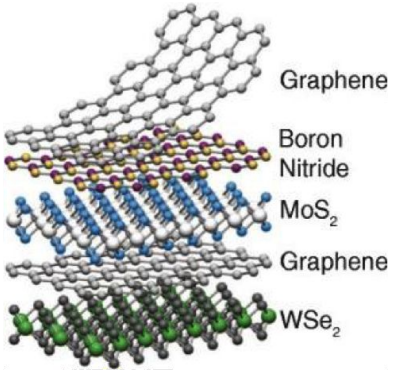
Investigating bilayer and thick WTe_2

Moira Miller

Mentor: Professor David Cobden

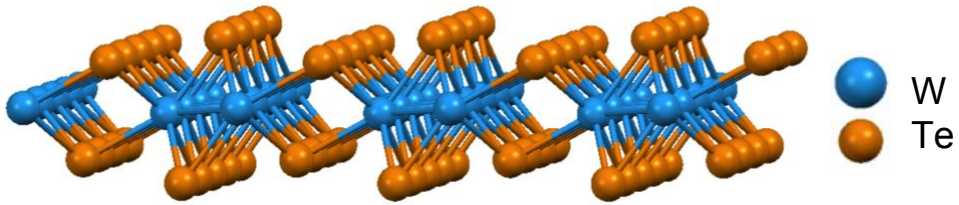
2D Van der Waals structures

- Semimetals (graphene)
- Semiconductors
- Superconductors
- Insulators (hBN)
- Investigate new physics in 2D
  - easier to change the carrier density
  - tuning between electronic states



Example of 2D heterostructure

WTe_2 (Tungsten Telluride)



Monolayer lattice structure

Trilayer and above act like a semi-metal

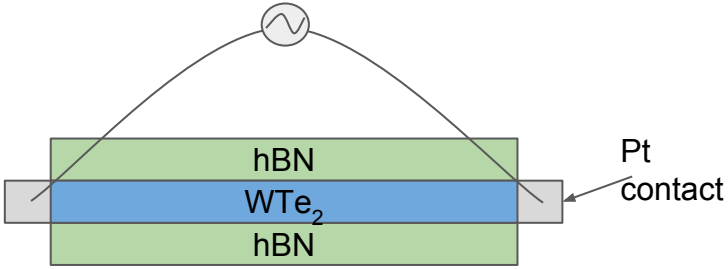
Try to classify behavior of monolayer and bilayer

Encapsulating WTe_2

WTe_2 oxidizes in air

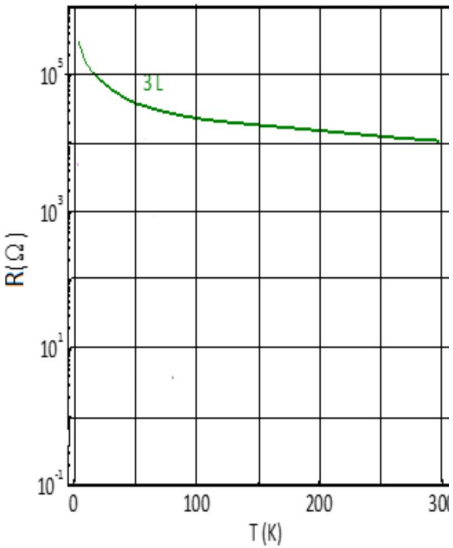
Encapsulated WTe_2 acts like a semi-metal

Encapsulate with hBN, an inert dielectric

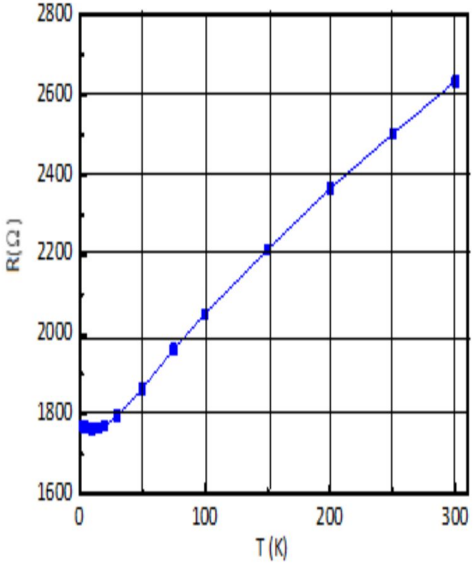


Encapsulated WTe_2

Non-encapsulated tri-layer WTe_2



Encapsulated tri-layer WTe_2

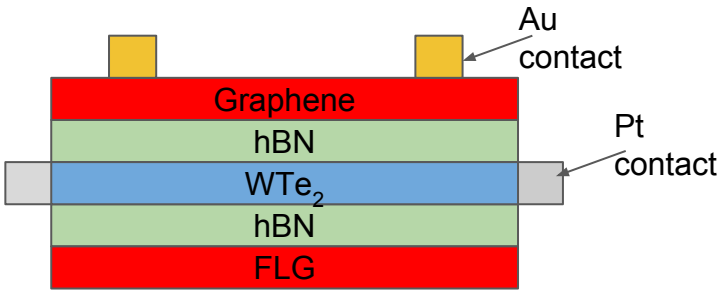


Top and bottom gates

Ramp top and bottom gate voltages to change the electric field and carrier density on the WTe_2

Observe by probing the WTe_2

Want to see if we can observe an effect on the top gate



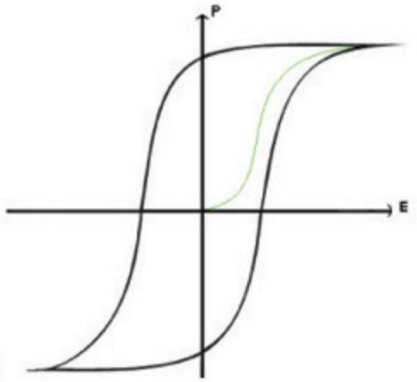
$$D \approx \frac{1}{2}(D_b + D_t) \approx \frac{1}{2}\epsilon_{BN}\left(\frac{V_{bg}}{d_{bg}} - \frac{V_{tg}}{d_{tg}}\right)$$

$$\Delta(n-p) = \epsilon_{BN}\left(\frac{V_{bg}}{d_{bg}} + \frac{V_{tg}}{d_{tg}}\right)$$

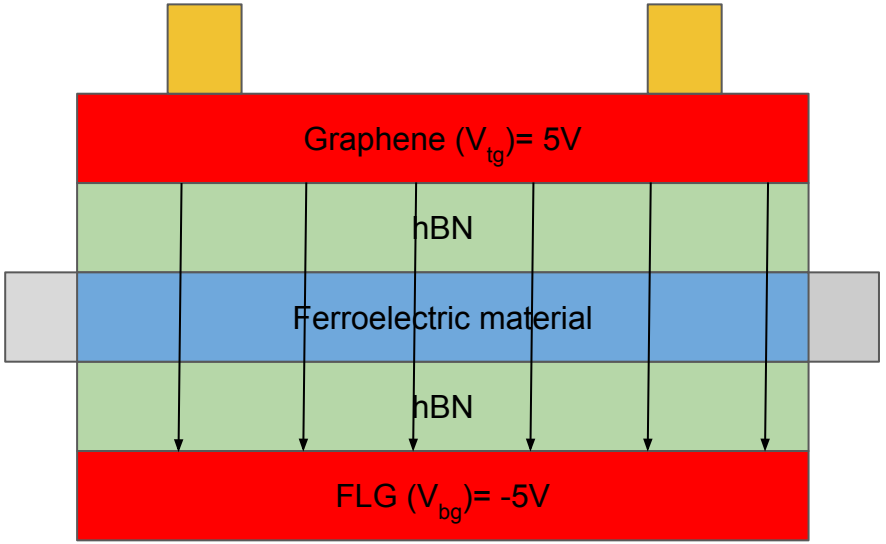
Ferroelectric materials

Switchable macroscopic polarization induced by a transverse electric field

Observed by an induced hysteresis in polarization as a result of changing electric field



Hysteresis loop[1]



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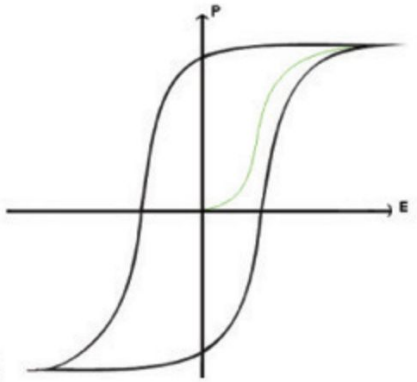
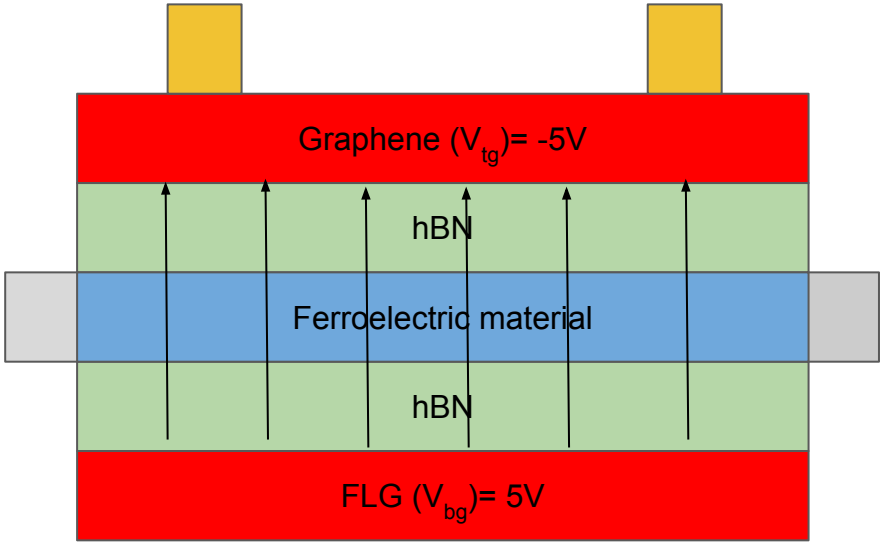


Hysteresis loop[1]

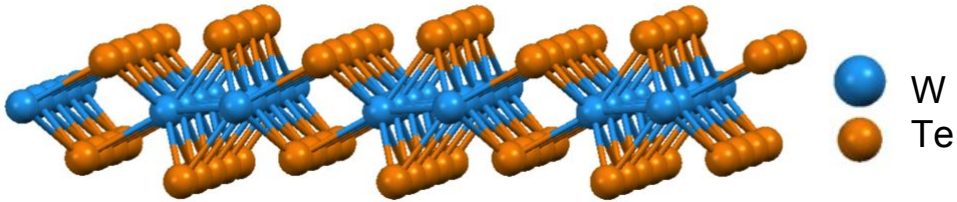


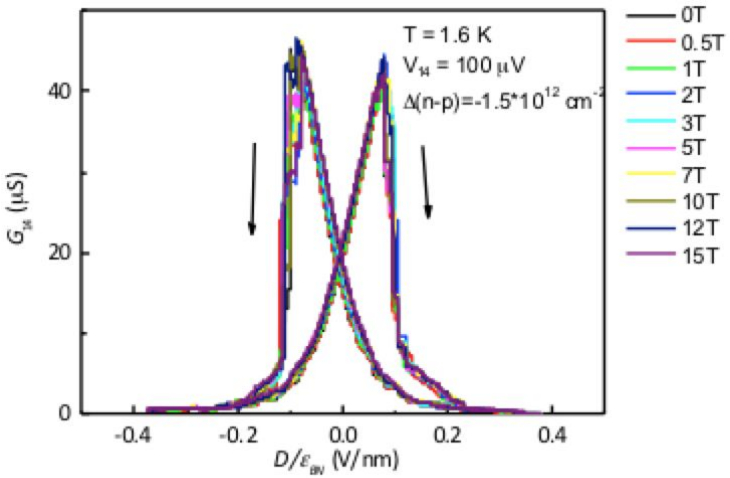
WTe_2 ferroelectric metal?

In a metal, free electrons are expected to screen the ability of dipole moments to affect overall electrostatic forces

Bilayer and trilayer WTe_2 show strong hysteretic conductance

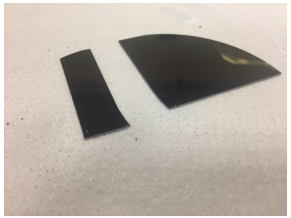
Inversion symmetry



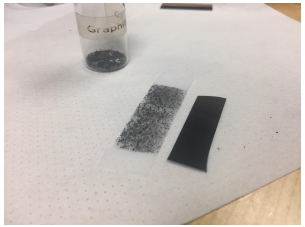


Hysteresis observed in previous bilayer device

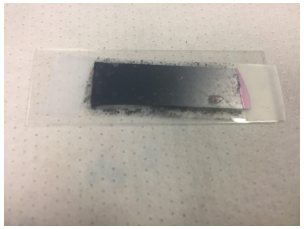
Exfoliating using the Scotch tape method



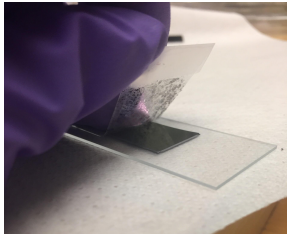
SiO_2 substrate



Crystals exfoliated on Scotch tape to create few layers (pictured: graphite)



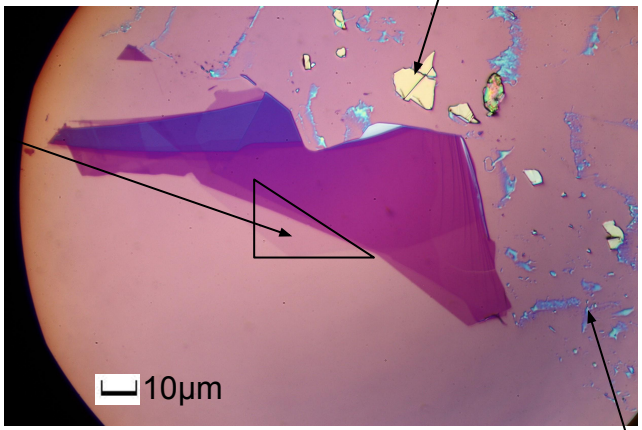
Tape pressed down on SiO_2, heated at 100C

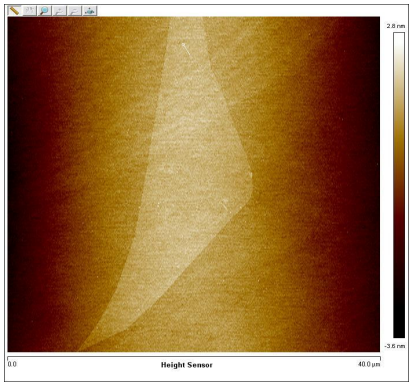


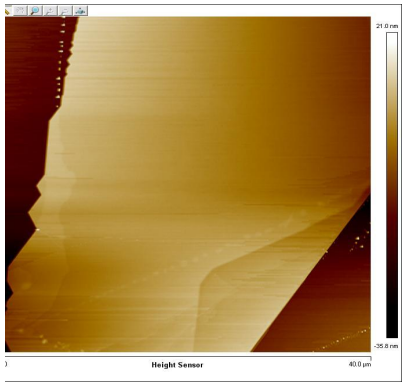
After cooled, tape removed

Searching

Search in optical microscopes, looking for color, shape, and size

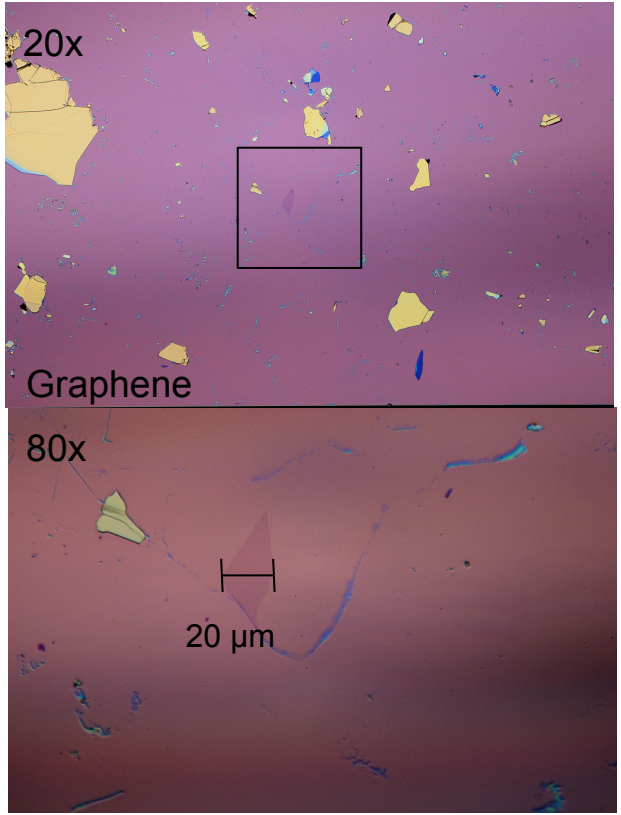


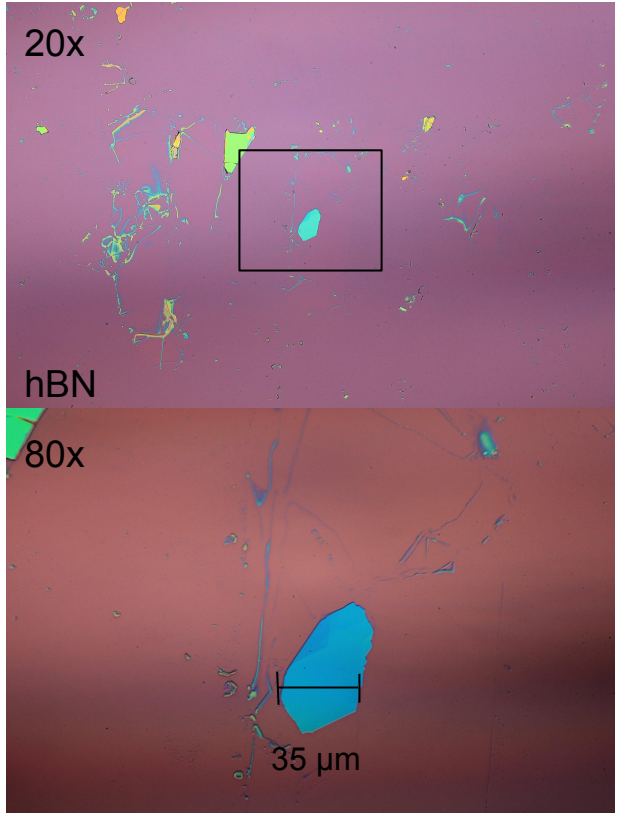




AFM image

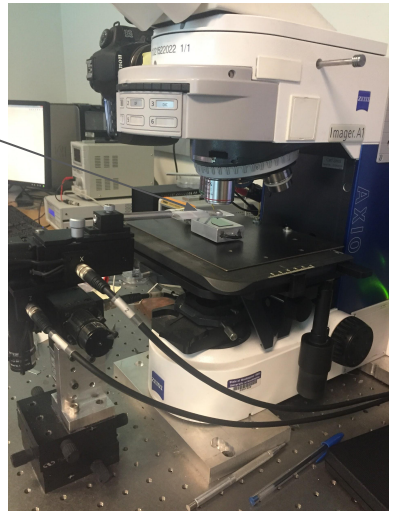
Searching





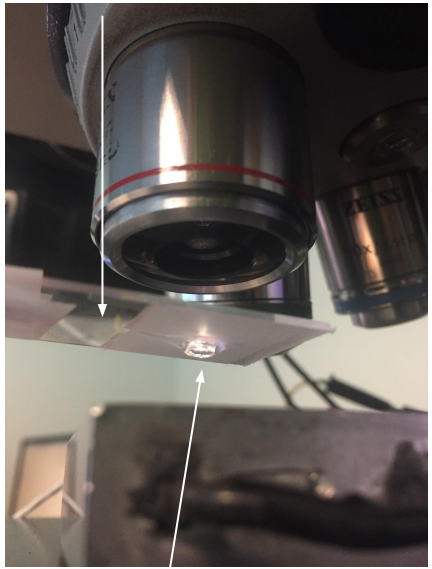
Transfers

PC and PDMS stamp

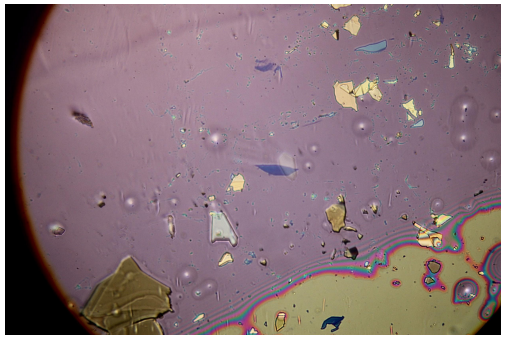


Transfer setup

Glass slide

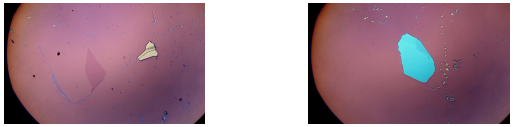


Compressible PDMS covered with sticky PC (polymers)

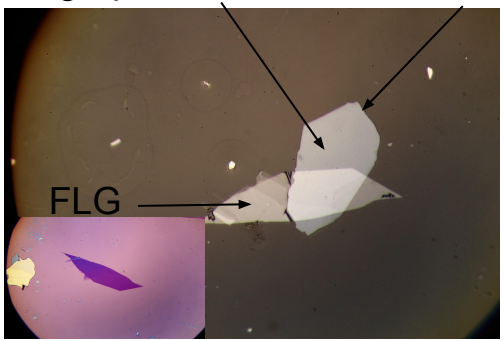


Stamp approaching FLG

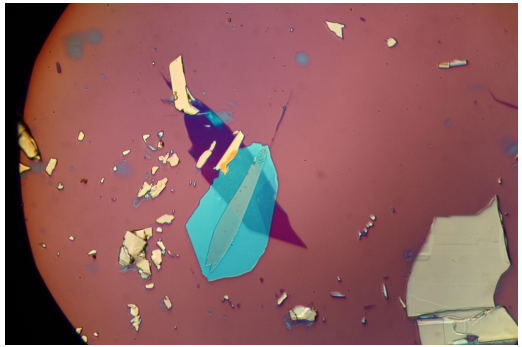
Transfers, contacts, wire bonds



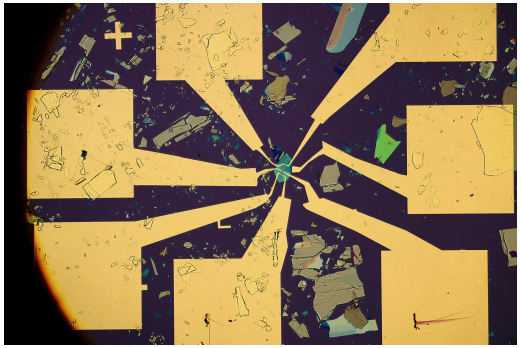
graphene hBN



Device on stamp (all photos in 100x)

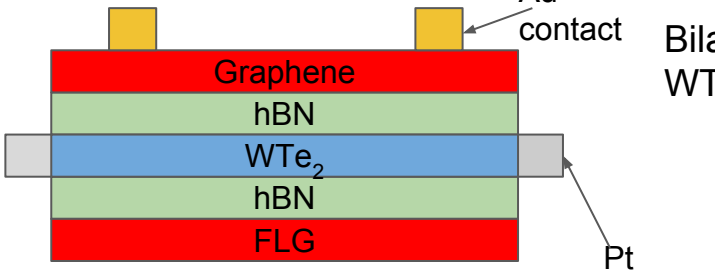


Device after melting down on WTe_2

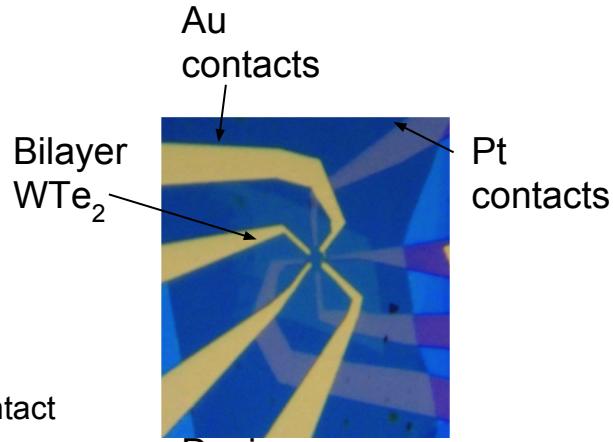


Electron beam lithography to create the pattern, evaporated gold

Bilayer device



Device layers

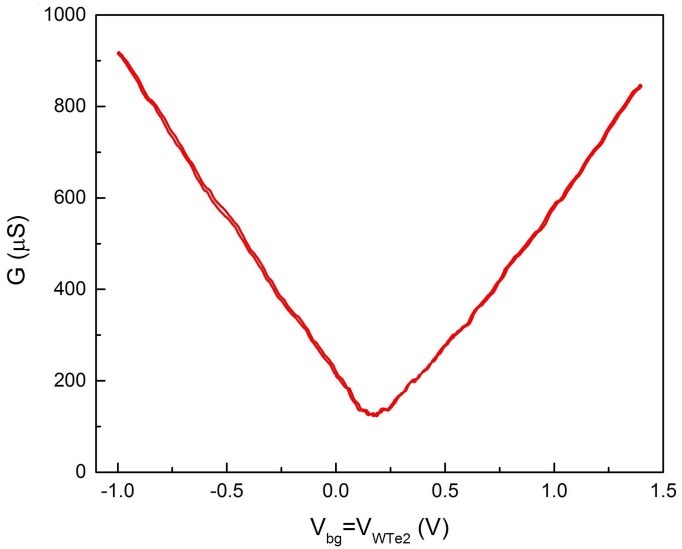


Device geometry

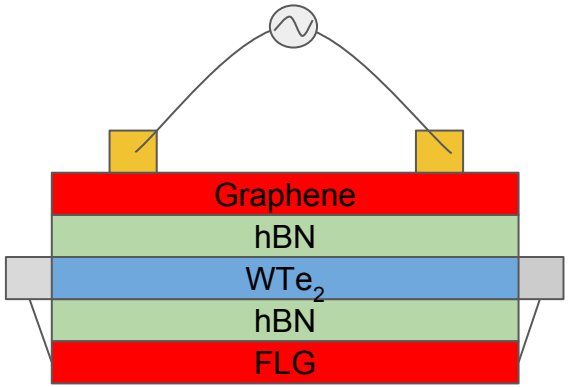
Cryostat used for measurements

Demonstrate carrier density in bilayer device

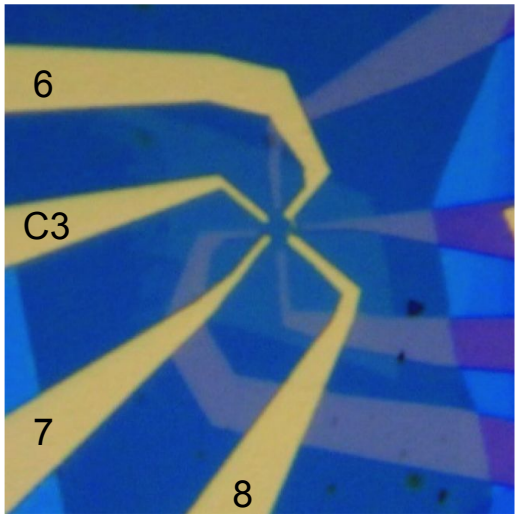
Conductance vs. gate voltage in graphene



G= I/V, at 4K

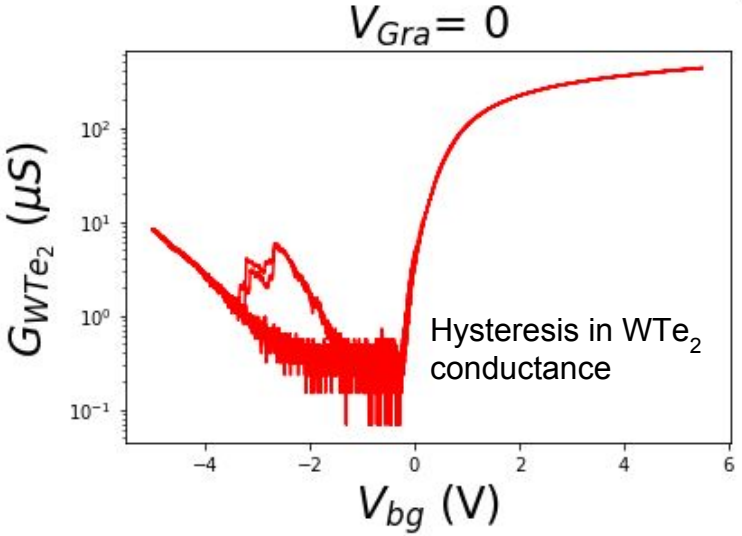


Device layers

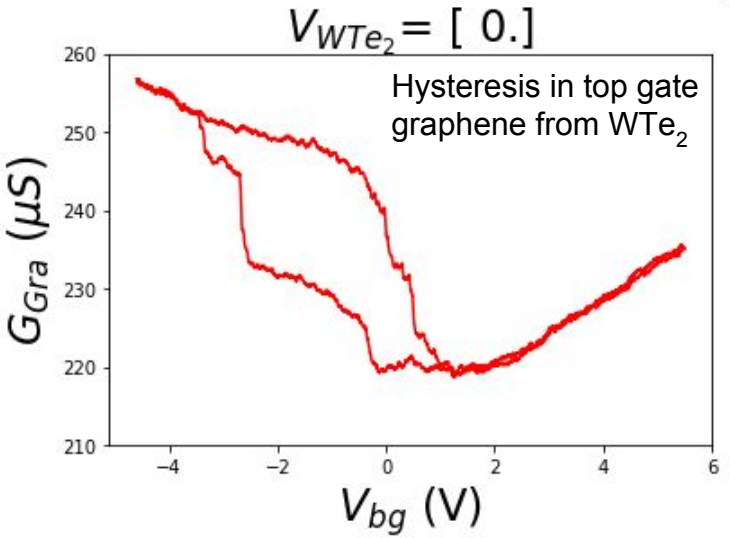


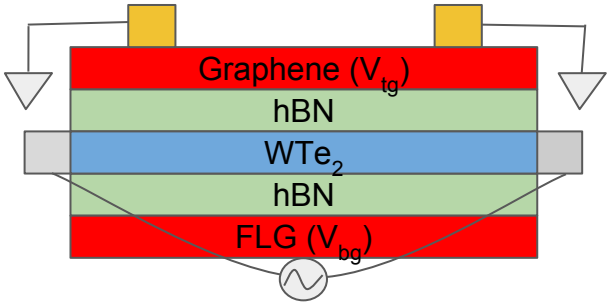
V_{bg} set to V_{WTe2}, contacts not being probed grounded

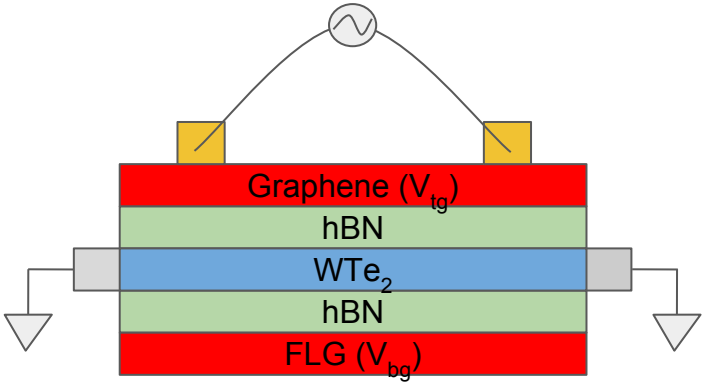
Hysteresis features



4K



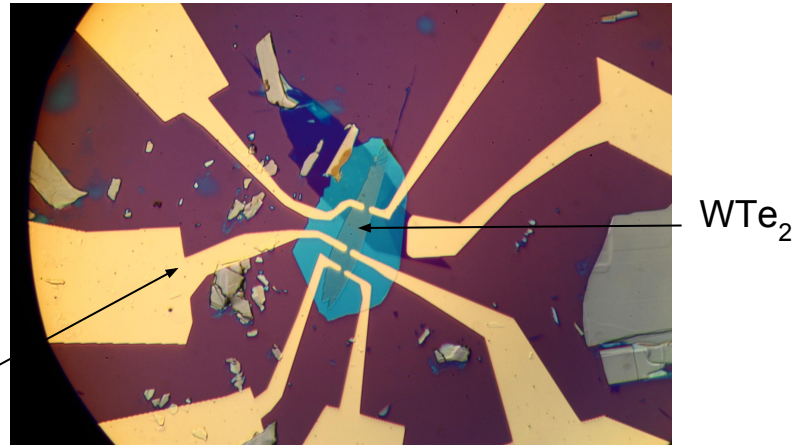


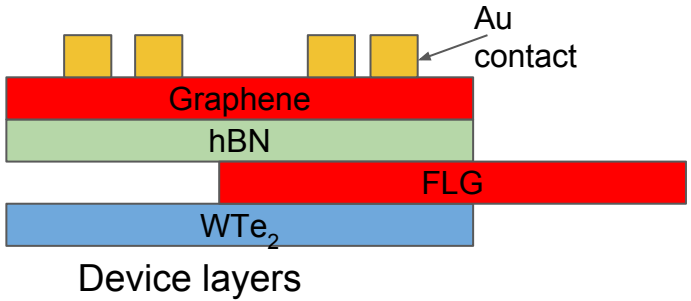


Bulk WTe_2, device

Hope to see if WTe_2 in bulk can have the same ferroelectric switching in the top few layers

Use WTe_2 as the back gate





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1. https://www.doitpoms.ac.uk/tlplib/ferroelectrics/printall.php