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2D Materials: An Introduction

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About Me:

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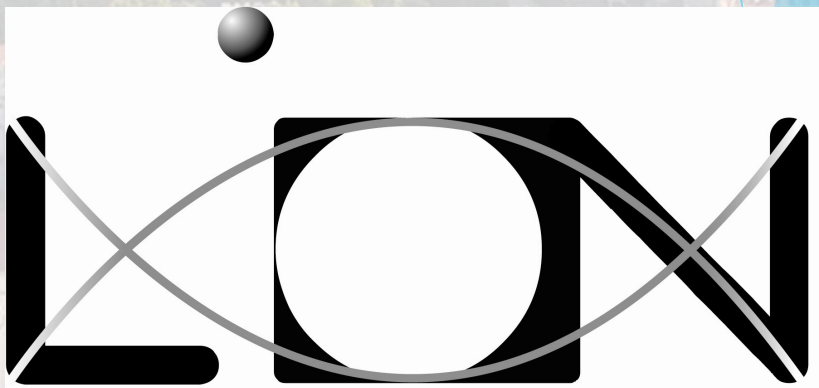
UiO :

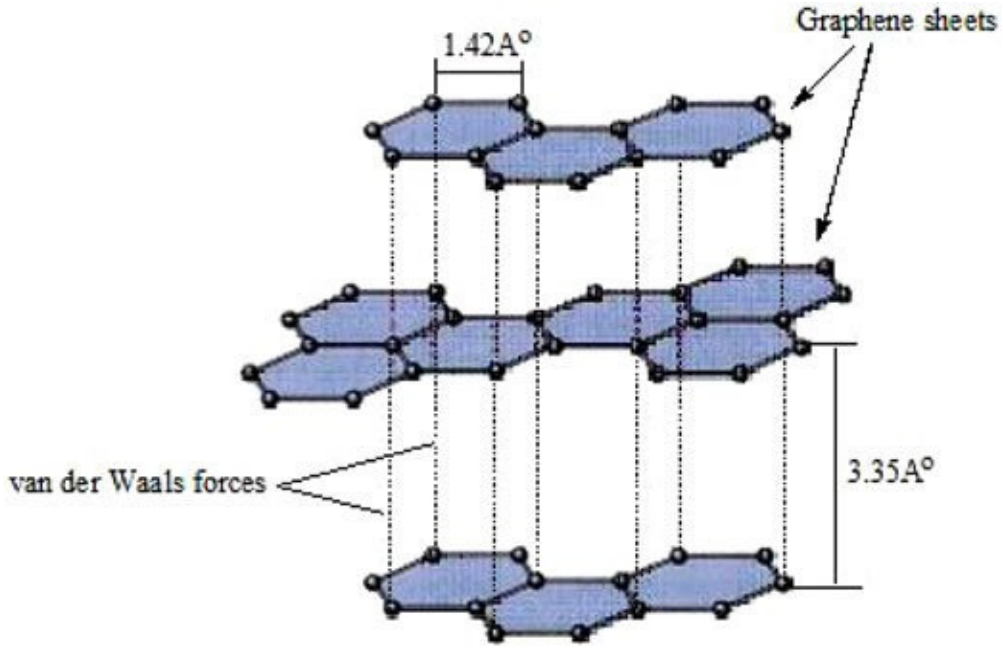


What are van der Waals materials????

-Layered
-Strong bonding within layers, weak bonding between layers

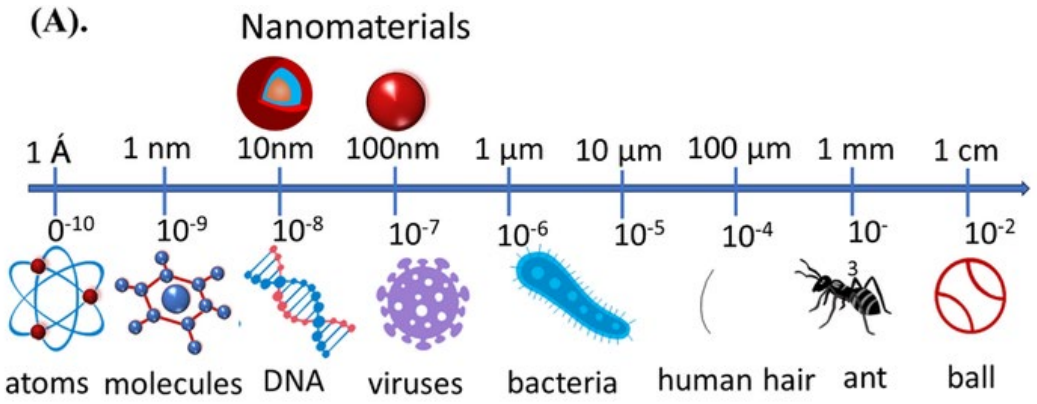
A familiar example: Graphite!
-Pencils are made from graphite, several layers of graphite – graphene is deposited onto the paper when we write

Layered means: we can decide how many layers we want! (well, kind of)

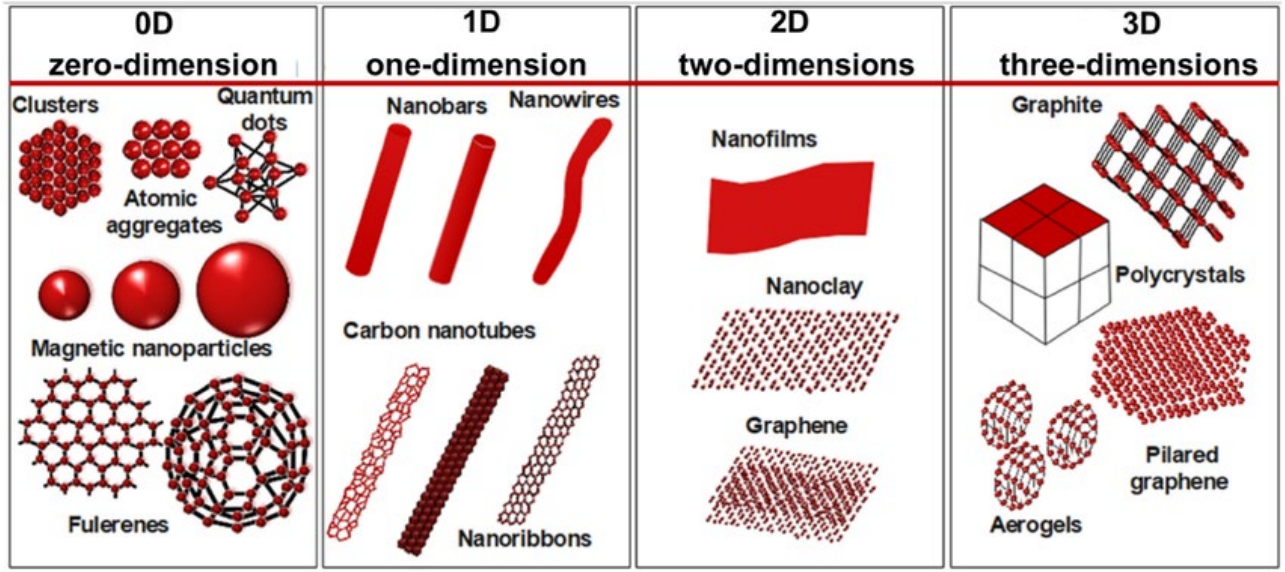


Shah, Rahim & Kausar, Ayesha & Muhammad, Bakhtiar & Shah, Sayed. (2015). Progression from Graphene and Graphene Oxide to High Performance Polymer-Based Nanocomposite: A Review. Polymer-Plastics Technology and Engineering. 54. 173-183.

Scales we work with:



(B).



-MUCH smaller than bacteria and viruses (1000 times smaller)

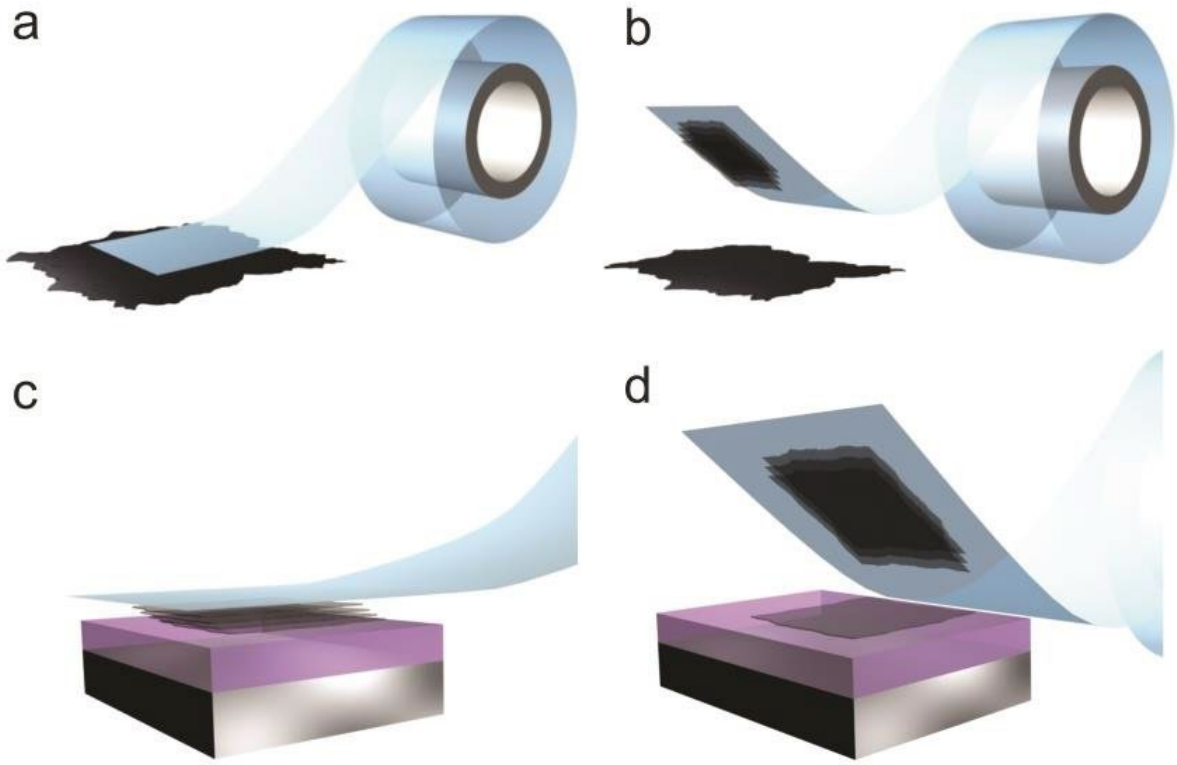
-monolayers (single layers of vdW materials, only one atom thick) around 1 nm thick

Asghar, Nosheen & Hussain, Alamdar & Nguyen, Anh & Ali, Salar & Hussain, Ishtiaque & Junejo, Aurangzeb & Ali, Attarad. (2024). Advancement in nanomaterials for environmental pollutants remediation: a systematic review on bibliometrics analysis, material types, synthesis pathways, and related mechanisms. Journal of Nanobiotechnology. 22. 10.1186/s12951-023-02151-3.

How to get thin layers?

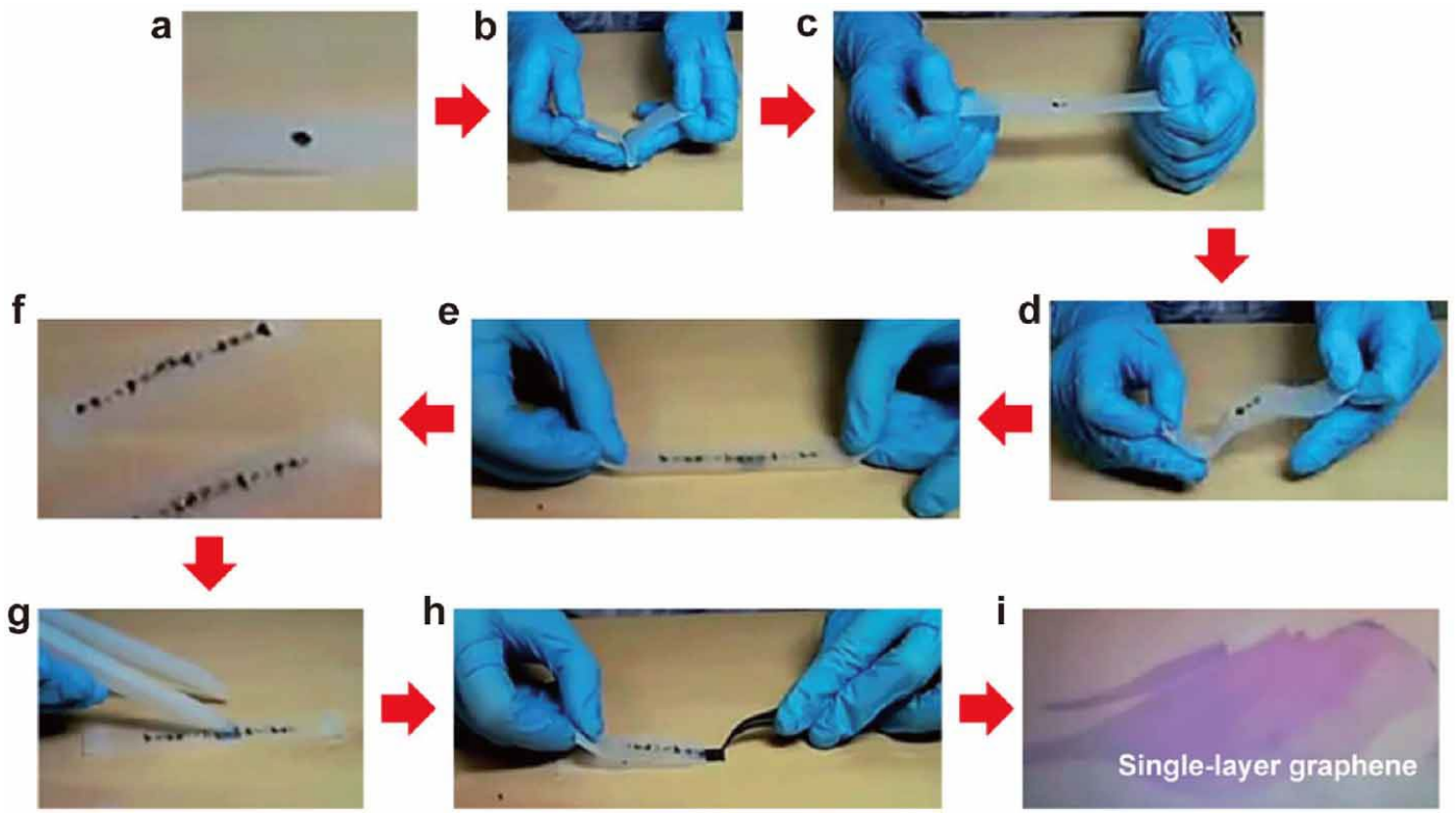
Answer: exfoliation
Tool: Scotch tape!!

A simplified schematic of mechanical exfoliation



Freire Soler, Victor Manuel. (2014). Fabrication and Characterization of Macroscopic Graphene Layers on Metallic Substrates.

Some Nice Illustration of “cleaving”



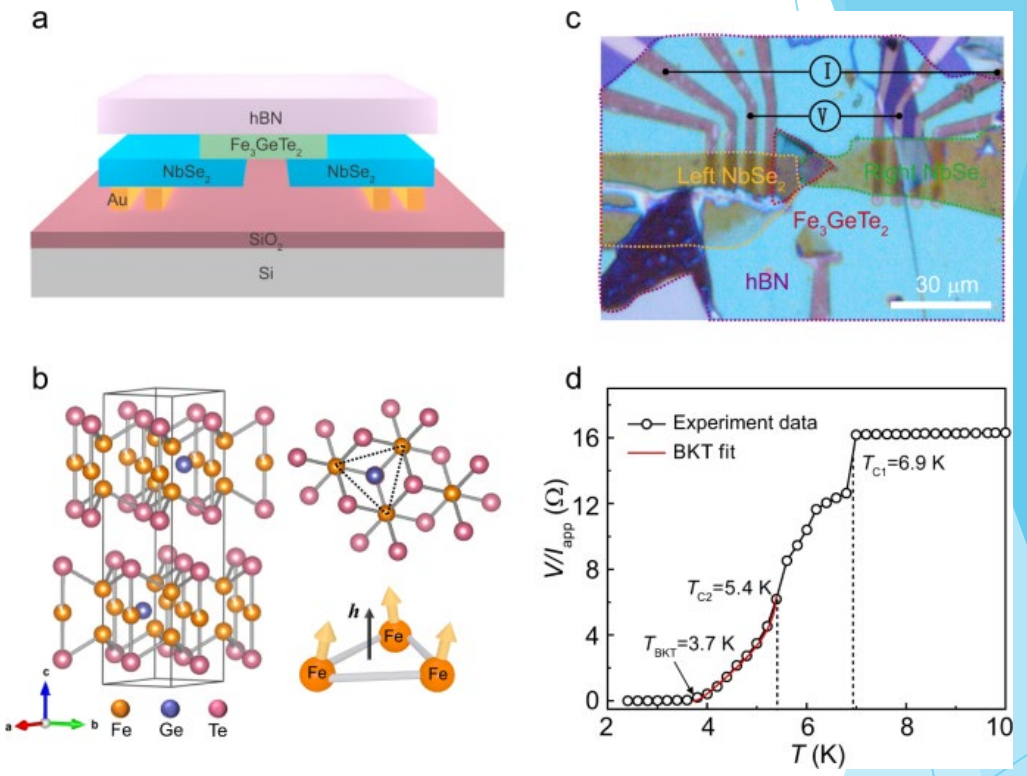
Z. Cheng, R. Cao, K. Wei, Y. Yao, X. Liu, J. Kang, J. Dong, Z. Shi, H. Zhang, X. Zhang, 2D Materials Enabled Next-Generation Integrated Optoelectronics: from Fabrication to Applications. *Adv. Sci.* 2021, 8, 2003834. https://doi.org/10.1002/advs.202003834

What I work on: Room temperature ferromagnets

- 2D magnets
- Common magnets: iron
- Magnetic materials form magnetic fields around them, and they interact with other magnetic materials via these fields (attraction/repulsion)
- NOT common to have room temperature magnetism in thin materials
- Fe5GeTe2 and Fe3GeTe2 both only gained attention in the past 5-10 years
- Magnetic order in materials can be disrupted above a temperature, we call this T_c curie temperature
- Above T_c → Not a magnet anymore
- Fe5GeTe2 has T_c of 270-310 K (-3.15 to 36.85 C), Fe3GeTe2 has T_c of 220K (-53.15 C)

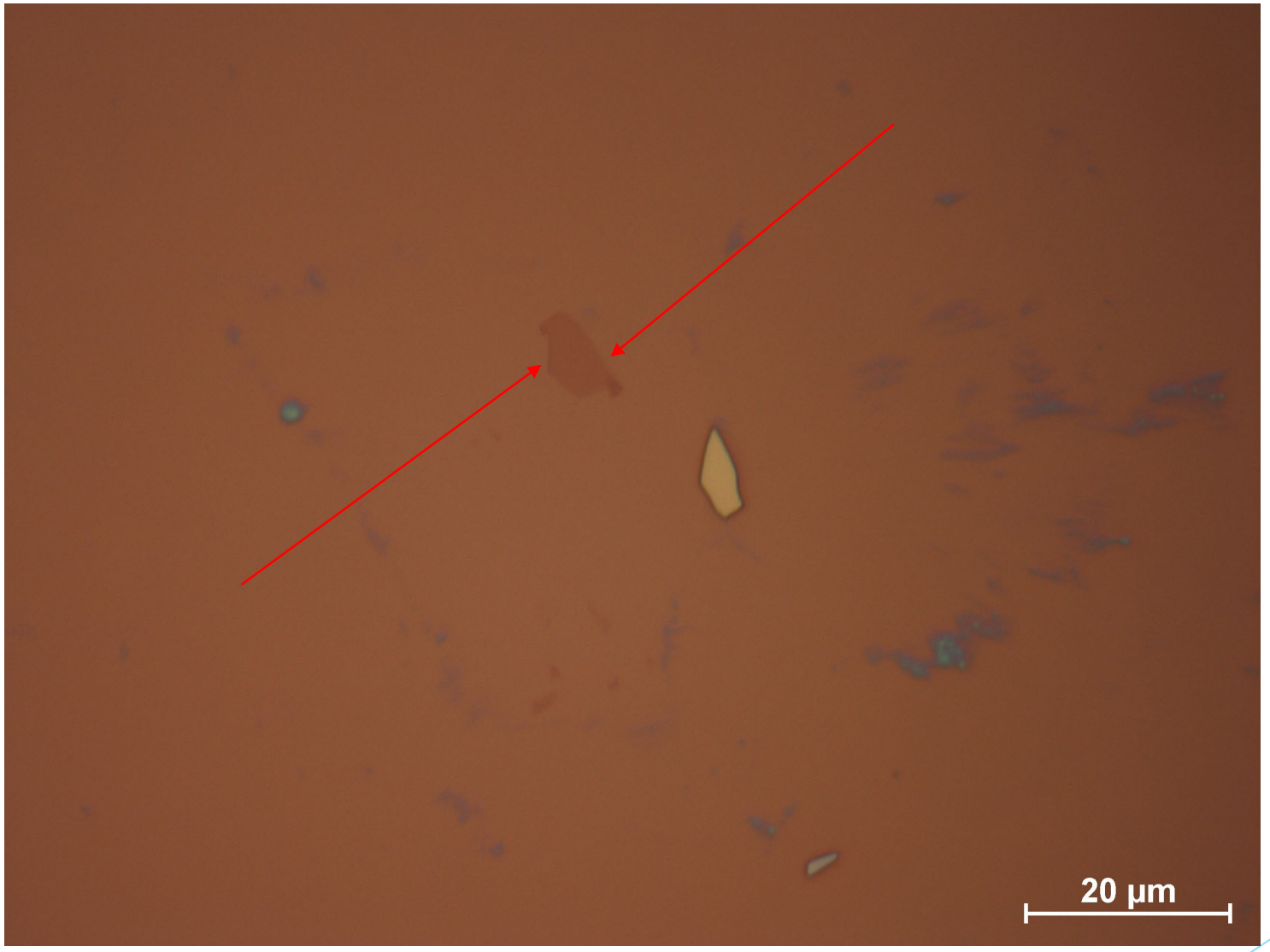
OK? So what?

- Nonvolatile Magnetic Memories (RAM, random access memory), store information without power
- Traditional memories need constant charging from capacitors to store info or else it's lost
- High efficiency computing architecture
- Easy to stack with other 2D materials and make different devices
- Picture shows a superconducting heterostructure made by stacking FGT and NbSe2 (a superconductor)



Hu, G., Wang, C., Wang, S. *et al.* Long-range skin Josephson supercurrent across a van der Waals ferromagnet. *Nat Commun* **14**, 1779 (2023). https://doi.org/10.1038/s41467-023-37603-9

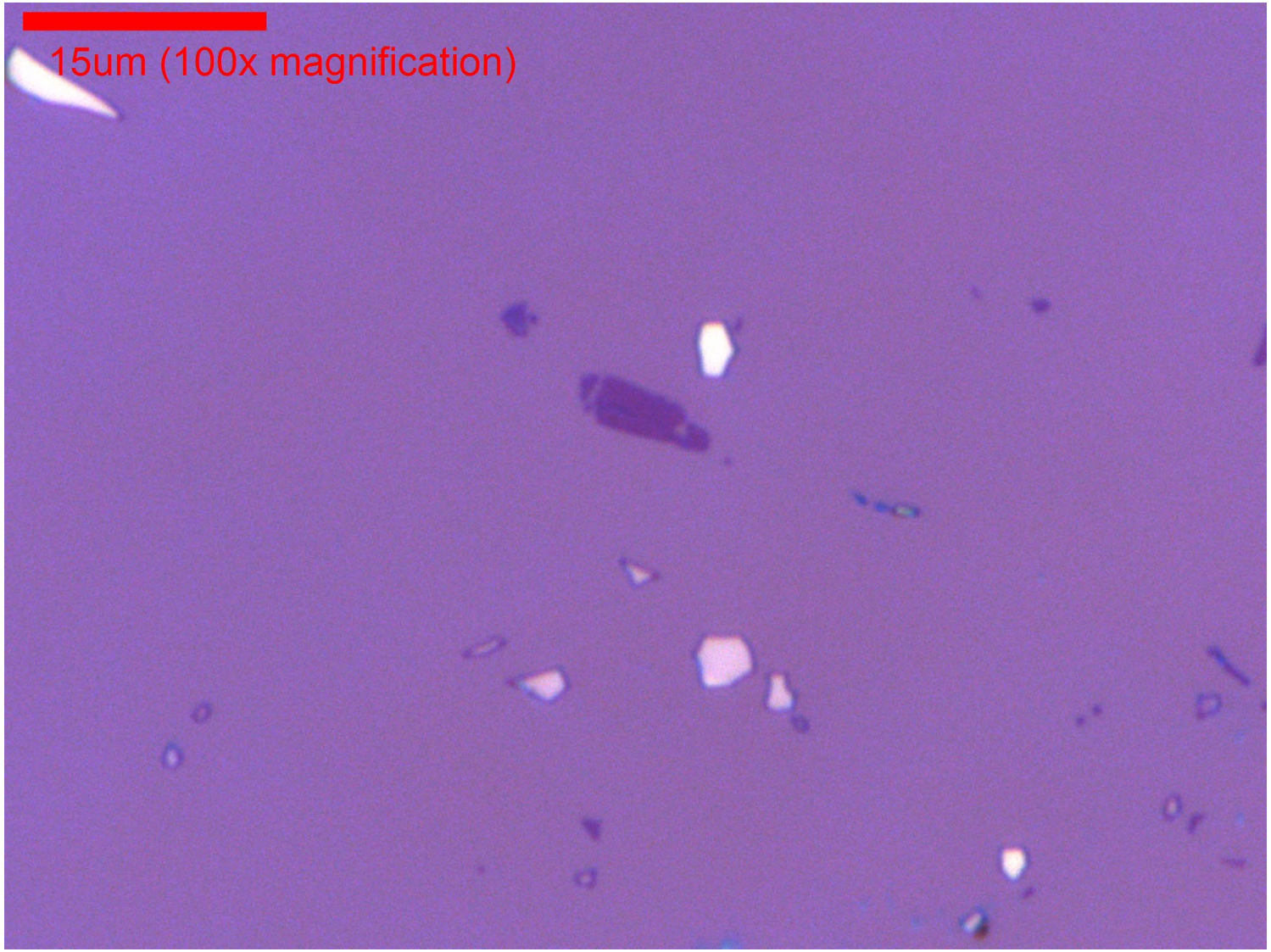
Microscope picture time!



-A monolayer flake of graphene

-Almost transparent

More!



A thin Fe5GeTe2 Flake

Note: this flake is BIG!

Ongoing Investigation

- Air insulation box for Fe5GeTe2 air protection
- Do RAMAN spectroscopy measurements on air insulated flakes at spaced out timeframes
- Inspect spectra to confirm whether oxidation/degradation occurred
- Optimized exfoliation protocol for Fe3GeTe2 and Fe5GeTe2

Questions!