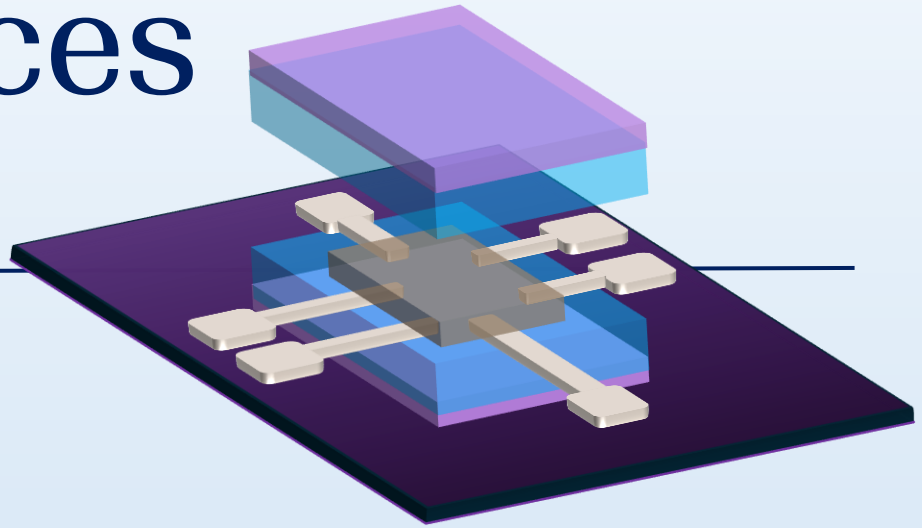
Developing Low Temperature Contacts for Monolayer TMD Heterostructure Devices



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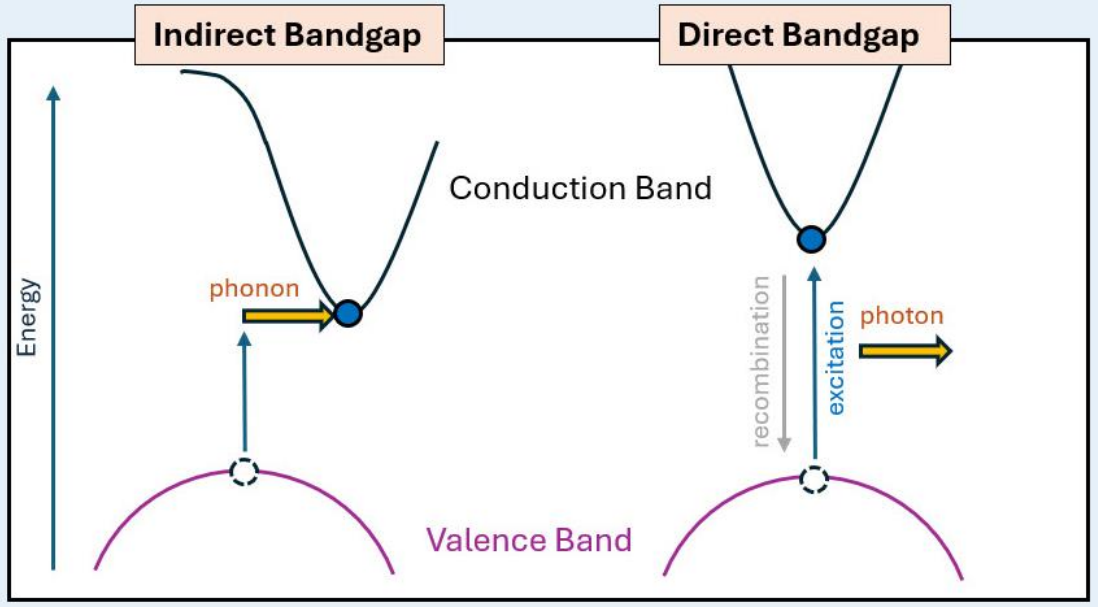
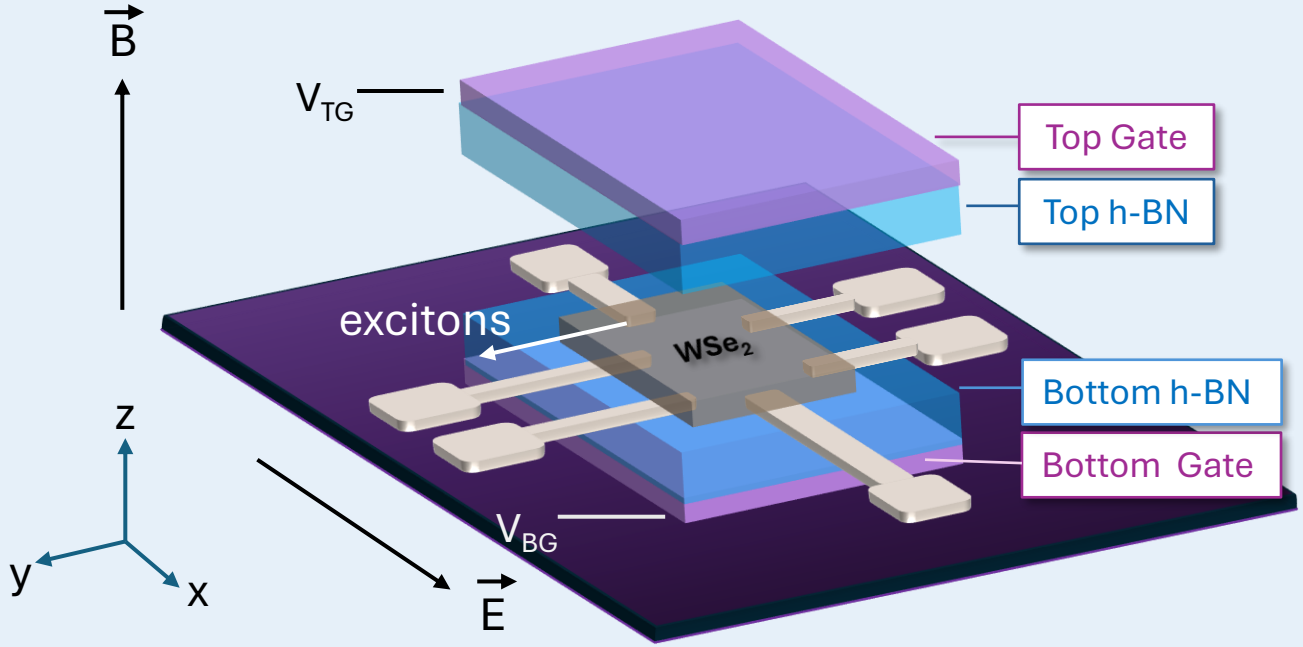
Background

Semiconductor transition metal dichalcogenide (TMD) devices bring efficiency to electronics.

- Silicon-based chip
- **Direct band gap** in the monolayer limit, by which a photon can be emitted without the aid of a phonon

WSe_2 and device quality through **Photoluminescence (PL)**

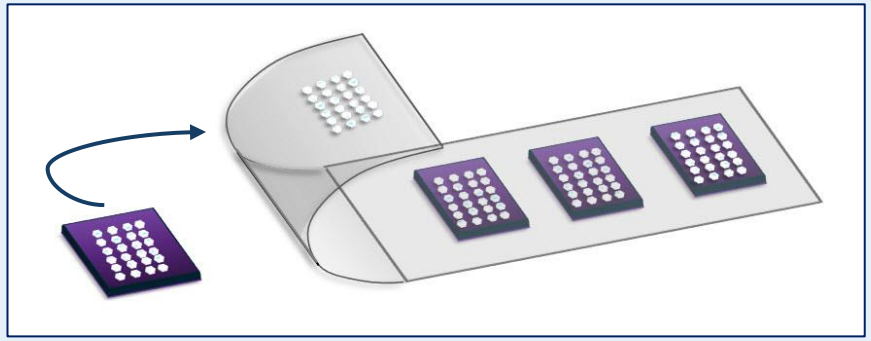




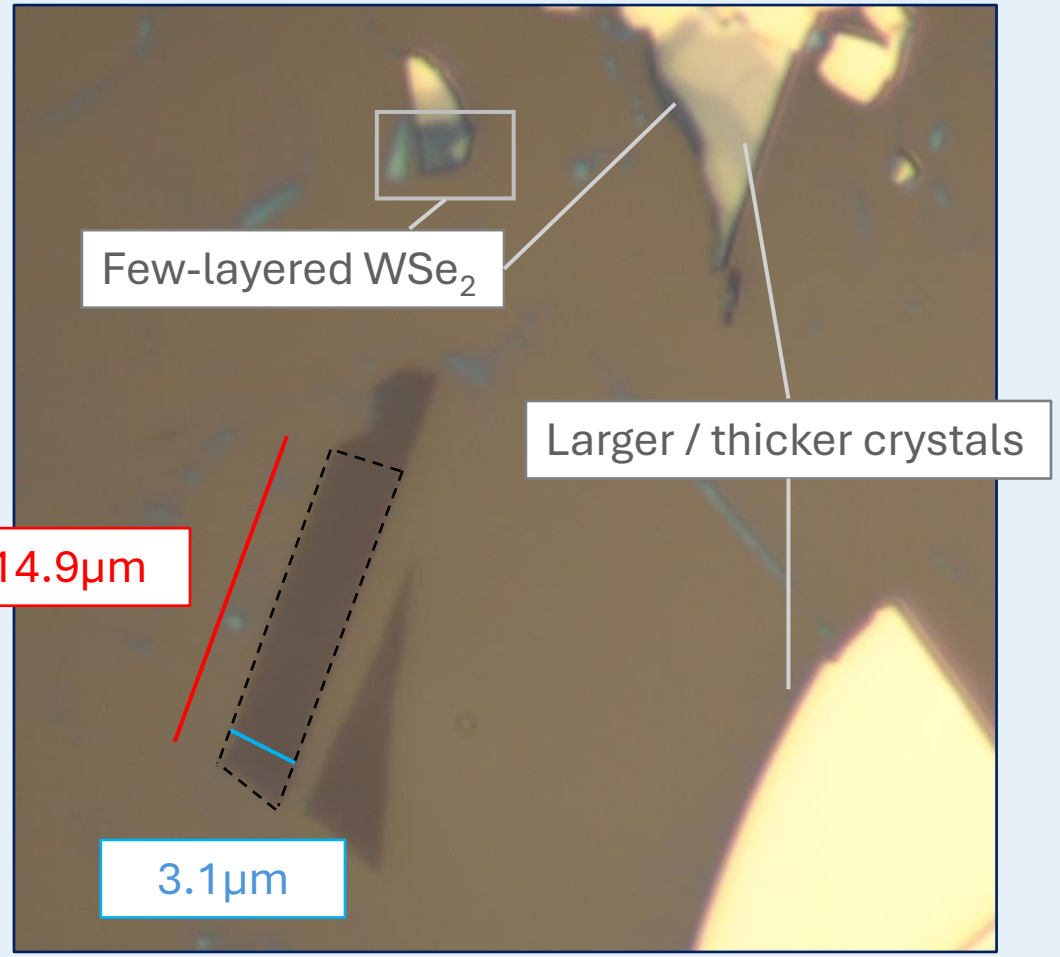
Device Fabrication Method

Mechanical Exfoliation

- Scotch tape cleaves bulk material at where vdW forces < chemical bonds
- An array of replicated, sheared bulk material pressed down onto substrate.
- **O_2 plasma** *organic materials*
- **Heating** of tapes *varied adhesion*



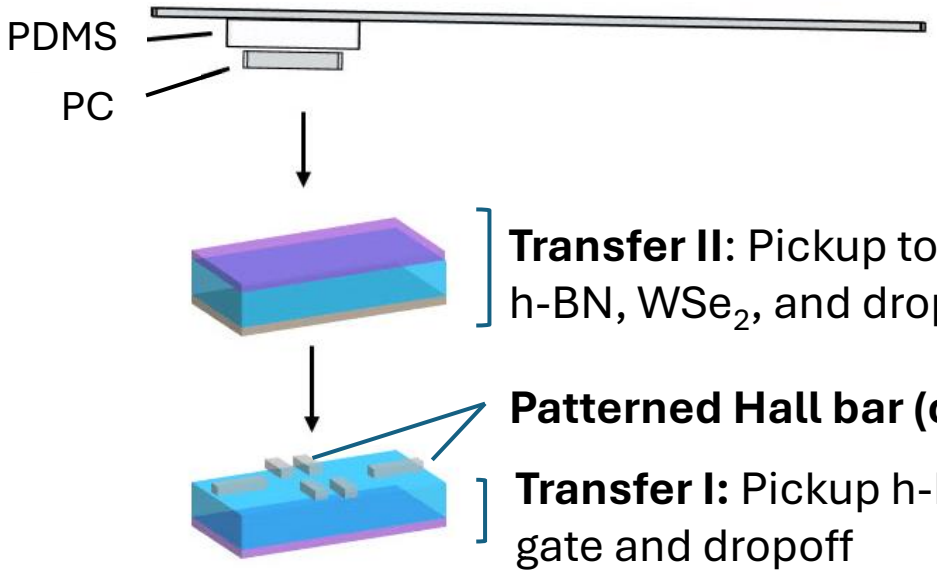
Graphite, h-BN (illustrated), and WSe_2 onto wafer chips

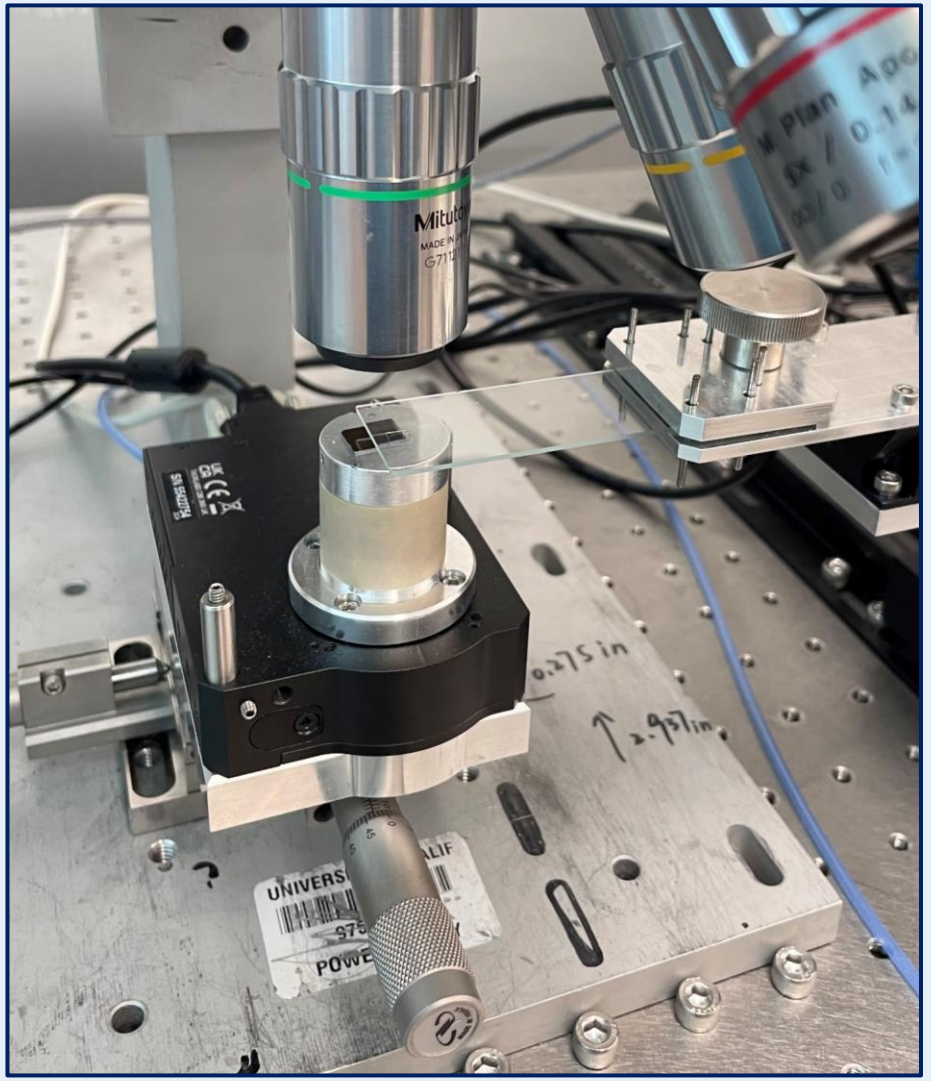


WSe_2 monolayers (Measurements scaled at 100x on 90nm SiO_2)

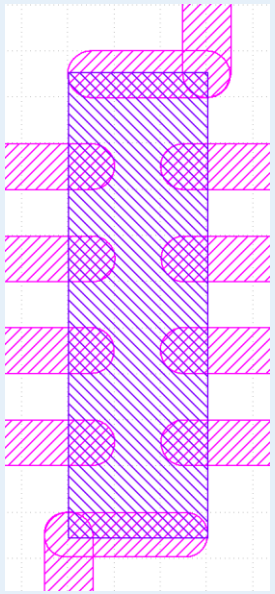
Dry Transfer

- Stacking of samples through picking up and dropping off with **PDMS/PC** stamp on microscope slide
- Heating / cooling of stamp for adhesiveness



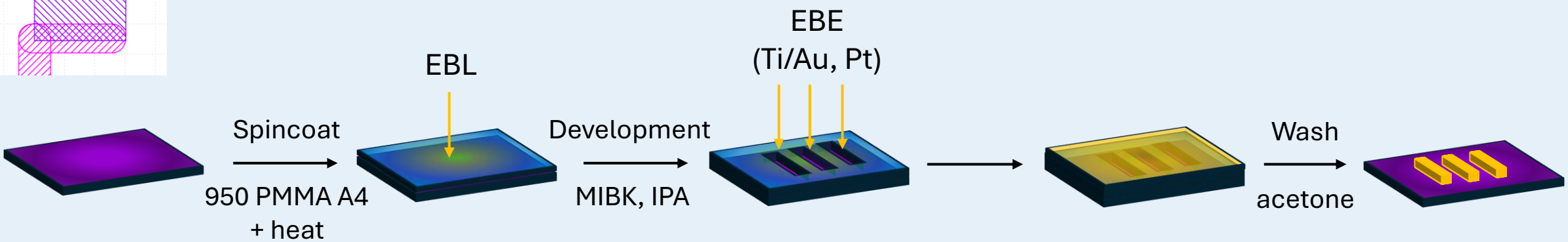


Patterning



Hall bar design on KLayout

- Alignment marks and pre-patterned contacts
- Unique pattern superimposed on alignment marks with transferred on with identical coordinates



SiO_2 substrate, ideally high R

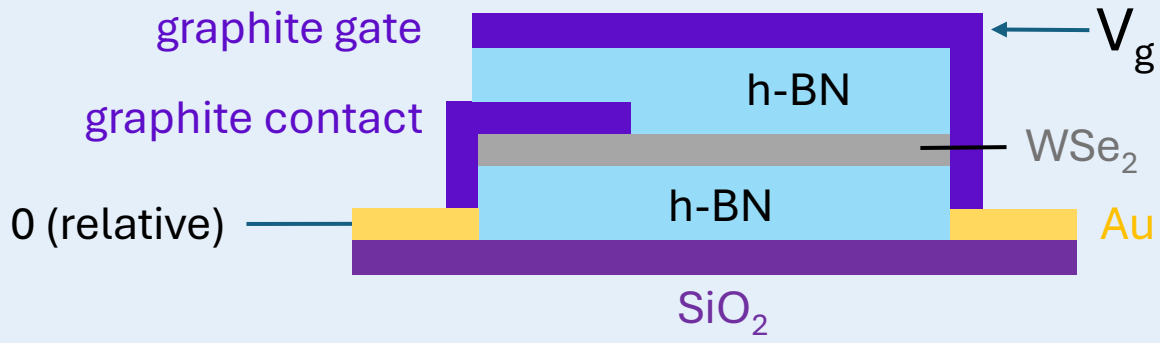
E-beam lithography (EBL) etches design out of polymer

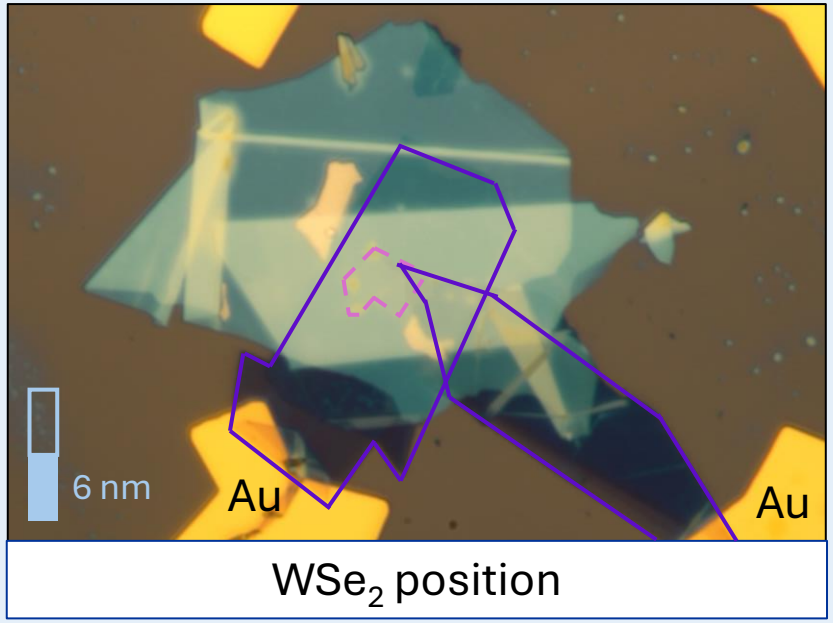
E-beam evaporation (EBE) deposits material onto surface

Pattern in material revealed on substrate

Optical (PL) data for gate tunability

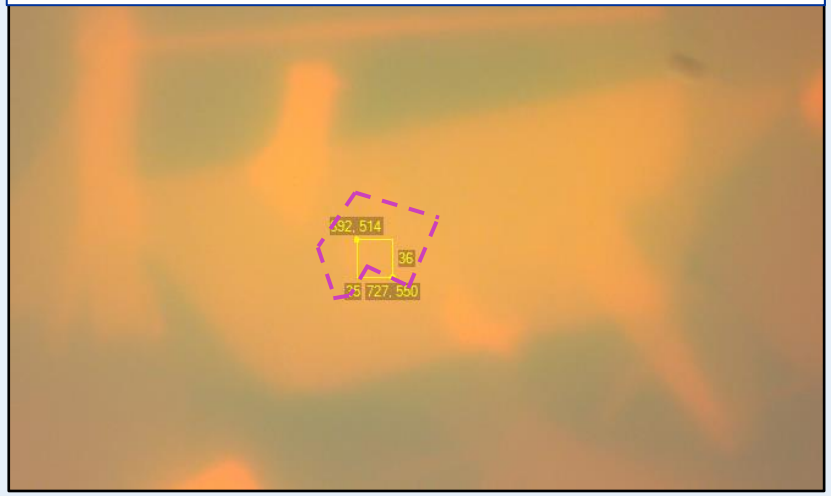
- Single-gated device with graphite contact to prepattern





WSe_2 position

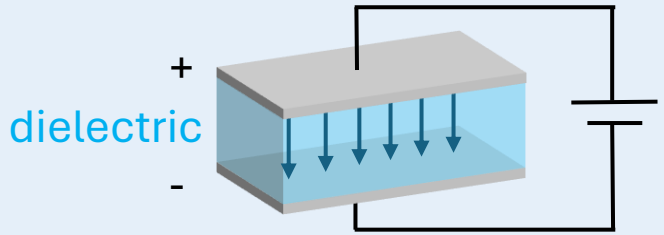
Laser position



- Au vs Pt

Applied voltage values → Wavelength and intensity of light emitted (PL)

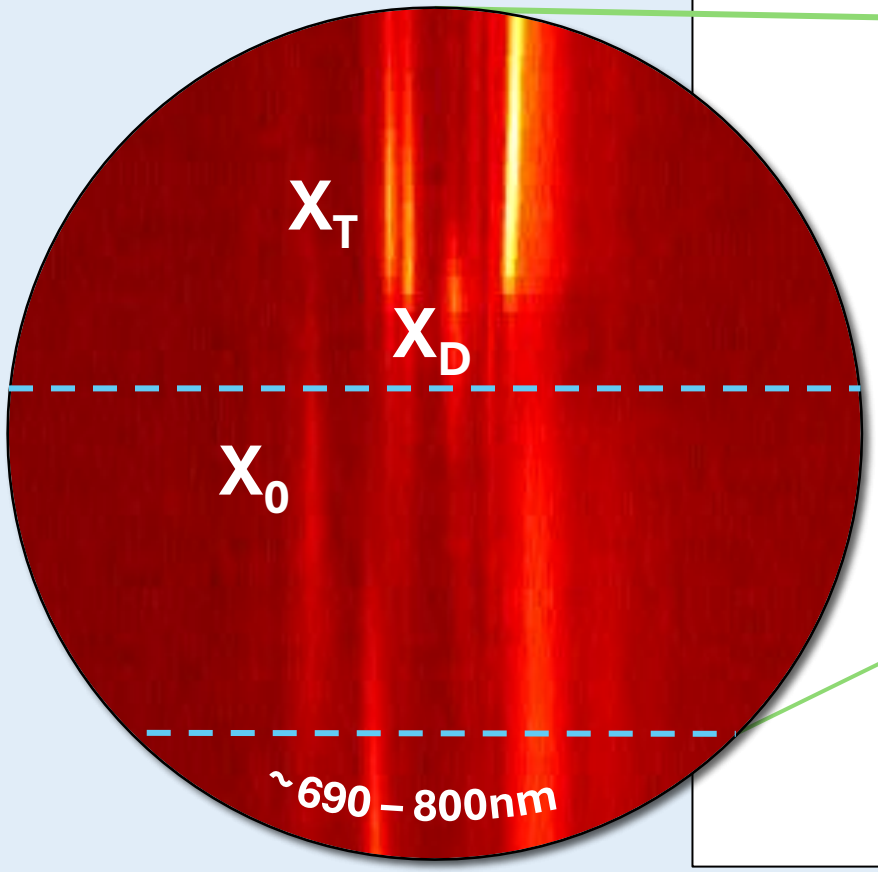
- Electron doping

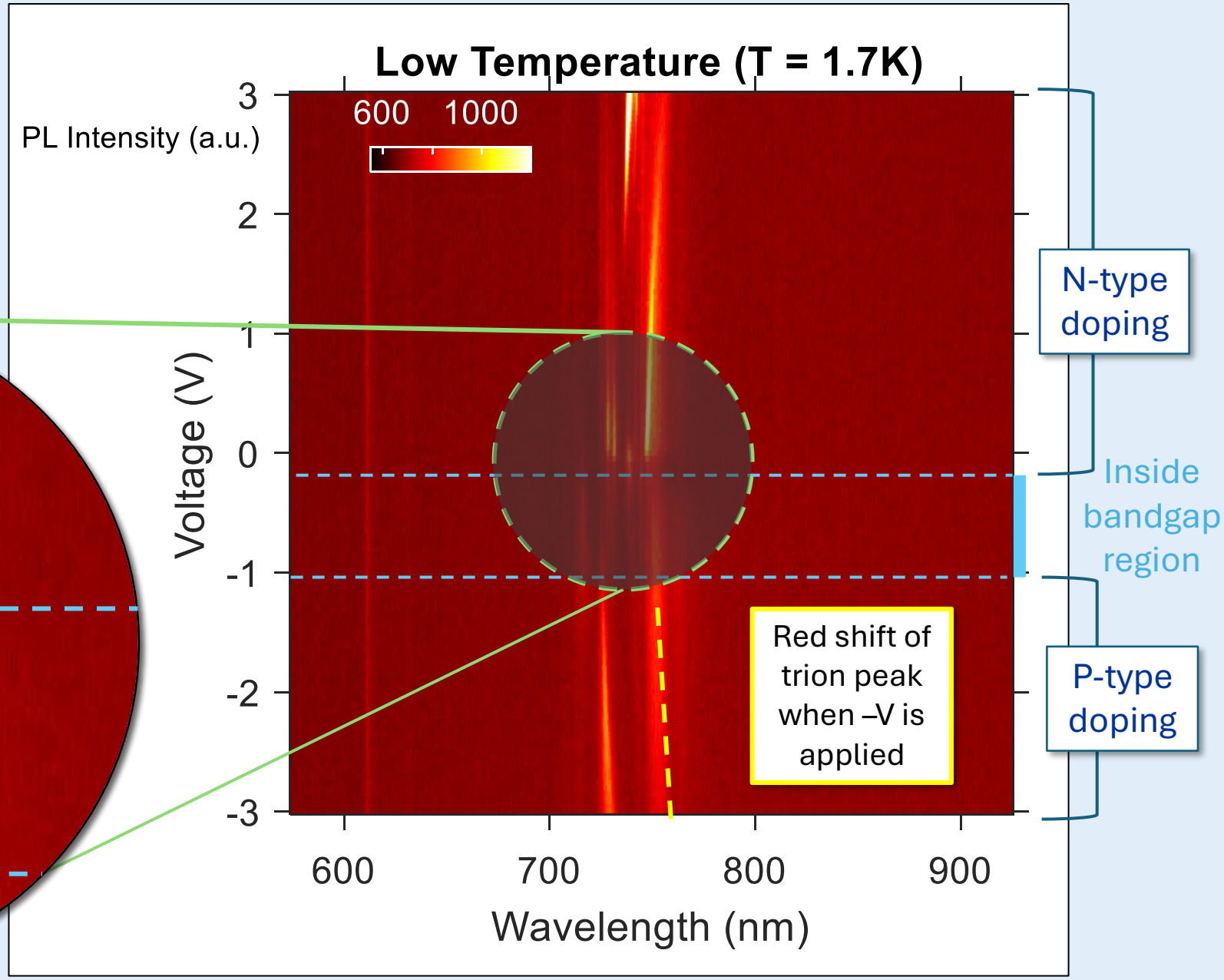


X_0 = neutral exciton emission

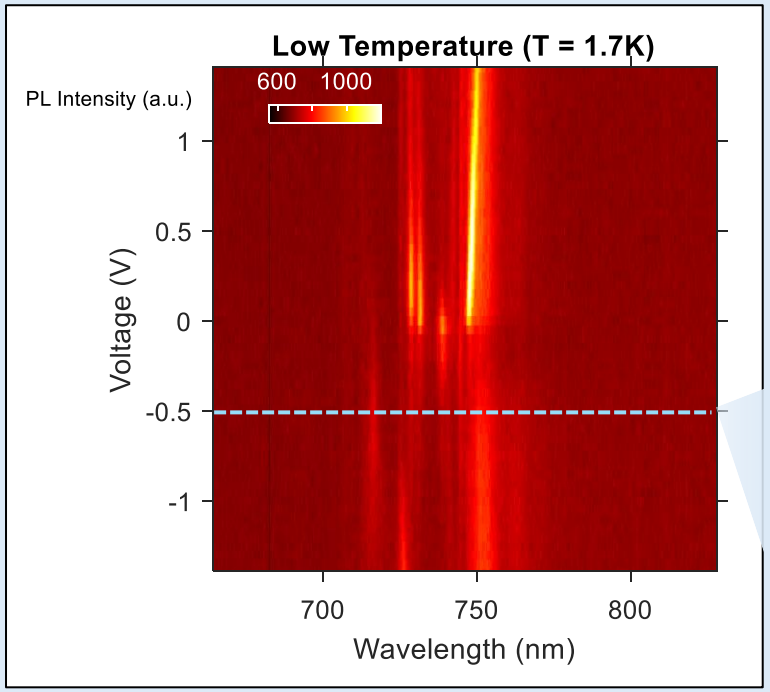
X_T = charged exciton emission

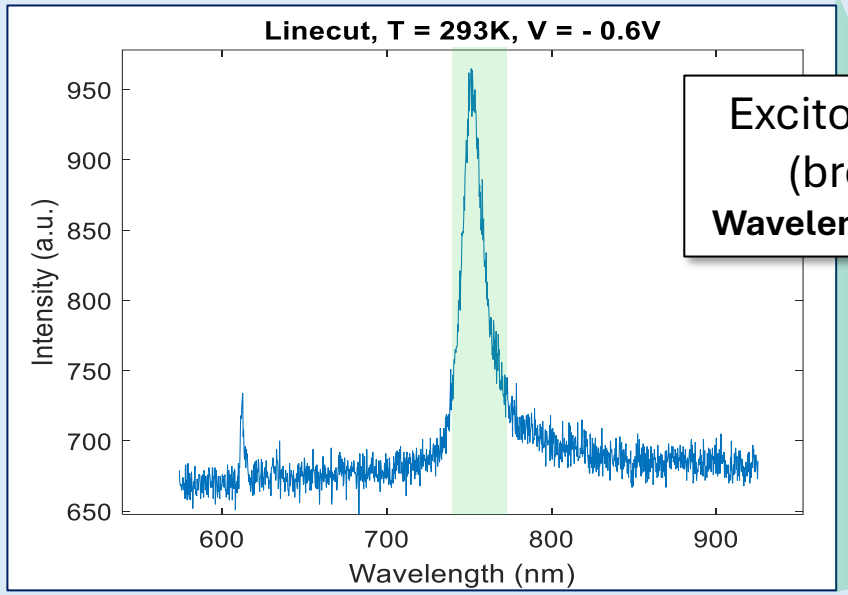
X_D = dark exciton, out-of-plane transition dipole moment



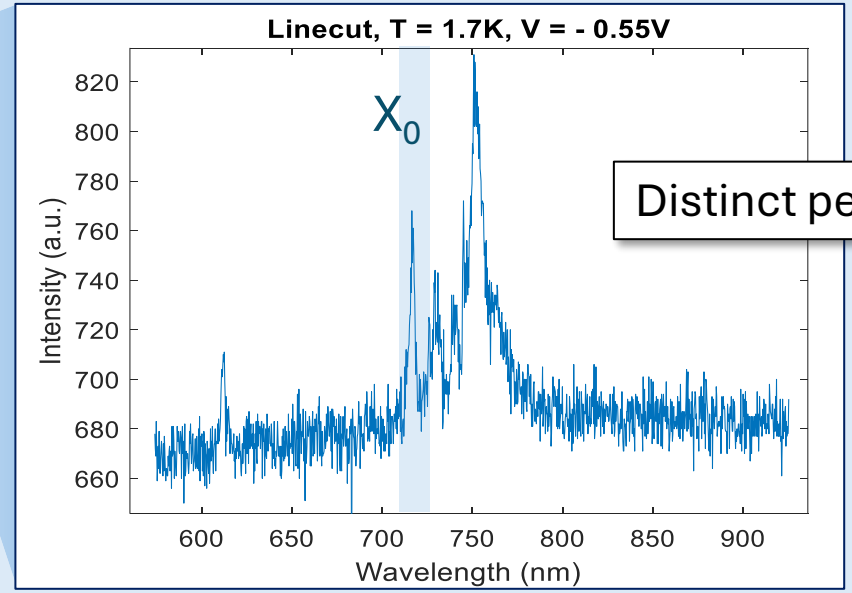


Horizontal linecuts of PL plots



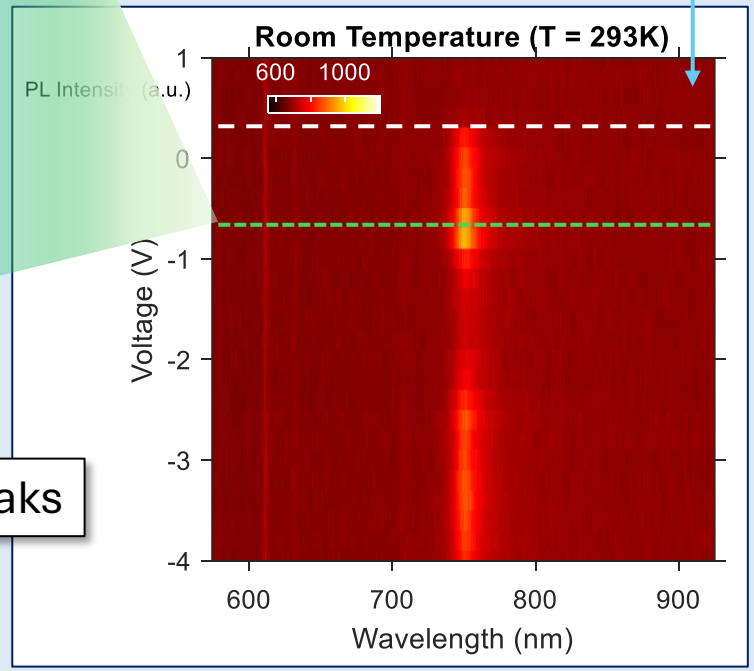


Exciton activity (broader)
Wavelength ~750nm



Distinct peaks

Doped region



Linecut fitted to Lorentzian function

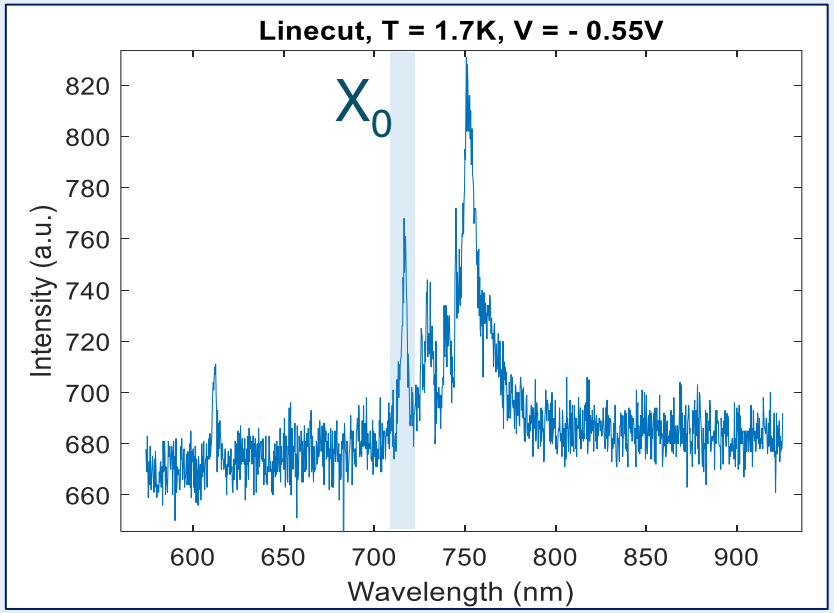
Line width

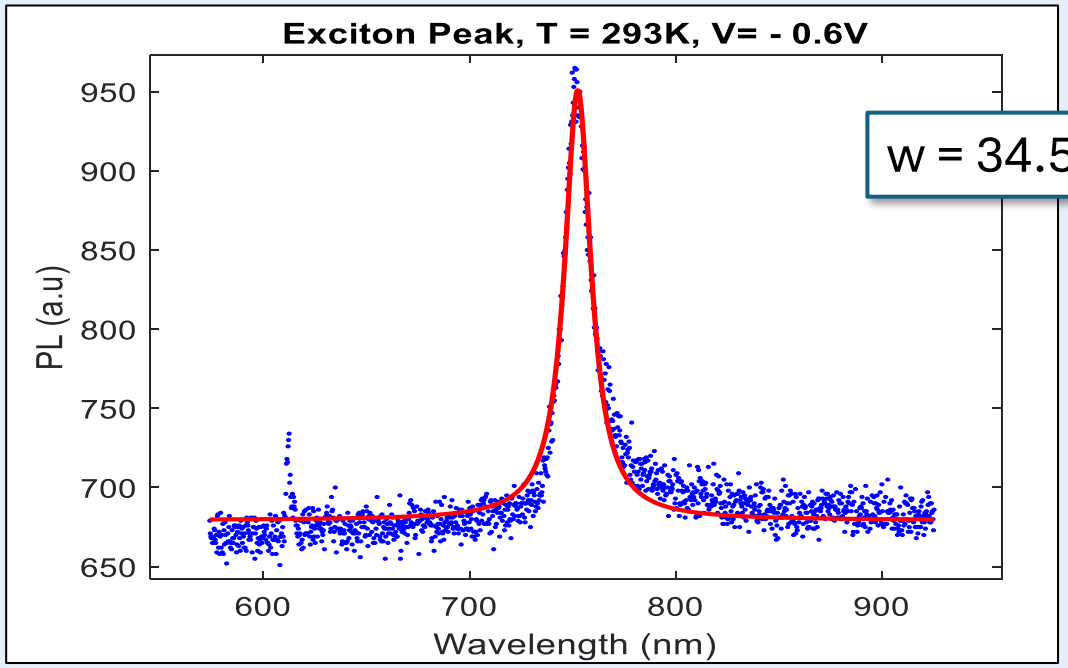
Wavelengths in a spectral line; width at half max

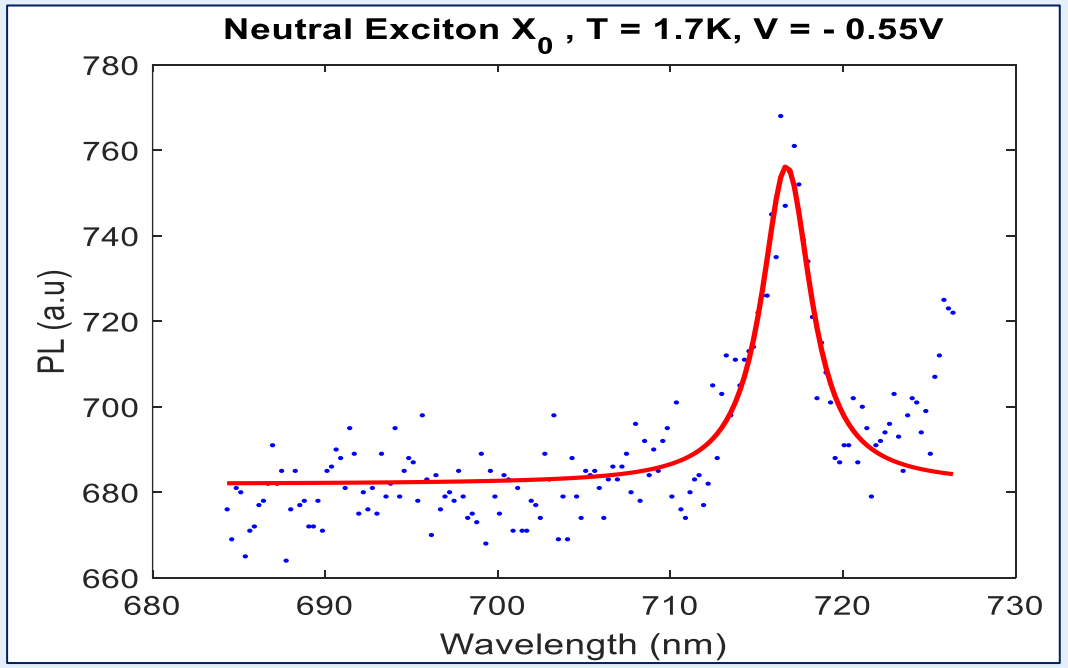
Narrow → identical exciton behavior (ideal) → w = 8.4 meV

Broad → Various wavelengths emitted; Defects from cleanliness or temperature → w = 34.5 meV

w = 2 - 4 meV at 4K (Zhou, et al. *Nat. Nanotech.*)



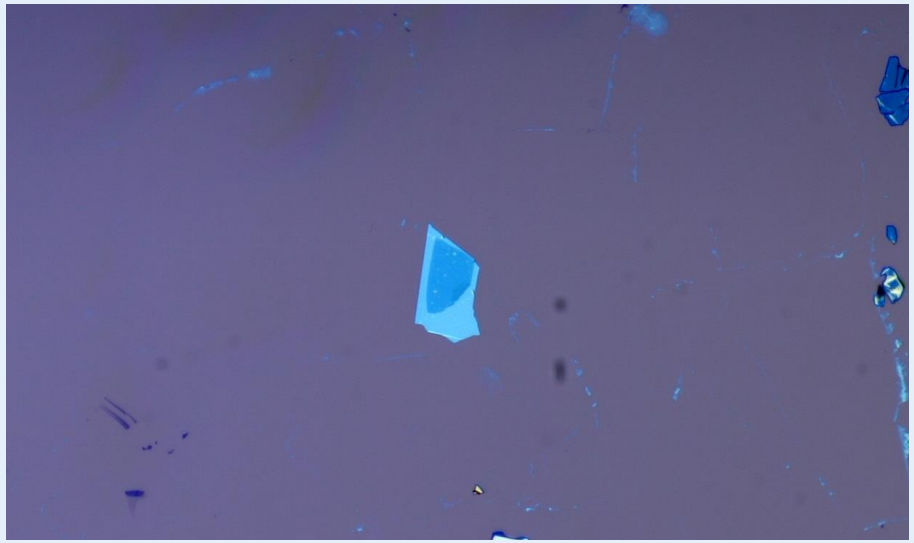


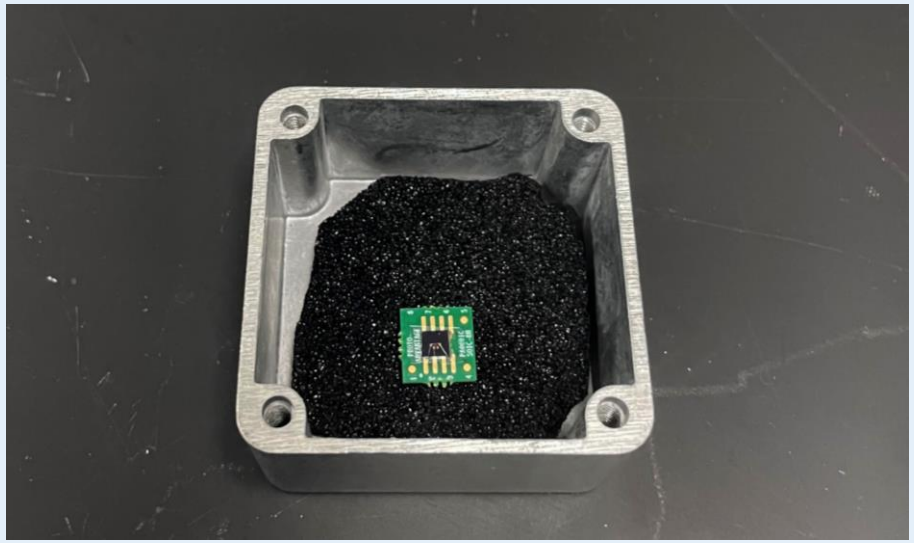


Conclusion

- With current data, we continue with the fabrication of a device with Hall bar patterning
- Current data determine quality of WSe_2
- Guidance for PL

Our reference brings us closer to the ultimate goal of our research of measuring charged transport in developed contacts for WSe_2





Acknowledgements

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2D materials - hBN

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