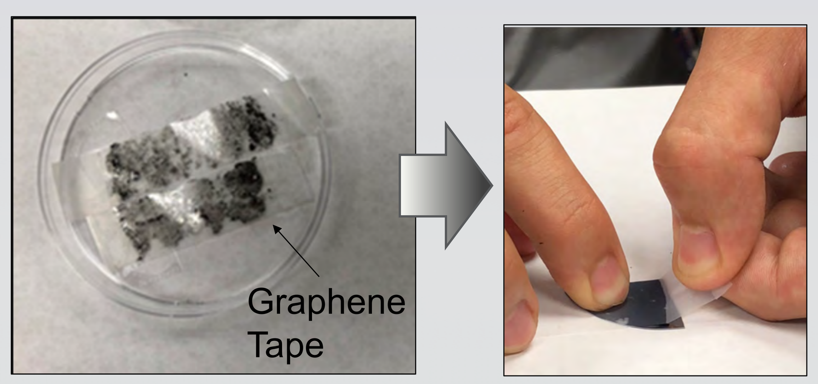
Exploring the Electrical Properties of Twisted Bilayer Graphene

William Shannon, Joel Toledo-Urena, Joseph Murphy, Byron Greenlee, Dr. Jennifer Heath
Department of Physics, Linfield College

Abstract

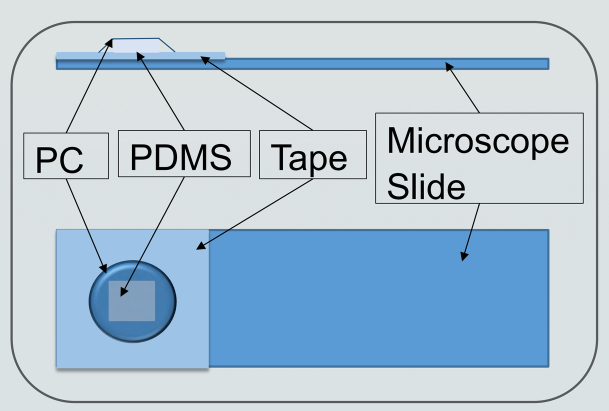
Two-dimensional materials exhibit properties unlike anything else seen in conventional substances. Electrons in these materials are confined to move only in the plane. In order to explore the effects of these materials, we have built apparatus and refined procedures with which to create two-dimensional structures. Two-dimensional devices have been made using exfoliated graphene and placed on gold contacts. Their topography has been observed using Atomic Force Microscopy (AFM) confirming samples with monolayer, bilayer, and twisted bilayer structure. Relative work functions of each have been measured using Kelvin Probe Force Microscopy (KPFM) showing that twisted bilayer graphene has a surface potential 20mV higher than that of monolayer graphene and 35 mV below bilayer graphene.

Exfoliate a 2D film



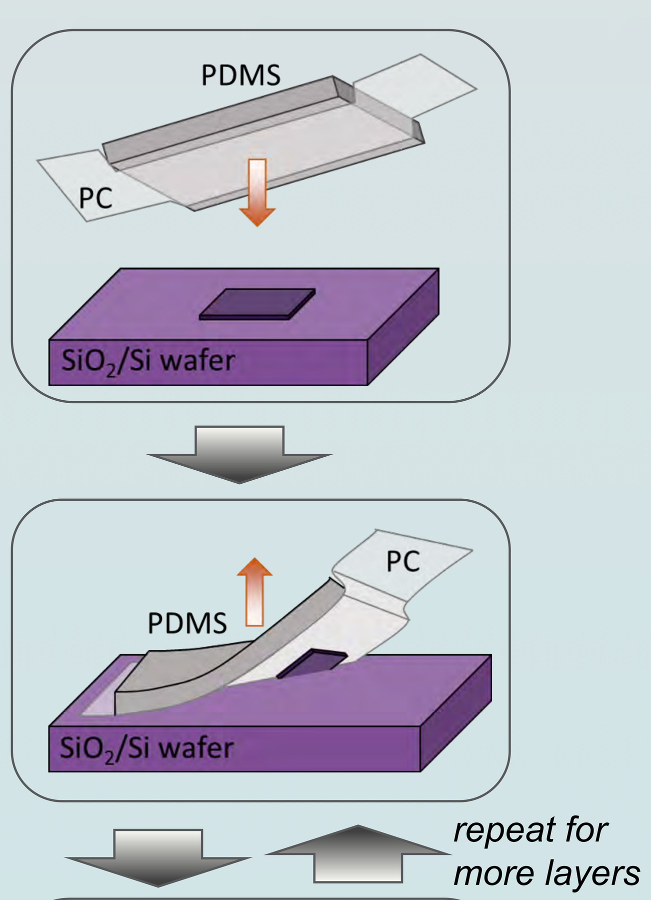
The exposed surface of the crystal sticks to the silicon wafer substrate. Bulk crystal peels off with the tape, leaving a 2D film.

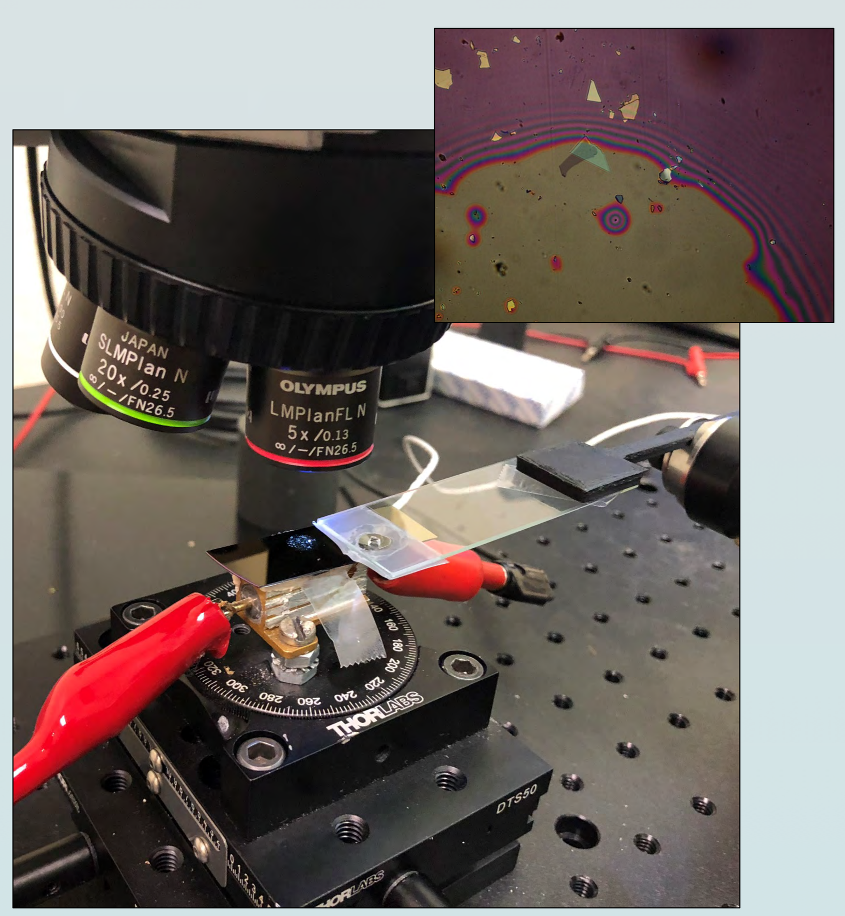
Move the film around with a stamp

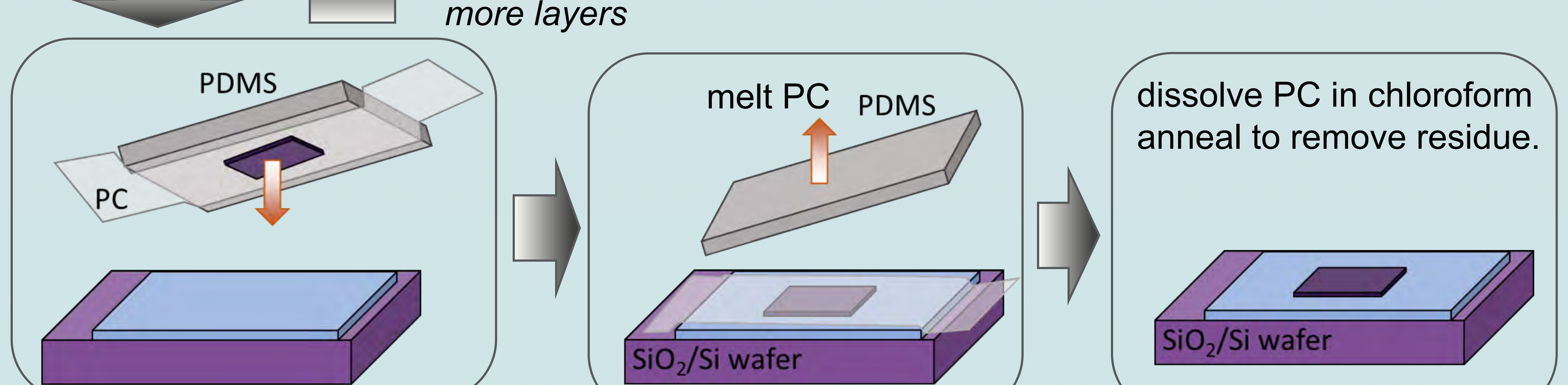


The stamp has a thin transparent polycarbonate (PC) layer over a thicker poly-dimethylsulfate (PDMS) pad, all attached to a glass slide. The PC is sticky and has a lower melting point than PDMS.

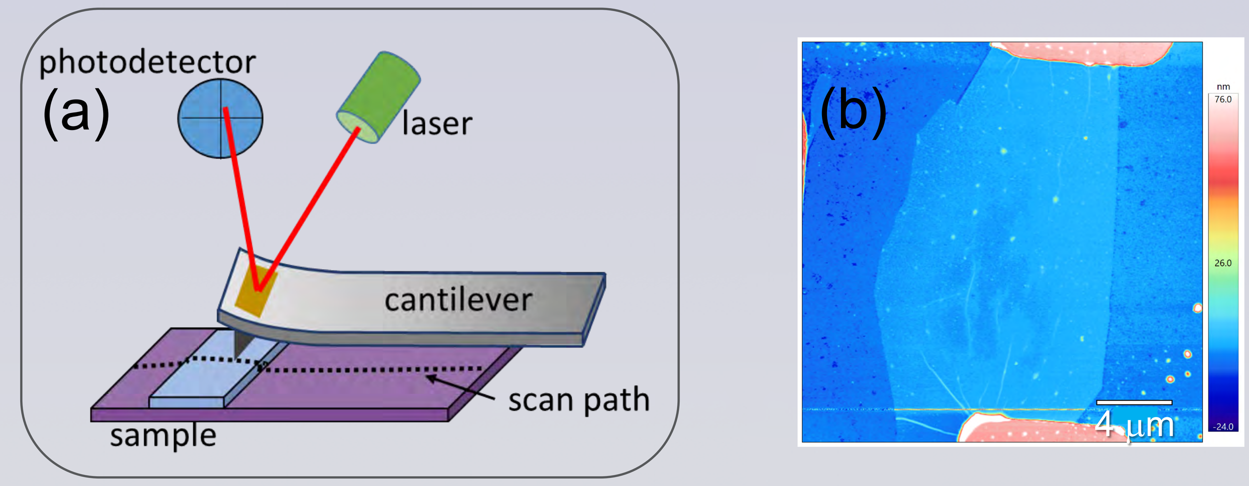
Layer films together





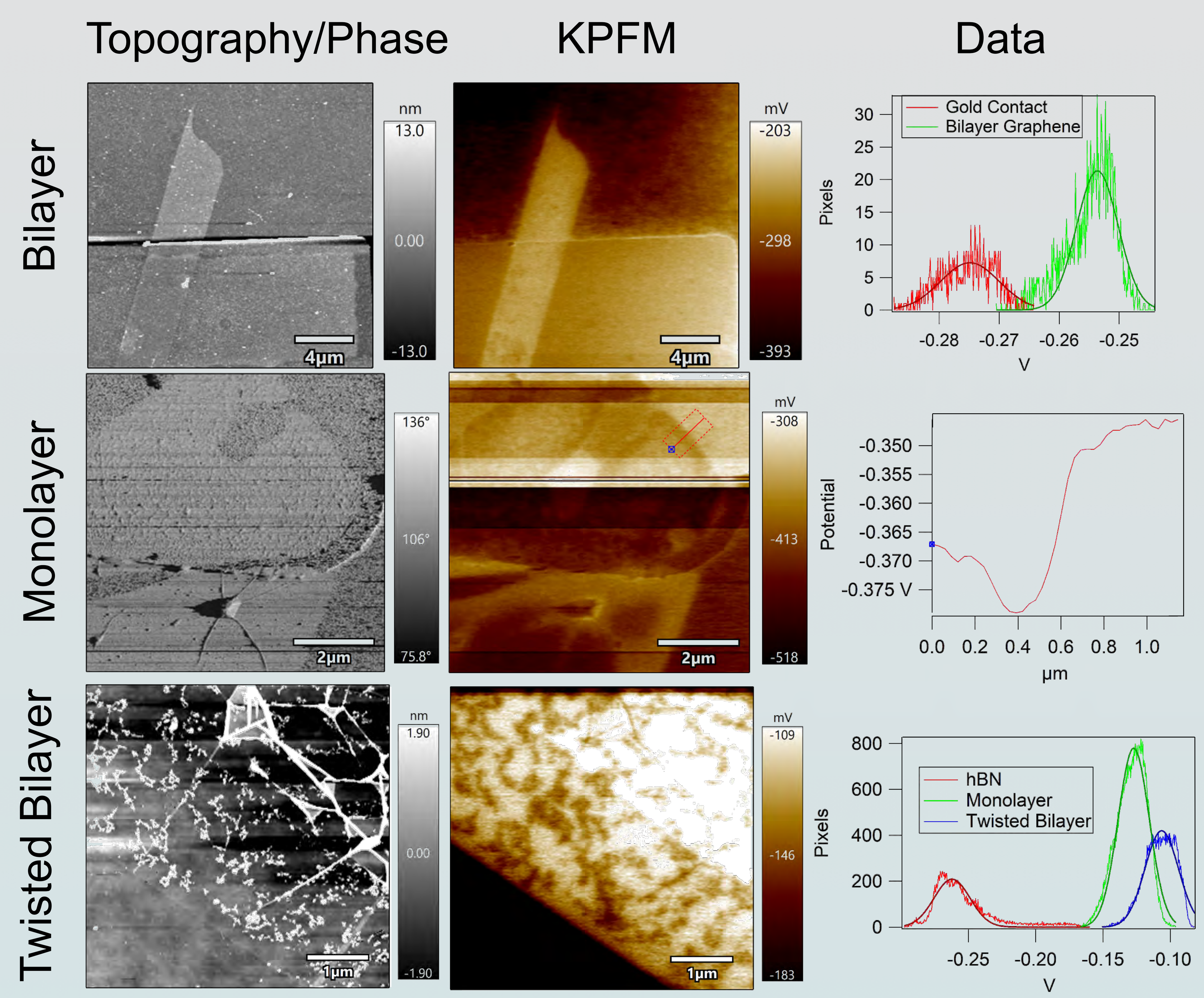


Measure the devices with AFM



(a) Diagram showing the working mechanism of an Atomic Force Microscope
(b) Atomic Force Microscope image of a graphene flake across two gold contacts.

Surface Potential Measurements



Topography, surface potential images, and corresponding data for bilayer graphene on gold contacts, monolayer graphene on gold contacts, and twisted bilayer graphene on hBN.

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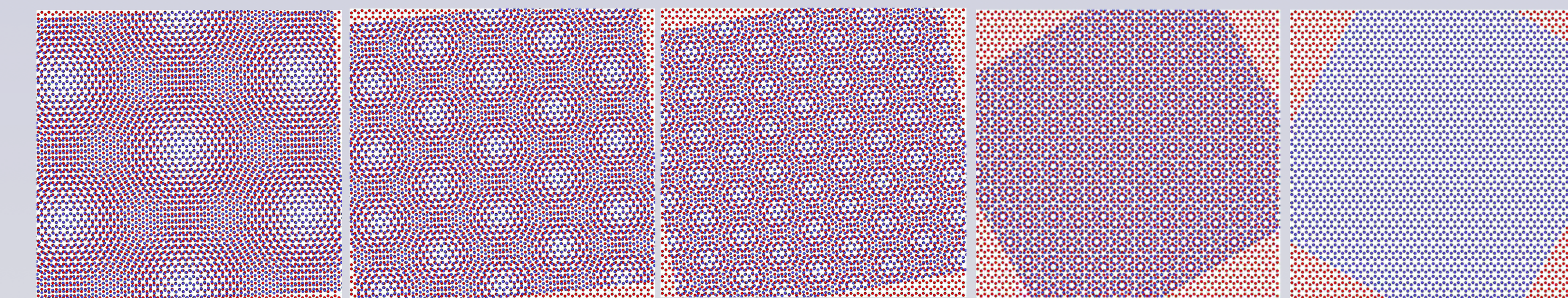
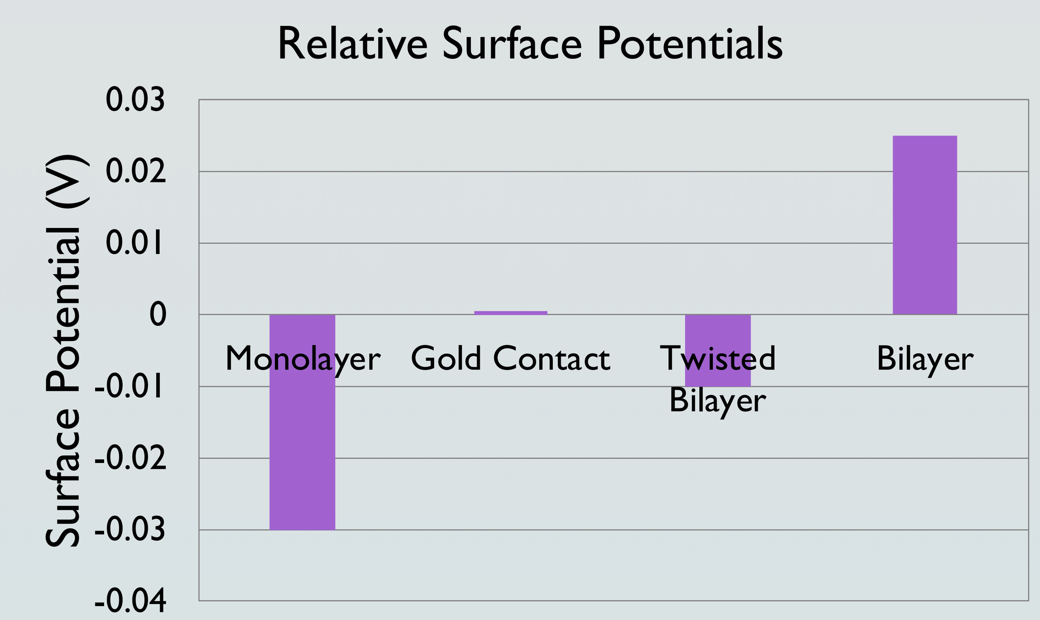
Twisted Bilayer Graphene



Layering two graphene films together with a slight twist creates a Moiré pattern. It changes the electrical characteristics of the normally semi-metal film.

Data Analysis

- KPFM results were analyzed to estimate relative values of surface potential, using the gold contact as a reference point
  - $\Delta\phi_{Mono-Twisted} = 20mV$
  - $\Delta\phi_{Gold-Mono} = -30mV$
  - $\Delta\phi_{Gold-Bilayer} = 25mV$



- Results are consistent with published values. However, surface contamination would affect these measurements.

Conclusion and Future Directions

- Successfully made 2D devices and measured them with AFM.
- Data suggests twisted-bilayer graphene may make the best contact to gold.
- Effect of surface treatment on work function requires further investigation.
- Understanding the work function of these materials is an important first step to understand electronic properties and optimize devices.

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