Structural characterization of 2D layered complexed hetero-Ion systems

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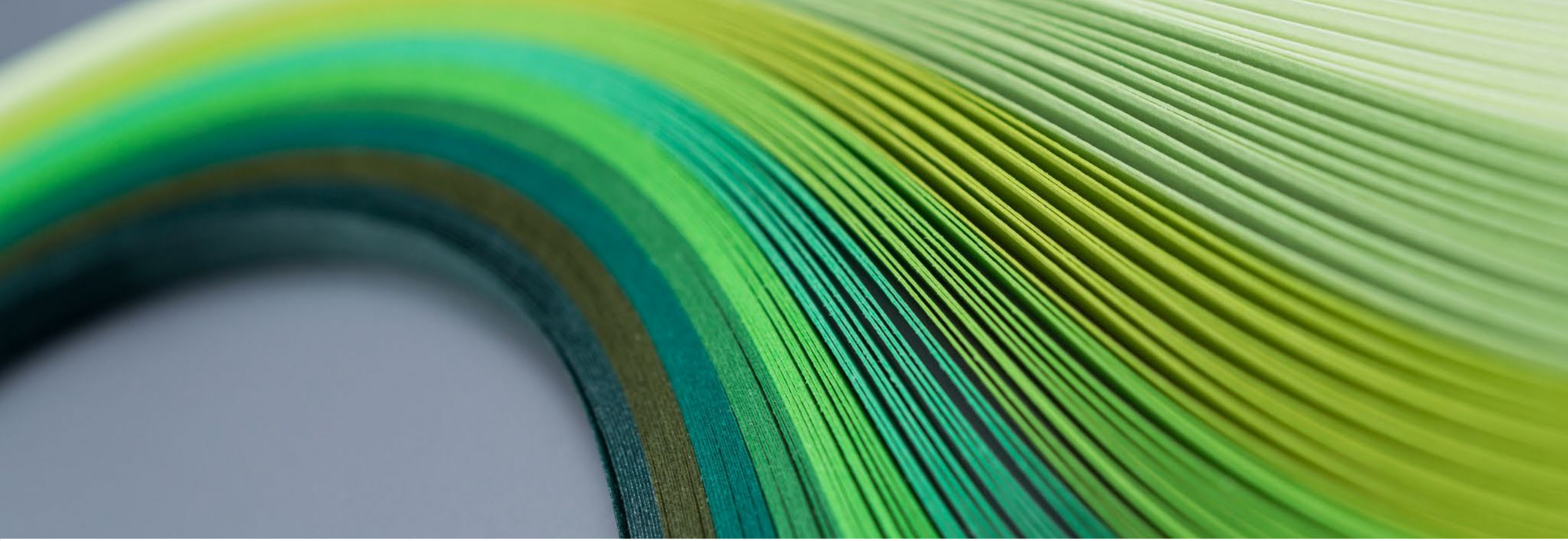
MOTIVATION AND BACKGROUND

- Ongoing trend in the miniaturization of smart devices to achieve a more portable and advance system.
- 3D materials suffer from dangling bonds
- In studying multiferroic 2D materials, we hope to replicate various functions on a small-scale factor.

Background

Multiferroic materials are a rare class of materials that is versatile enough to possess at least two of the following properties: ferroelasticity, ferroelectricity (FE), ferromagnetism (FM), and ferrotoroidicity. [4]

Magnetoelectric multiferrocity, may be applied in spintronic, ferroelectric photovoltaic, magnetic memory for more advance computing.

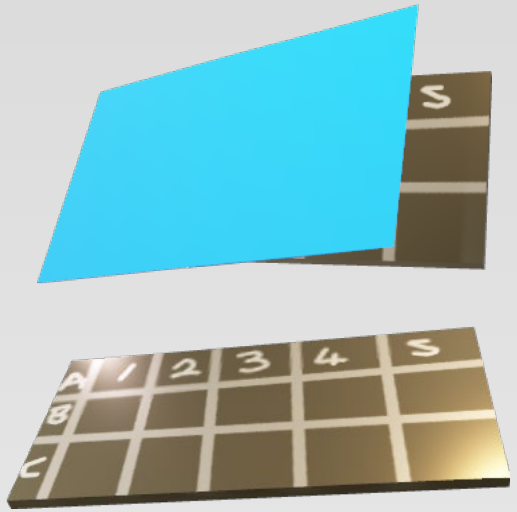


INVESTIGATION

- The Metal Chalcophosphate family of materials is a layered system
- Correlate the observed emerging properties with the structure of such materials by confirming monolayer flakes

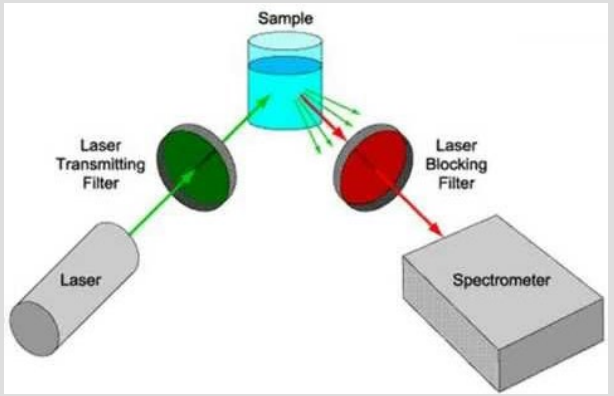
Preparation

Sample Prep



Exfoliation

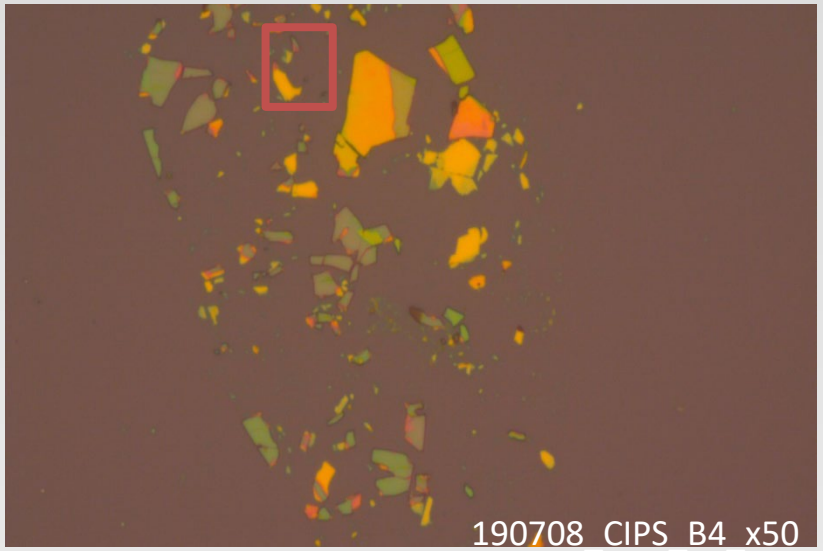
Optical microscope

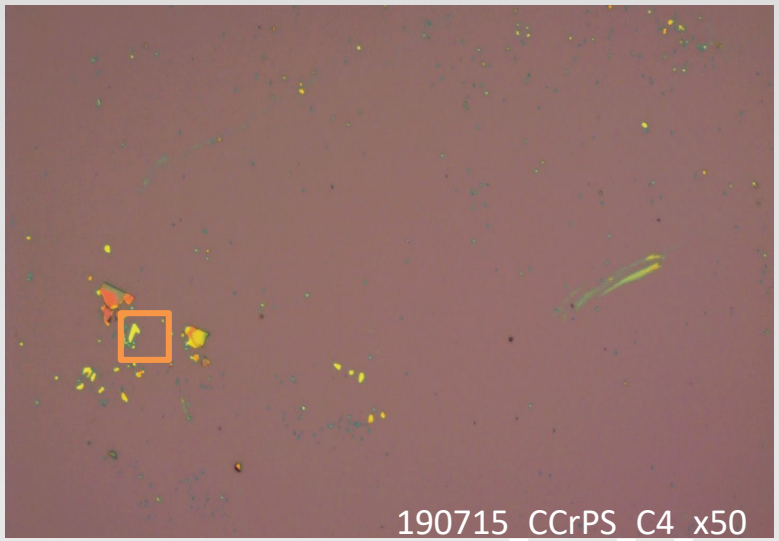


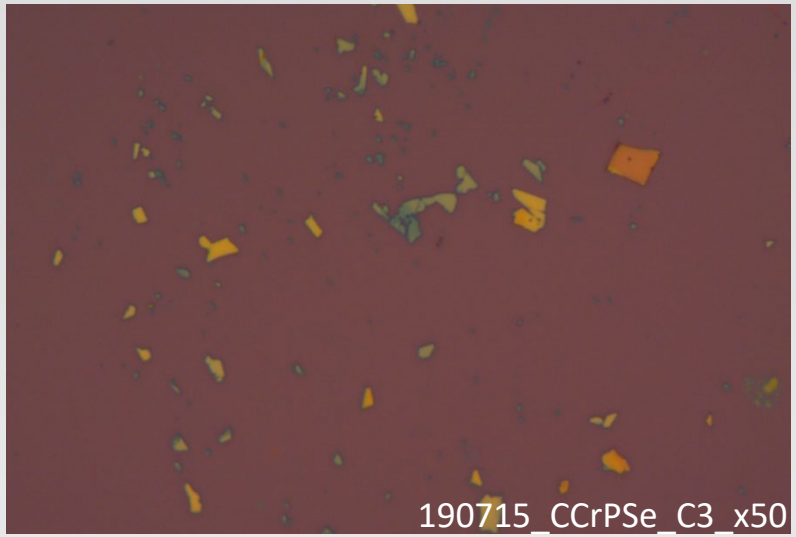
Raman spectrometer

AFM & Raman

RESULTS



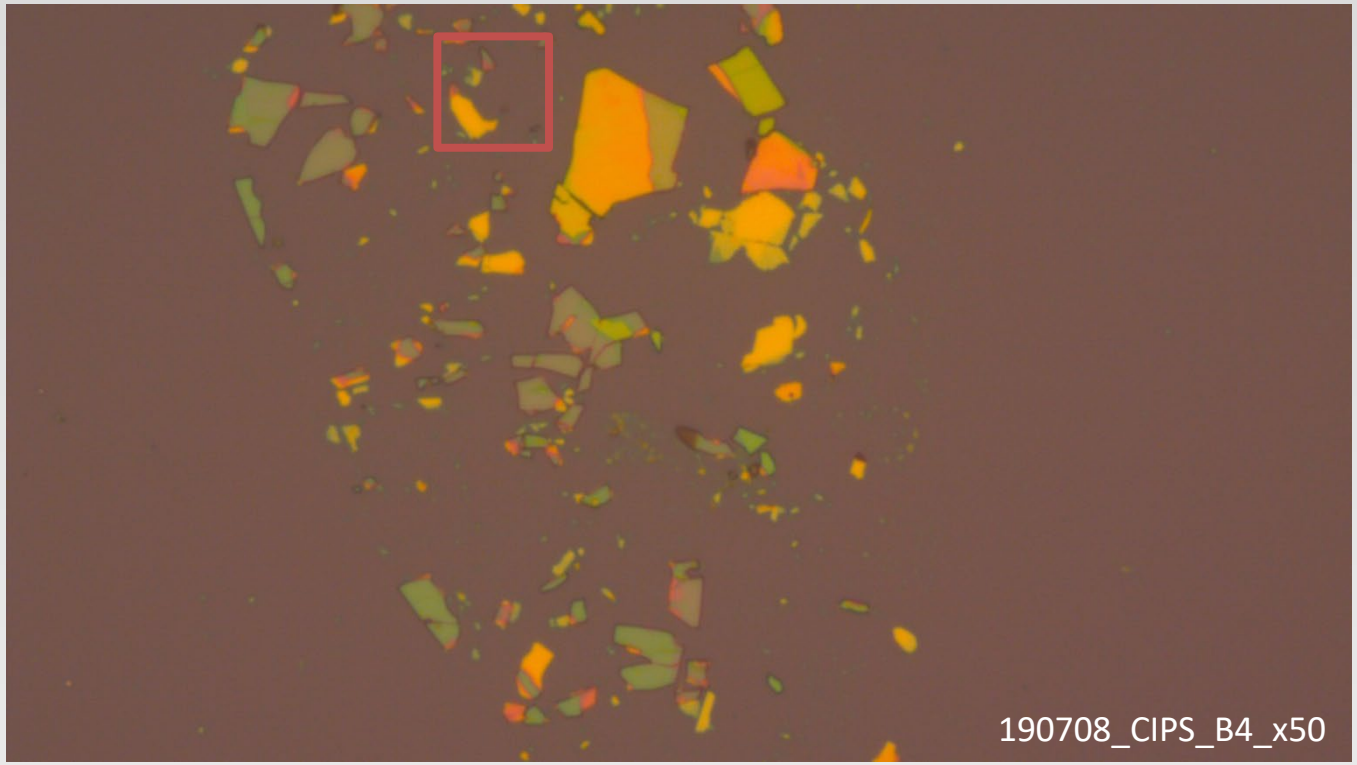




$CuInP_2S_6$ (CIPS)

$CuCrP_2S_6$ (CcrPS)

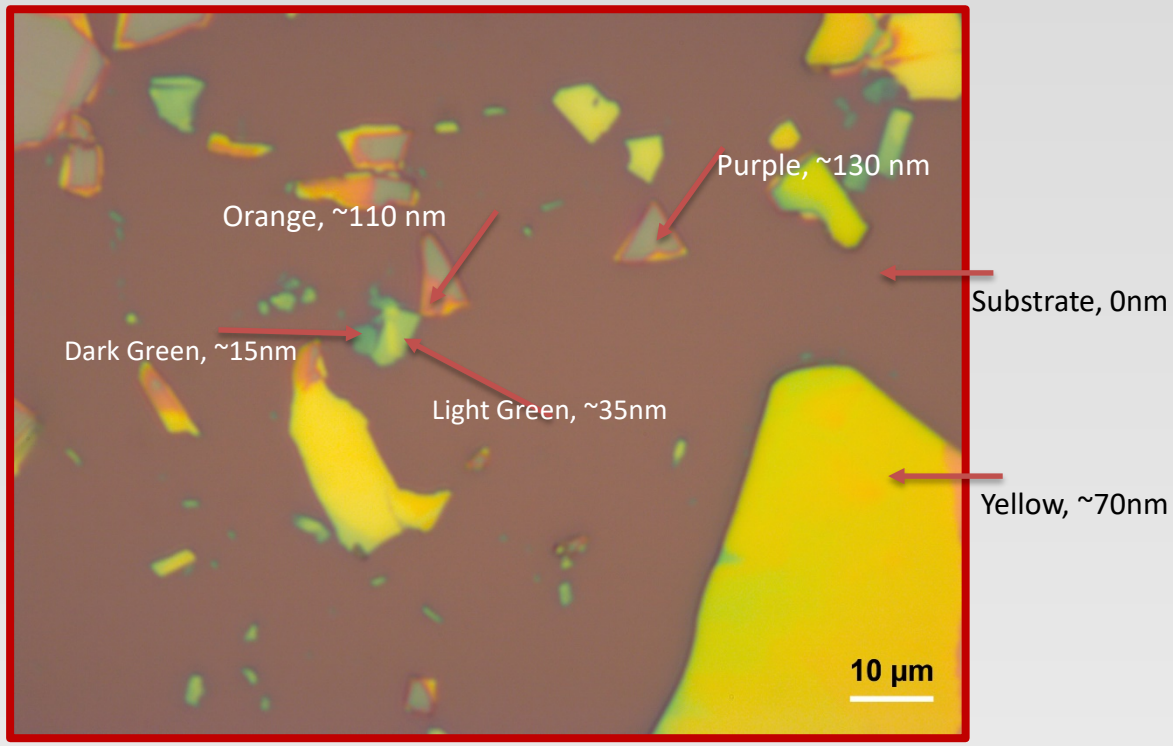
$CuCrP_2Se_6$ (CCrPSe)



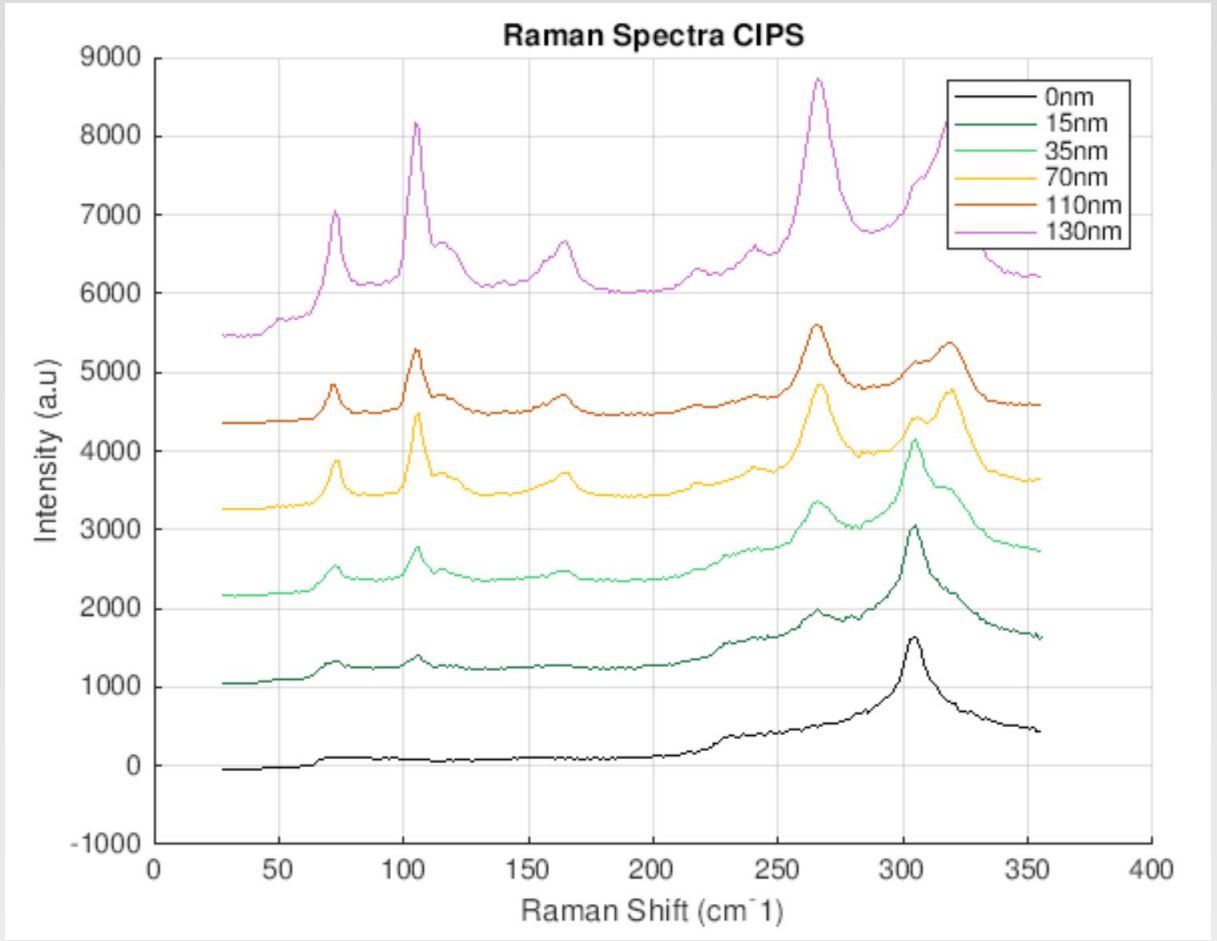
$CuInP_2S_6$ (CIPS)

- CIPS is known for exhibiting well-defined long-range order [3]
- CIPS exhibits large dielectric tunability which hints at ferroelectric properties in the nanoscale limit. [3]

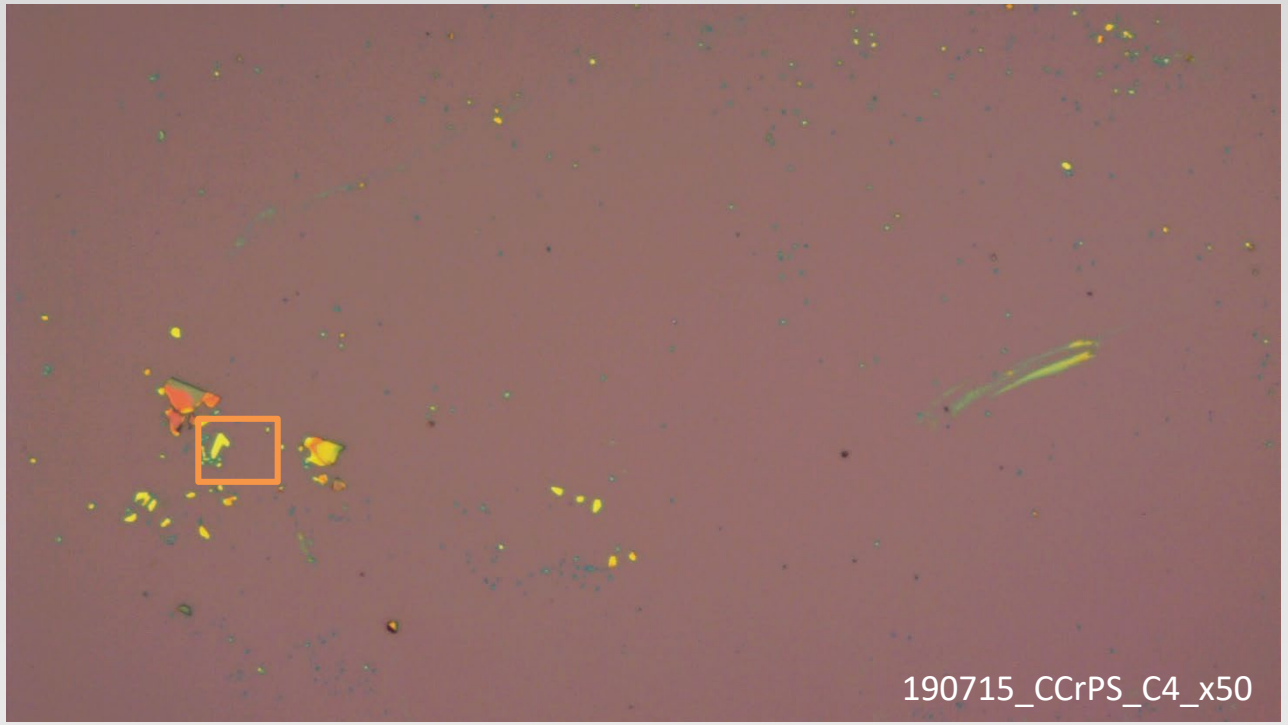
Data - CIPS



190708_CIPS_B4_x100



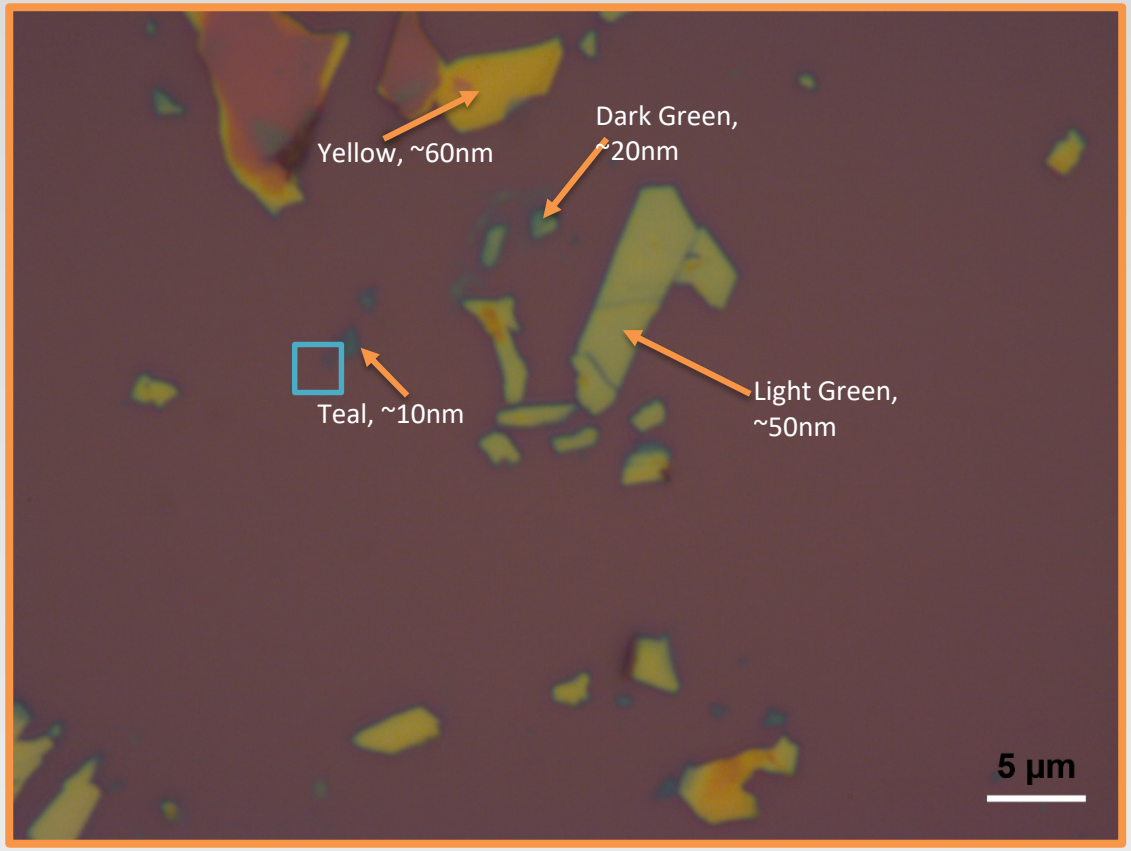
AFM scan assures thickness of each primary color to be Dark Green, ~15nm, Light Green ~35nm; Yellow, ~70nm; Orange, 110 nm, Purple, ~130 nm



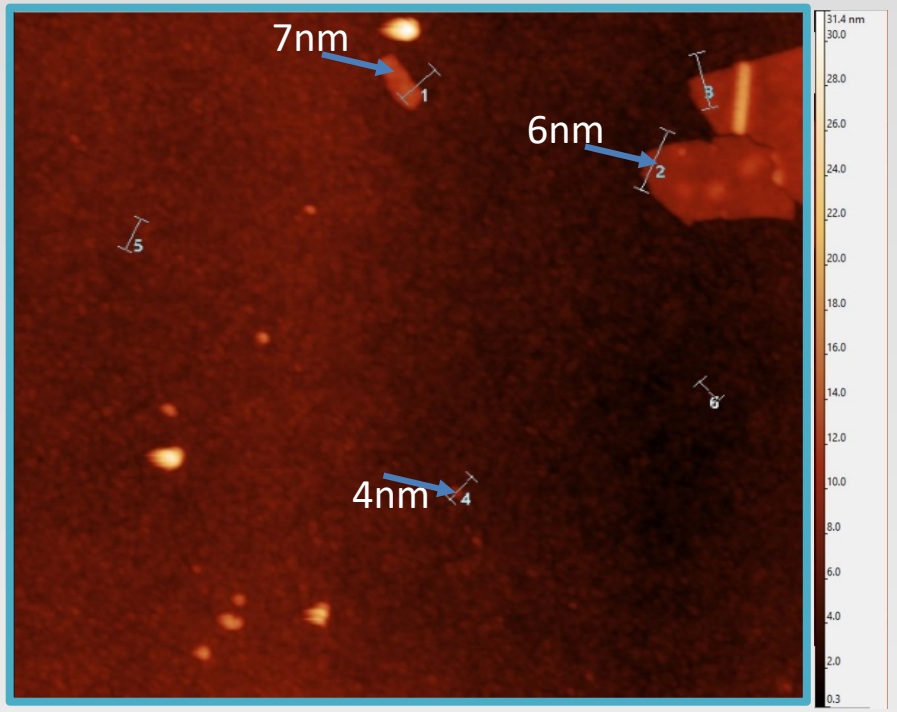
$CuCrP_2S_6$ (CCrPS)

- $CuCrP_2S_6$ possess out-of-plane electric polarization [1]
- Meanwhile, the spin-orbital coupling enables magnetoelectric coupling effect [1][2]

Data - CCrPS



190715_CCrPS_C4_x100

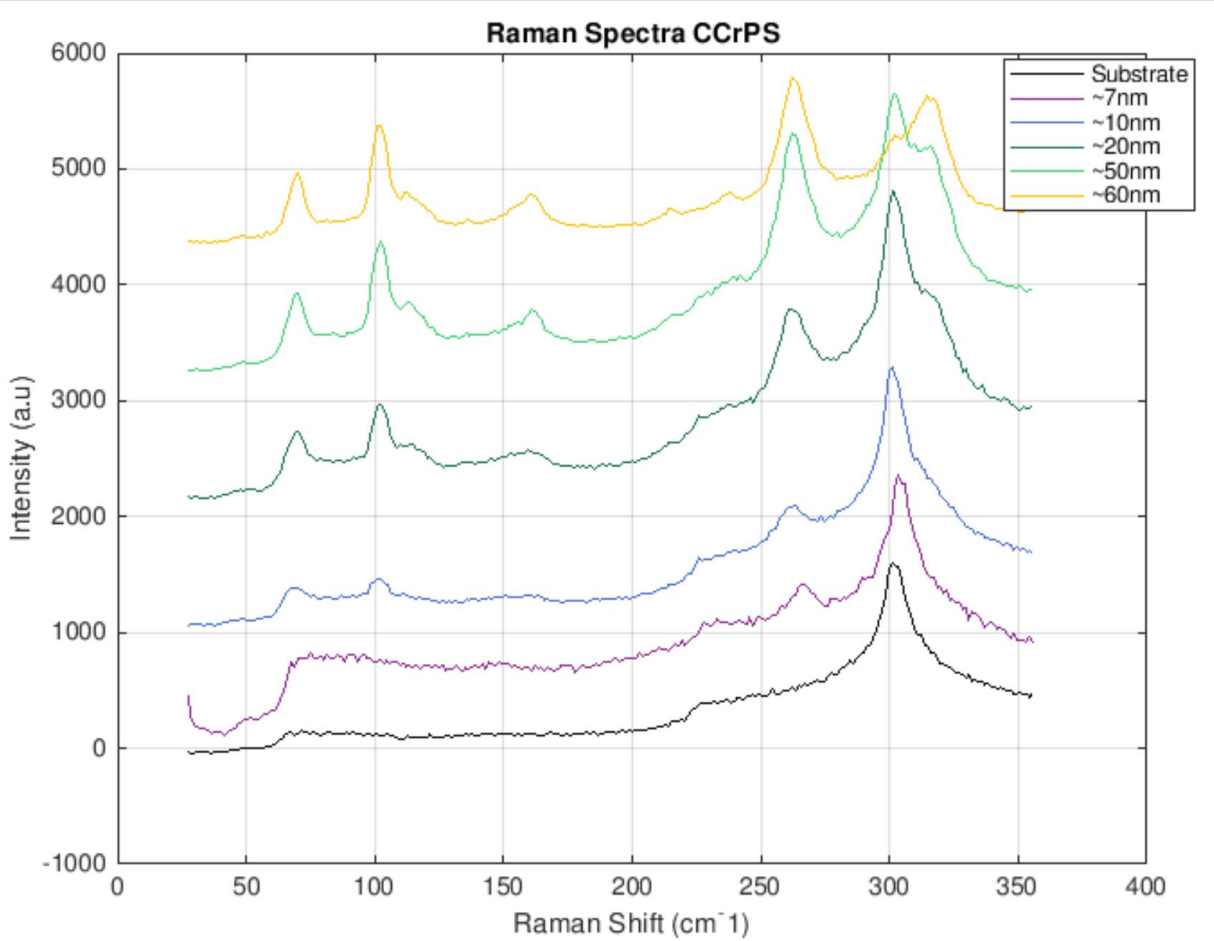


190715_CCrPS_C4_1:1ratio_ 3µm Scansize

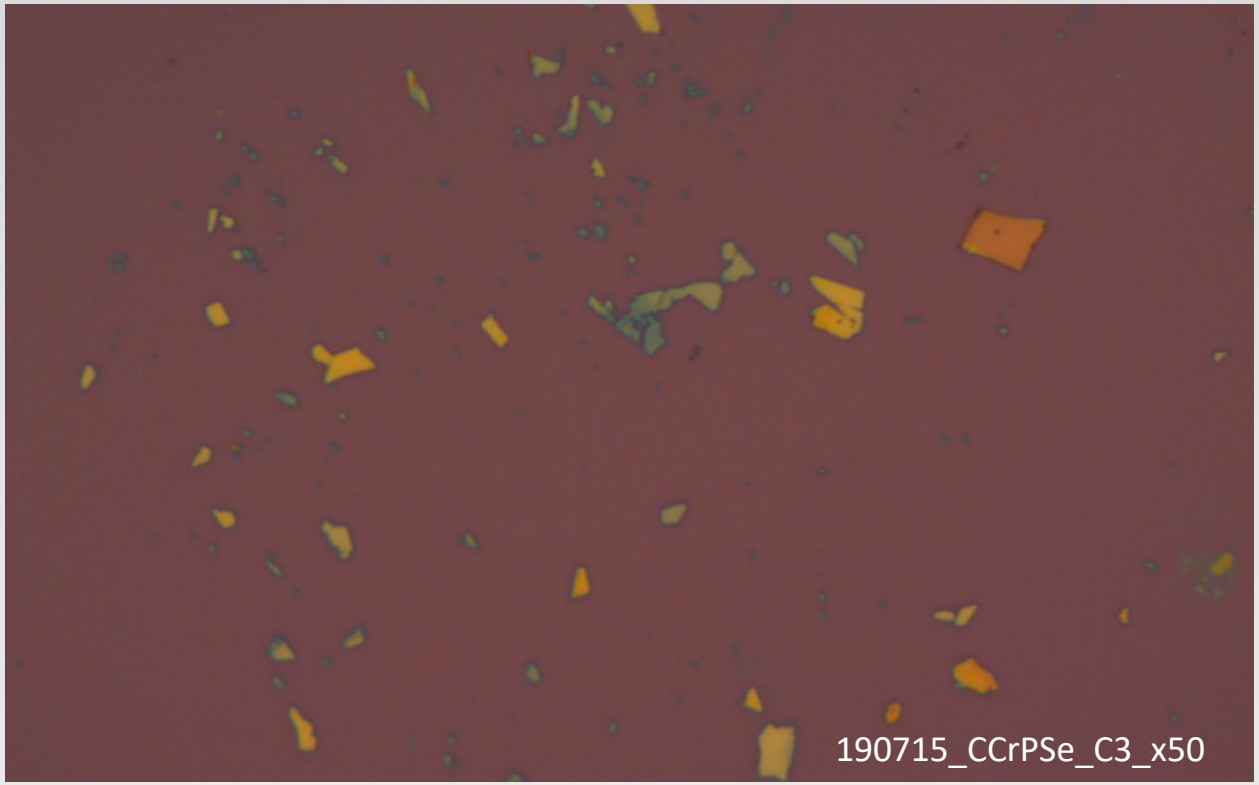
The AFM scan resolution is not high enough to measure sub 10nm flakes.

Teal, ~10nm, dark green, ~20nm, light green, ~50nm and yellow, 60nm

Data - CCrPS



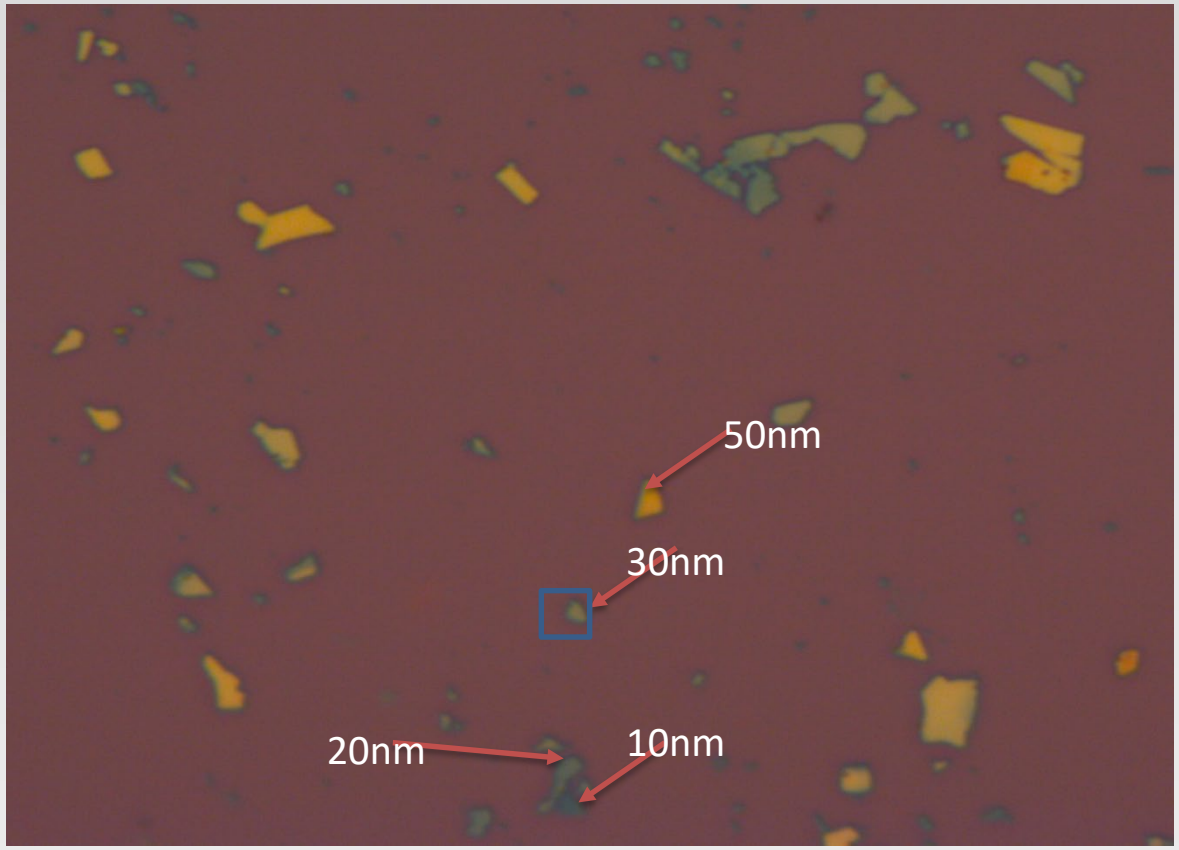
- Displays an upward trend in peak intensity in correlation to thickness
- The expectation is for sub 10nm flakes to have signature that is close to the substrate's signature while maintaining peaks from certain Raman-shift



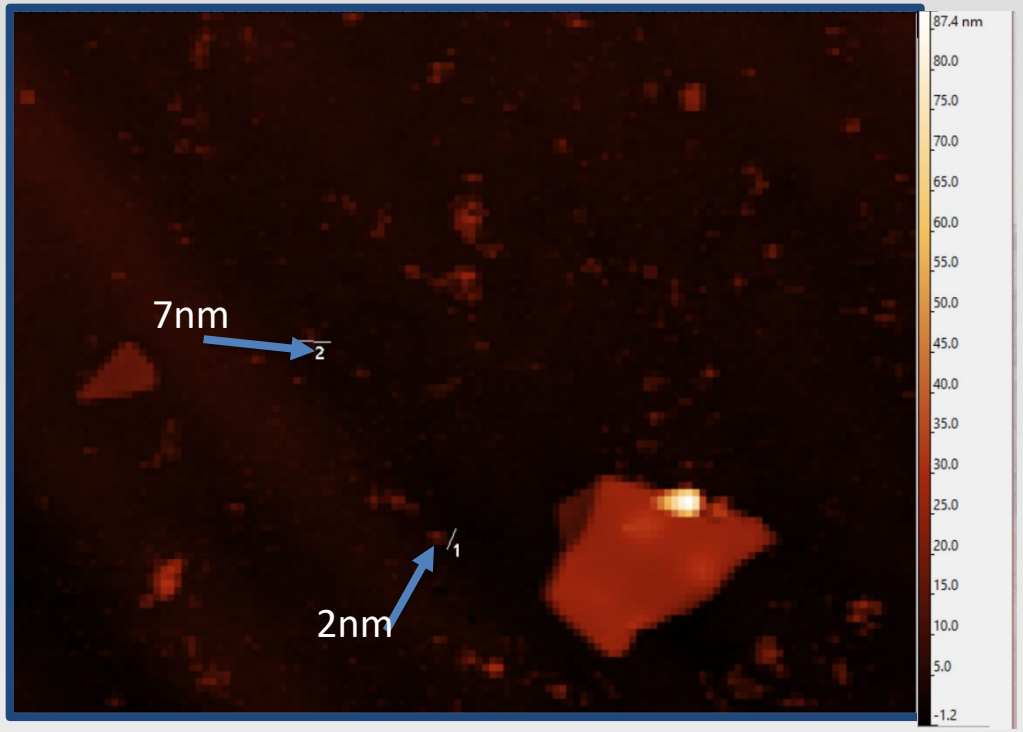
$CuCrP_2Se_6$ (CCrPSe)

- CCrPSe has large transitory energy barrier towards the FE phase.[4]
- In addition, magnetism originates from Cr, which is principally at the FM phase and more stable than AFM (Antiferromagnetic). [4]
- Suitable for 2D ferroelectric nanoscale switch and memory applications[4]

Data - CCrPSe



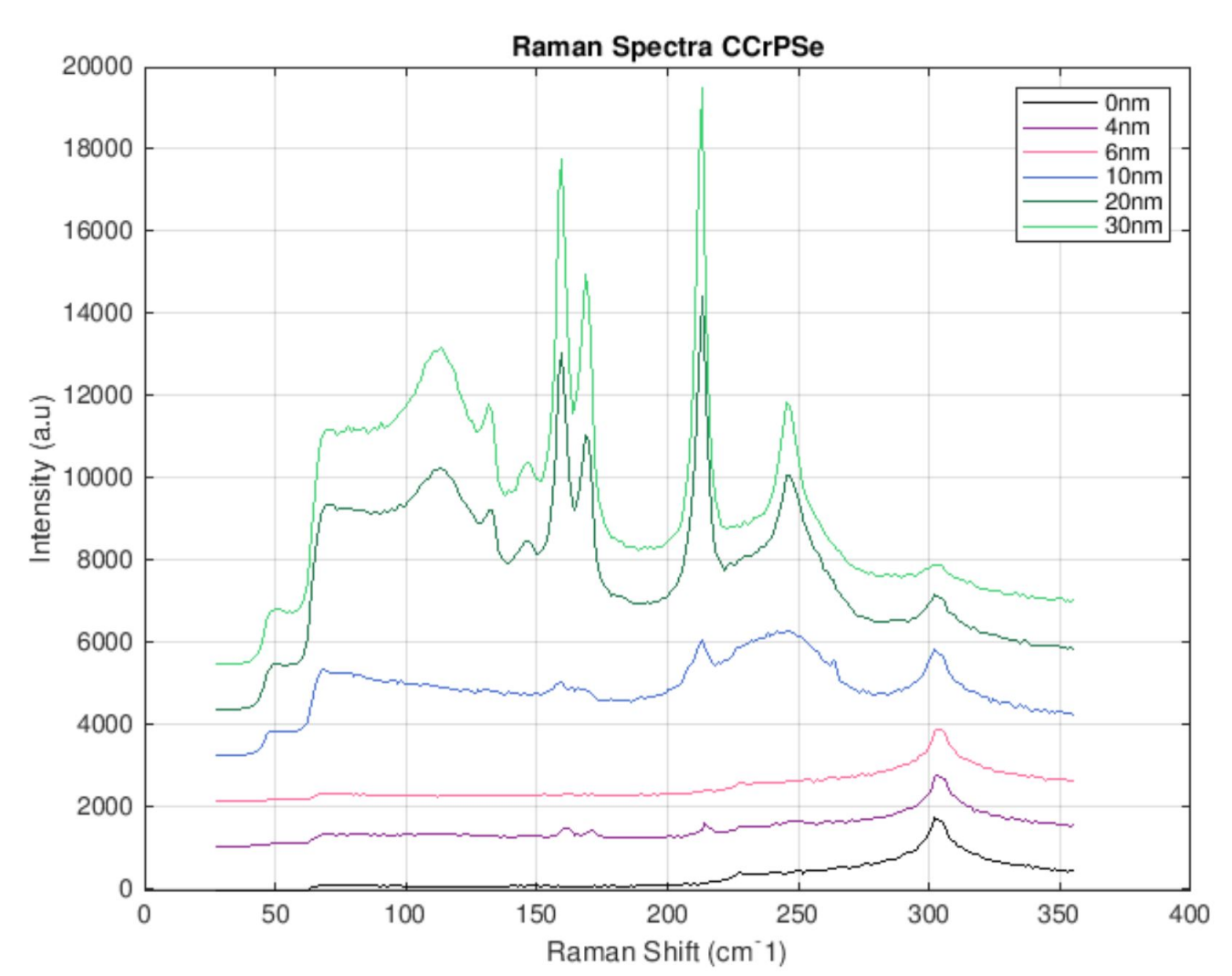
190715_CCrPSe_C3_x50



190715_CCrPSe_C3_ 3x6µm Scansize

The imaging analyzing software, Gwyddion helped to find thinner flakes ranging from 2 – 7nm within the same region of interest.

Data - CCrPSe

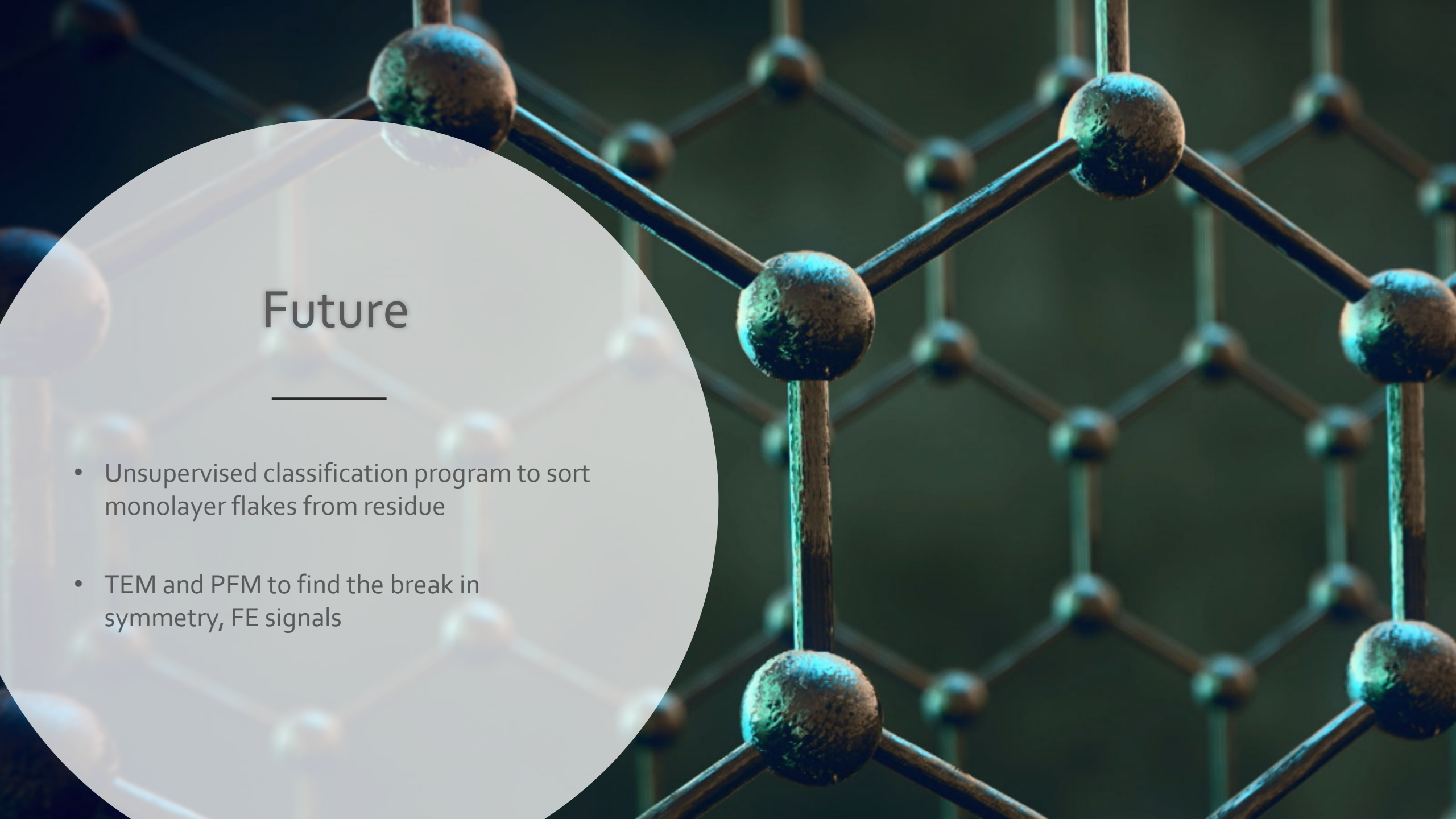


- The qualitative measurements of the Raman Spectroscopy confirm the same trend.
- Focusing on sub 10nm flakes, the expectation is to see a signature that is close to the substrate's signature with distinct peaks

MOVING FORWARD

Conclusion

- Magnetoelectric multiferroic materials are versatile and compact
  - Ferroelectric, enabled by spontaneous shift of electric dipoles
  - Ferromagnetic, enabled by ordered magnetic moment
- The combination of using the Atomic Force Microscope and Raman spectrometer proved to be consistent



Future

- Unsupervised classification program to sort monolayer flakes from residue
- TEM and PFM to find the break in symmetry, FE signals

SHyNE
Soft and Hybrid Nanotechnology Experimental Resource

National Nanotechnology Coordinated Infrastructure

Thank You

VPD GROUP

Northwestern | INTERNATIONAL INSTITUTE FOR NANOTECHNOLOGY

NUANCE

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