Capacitance Bridge for Characterizing 2D Materials

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Mentor: David Cobden

Outline

- Motivation
- Process of making 2D materials and nanodevices
- Design of Capacitance Bridge
- Expected Results and Future Work

Van der Waals Structure

- Van der Waals materials are materials that consist of single plane of atoms

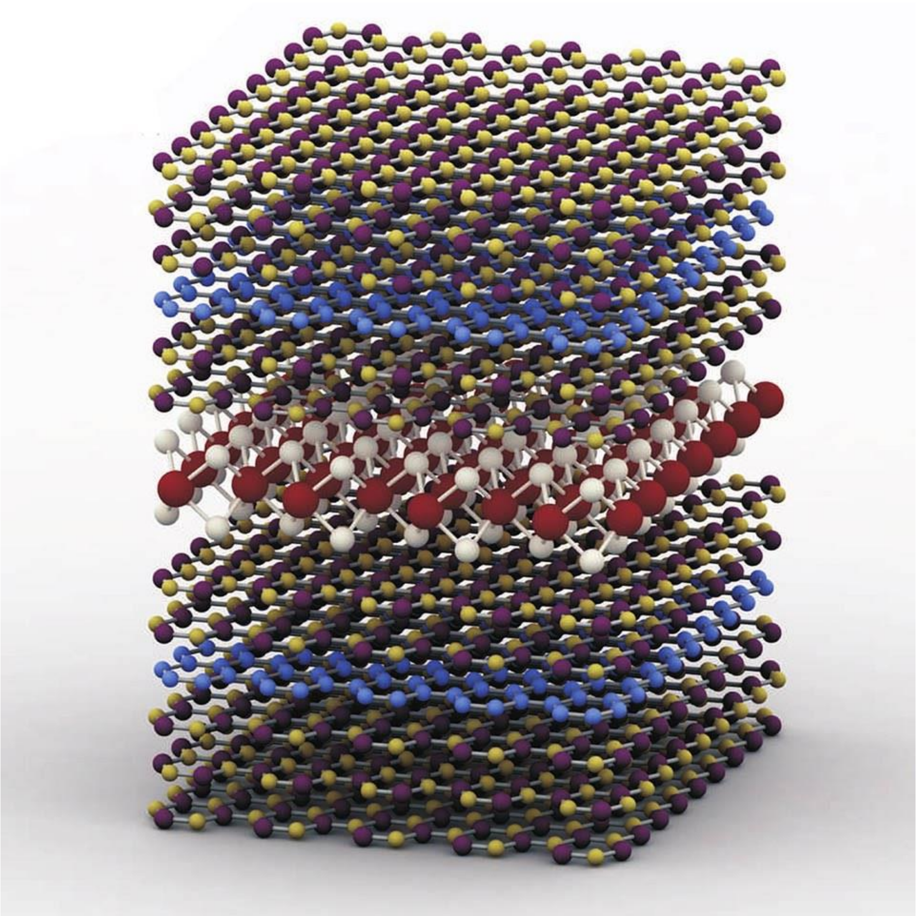
- Van der Waals Structures are structures made of layers of these materials that are held together by weak interactions between the layers

- Interesting because they have exotic properties that differ from their 3D counterparts

Light-emitting diodes by band-structure engineering in van der Waals heterostructures

F. Withers, O. Del Pozo-Zamudio, A. Mishchenko, A. P. Rooney, A. Gholinia, K. Watanabe, T. Taniguchi, S. J. Haigh, A. K. Geim, A. I. Tartakovskii & K. S. Novoselov

Nature Materials **14**, 301–306 (2015) | Download Citation



Motivation

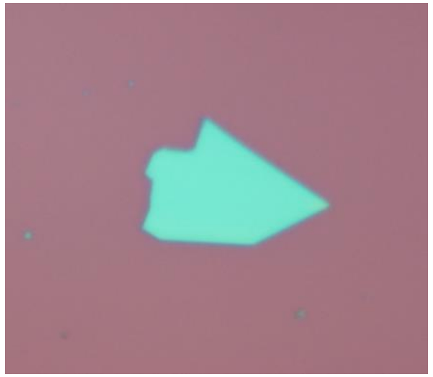
- Characterization of 2D materials is important to understanding and applications
- High Resolution Capacitance Bridge design can help to find the capacitance of these 2D materials
- Capacitance measurements are directly related to the density of states
- Use graphene as a general material
- If effective will be used to characterize more exotic materials such as WTe_2(tungsten ditelleride)

Materials Used

Graphite
- Thickness:11.2 nm
- Size: 35 microns
- Top of Structure

Graphene
- Thickness: 0.3 nm
- Length: 60 microns
- Bottom of Structure

Hexagonal
Boron Nitride



h-BN
- Thickness:50 nm
- Length: 24 microns
- Middle of Structure

Method for Obtaining Materials

- Spread graphite crystals onto scotch tape for Exfoliation

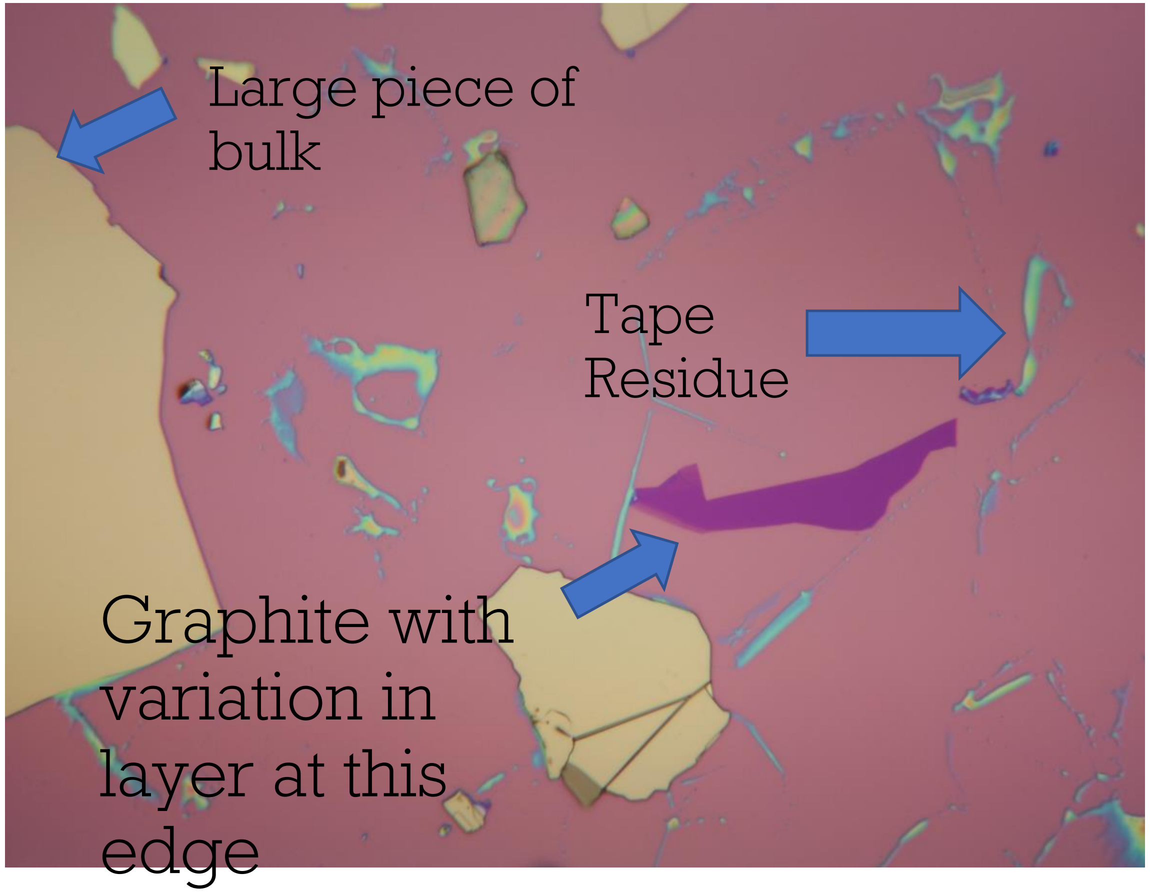
- Stick and Tear

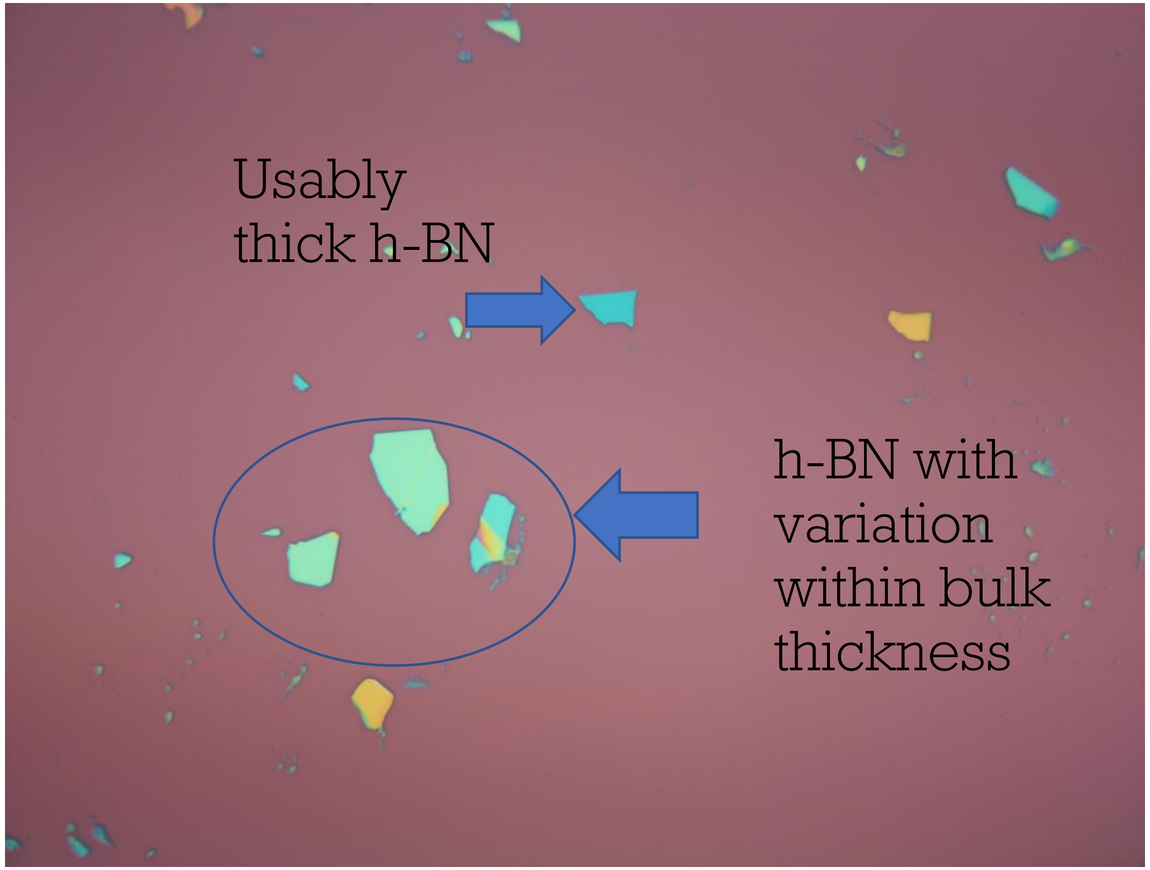
- Exfoliate Crystals onto plasma cleaned SiO_2 chips

- Heat to 100°C

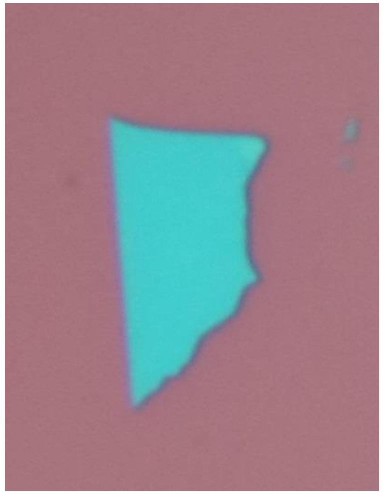
- Cool to Room Temperature and peel tape

Searching for Materials

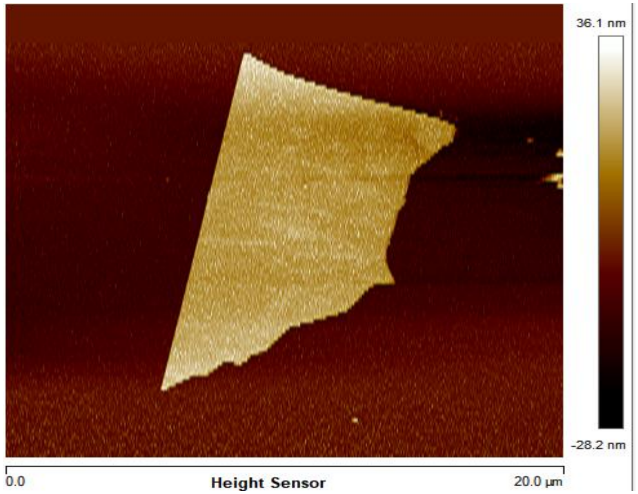




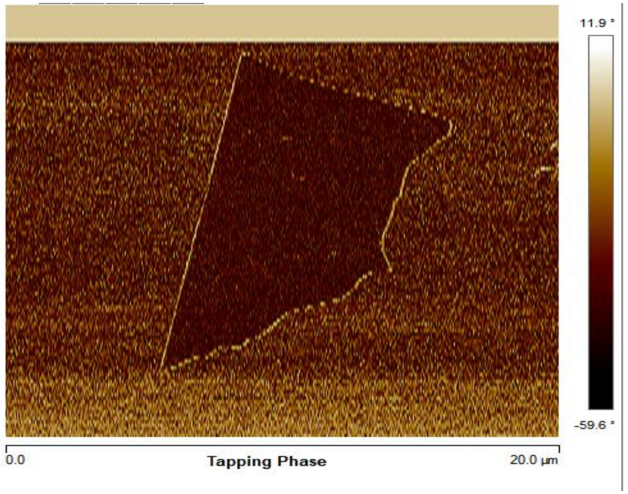
Characterizing Components



Optical Image



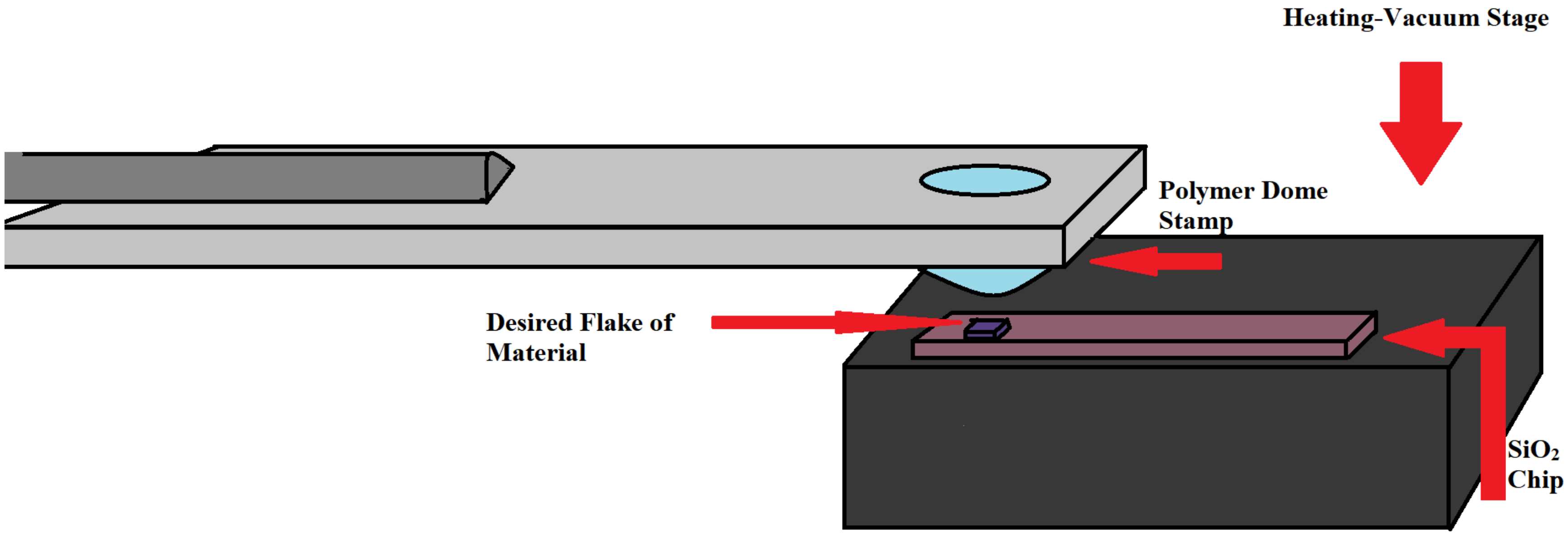
Thickness



Cleanliness

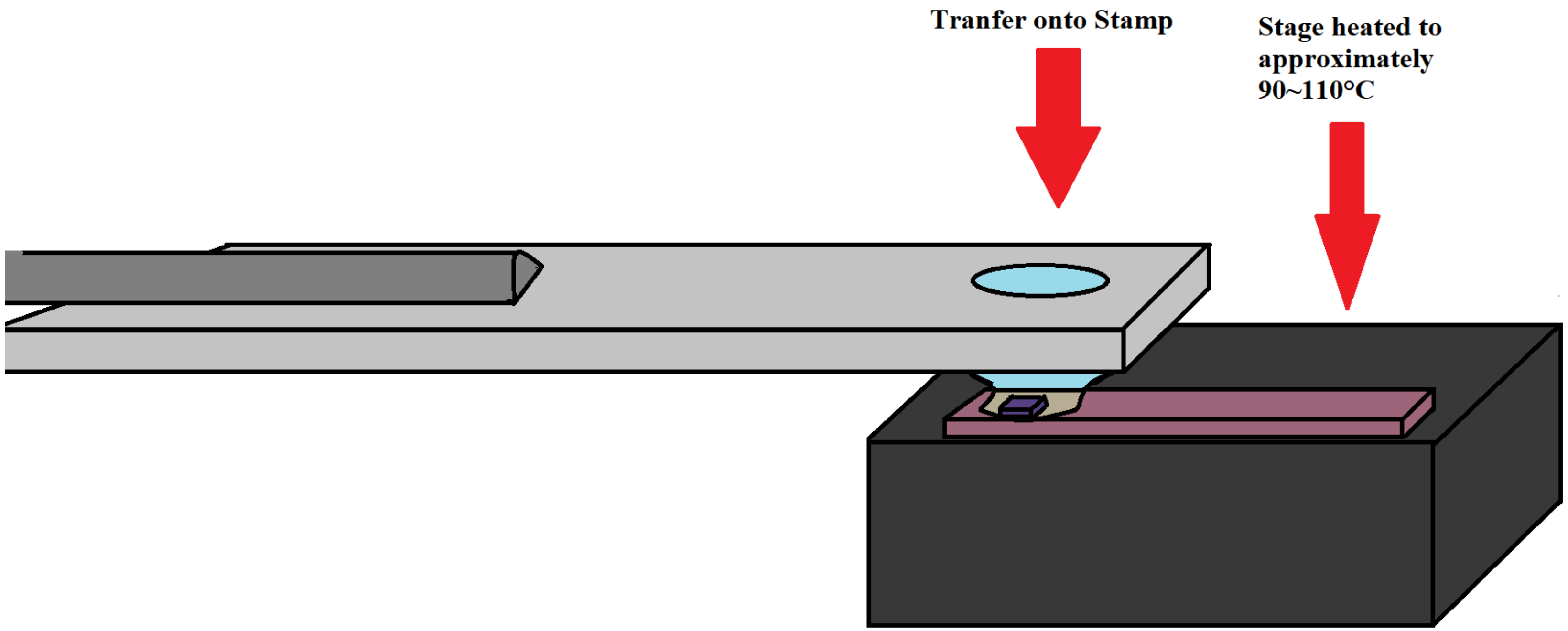
Transfer Method

Position Stamp



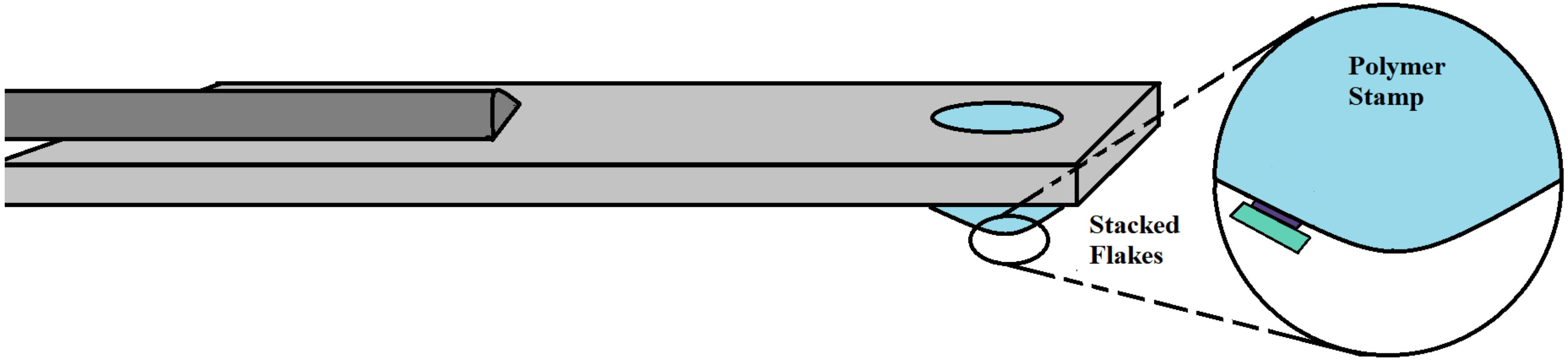
Transfer Method

Pick-up material



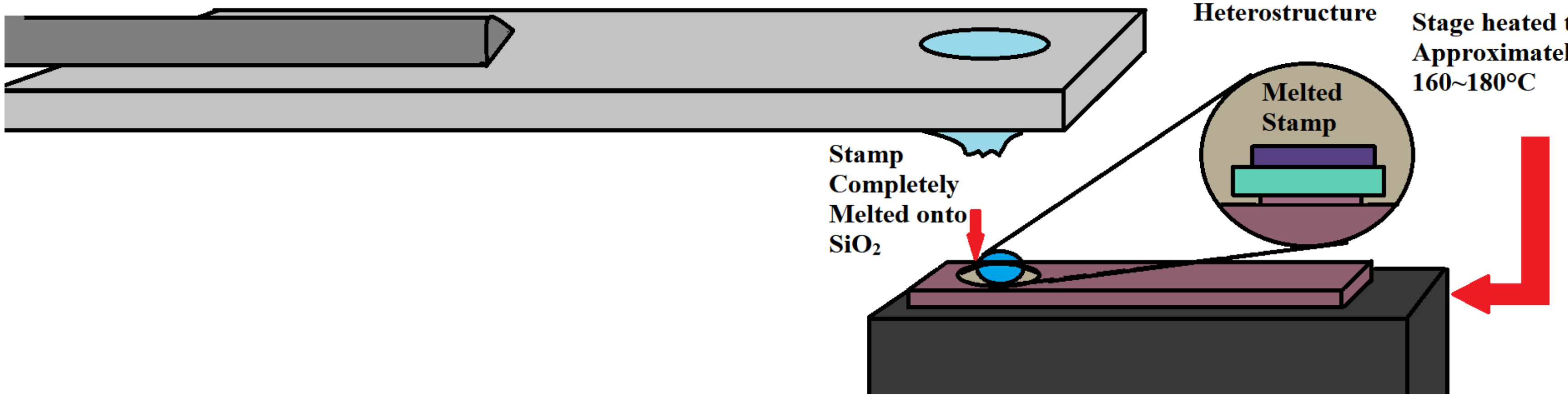
Transfer Method

Desired Structure on Stamp



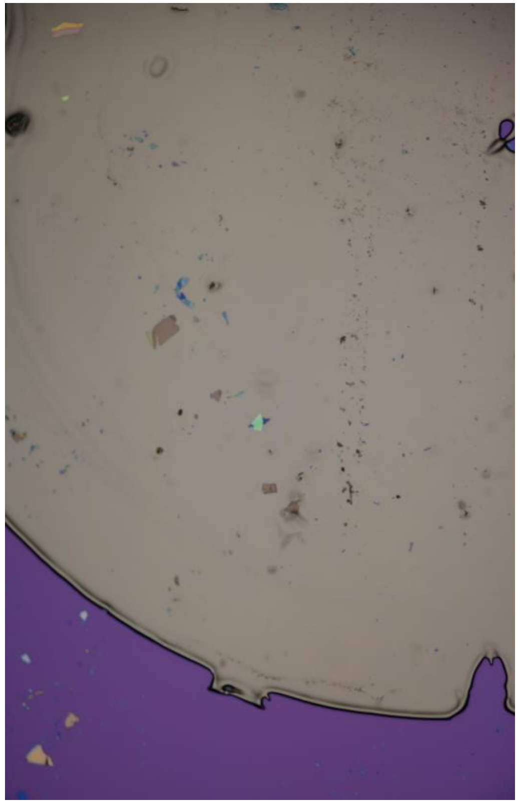
Transfer Method

Melt Stamp onto Bottom Flake

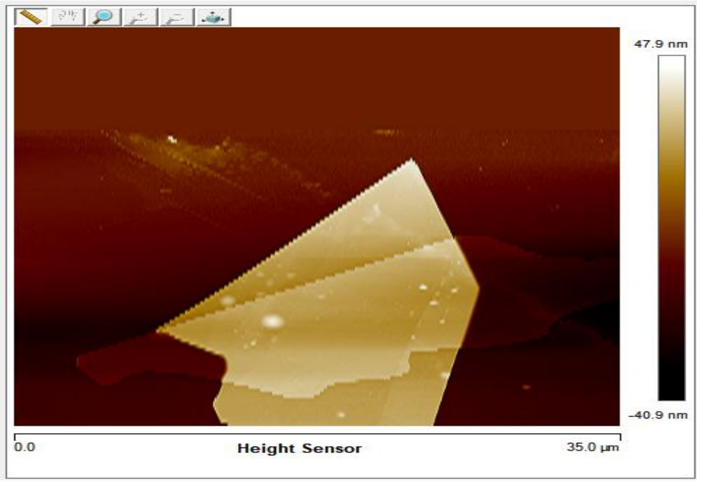


Structure of Device

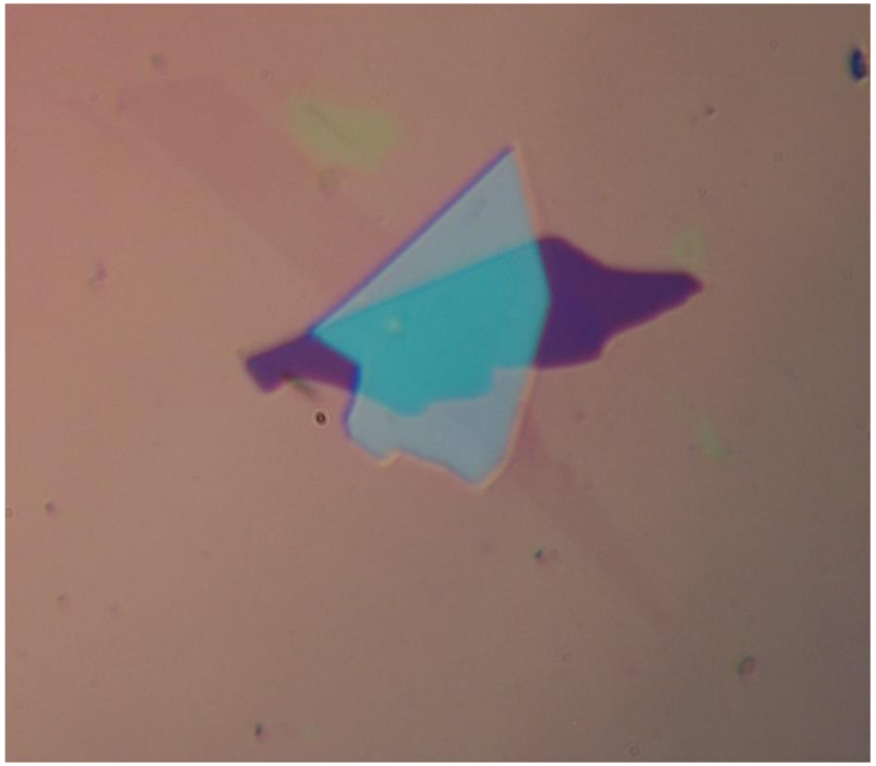
Design of the Structure



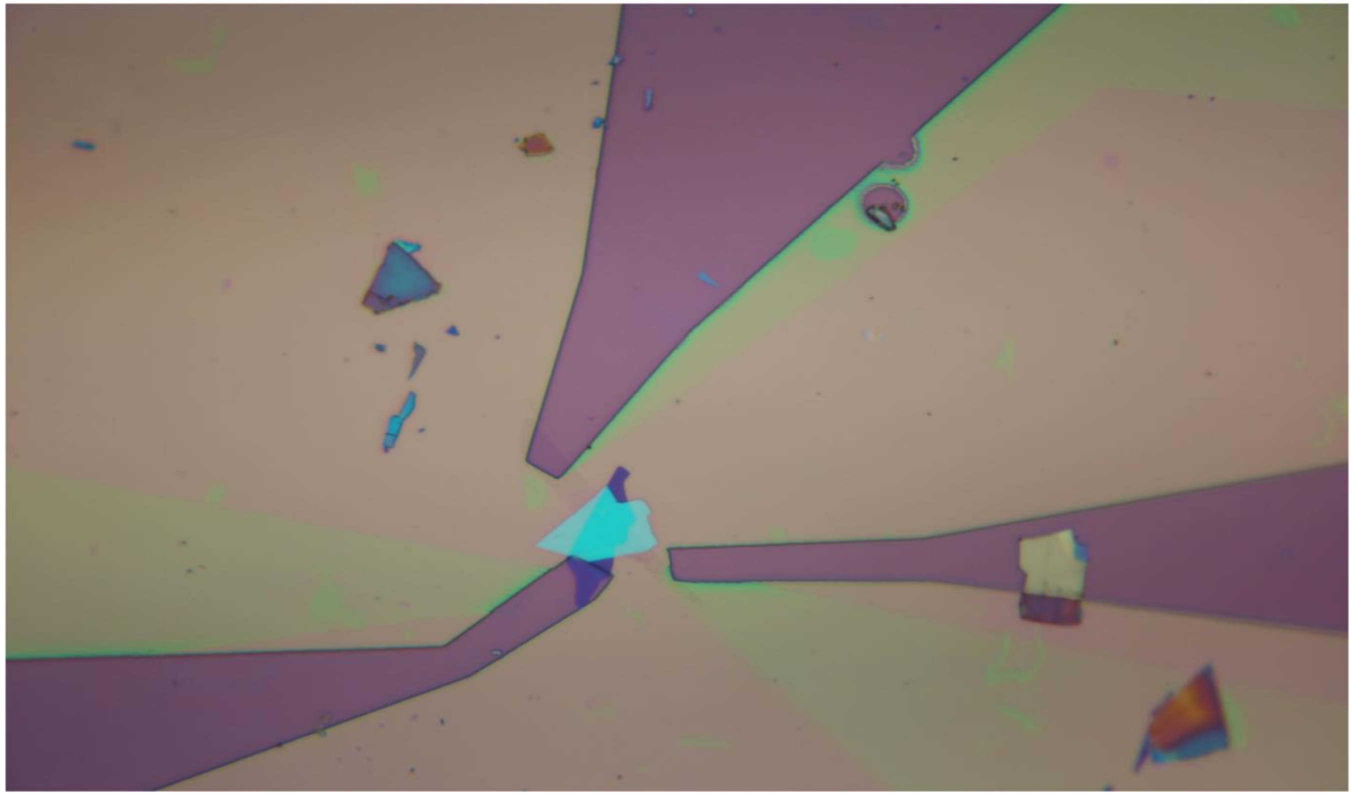
After cleaning in chloroform, and isopropanol, then annealing in furnace



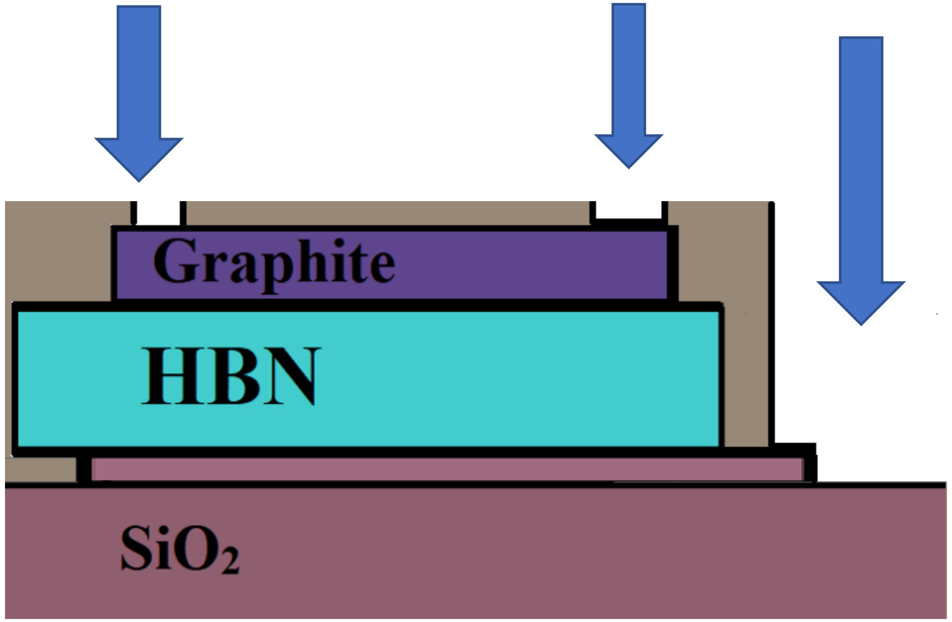
Spin Polymer for Electron Beam Lithography



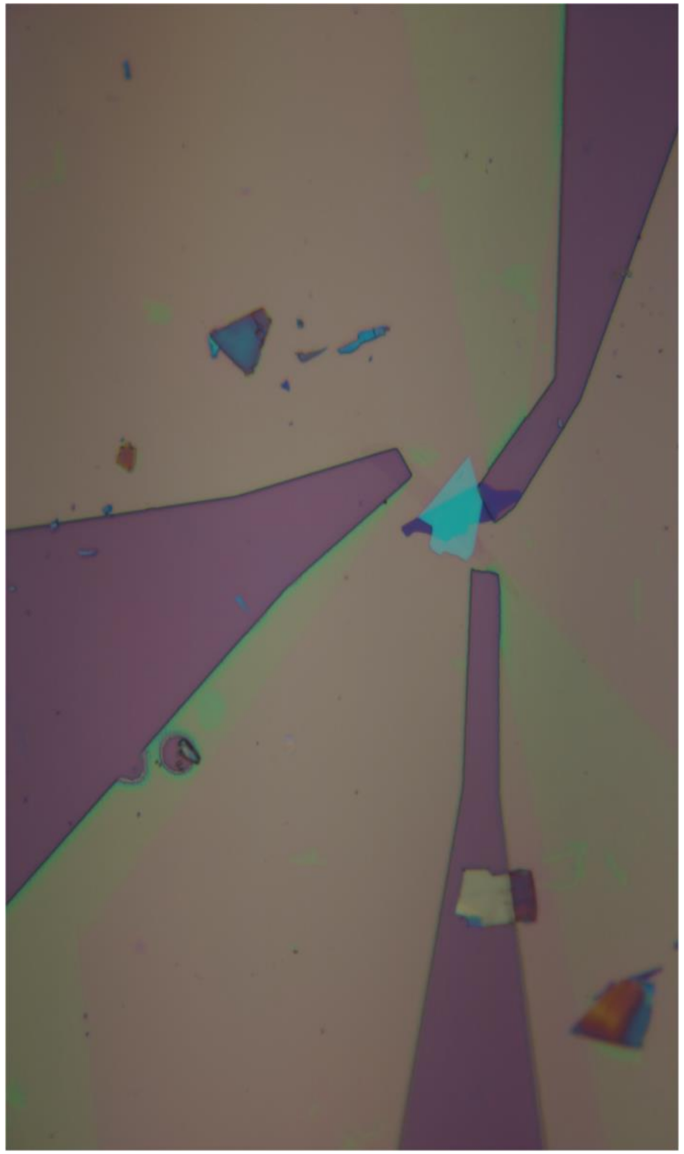
PMMA Cut from Structure



Holes for electrical contacts

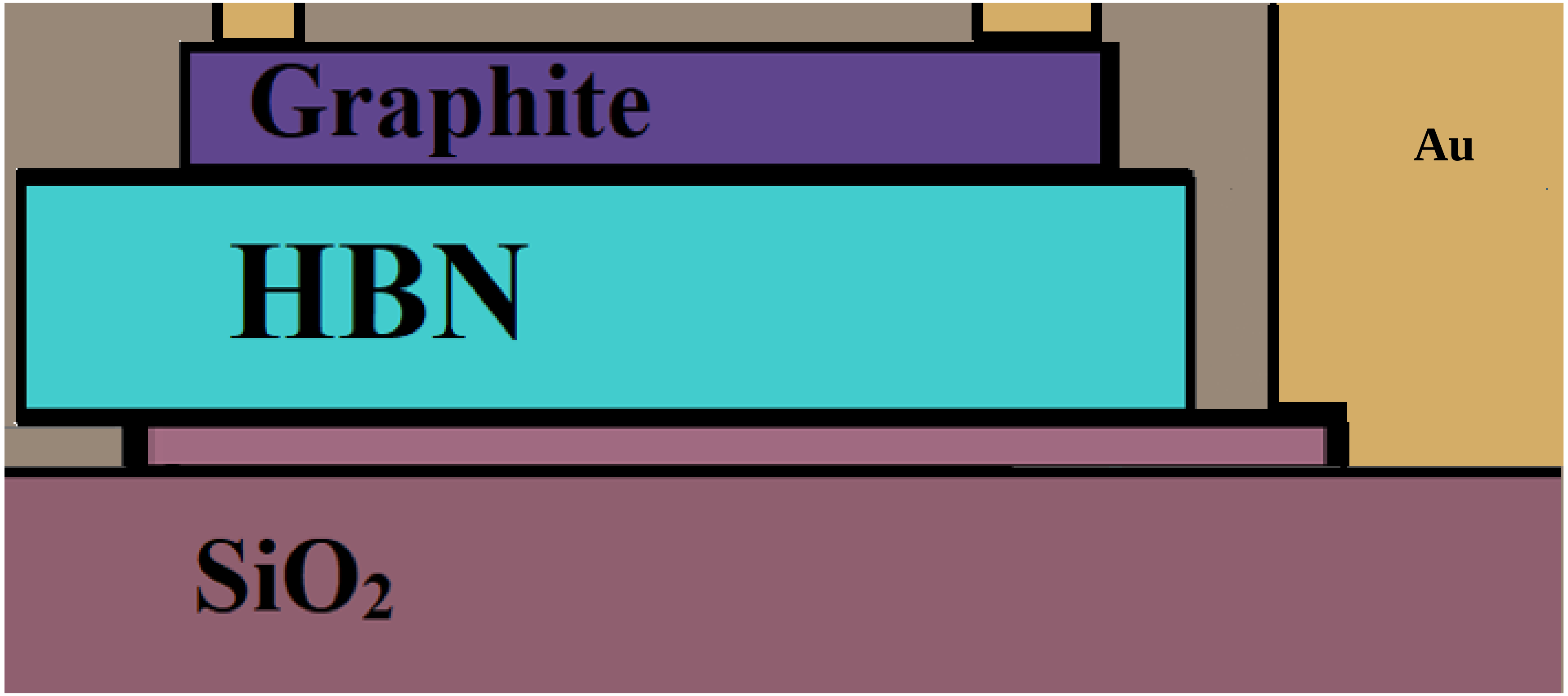


Result of EBL



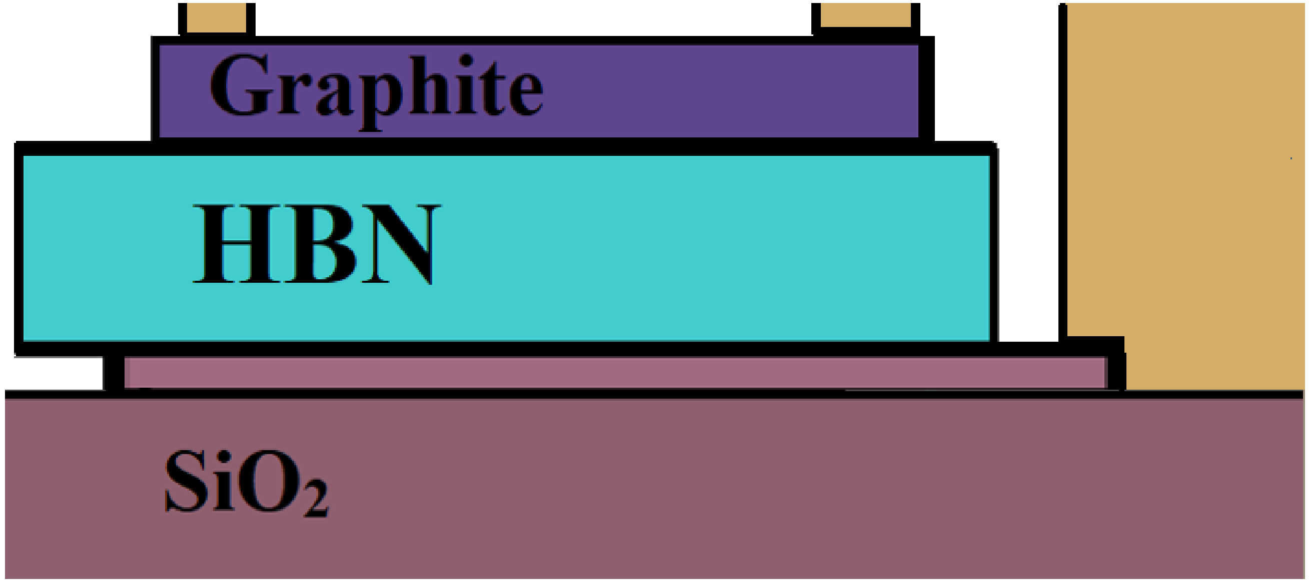
Creates holes in the polymer to evaporate gold onto

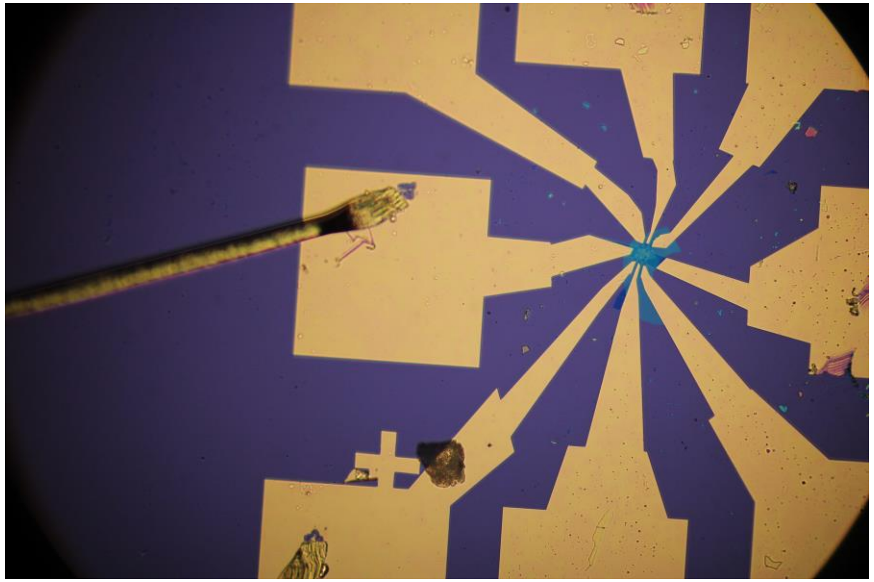
Evaporation



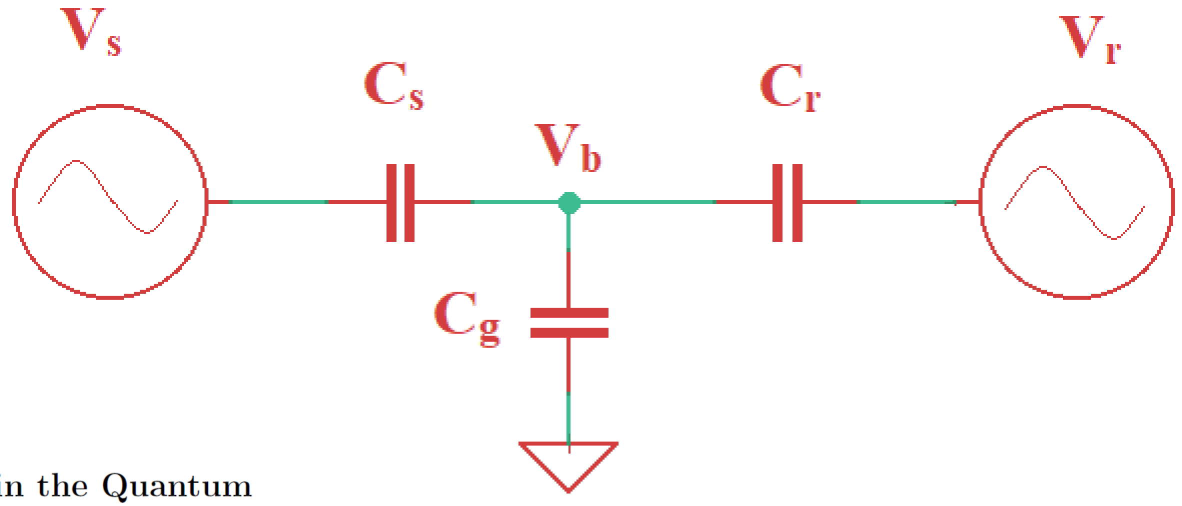
Wire Bonding

After evaporating the metal onto the device the polymer is cleaned off then the contacts are wire bonded for use





Capacitance Bridge



Imaging Transport Resonances in the Quantum Hall Effect

by

Gary Alexander Steele

Thesis, 2006

Equations of Capacitance Bridge

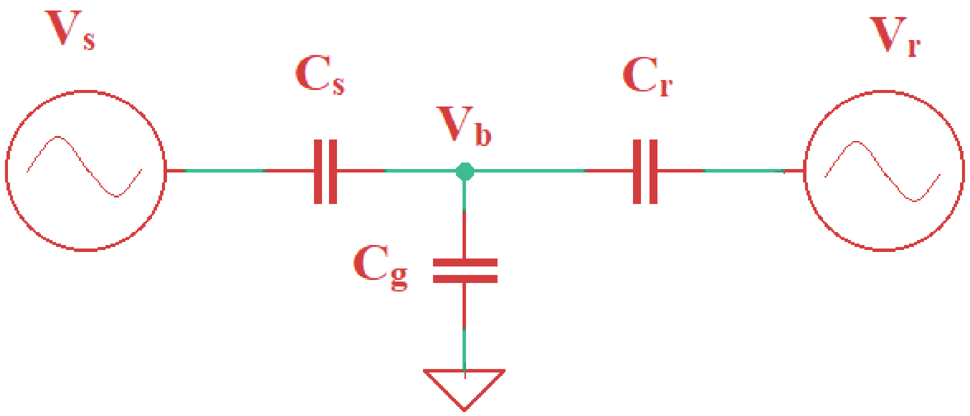
$$C_s V_s + C_r V_r = C_T V_b$$

$$C_T = C_s + C_r + C_g$$

C_r –Ref. Capacitance

C_r –Dev. Capacitance

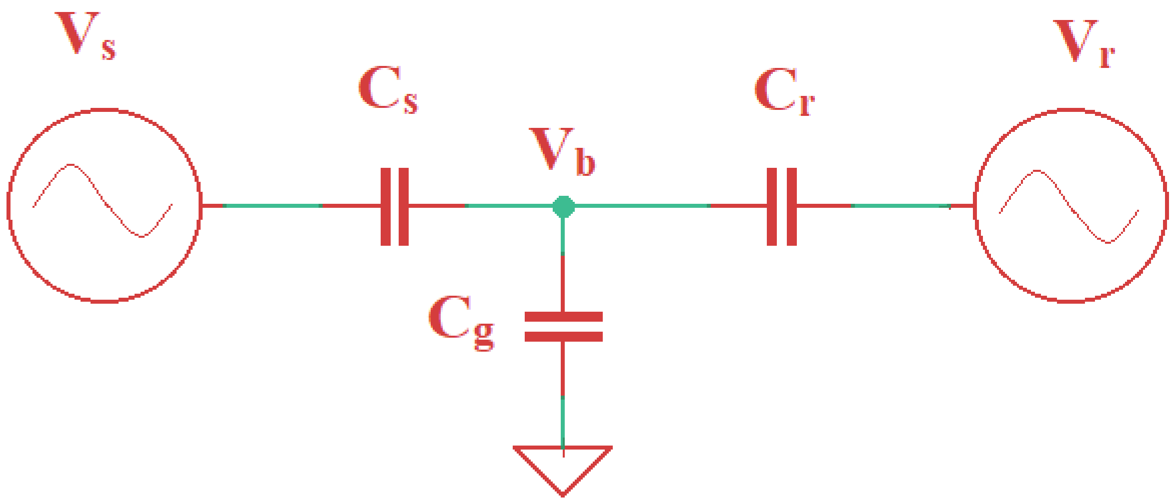
C_g – Stray Capacitance to Ground



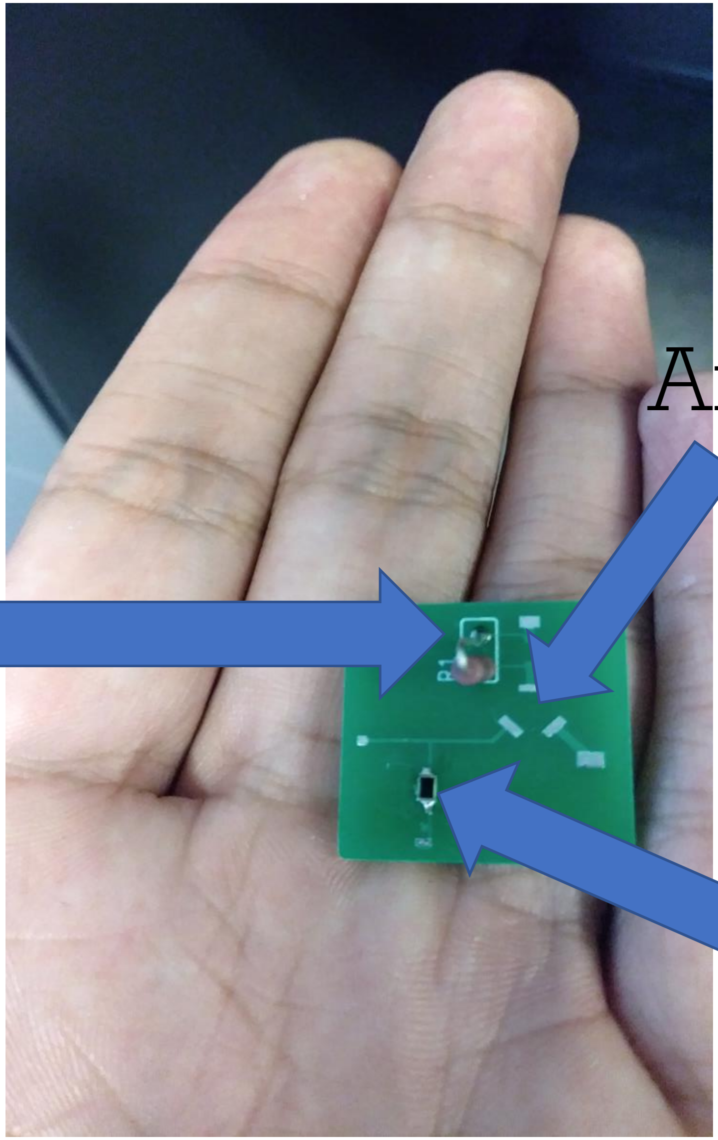
Equations of Capacitance Bridge

V_r is tuned so $V_b = 0$

$C_s V_s = C_r V_r$



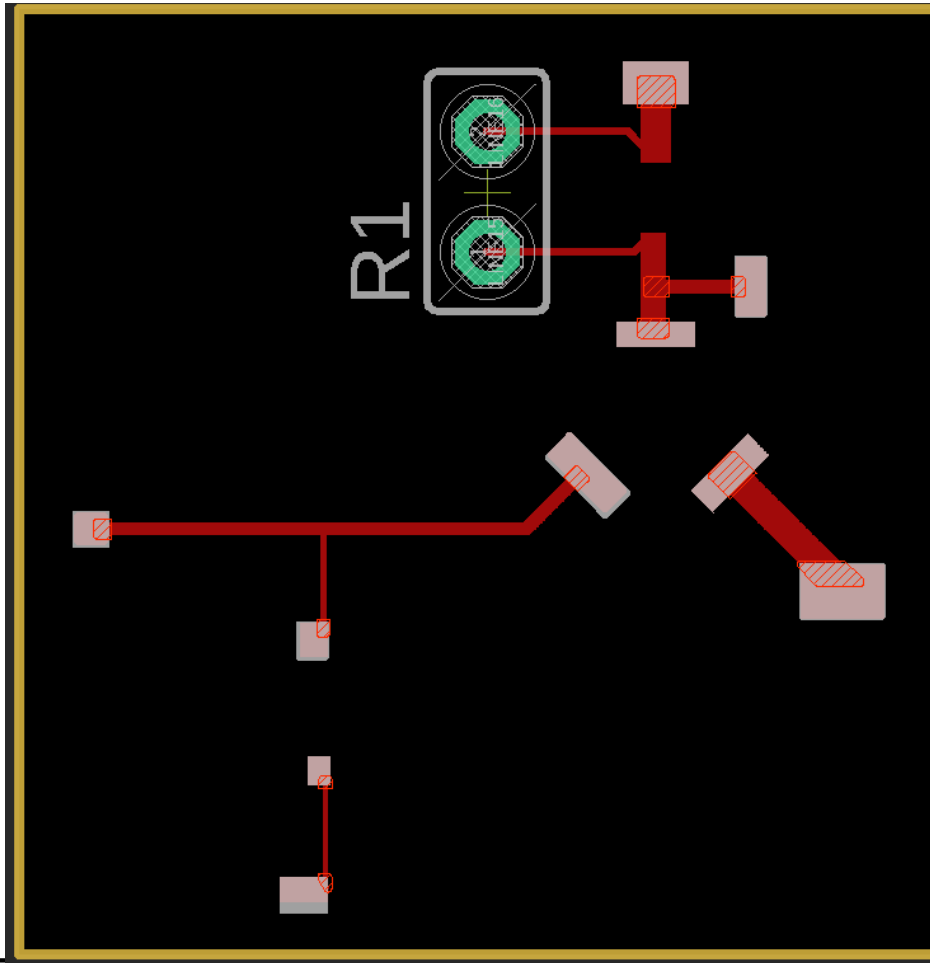
Custom PCB



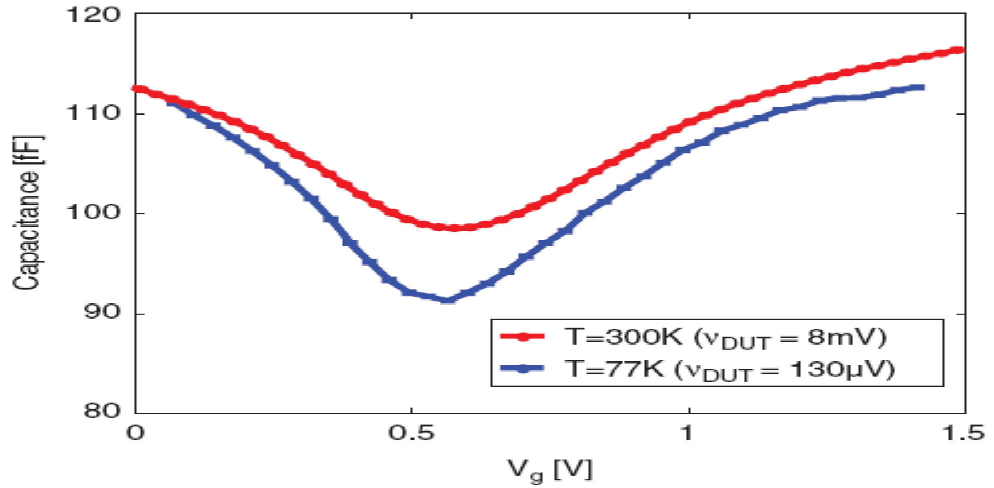
Load Resistor

Amplifier

Thin Film Resistor



Expected Results/More work



Assembling this will create higher resolution measurements

REVIEW OF SCIENTIFIC INSTRUMENTS **82**, 053904 (2011)

An integrated capacitance bridge for high-resolution, wide temperature range quantum capacitance measurements

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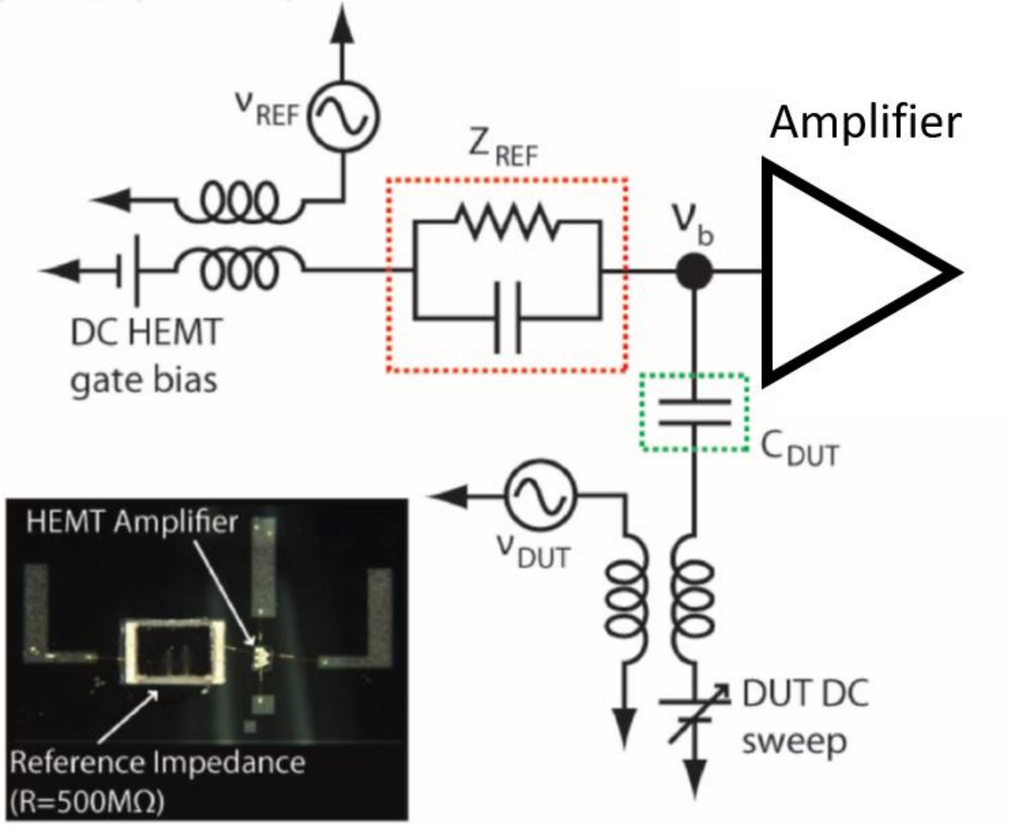

Conclusion

- Project can lead to better characterization of materials in the lab
- Proof of Concept

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