EPFL

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2D MATERIAL HETEROSTRUCTURES

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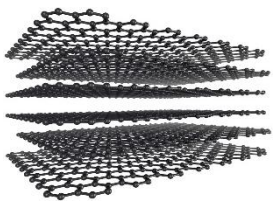
LAIDLAW SCHOLARS

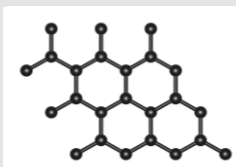
1 What is a 2D material?

- Also called **Van der Waals crystals,** they consist of a stacking of monolayers
- Atoms bond **strongly within the plane** [1]
- Planes held together only **weakly by Van der Waals interactions**



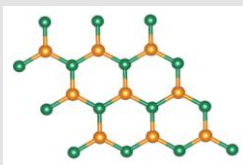
2D material layers

2 Properties of studied 2D materials



Graphene

- First 2D material to be isolated in **2004**, **Nobel Prize 2010**
- Semimetal → **high electrical conductivity**
- Hexagonal honeycomb lattice of C_{sp^2}

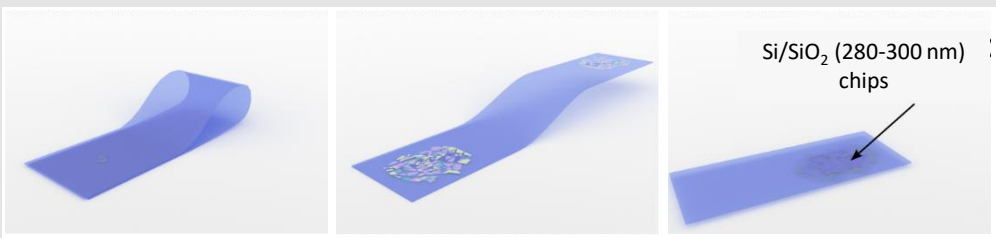


hBN

- Hexagonal Boron Nitride (hBN) has the same honeycomb lattice with atoms of **boron** and **nitrogen**
- Isoelectronic to graphene but **insulator**, band gap ≈ 6 eV

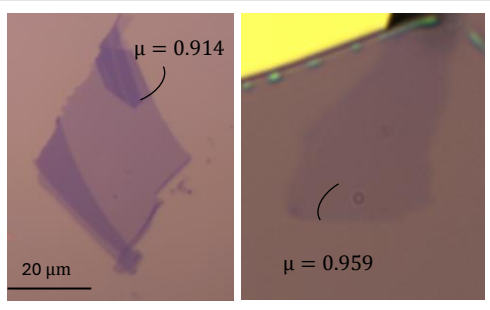
3 Sample preparation and exfoliation

- Sheets down to a **single layer** can be peeled off mechanically: a process called **exfoliation** [1]



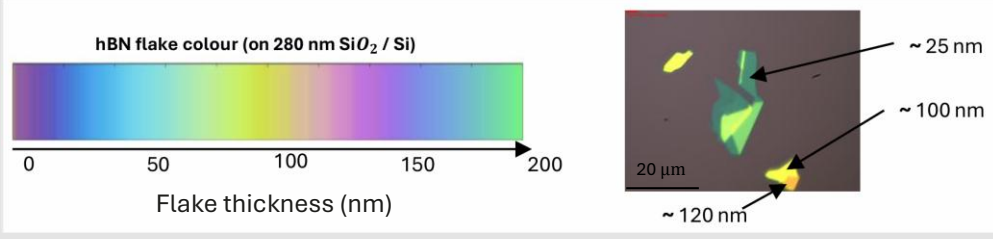
Exfoliation process *(top)* and results *(bottom)*

- **Graphene** flake thickness given by **optical contrast**
- $C_D = \frac{(I_{substrate} - I_{flake})}{I_{substrate}}$
- $\mu = \frac{I_{flake}}{I_{substrate}}$
- The slope μ **decreases linearly** with number of graphene **layers**



Graphene bilayer *(left)* and monolayer *(right)*

- **hBN** flake thickness dependent on **colour** [3]



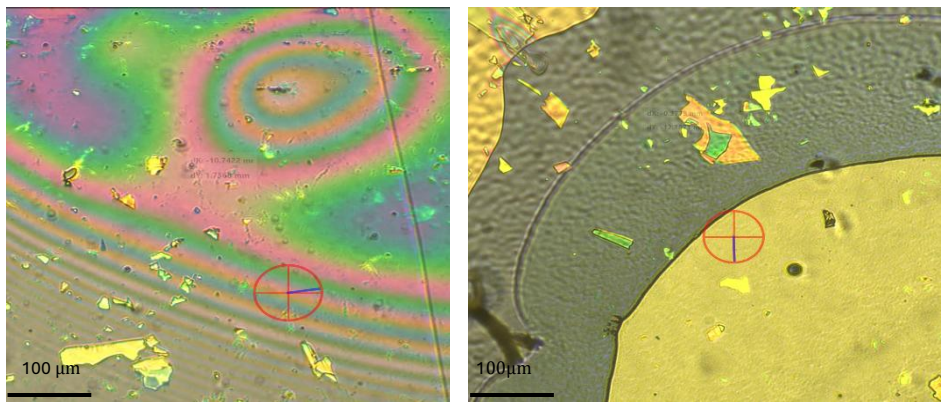
4 Deterministic transfers

- **Why?** 2D material Van der Waals heterostructures allow stacking of different layers without any **lattice-matching** constraint → structure with on-demand properties [4]
- **How?** A PDMS stamp capped with a **polymer film** (PVC) is brought into contact with the chip on a heated stage: the flake is picked up at 70 °C and released at 130 °C [5,6]

5 What's new?

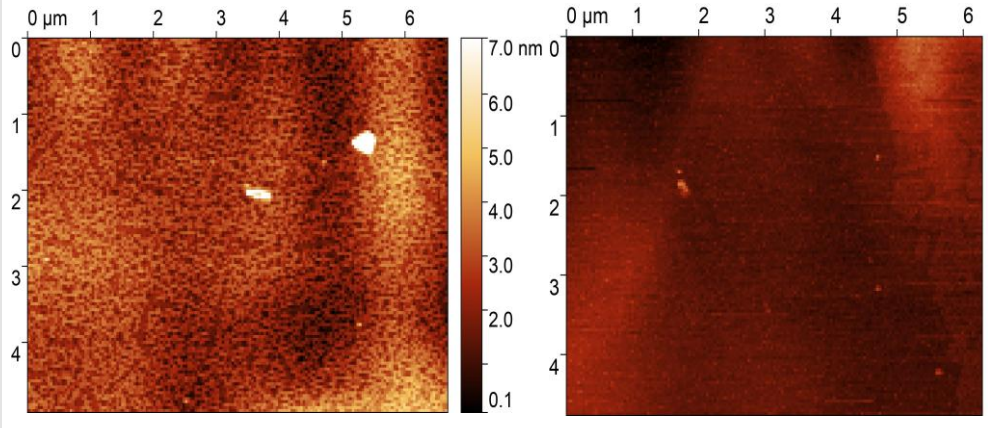
- We developed a method to perform deterministic transfers using a membrane of mica, a **Van der Waals crystal**, instead of a polymer

- Mica is far **less flexible** so the contact line advances irregularly and pins on impurities making transfers **harder to achieve**



Mica contact with substrate *(left)* and PVC contact with substrate *(right)*

- Mica is crystalline and non-polymeric so it leaves much **less residue** on the heterostructure than a polymer stamp.
- This method offers a much easier way (avoiding a complex cleaning process) to fabricate **samples with a smooth surface** on which it is possible to perform very precise experiments such as **slip length measurement**



AFM (Atomic Force Microscopy : scanning probe maps a surface's topography down to a nanometer scale) scan of a heterostructure built using a PVC *(left)* and mica *(right)* stamp

References

[1] Novoselov et al. Science (2004)
[2] Praz. Internship presentation, EPFL (2026)
[3] Blundo et al. Applied Sciences (2025)
[4] Lizée et al. arXiv preprint (2024)
[5] Fraunié. PhD thesis, LPCNO (2025)
[6] Babich et al. Nature Communications (2026)