

## Fabricating van der Waals heterostructures

Presented by: Justin Boddison-Chouinard, June 2019.

# Outline

## Introduction

### Methods of fabricating new materials

- The transfer setup
- Transfer methods
- Rotational alignment
- Cleaning procedures

### 2D material heterostructures for quantum confinement

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# Van der Waals materials

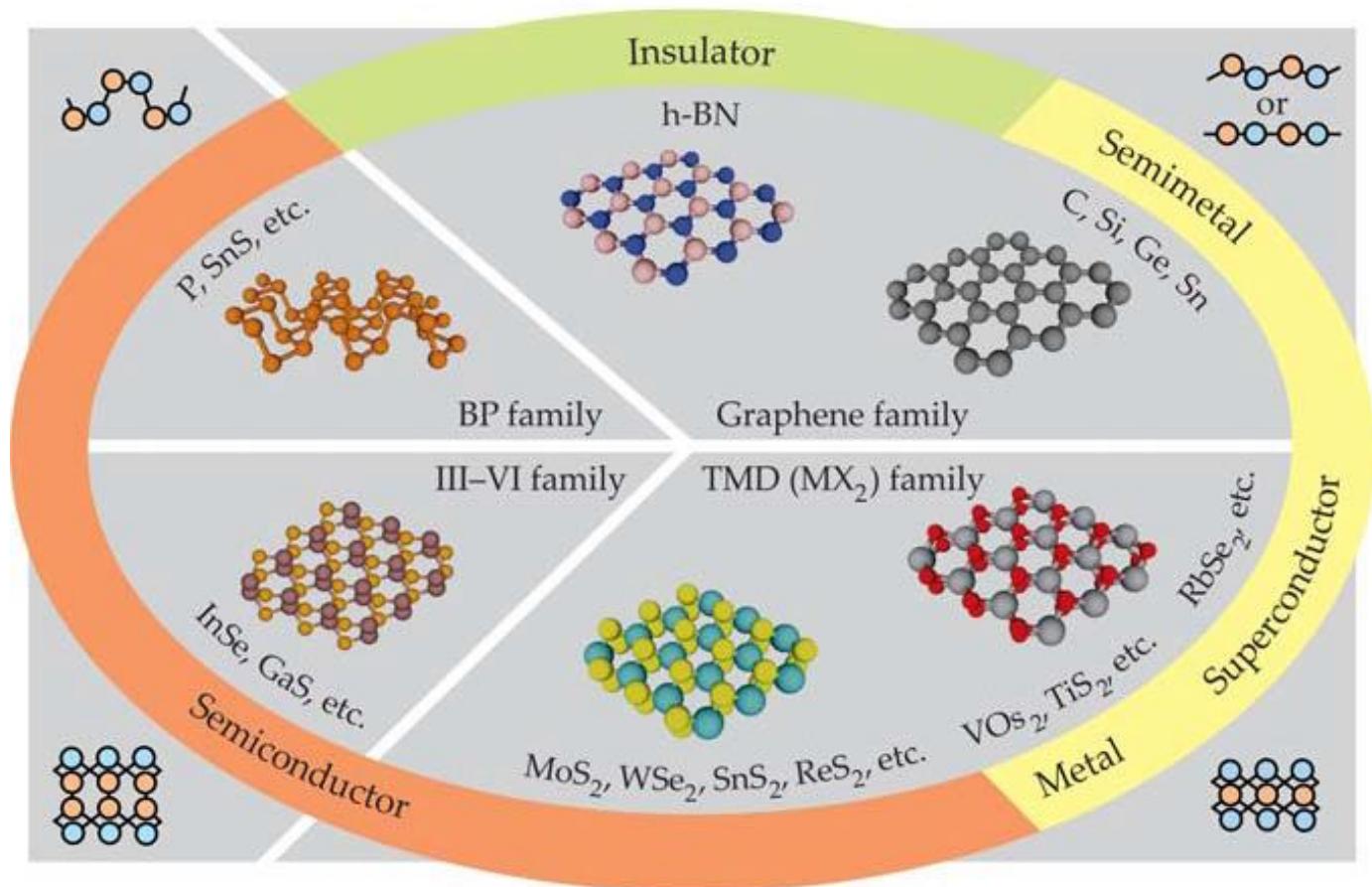
Crystal:

- Layered structure

Bonding:

- Strong in-plane covalent bonds
- Weak out-of-plane van der Waal bonds

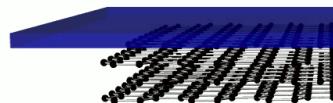
Van der Waals materials span the entire spectrum of electronic properties



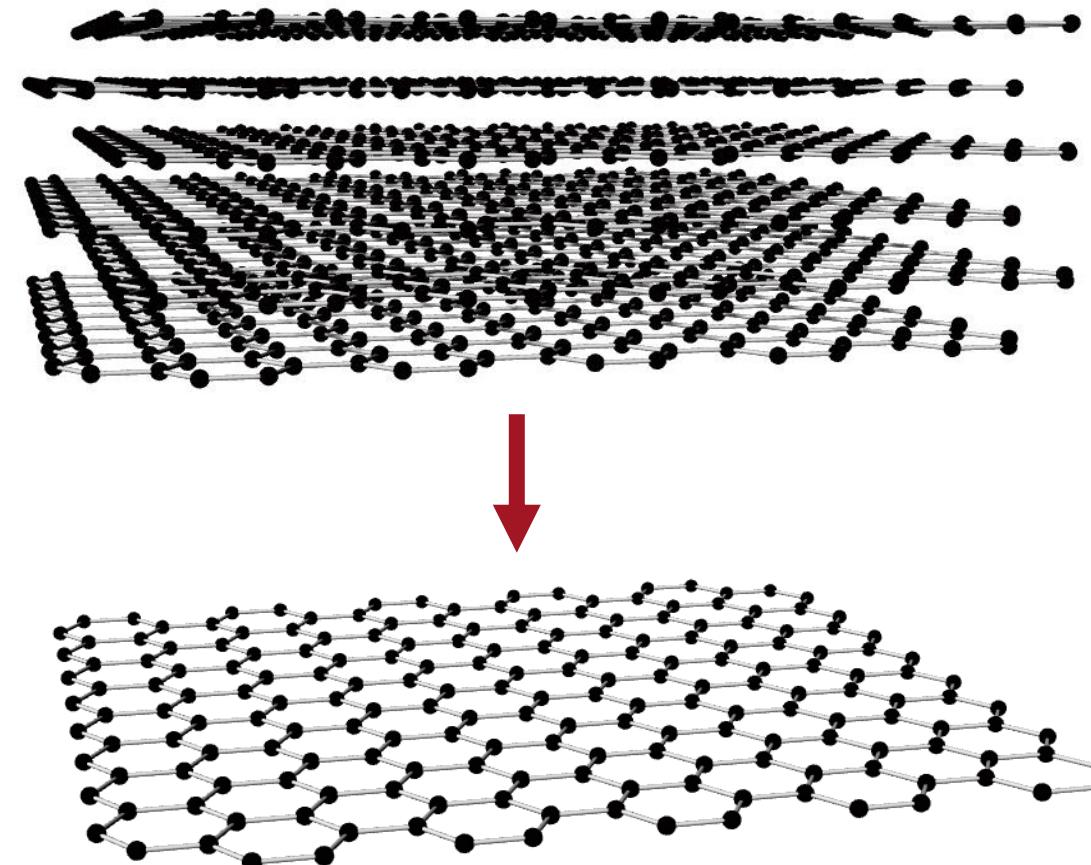
P. Ajayan, P. Kim, and K. Banerjee, *Physics Today*, 2016

## 3D to 2D

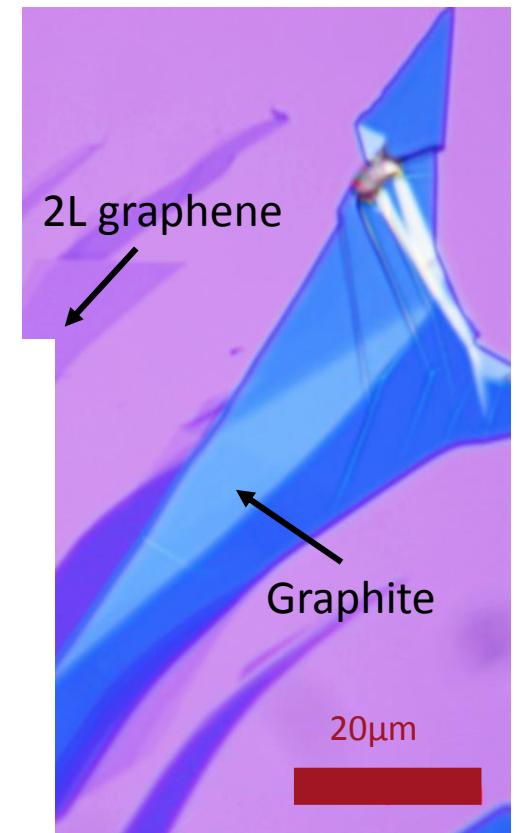
3D  
Adhesive tape



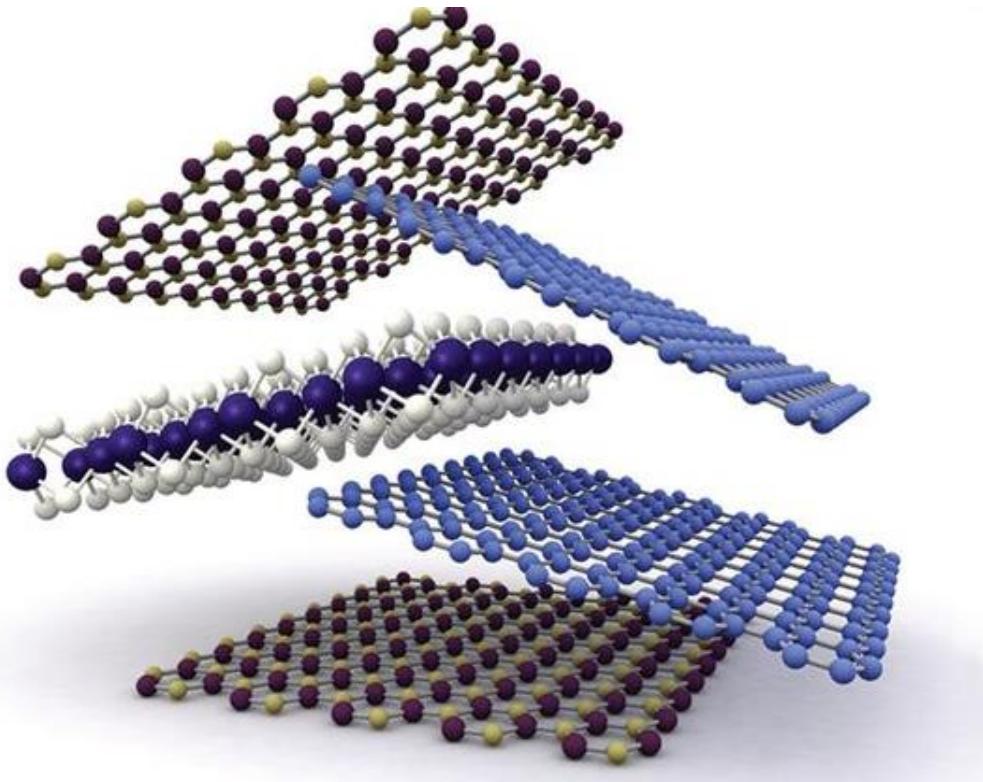
2D  
 $\text{Si}/\text{SiO}_2/\text{S}$



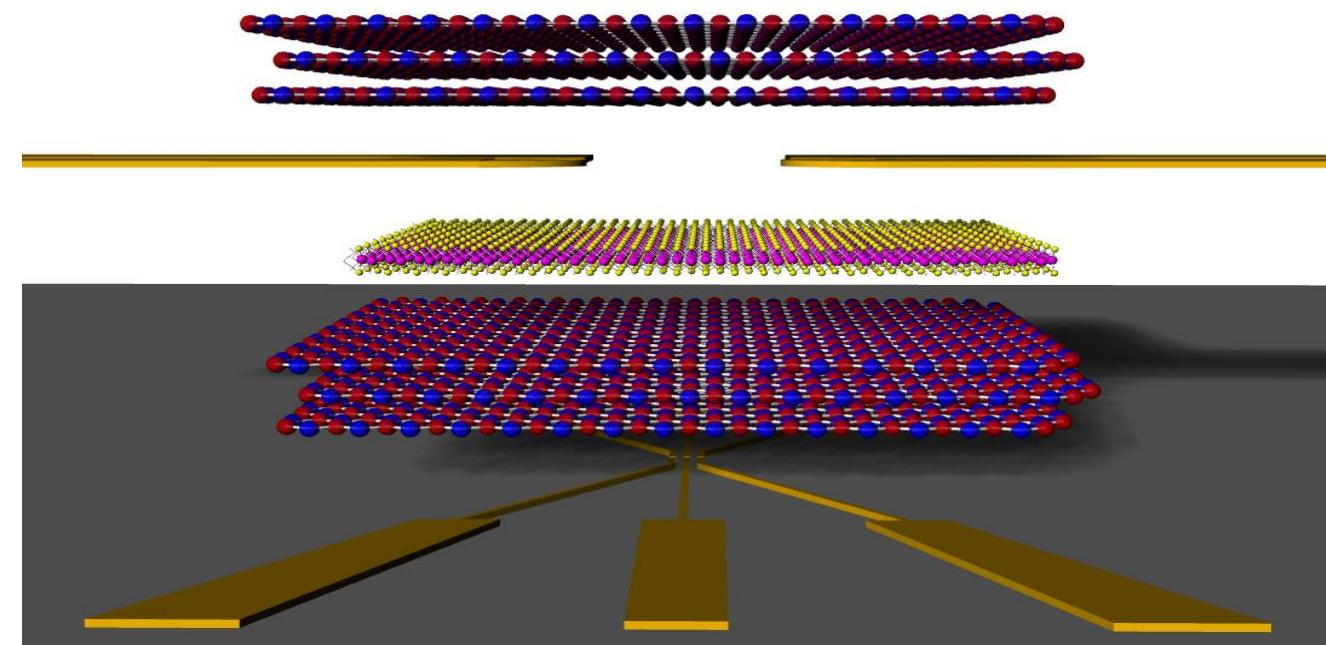
cope (100X)



# van der Waals heterostructures



New platform for quantum dots



K. S. Novoselov, A. Mishchenko, A. Carvalho, A. H. Castro Neto,  
*Science*, 29 Jul 2016

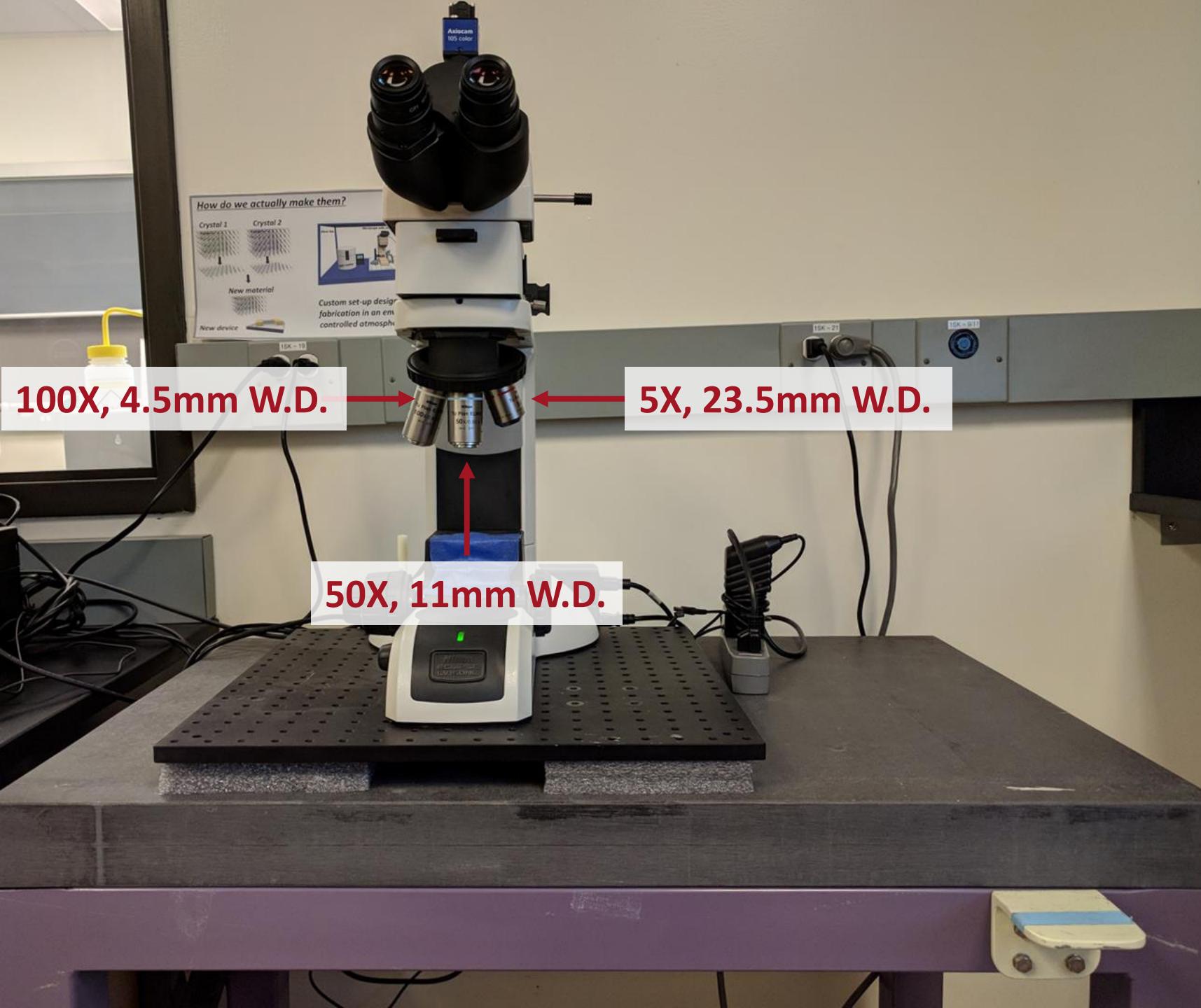
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# The transfer setup

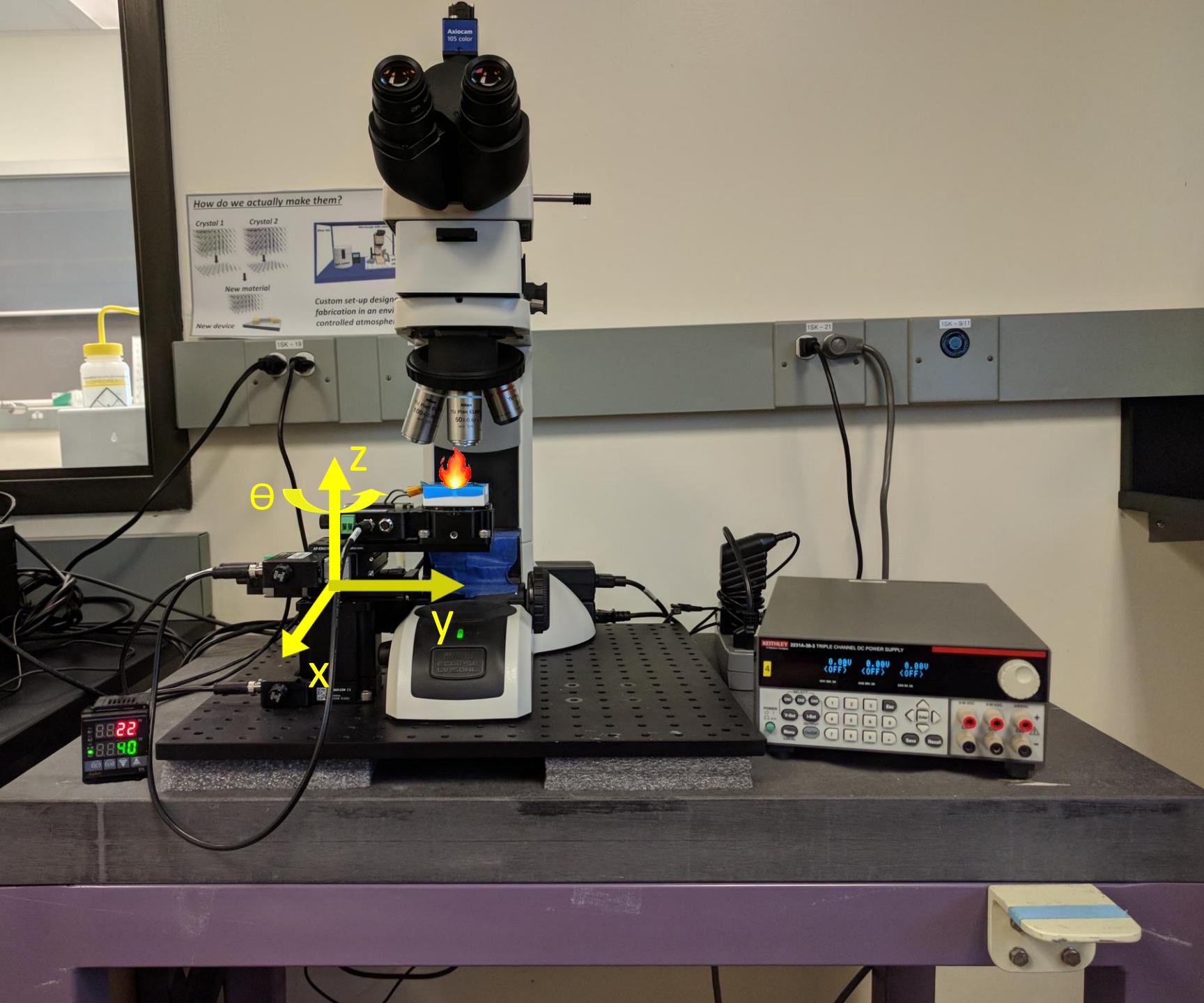
Optical microscope

Long working distance objectives



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# The transfer setup



**Bottom Stage:**

**XYZ $\theta$  motion**

**Heated stage**

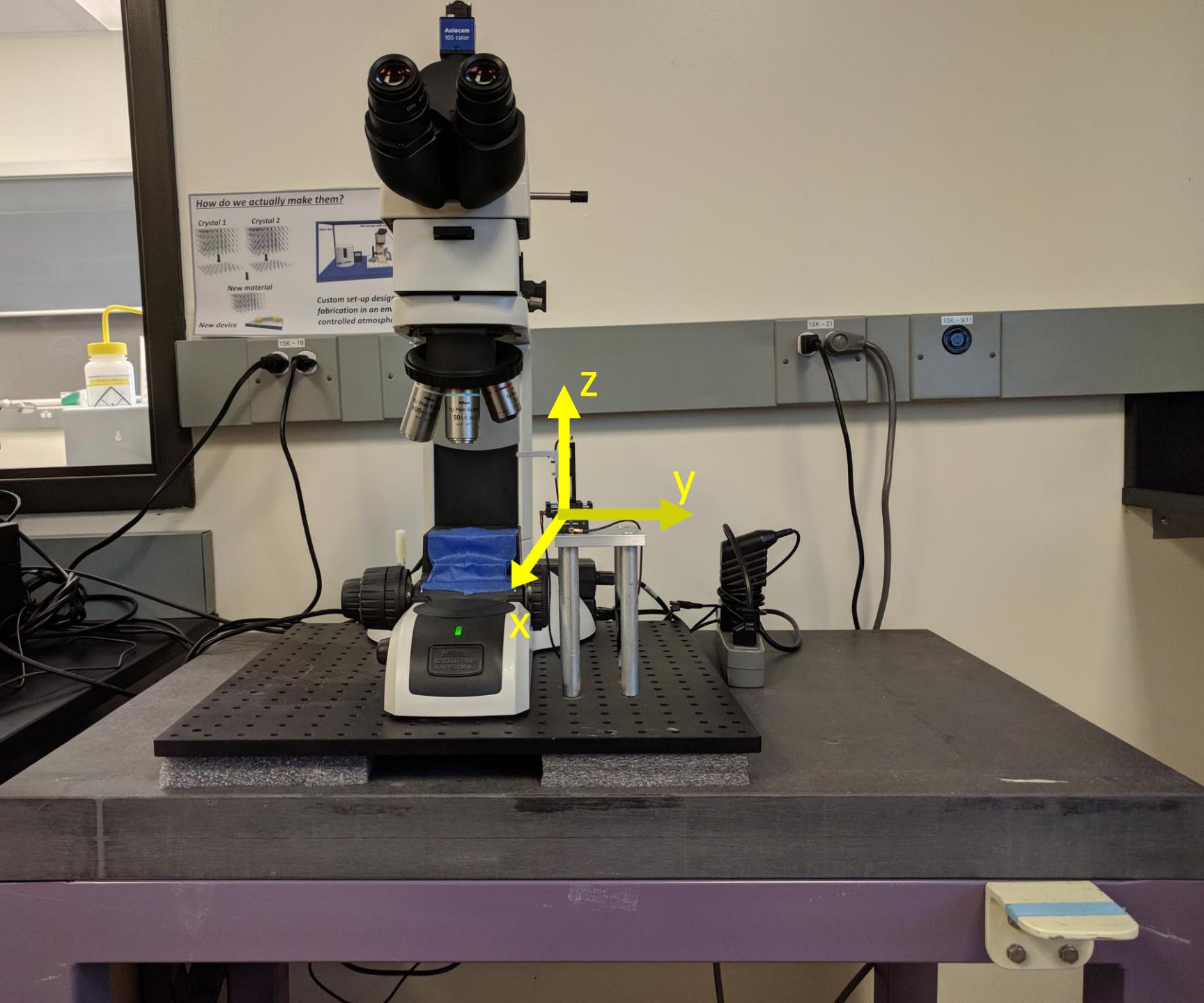


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# The transfer setup

**Top Stage:**

**XYZ motion  
(10nm step size)**



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# The transfer setup

Computer controlled

- Programmed with LabVIEW

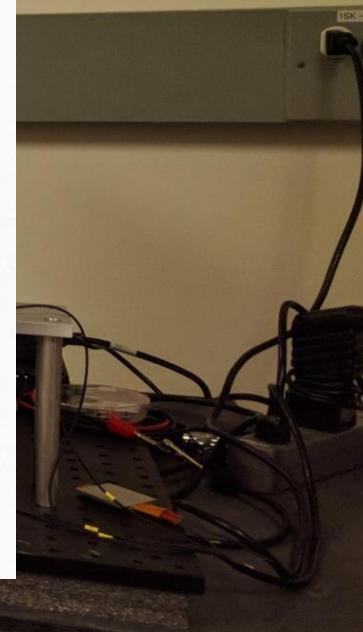
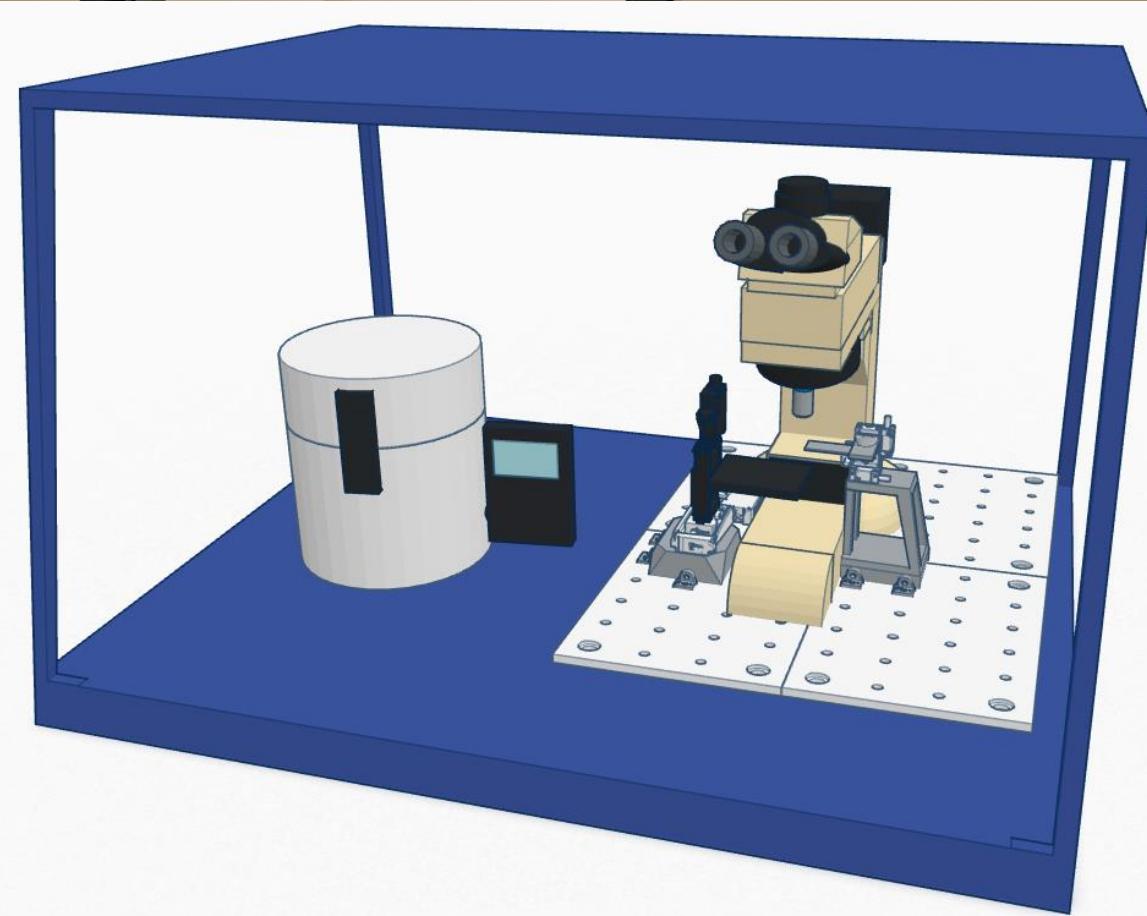
High resolution camera

Hands free

- Possibility to be moved into a glovebox

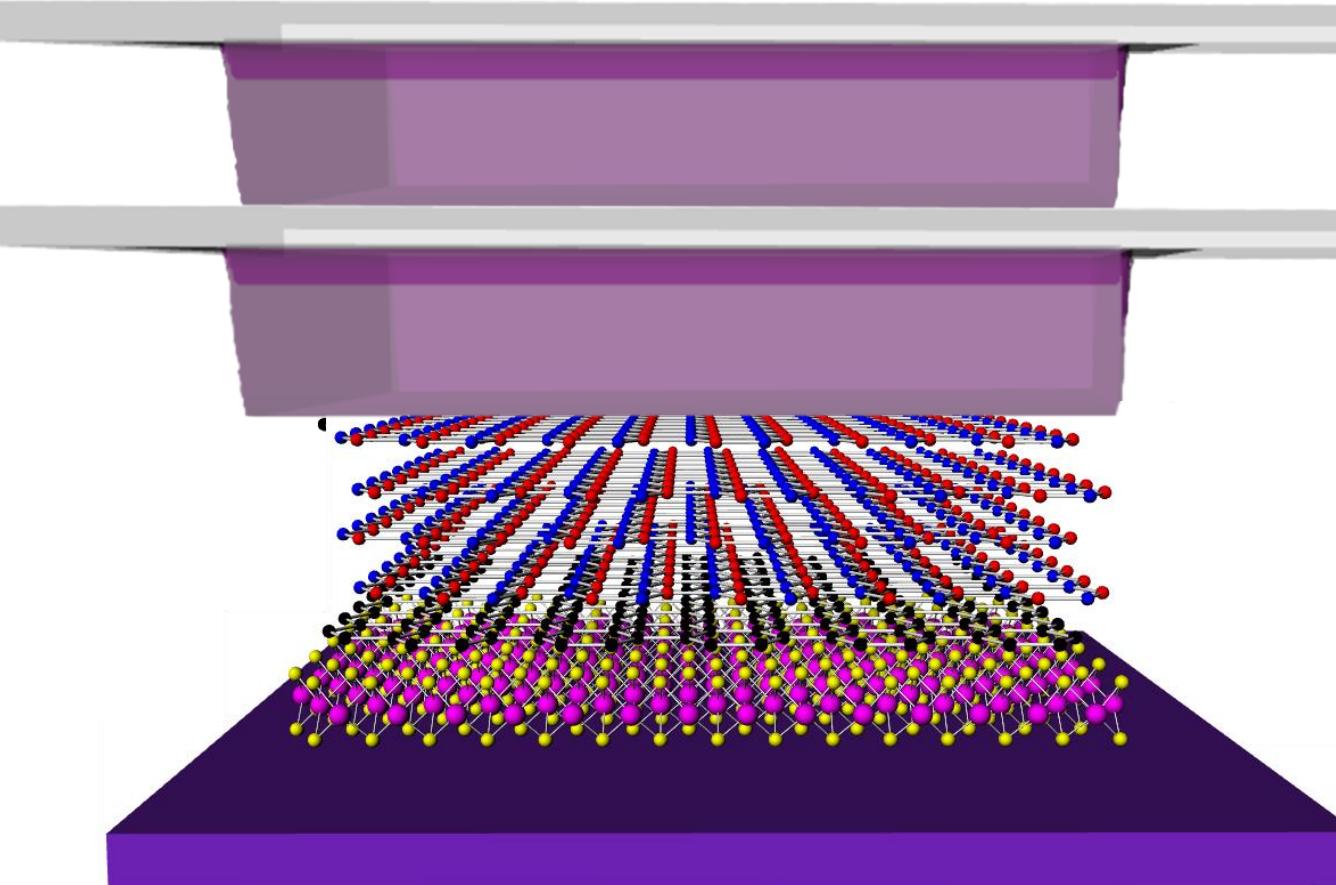


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# Transfer methods



Various methods:

- PMMA/PVA<sup>1</sup>
- Stamping<sup>2</sup>
- Pick-up<sup>2</sup>

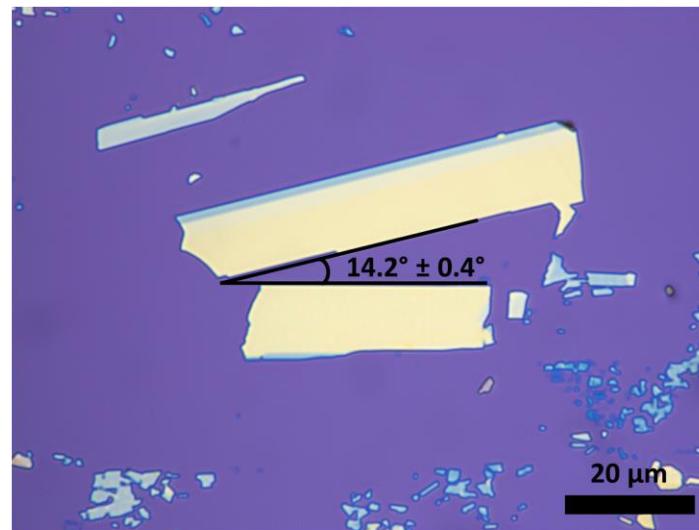
Polymers:

- PMMA
- PVA
- PPC
- PDMS

1. C. R. Dean, et al., *Boron nitride substrates for high-quality graphene electronics*, *Nature Nanotechnologies*, 2010

2. L. Wang, et al., *One-dimensional electrical contact to a two-dimensional material*, *Science*, 2013

# Rotational alignment

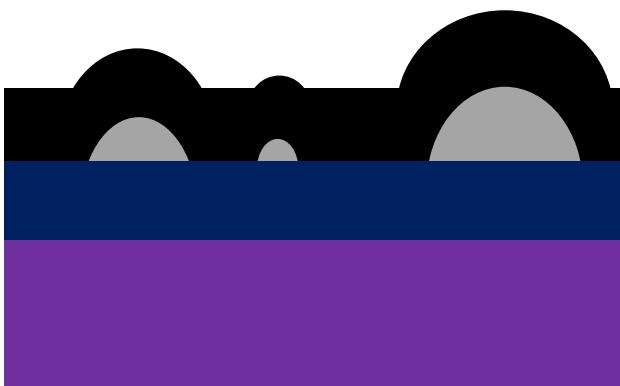


# Cleaning procedures

Polymer residues



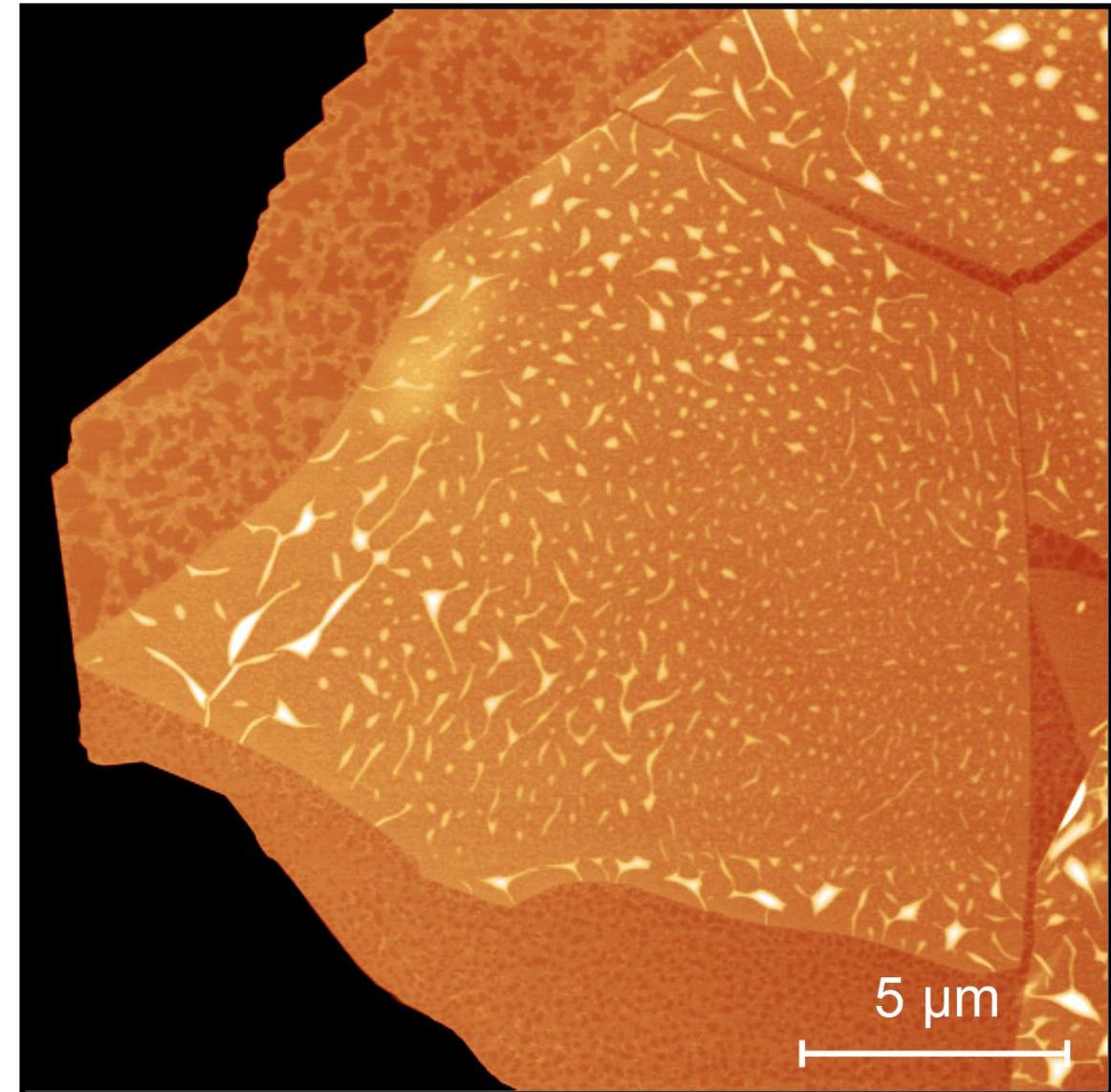
2<sup>nd</sup> layer



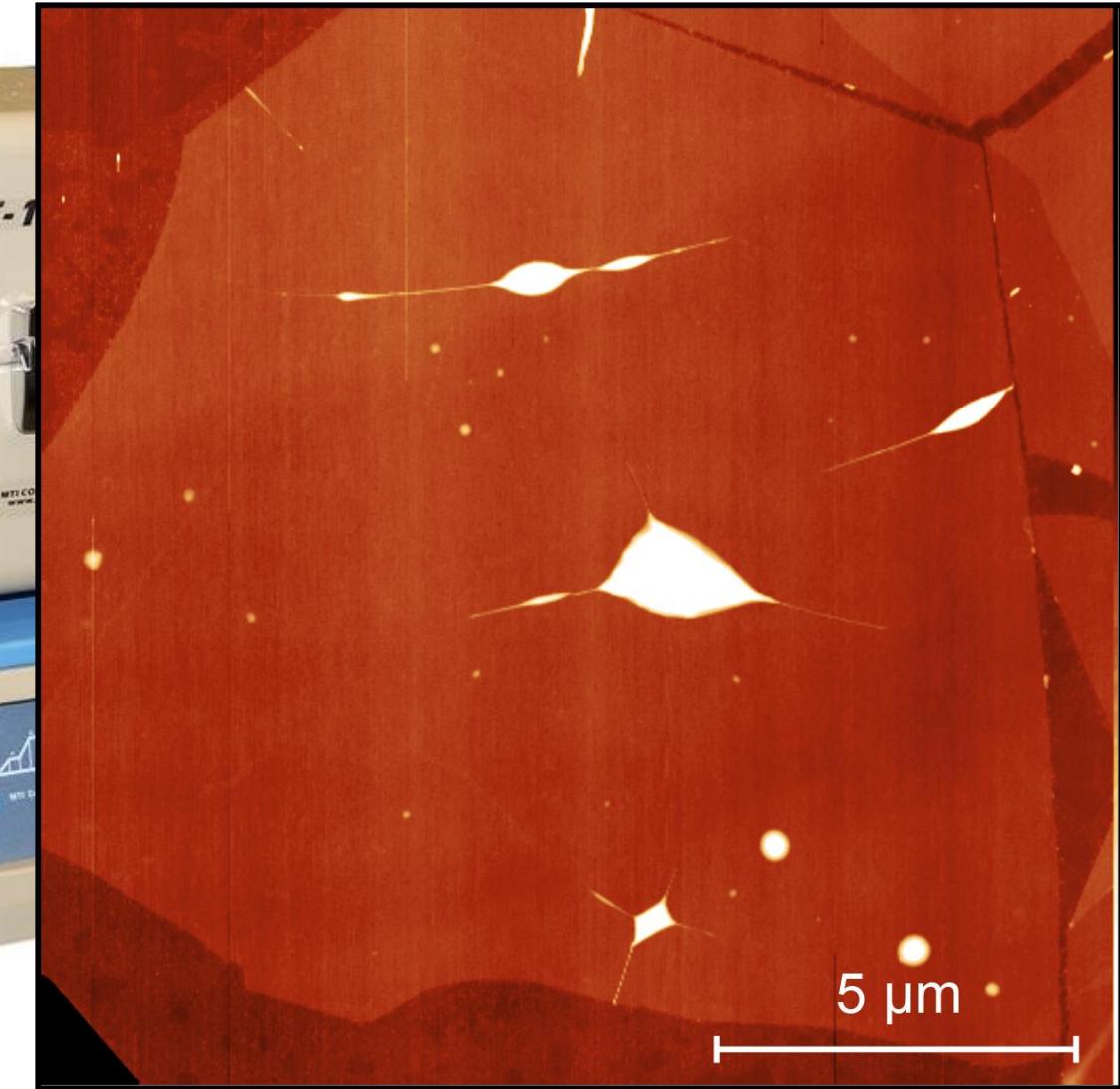
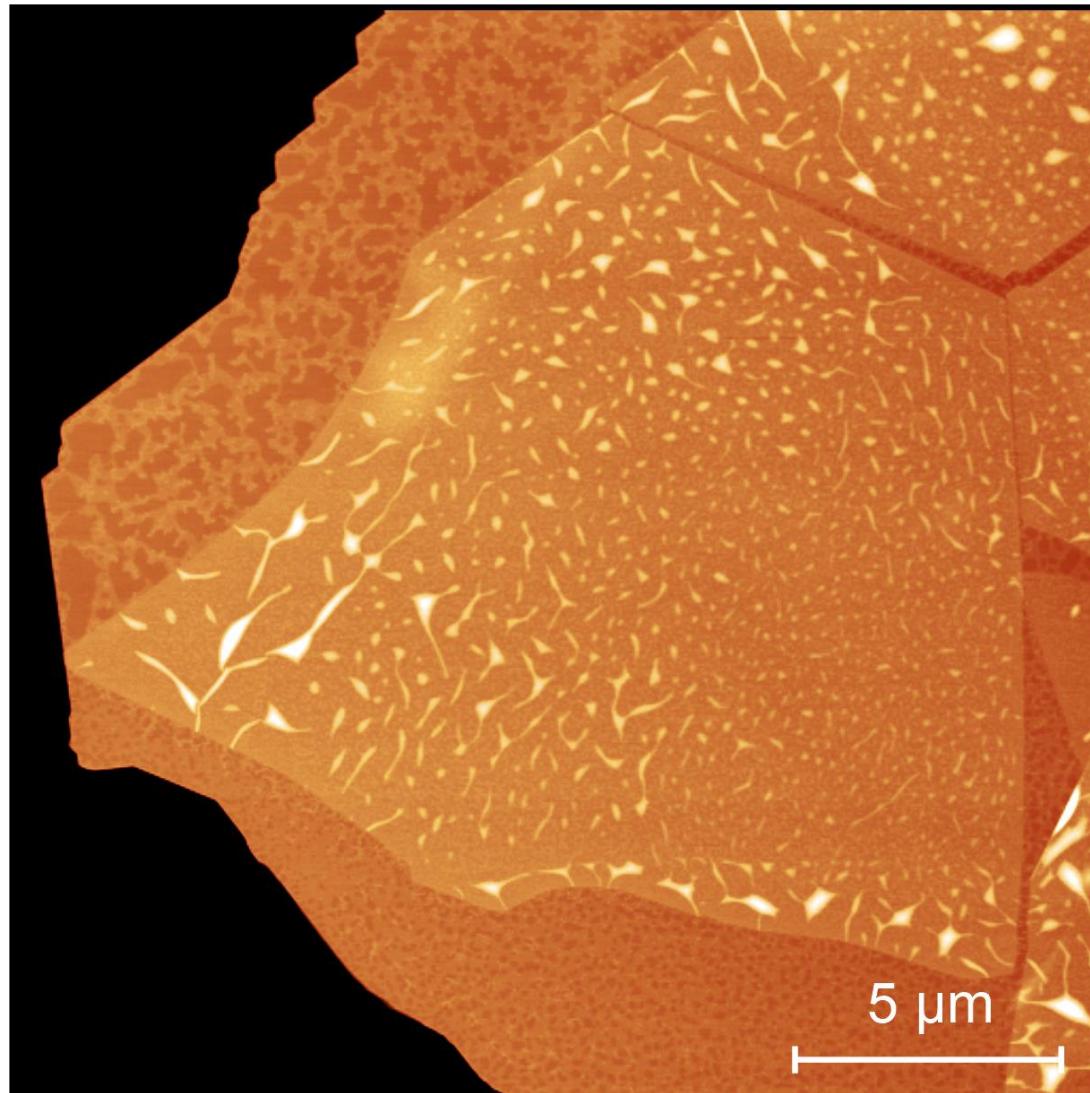
Bubbles and wrinkles

1<sup>st</sup> layer

Si/SiO<sub>2</sub>



## Cleaning procedures - thermal annealing



# Outline

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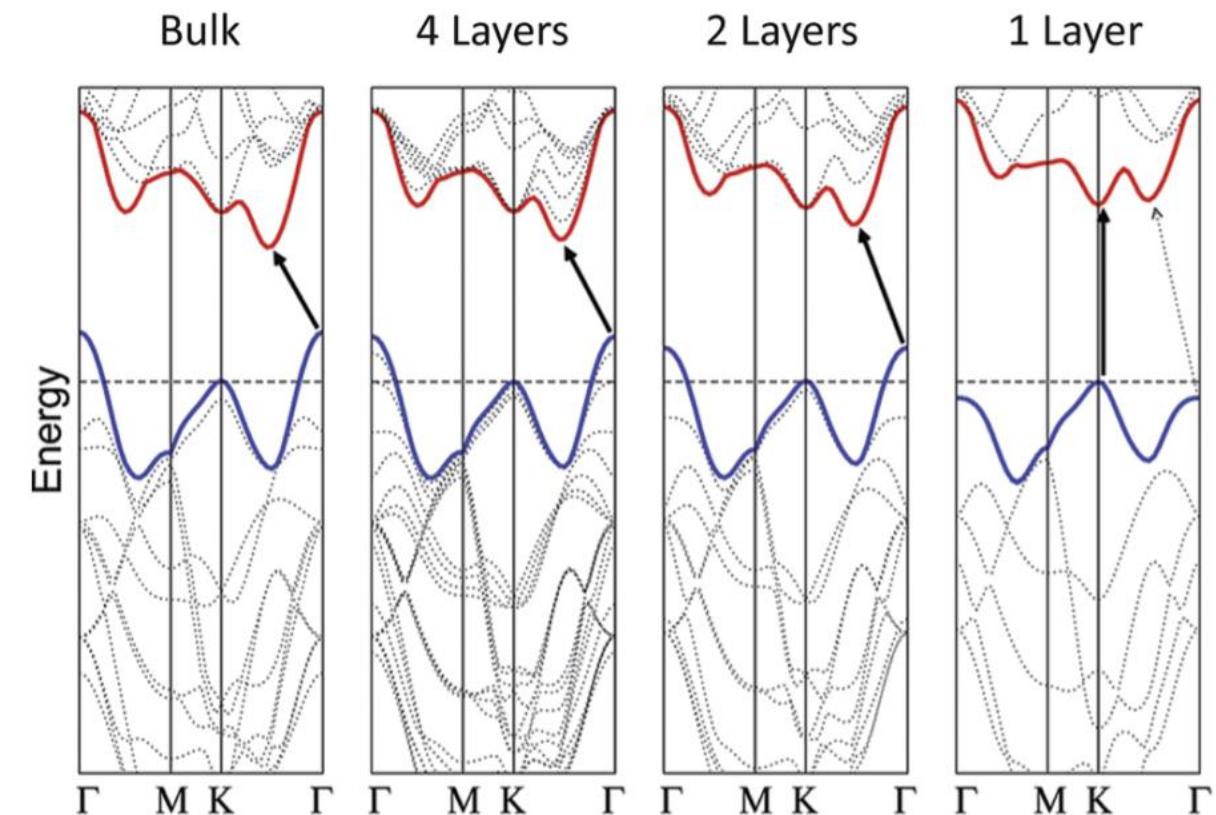
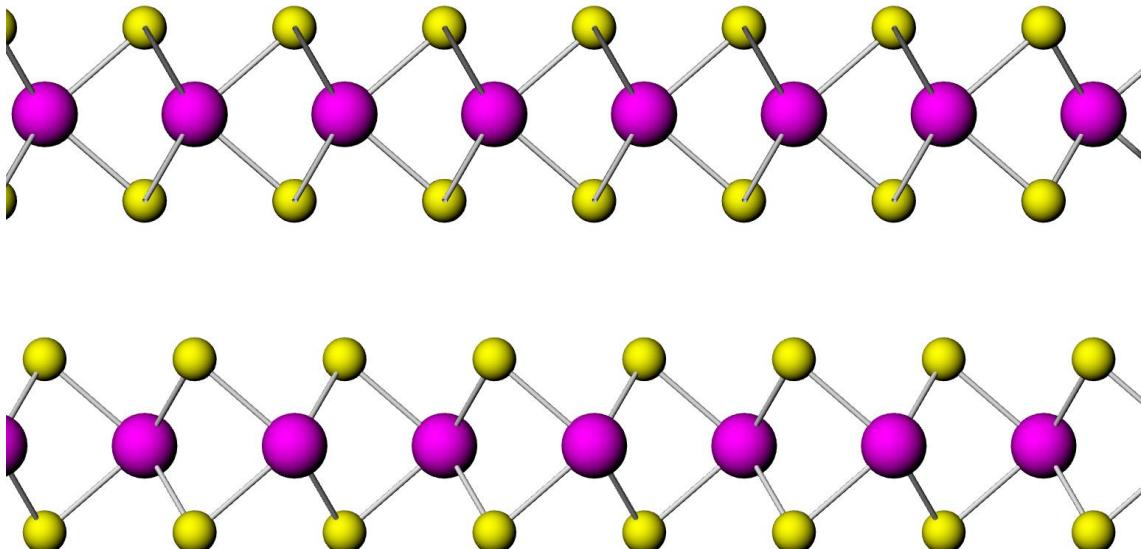
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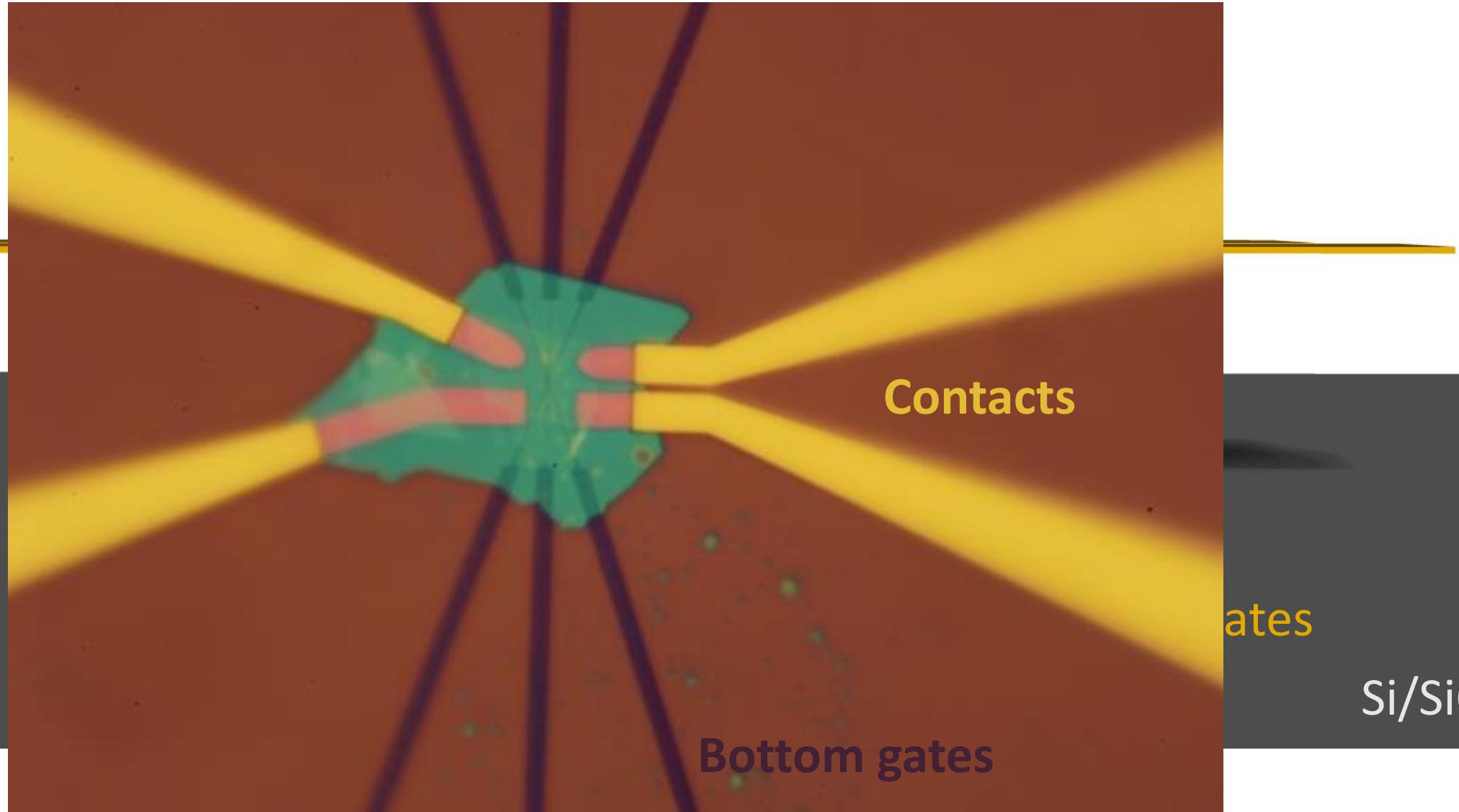
# Quantum confinement in 2D materials - graphene

# Quantum confinement in 2D materials – MoS<sub>2</sub>

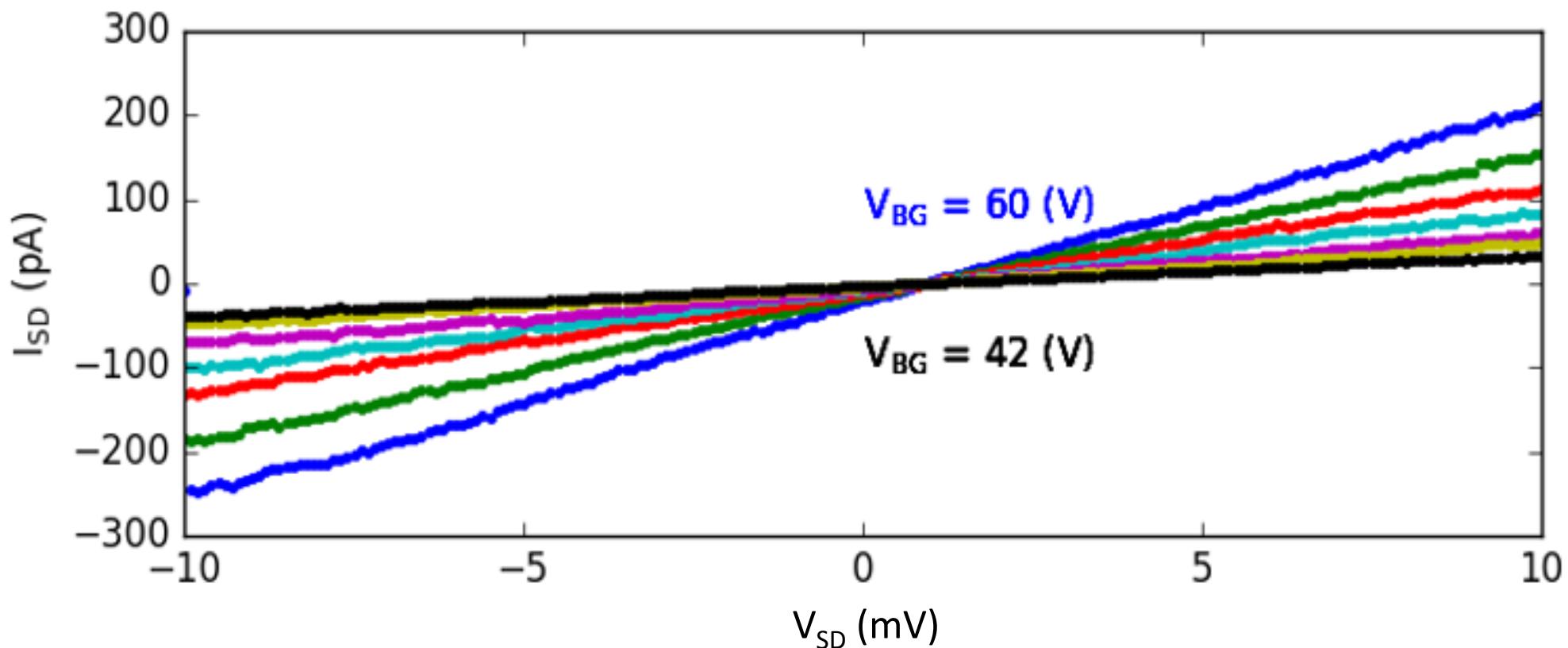
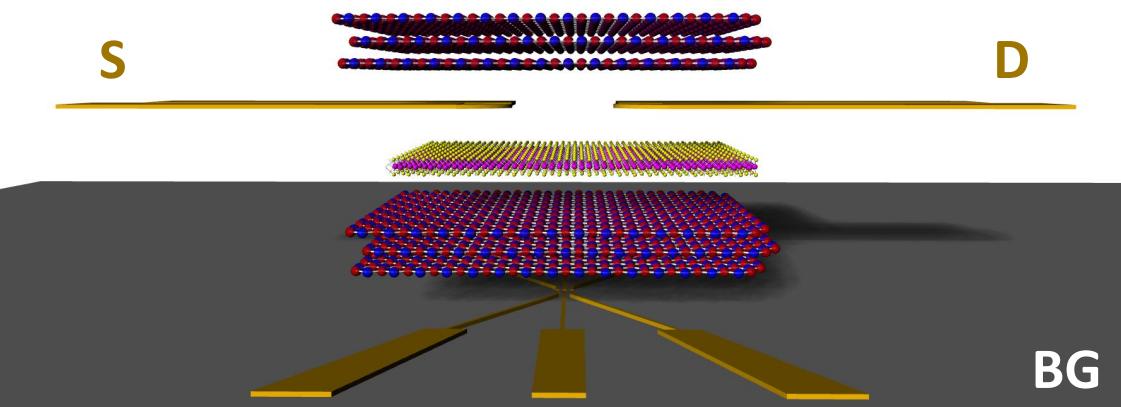


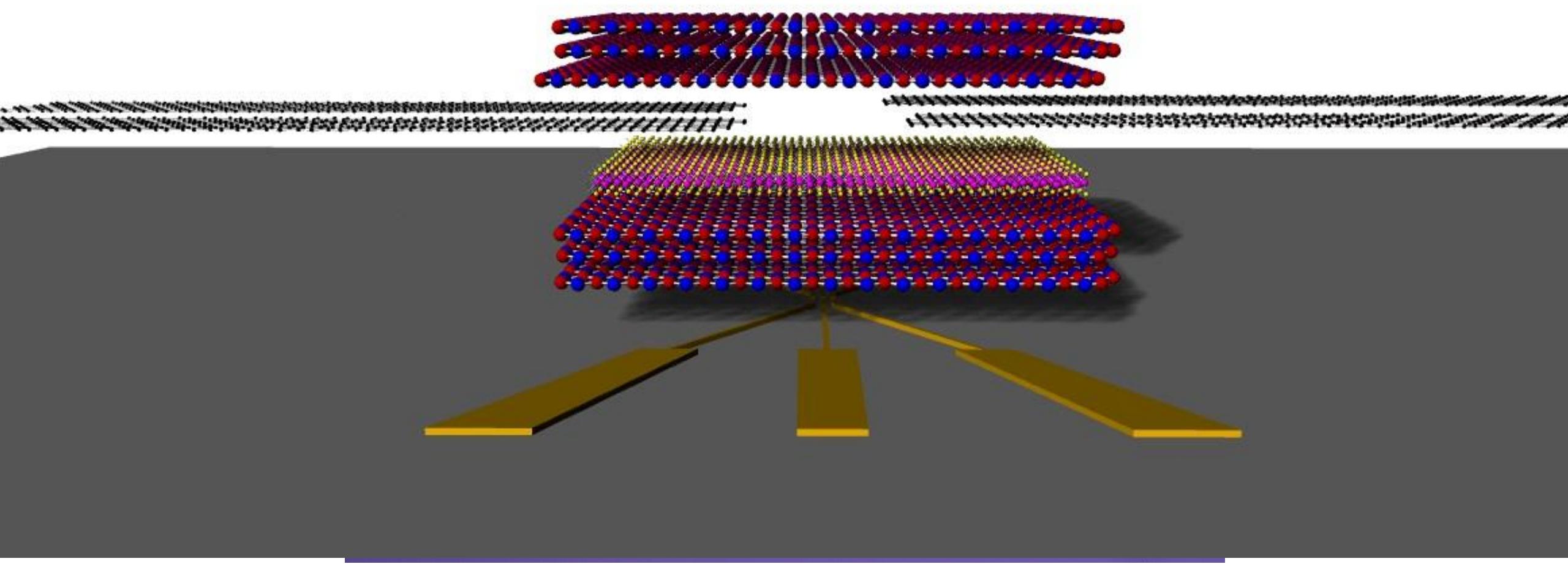
I. Song, C. Park, H. C. Choi, *Synthesis and properties of molybdenum disulphide: from bulk to atomic layers*. Royal Society of Chemistry, 2015

# Quantum confinement



# Quantum confinement



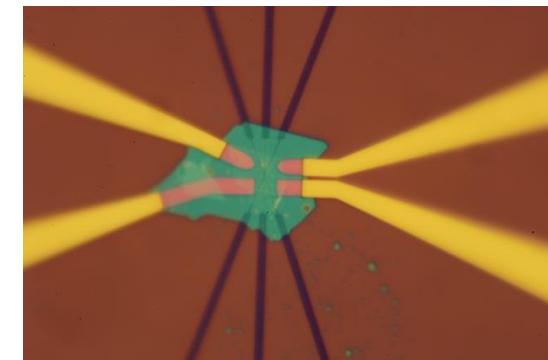
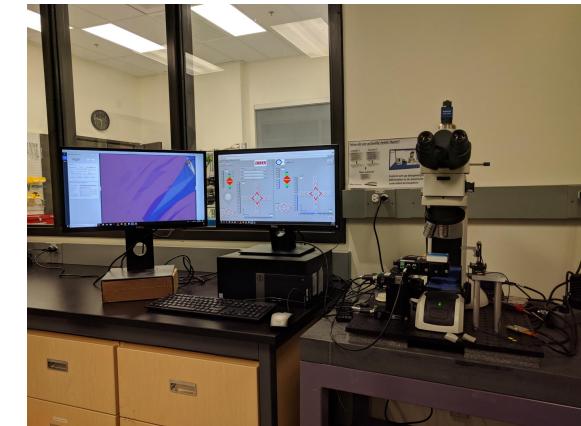
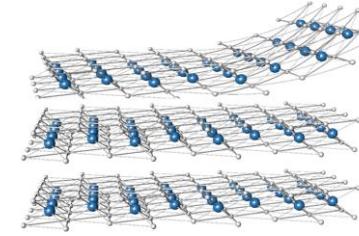


# Summary

## Introduction – 2D materials

**Methods to assemble custom, new, ultrathin crystals**

**2D material heterostructures for quantum confinement**



# Acknowledgments

## Prof. Adina Luican-Mayer group

Ryan Plumadore  
Samantha Scarfe

### Collaborators:

- Cleanroom facilities (uOttawa) 
- Raman spectroscopy  
Center for Advanced Materials Research
- National Research Council (NRC)

