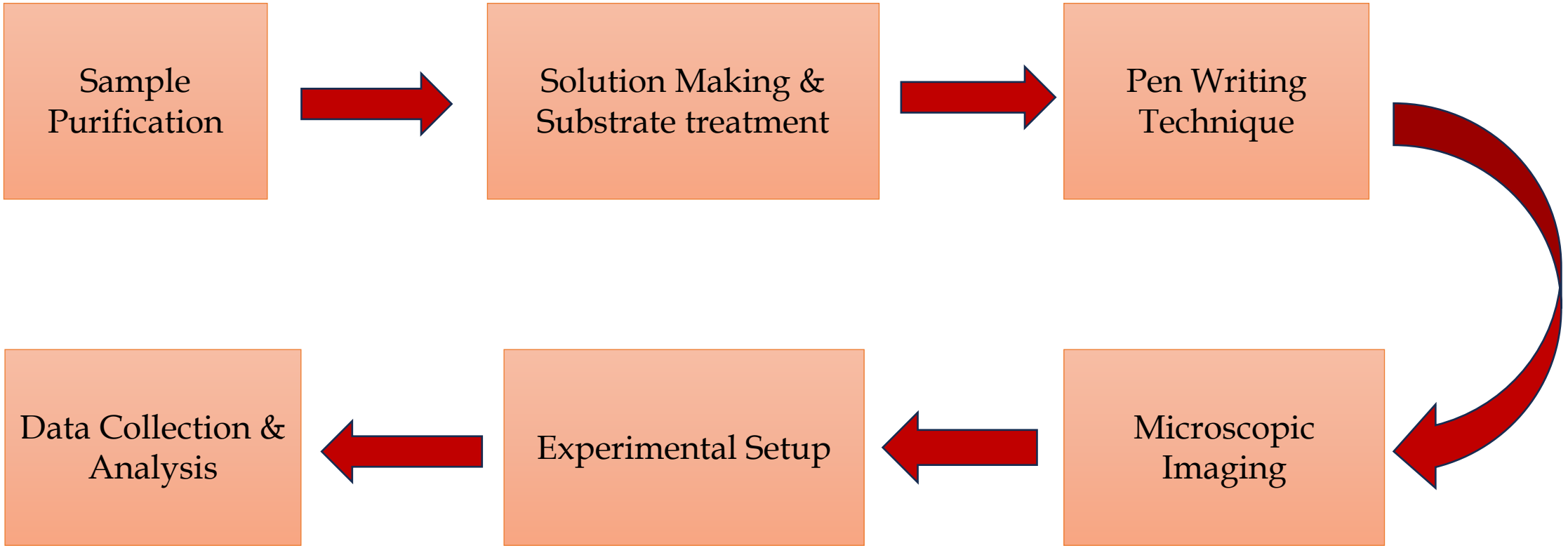


$100\ \mu m/s$



$400\ \mu m/s$

Map


Sample Purification
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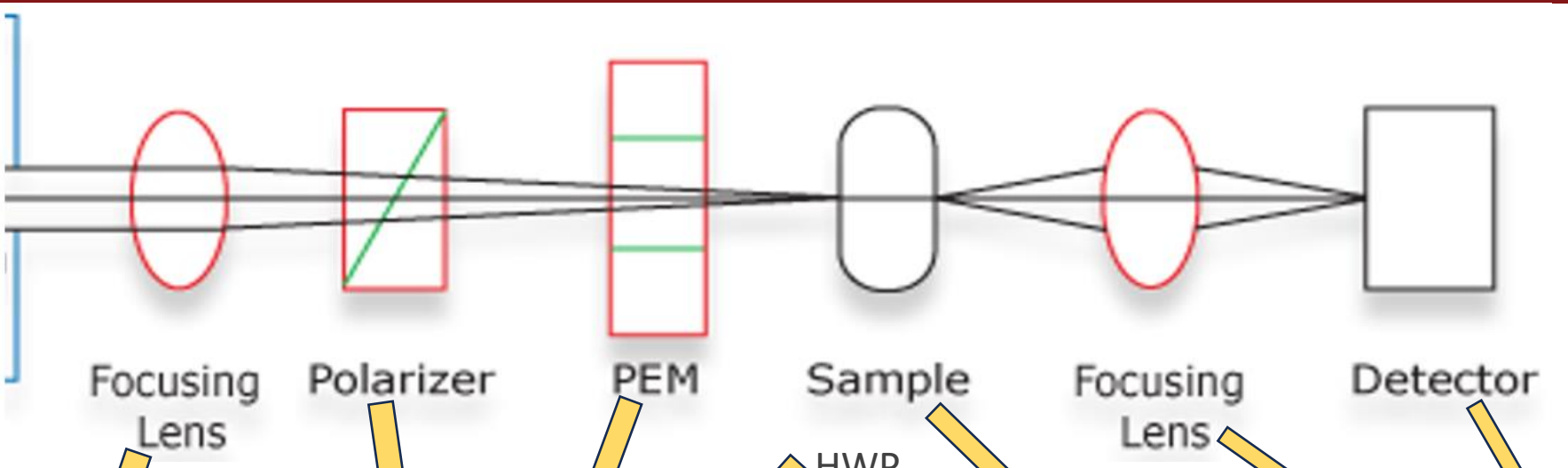
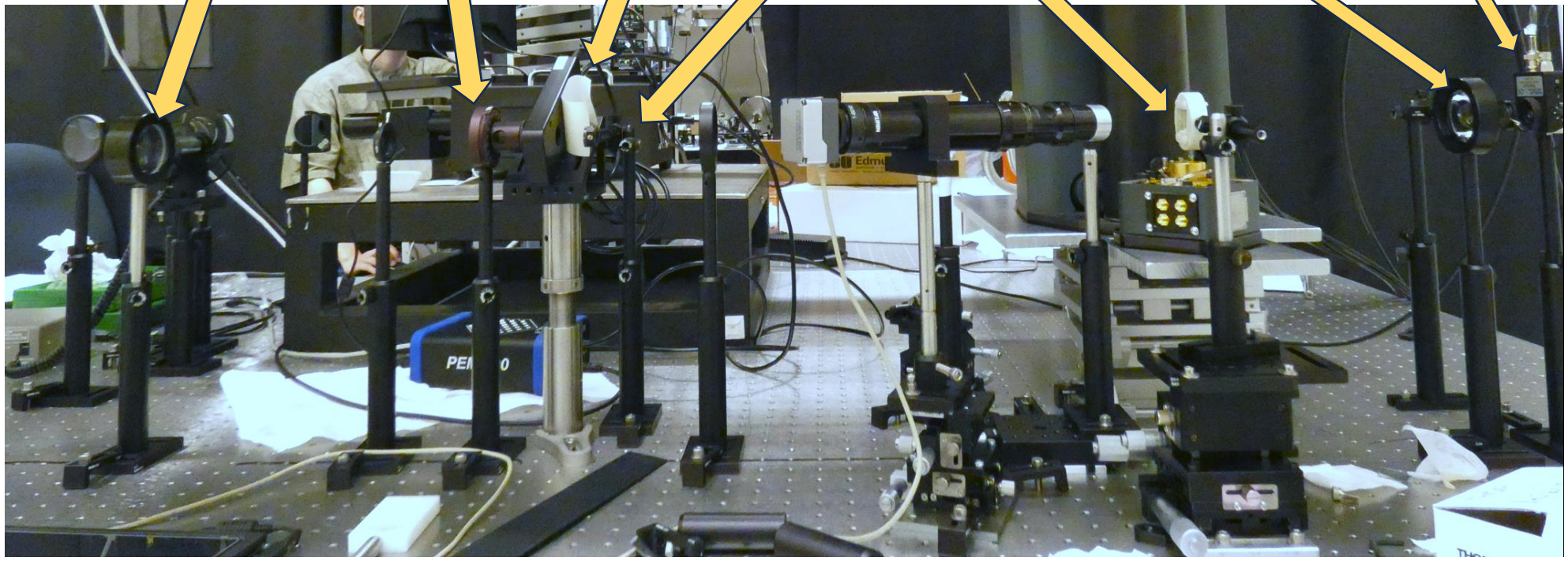
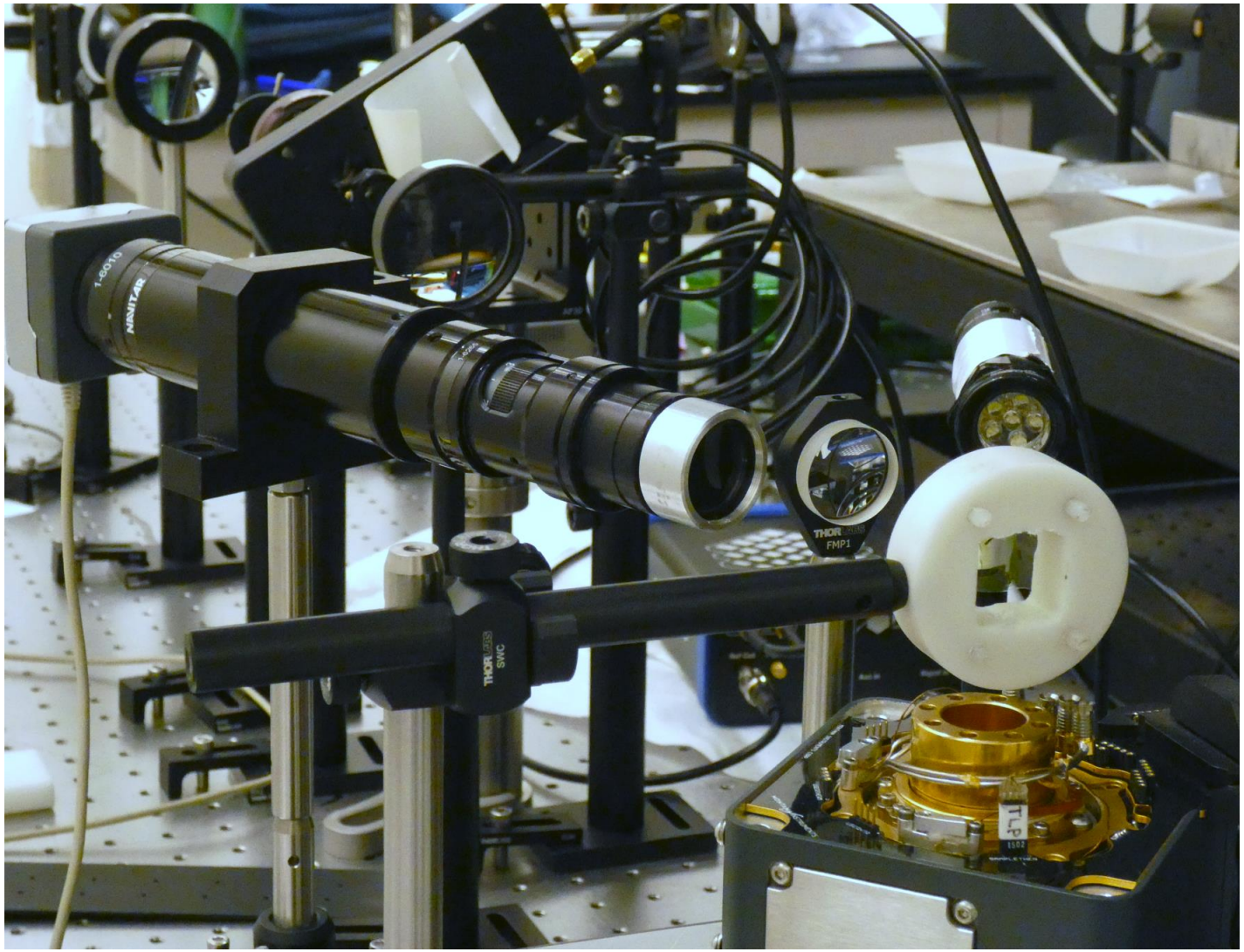
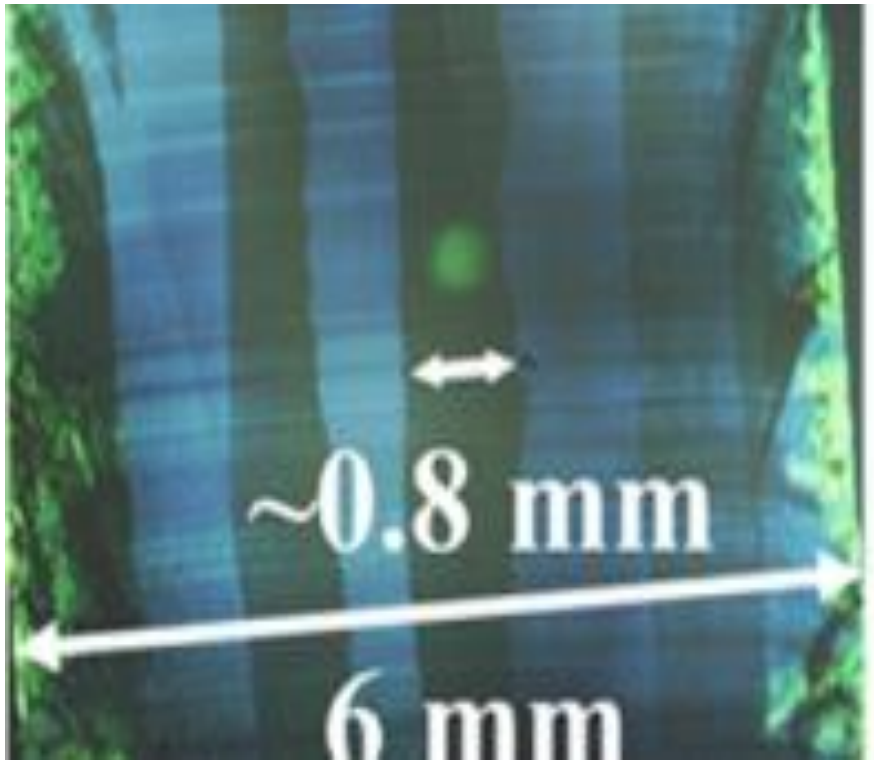
Experimental Setup





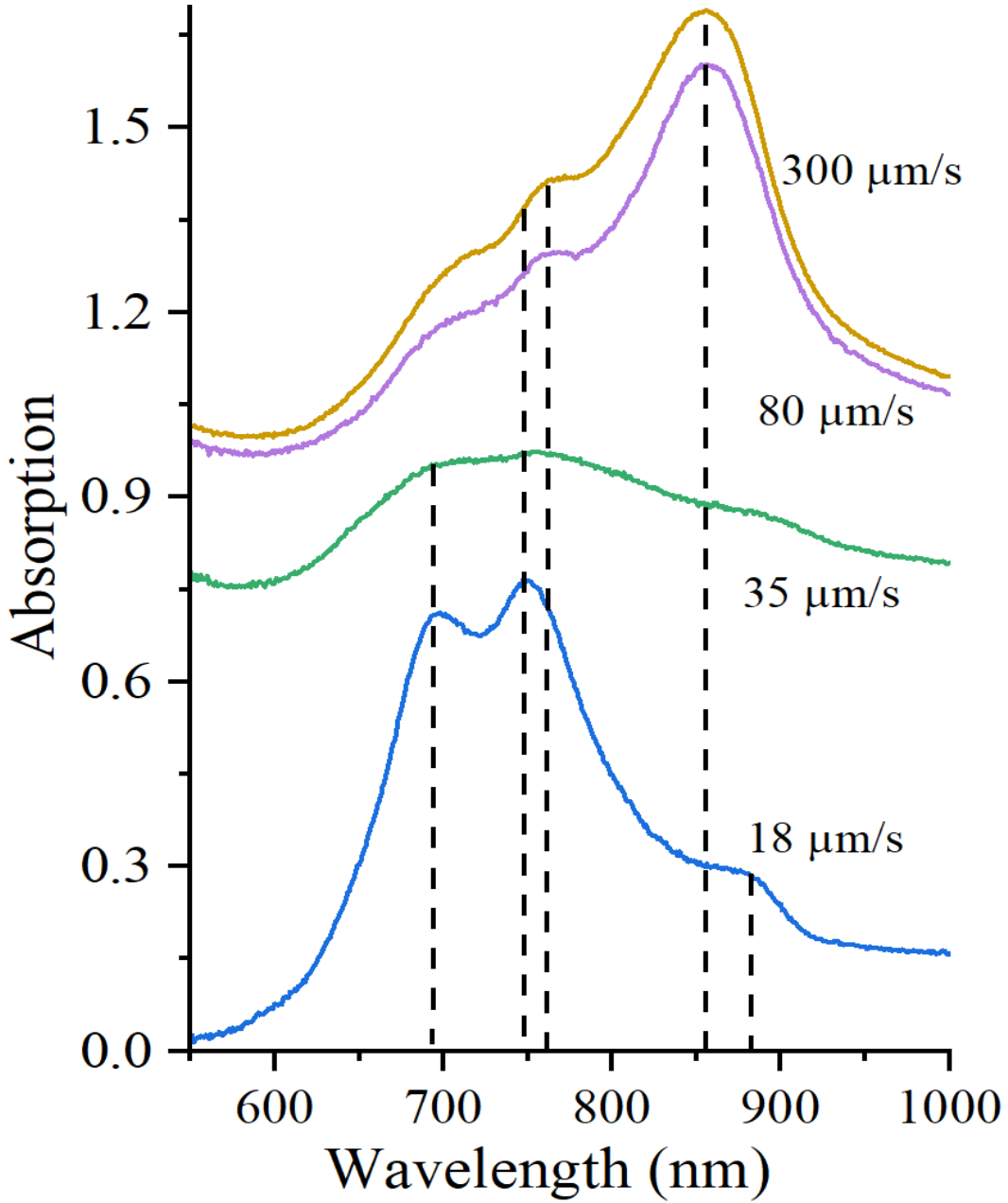
Mounting sample & Shining light

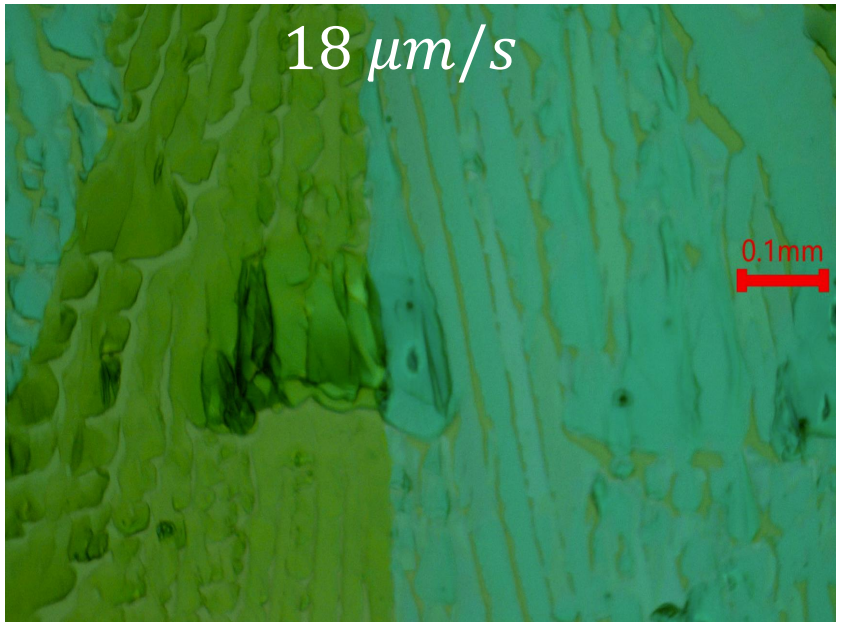




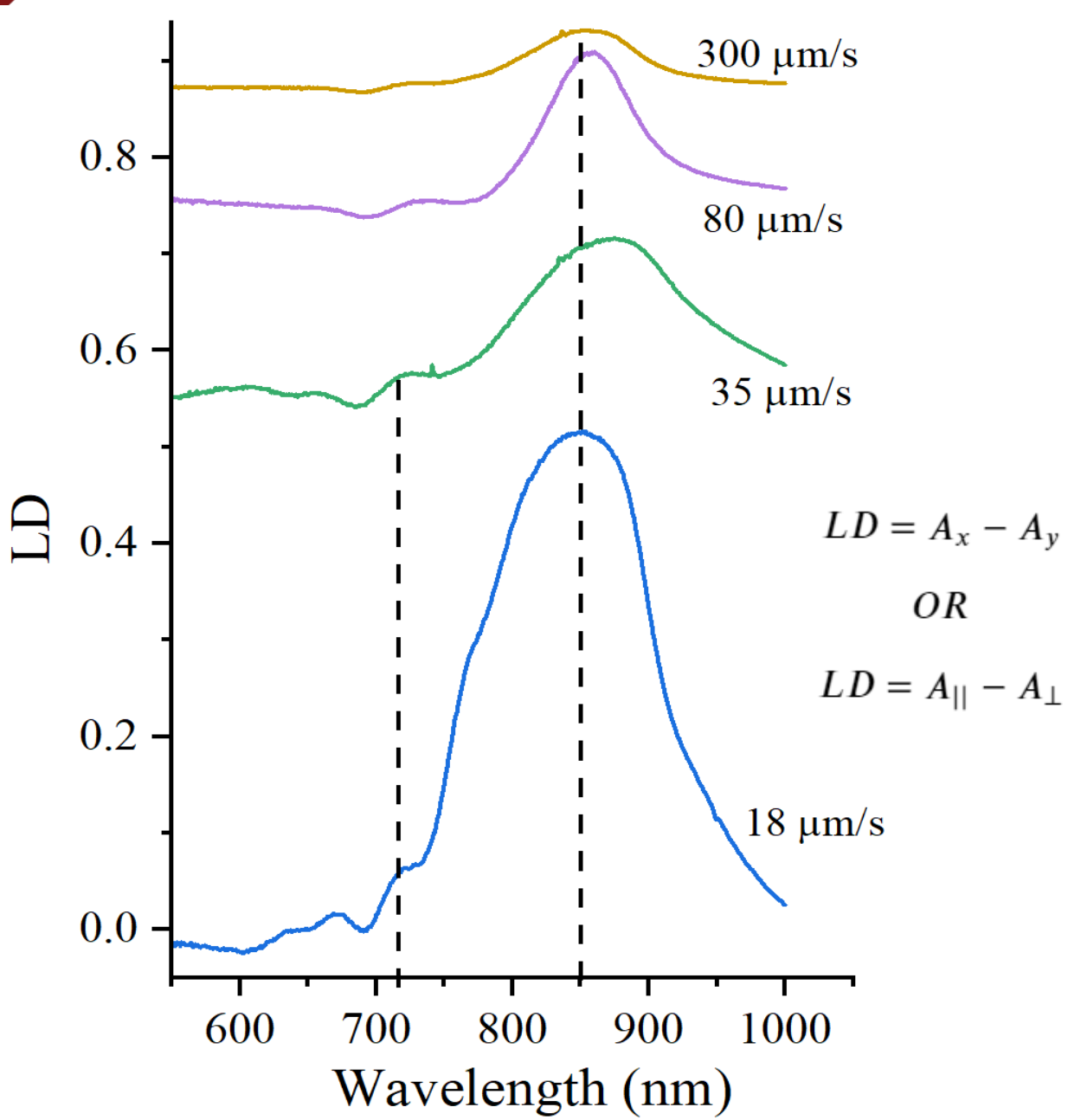
Source: *J. Phys. Chem. C* 2021, 125, 51, 27966–27974

Waterfall Diagram of Absorption for 0.5%, 25℃





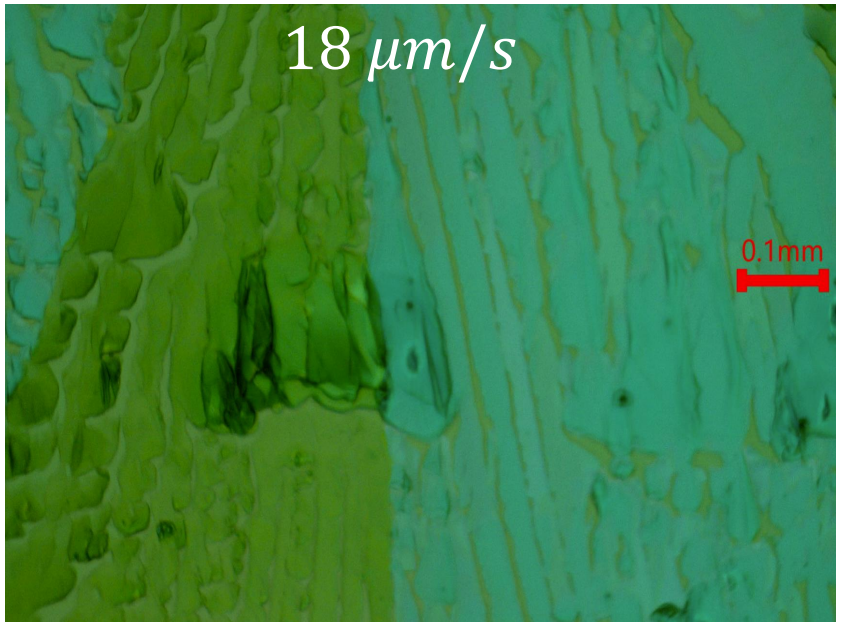
Waterfall Diagram of LD for 0.5%, 25°C



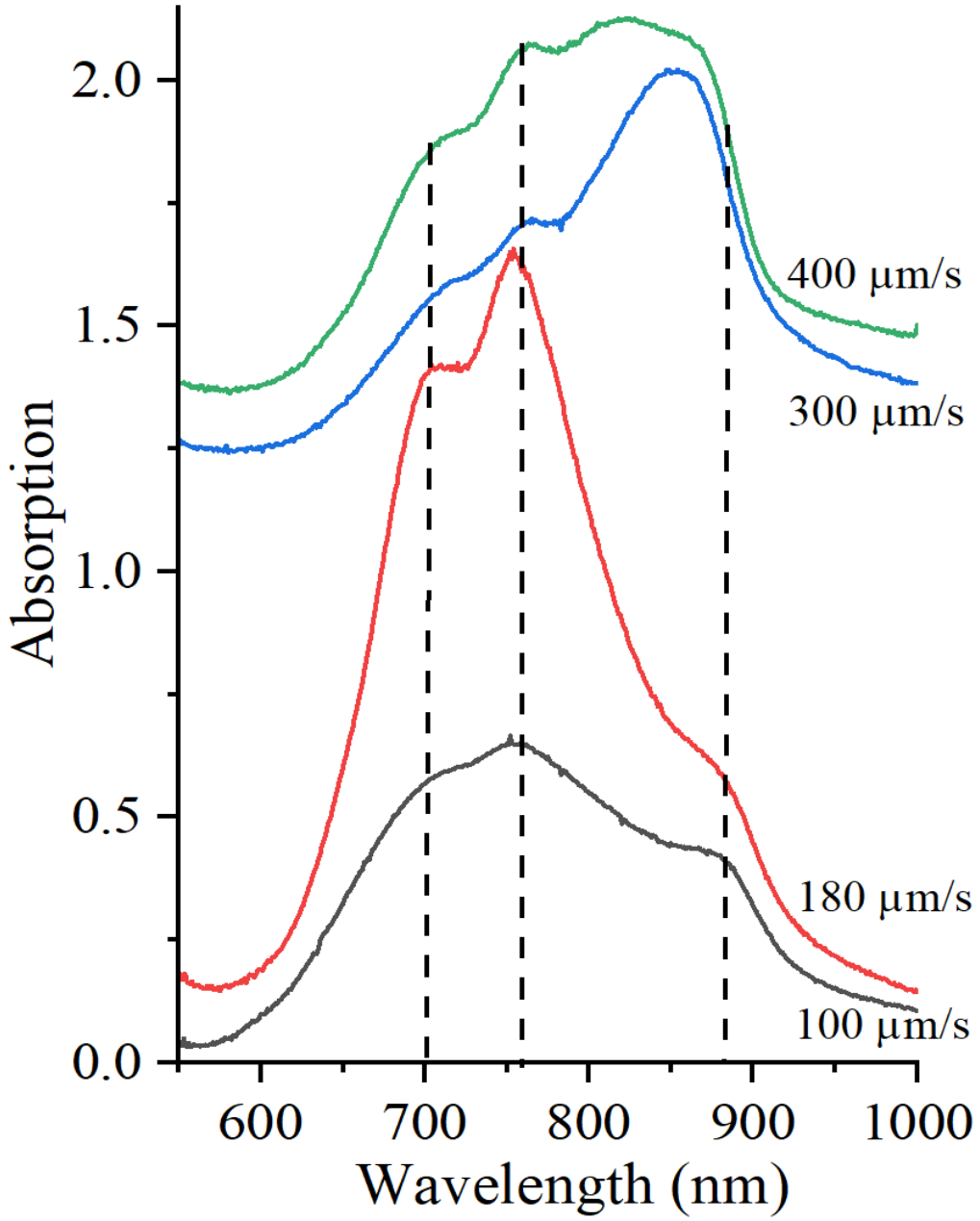
$$LD = A_x - A_y$$

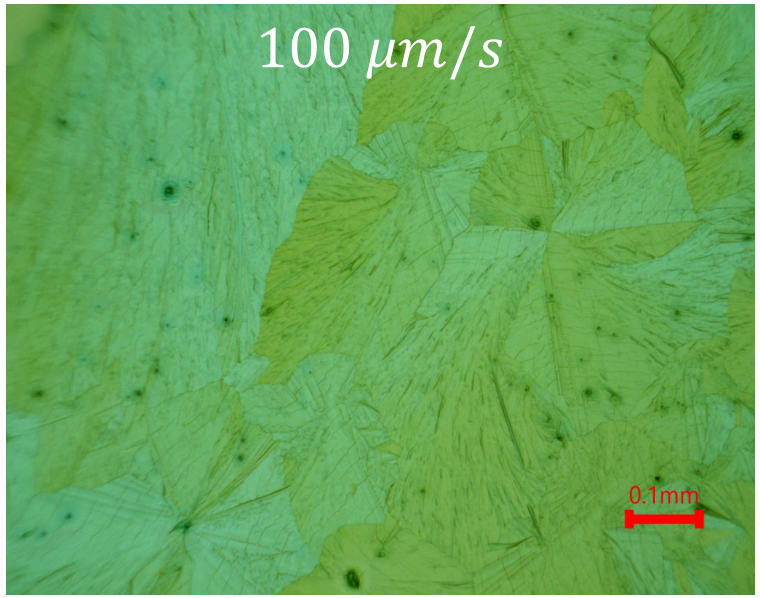
$$OR$$

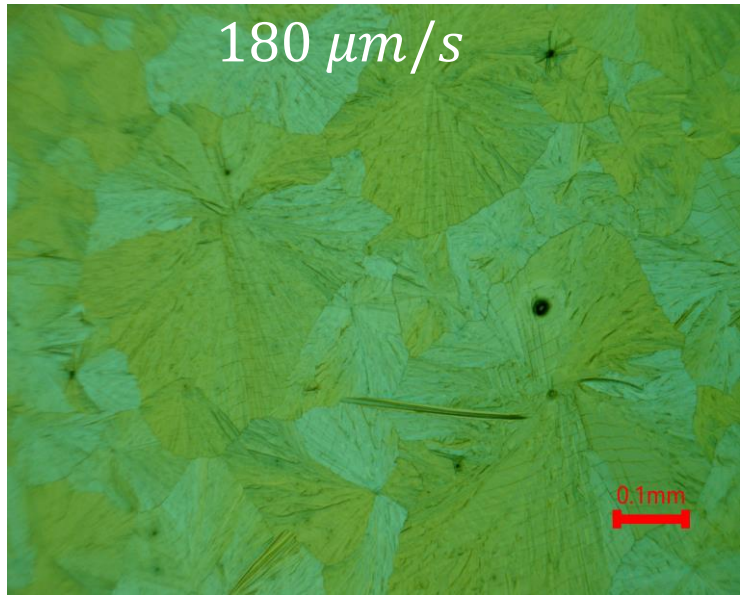
$$LD = A_{||} - A_{\perp}$$

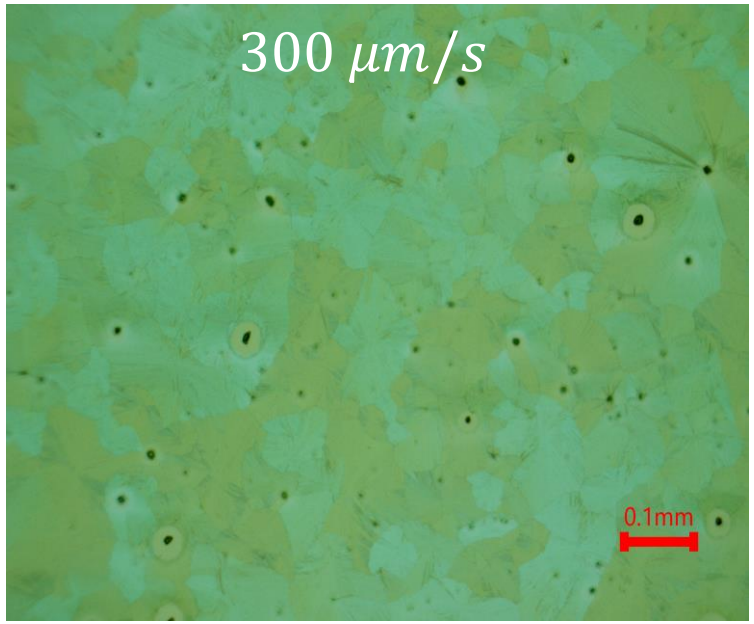


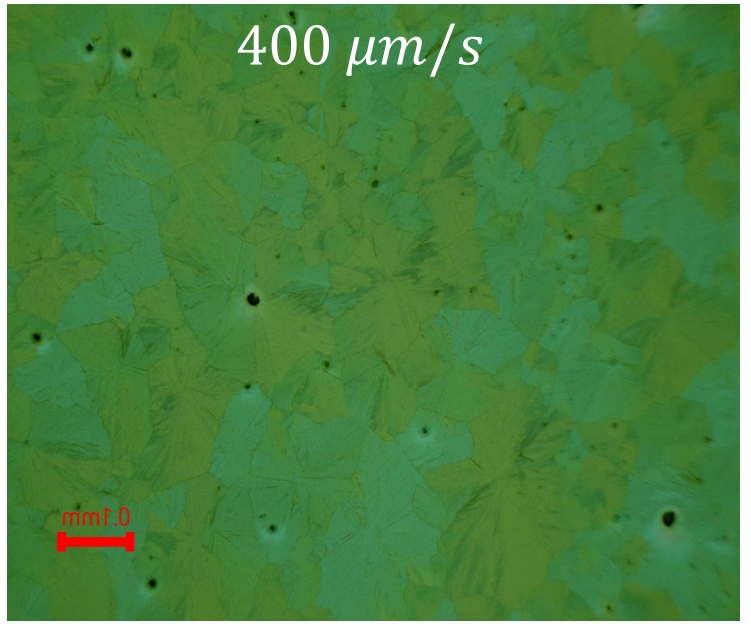
Waterfall Diagram of Absorption for 0.5%, 60°C



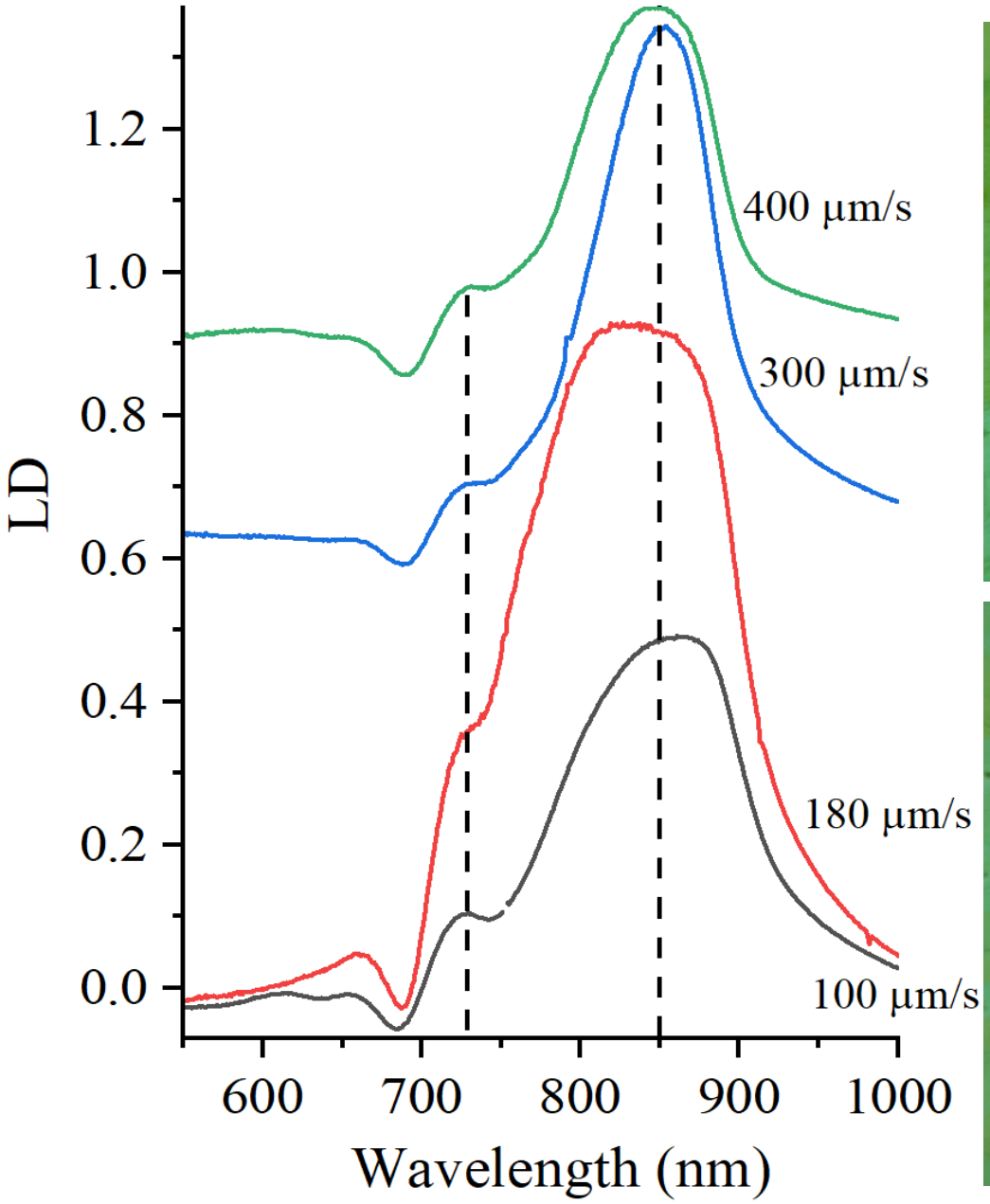


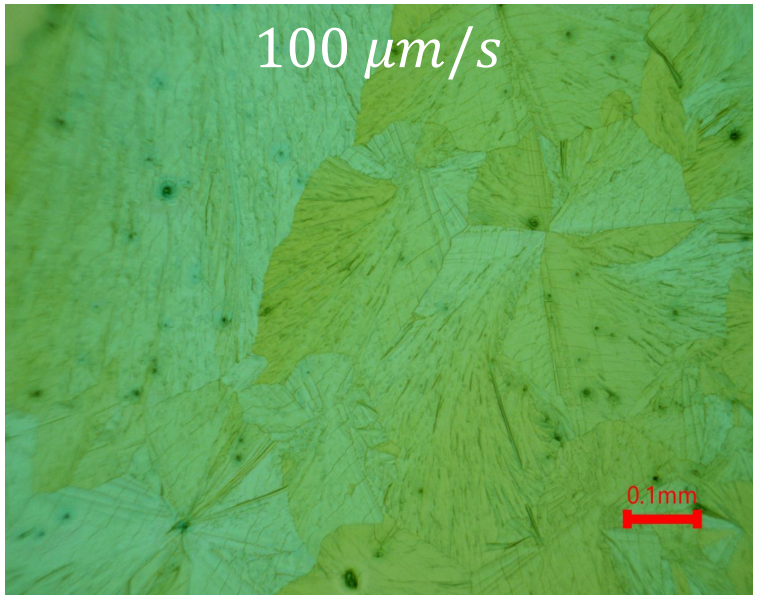


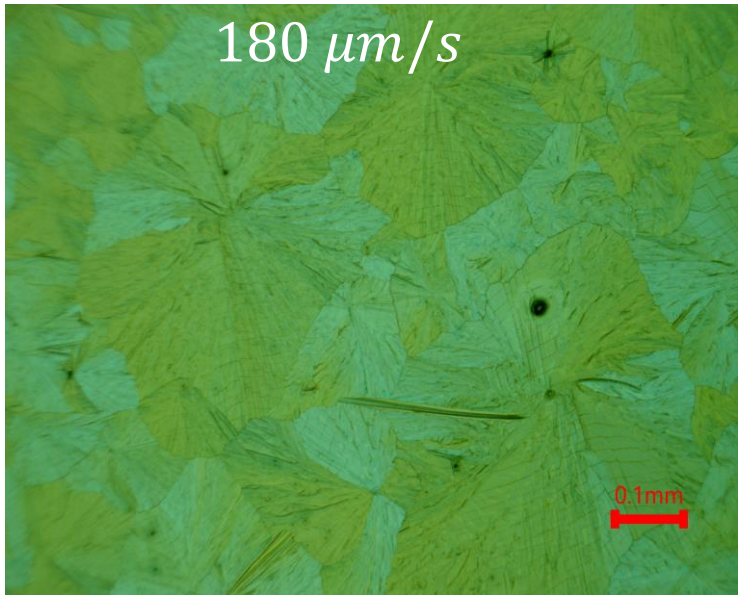


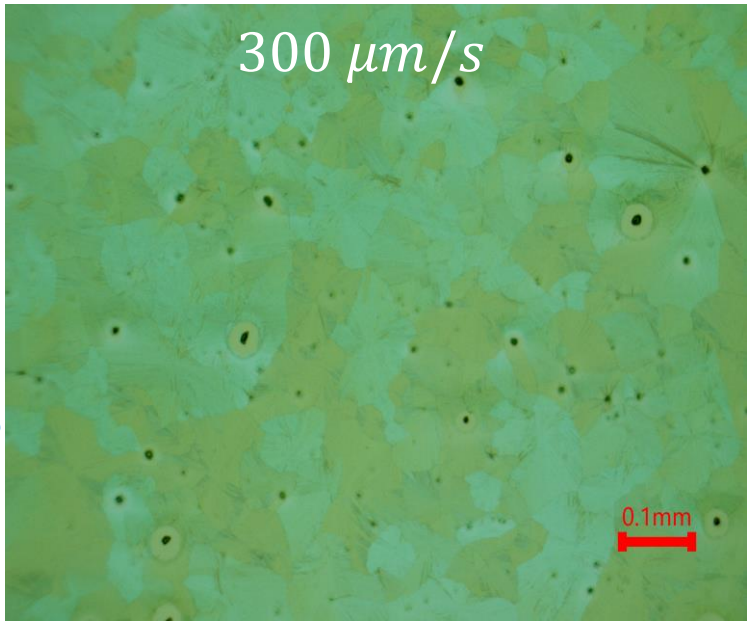


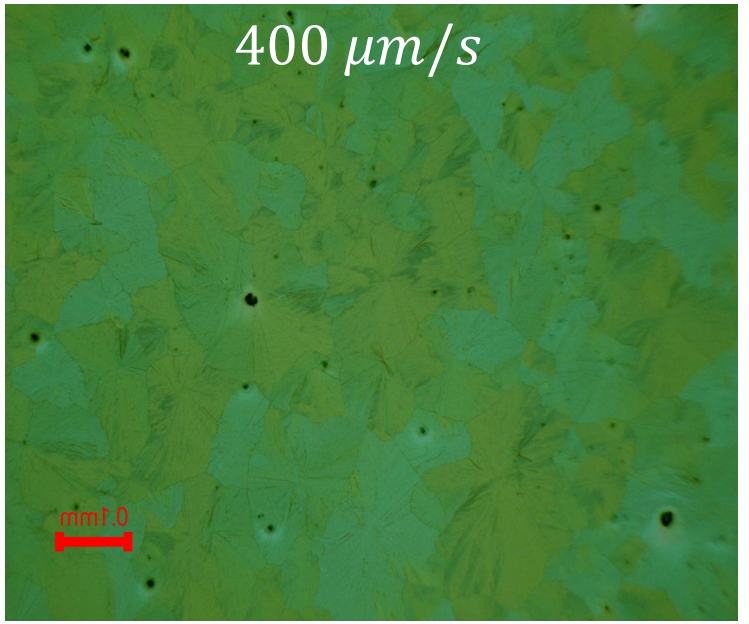
Waterfall Diagram of LD for 0.5%, 60°C



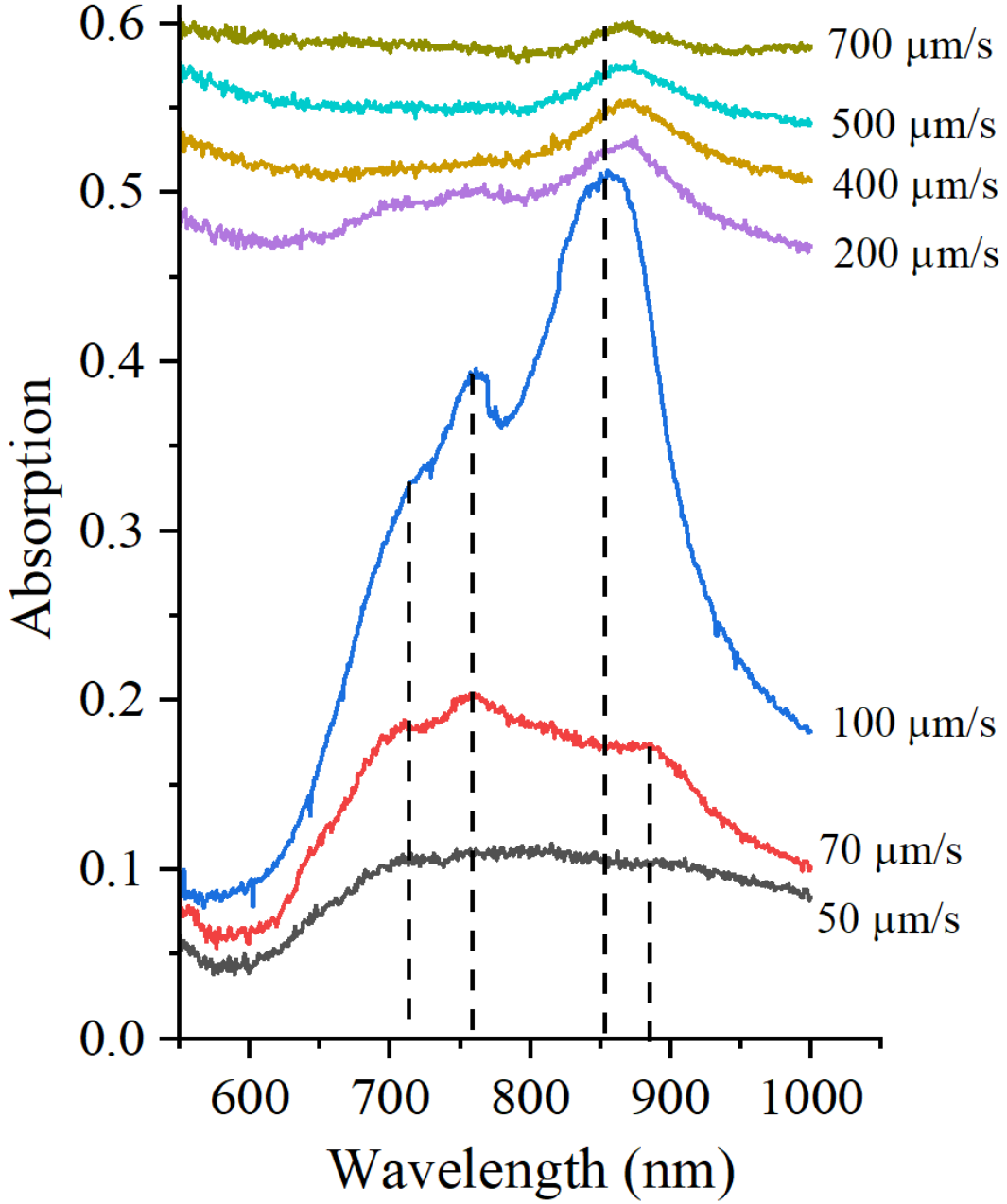


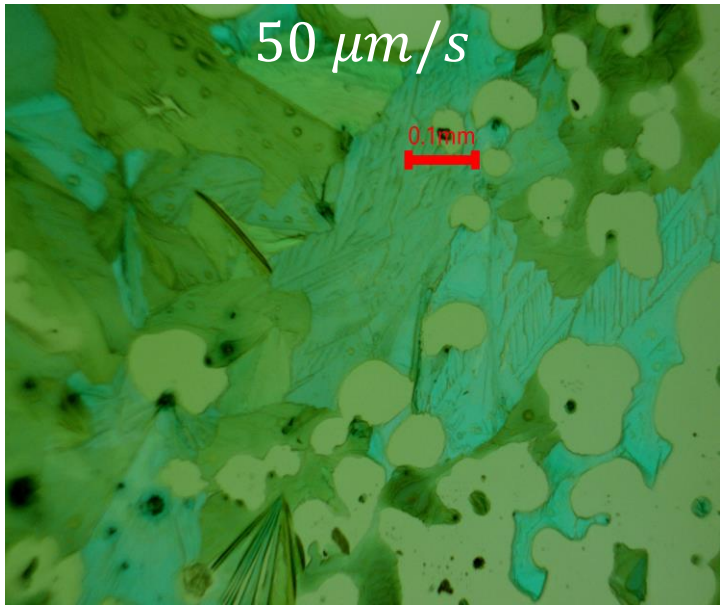


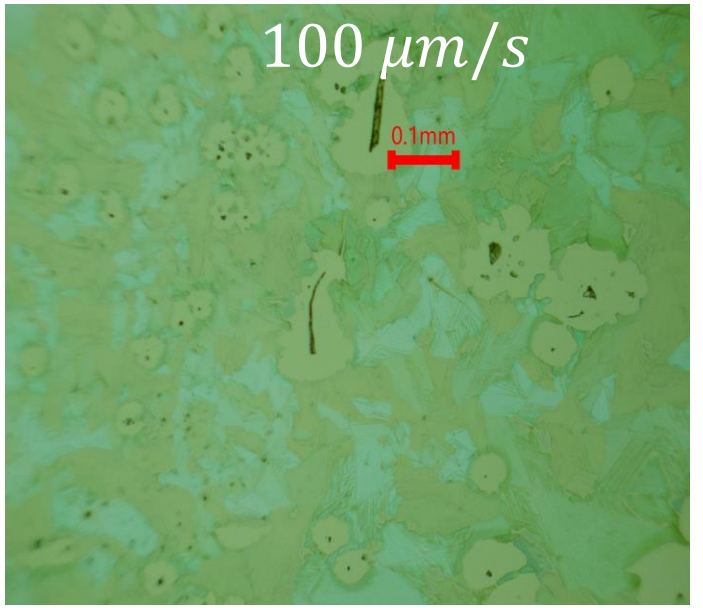


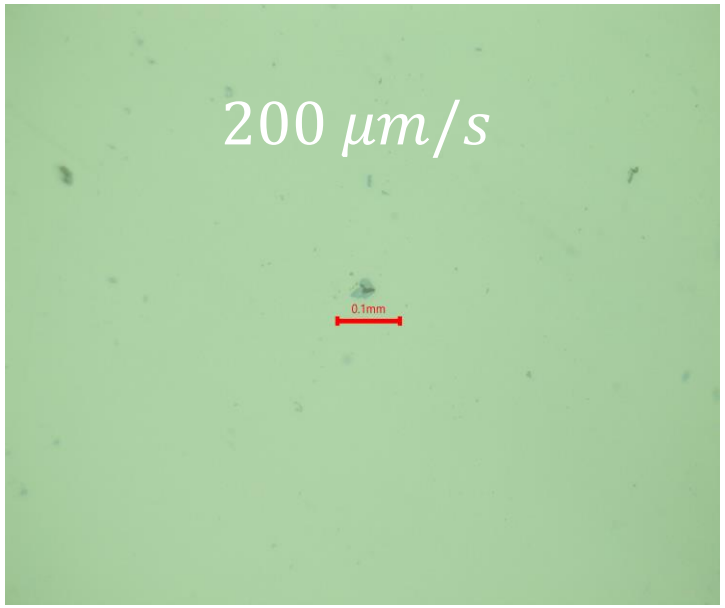


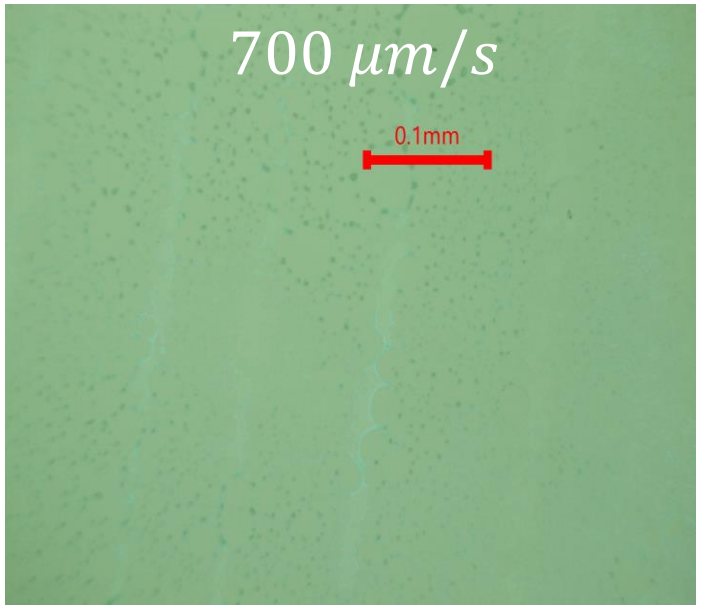
Waterfall Diagram of Absorption for 0.1%, 60°C



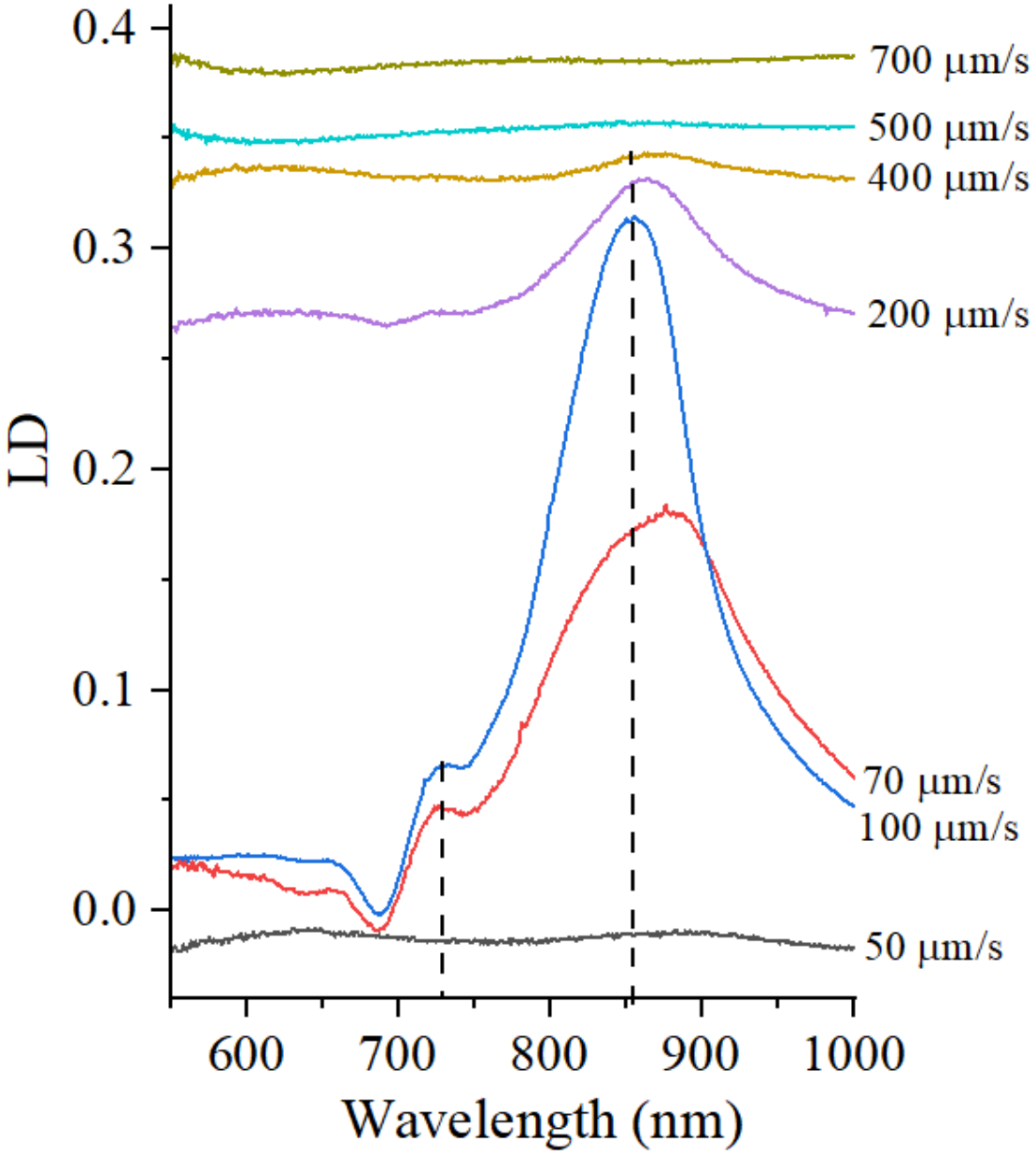


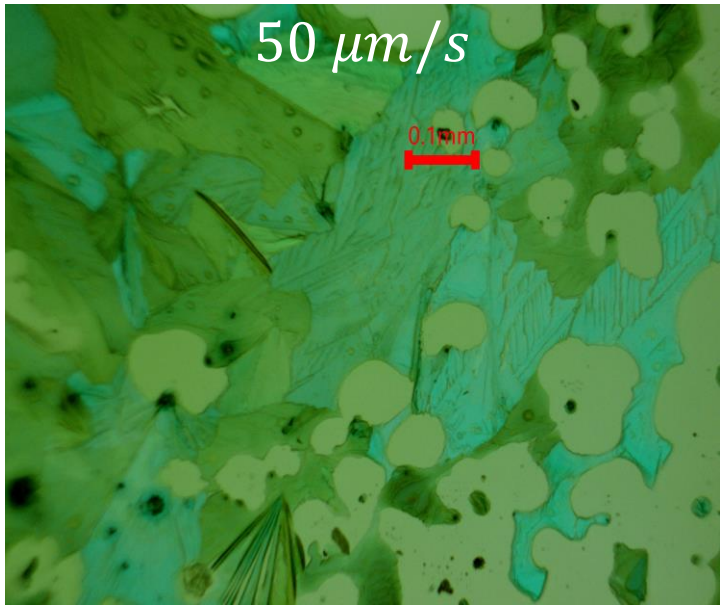


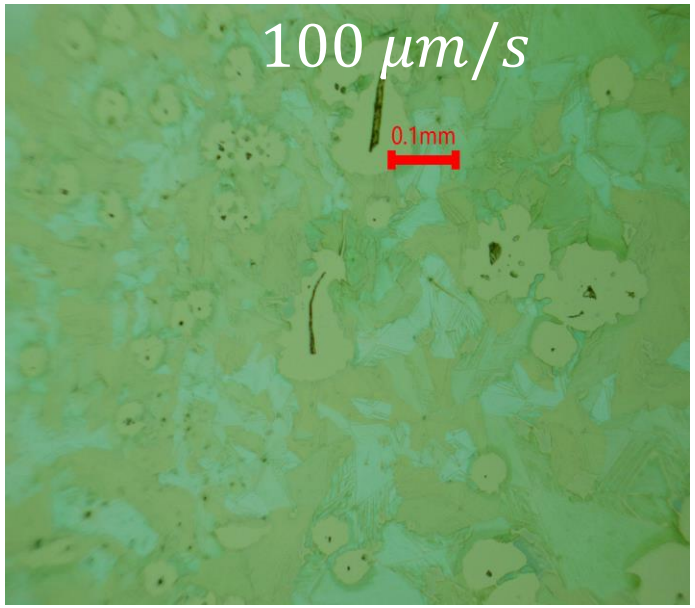


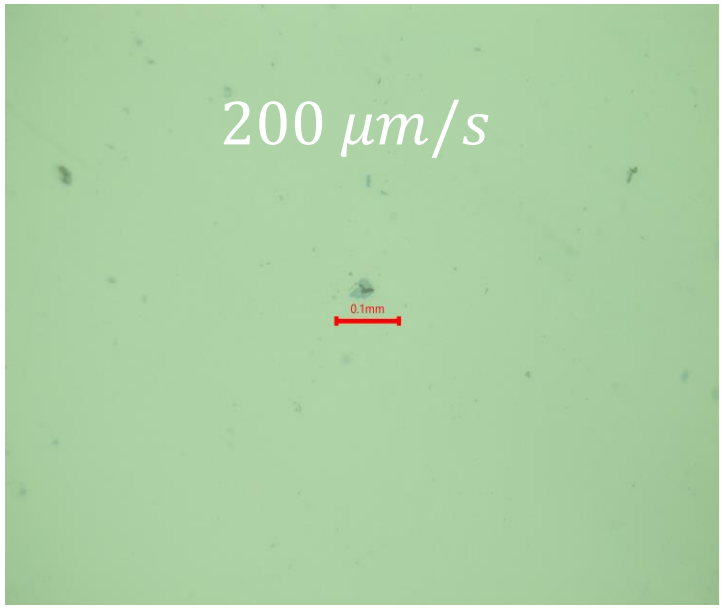


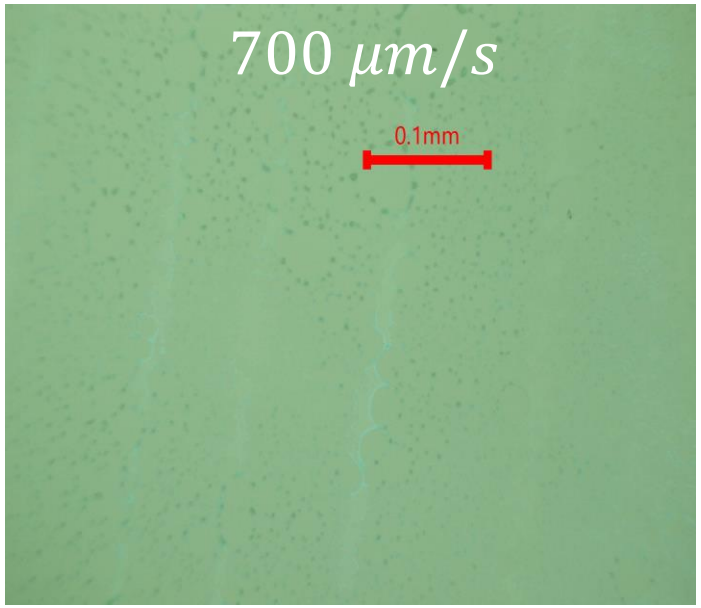
Waterfall Diagram of Absorption for 0.1%, 60°C







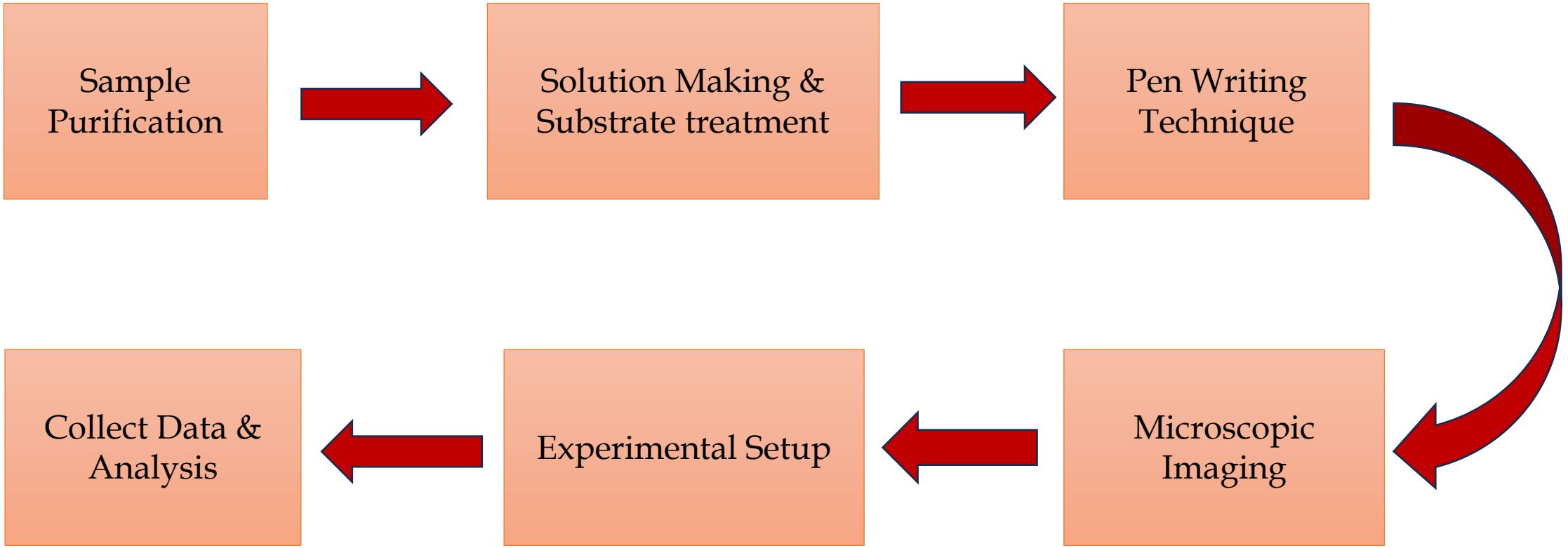




To Conclude

- We observed that the optical properties of organic thin films such as Phthalocyanines evolve with the changes in the *pen writing speeds, substrate temperatures, and solution concentrations.*
- Convective and LLD regimes were observed in Pen-Written samples.
- Millimeter sized grains were achieved & grain-like and fan-like structures were also seen.

Summary


Sample Purification
Solution Making & Substrate treatment
Pen Writing Technique
Microscopic Imaging
Experimental Setup
Collect Data & Analysis

Acknowledgements/References

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4. Tabassum Haque
5. Hinata Yokoyama

- https://warwick.ac.uk/fac/sci/chemistry/research/arodger/arodgergroup/research_intro/linear_dichroism/
- https://physics.stackexchange.com/questions/231962/linear-polarized-3d-glasses-and-the-physical-shape-of-light-waves
- https://www.hindsinstruments.com/wp-content/uploads/PEM-Technical-Overview.pdf
- Landau-Levich-Derjaguin; Ishviene Cour;Randall L. Headrick et al **"Origin of stress and enhanced carrier transport in solution-cast organic semiconductor films"** ***Journal of Applied Physics*** **114, 093501 (2013)**

Questions?