# Fabrication of Two-Dimensional Twisted-Angle Chromium Trihalide Heterostructures with Edge Alignment Method

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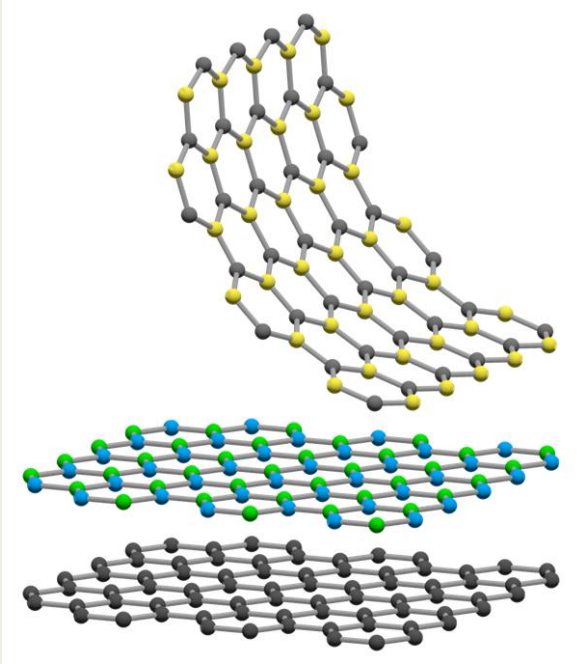
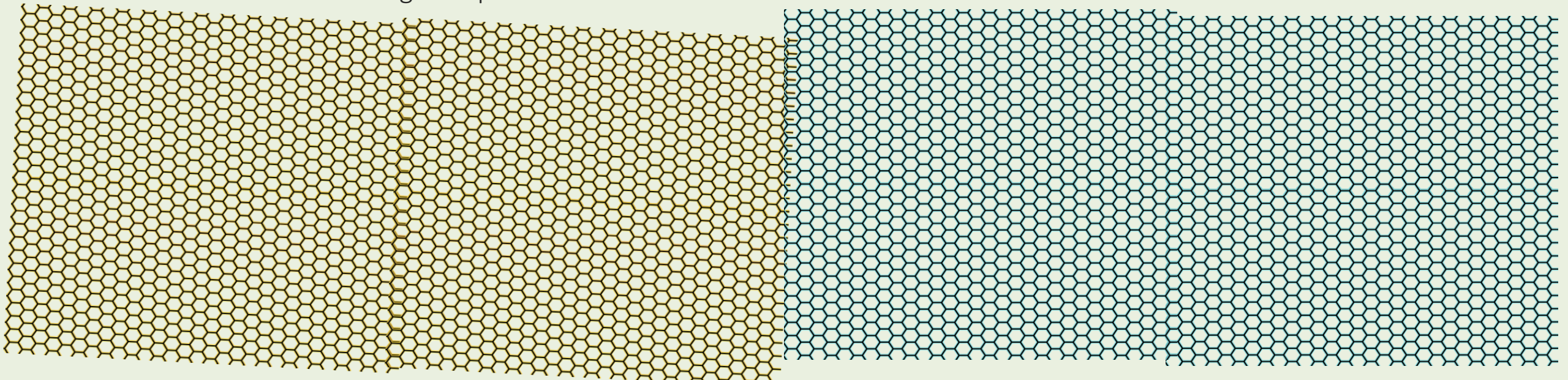
# Background

- What is a 2D heterostructure?
  - Any material that is less than a few nanometers thick in one dimension is considered “two-dimensional”
  - 2D materials exhibit different physical properties than their 3D counterparts
  - Recently, 2D magnets have started being studied extensively for their ability to alter the magnetic properties of a van der Waal heterostructure



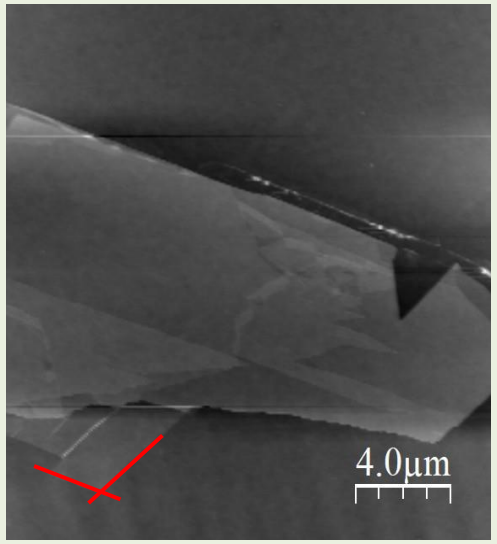
# Background

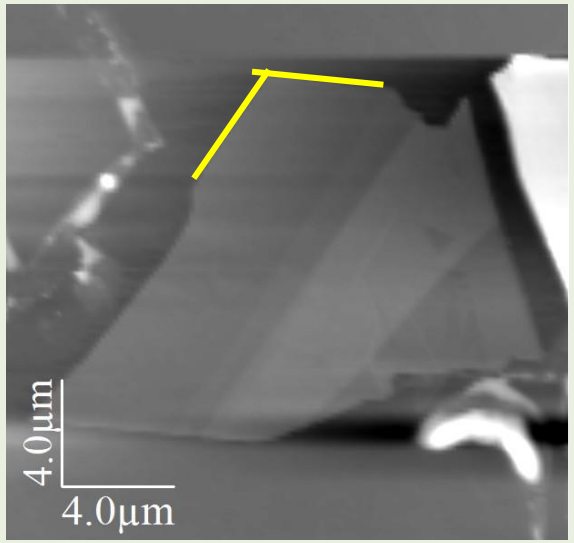
- What is twisted angle?
  - Twisted angle is the term used to describe a heterostructure where the lattice structure of each material is offset within a few degrees.
  - First studied with twisted bilayer graphene, fascinating physics inspired researchers to attempt twisted heterostructures with different materials
  - Attempting twisted heterostructures with 2D magnets introduce the additional ingredient of magnetism that can lead to observing new phenomena



# Background

- **What is the edge alignment method?**
  - The edge alignment method describes one of the first processes used to obtain a twisted angle heterostructure [1]
  - The method involves aligning straight edges of a crystal with another that has the same degree edge
    - Straight edges signify rotation of the crystal's lattice structure
  - Ideally, the layers will be stacked to form a heterostructure with the lattice structure aligned within a few degree offset

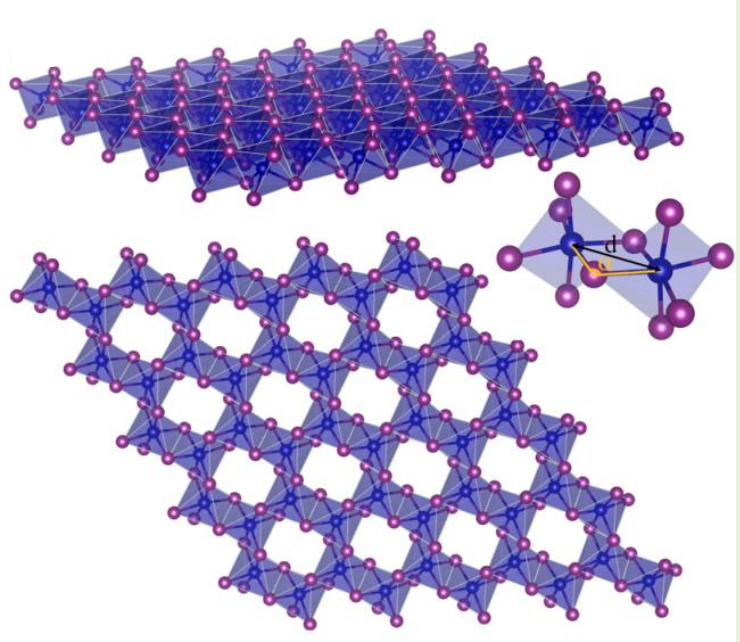



(1) L. A. Ponomarenko, R. V. Gorbachev, G. L. Yu, D. C. Elias, R. Jalil, A. A. Patel, A. Mishchenko, A. S. Mayorov, C. R. Woods and J. R. Wallbank, Nature, 2013, 497, 594–597.

# Background

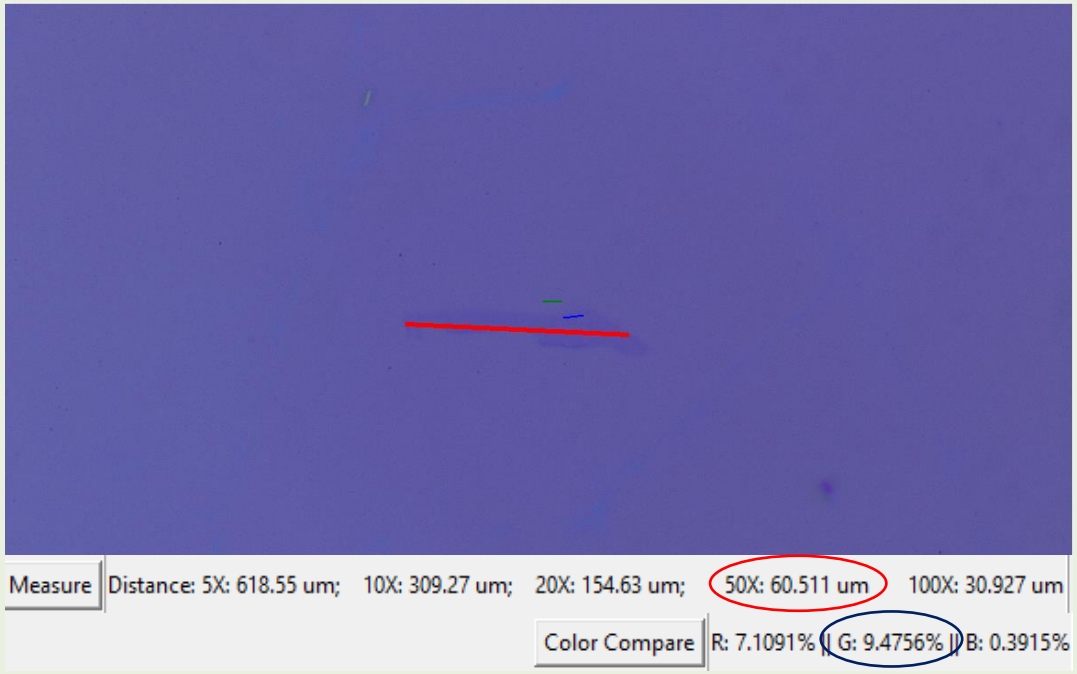
- **Why Chromium Trihalides?**
  - Chromium Trihalides ($CrX_3$: X=Br, Cl, I) have unique magnetic properties that can prove to be a useful magnet
  - $CrX_3$ have shown to be magnetic insulators with stronger properties as they get thinner
  - Air-sensitivity poses a problem because the material starts to degrade when out of a controlled environment

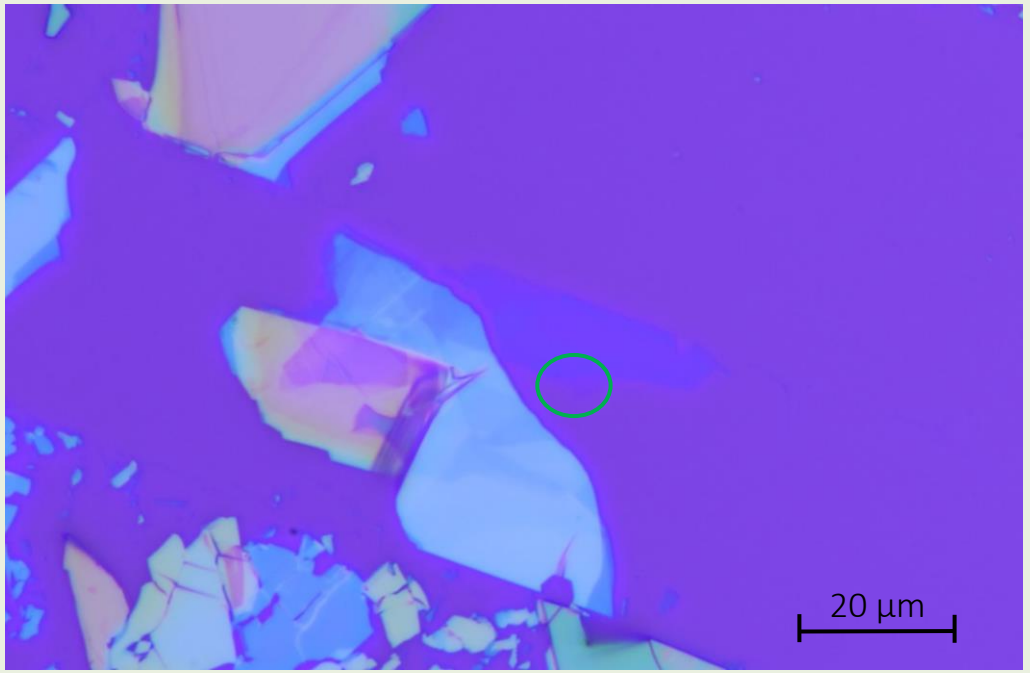


(3) Magnetic Two-Dimensional Chromium Trihalides: A Theoretical Perspective. D. Soriano, M. I. Katsnelson, and J. Fernández-Rossier, Nano Letters 2020 20 (9), 6225-6234

# Characterization of 2D Materials

- 2D flakes are exfoliated on 285 nm $SiO_2$ substrate and observed under optical microscope
  - Scotch tape method is utilized to exfoliate the thin flakes onto the substrate
  - Atomic force microscopy (AFM) is used to determine the thickness of $CrBr_3$ flakes
- $CrBr_3$ is encapsulated between few-layer graphene flakes to address the air degradation issue



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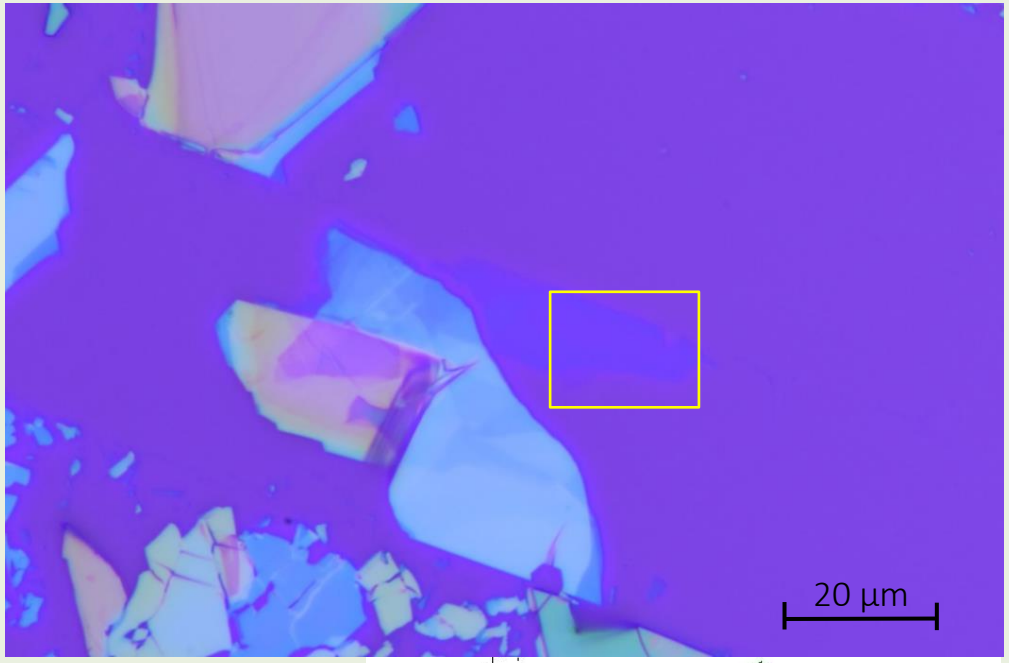
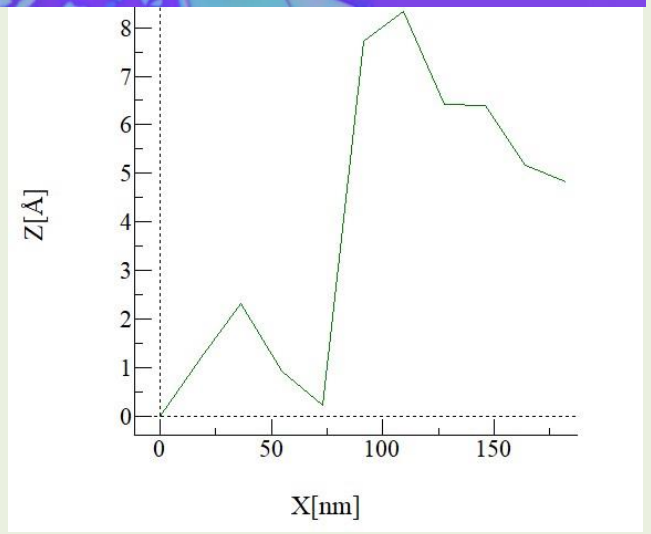
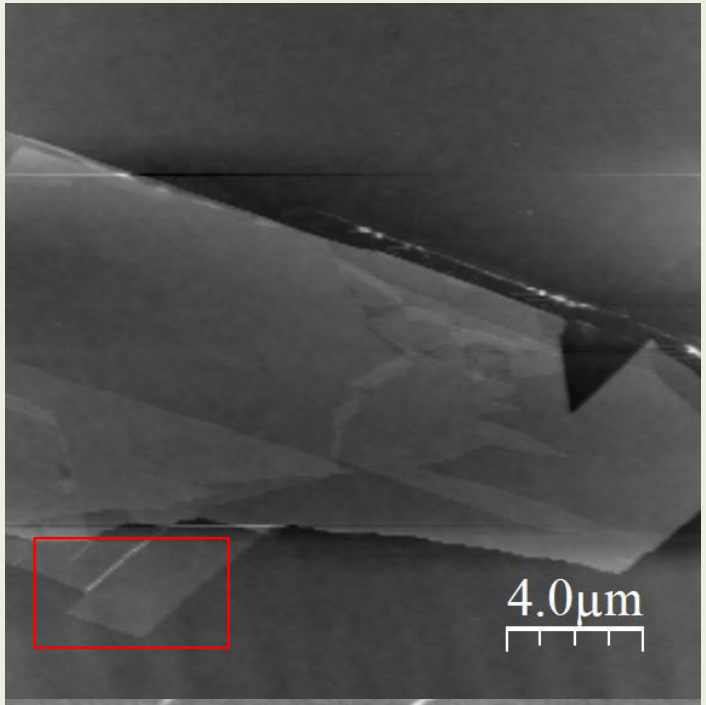
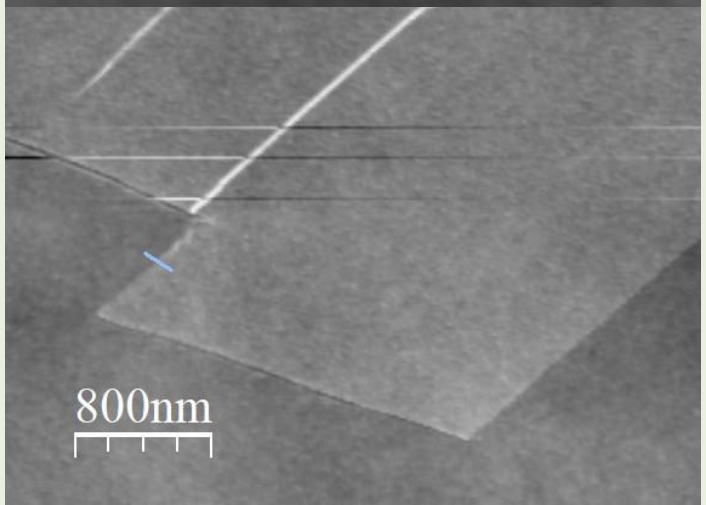


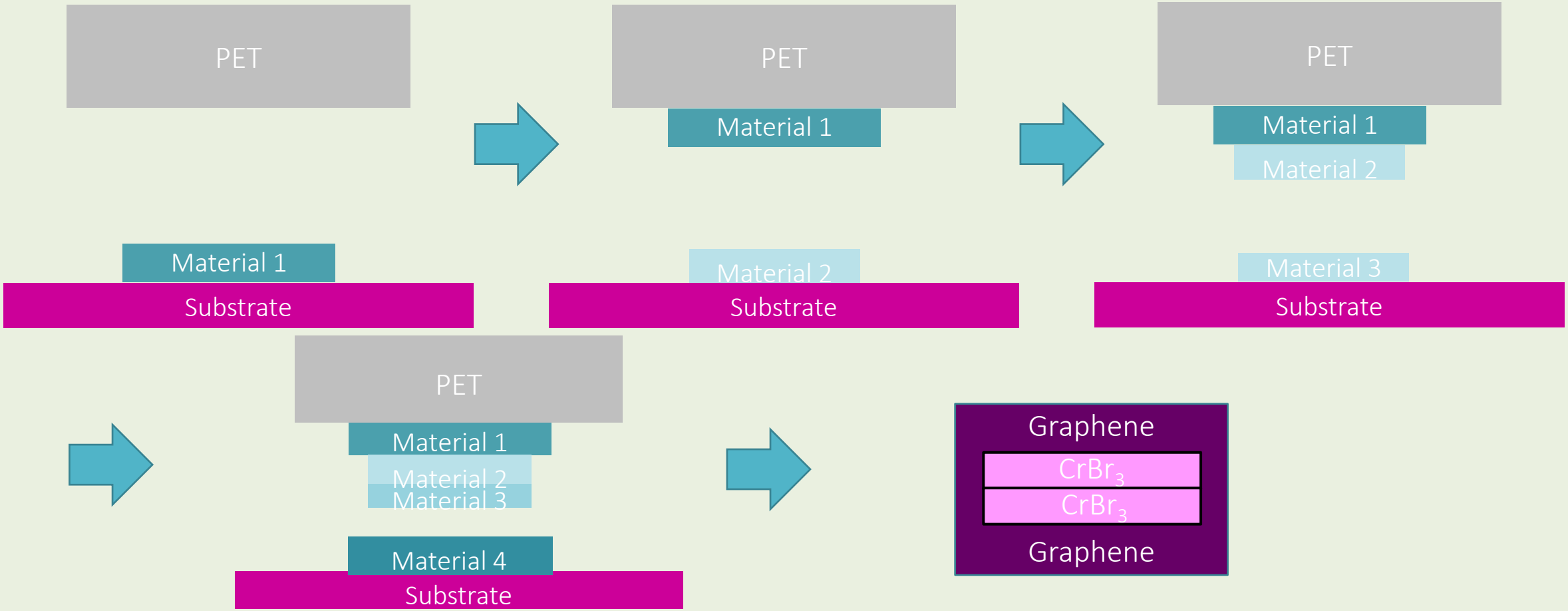



# Transfer Method

◊ PET “pick up” method is used to create these 2D stacks



# Twisted Angle Analysis

- Few-layer graphene and thin $CrBr_3$ can be studied under transmission electron miscroscopy (TEM) due to its sensitivity
- TEAM 1 from the Molecular Foundry at the Berkeley Lab is the instrument used to scan these fabricated stacks
- From completed stack fabrication, next step is to scan the sample under TEM
  - TEM scan will tell us if the lattice structures of the $CrBr_3$ layers are aligned with a few degree mismatch

# Conclusion

- 2D magnets offer the opportunity to include magnetism into 2D heterostructures
  - Twisted 2D magnets can offer the opportunity to discover new phenomena
- Encapsulation of the magnets allows for study outside of a controlled environment
- TEM scans will tell us the effect of twisted angle on the heterostructure

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