TECHNIQUES FOR THE FABRICATION OF GRAPHENE DEVICES

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Motivation

The goal of this project is to measure a π-junction through an SNS Josephson junction by applying an external magnetic field. In superconductors, electrons couple into Cooper pairs. In a Josephson junction, the Cooper pairs separate as they pass through the normal metal, and reconnect once across so that the junction has zero resistance. The introduction of a magnetic field in the normal metal pushes the electrons out of phase and stops their re-coupling. However, it is predicted that at large enough fields supercurrent can reform, in what is called a π-junction. To see this effect, the normal channel must be very thin, so we have chosen to use graphene as the metal. Graphene is a single atomic layer of carbon, and methods exist that allow us to consistently create and deposit graphene on a silicon substrate. We explored the methods of the creation of graphene devices.

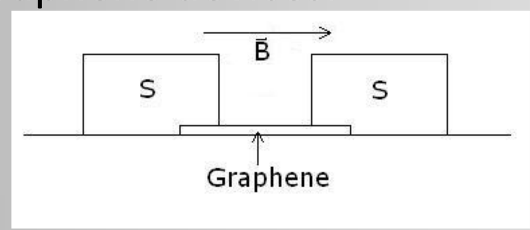

Fig 1: A cross-sectional view of an SNS Josephson junction using graphene, showing the direction of the proposed magnetic field

Graphene Visibility

Due to interference effects, graphene is visible through an optical microscope when on top of Si with 300 nm SiO_2 .

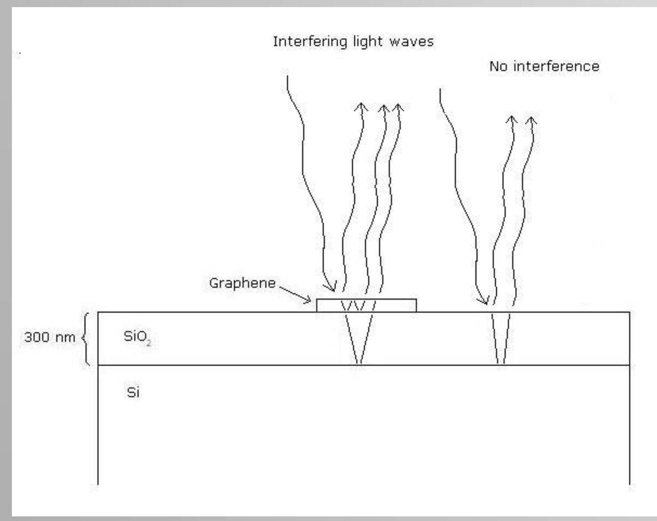

Fig 2: Diagram comparing light shone on graphene and light shone directly on the surface of SiO_2. The interference caused by graphene creates a slight contrast between the graphene sample and the bare substrate.

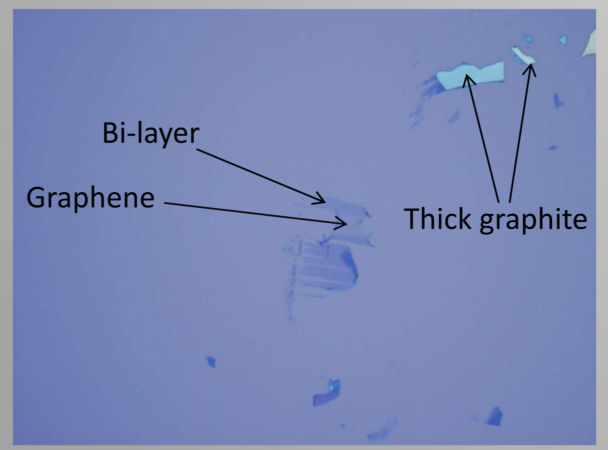

Fig 3: Deposits where layers of varying thicknesses can be seen, with the most transparent area being graphene

Experiment

•The technique of mechanical exfoliation (Scotch tape method) was used to separate layers of graphite and then to transfer them to a silicon chip. The transfer is completed by placing the piece of tape on the silicon chip, lightly rubbing the tape for several minutes with tweezers, and then peeling away the tape very slowly.

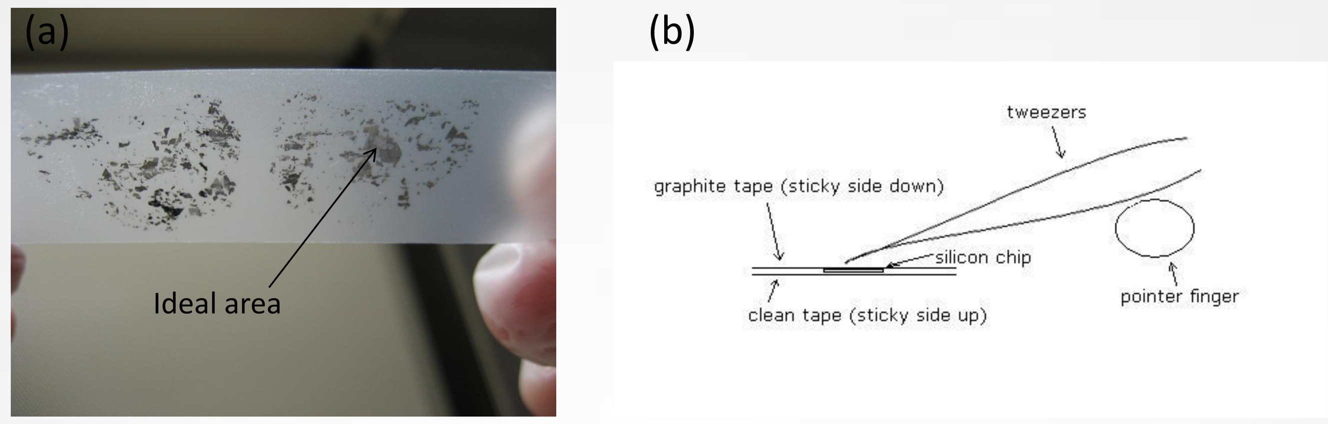

Fig 4: (a) A piece of tape with thin milky-gray graphite deposits, ideal for creating graphene. (b) A schematic for how to transfer graphite and graphene from tape to the silicon chip. The back end of the tweezers is used to lightly rub the tape against the chip.

•The transfer of graphene can leave behind large amounts of tape residue. This residue was removed by soaking the chips in acetone, or baking the chips at 400˚ C in an argon environment

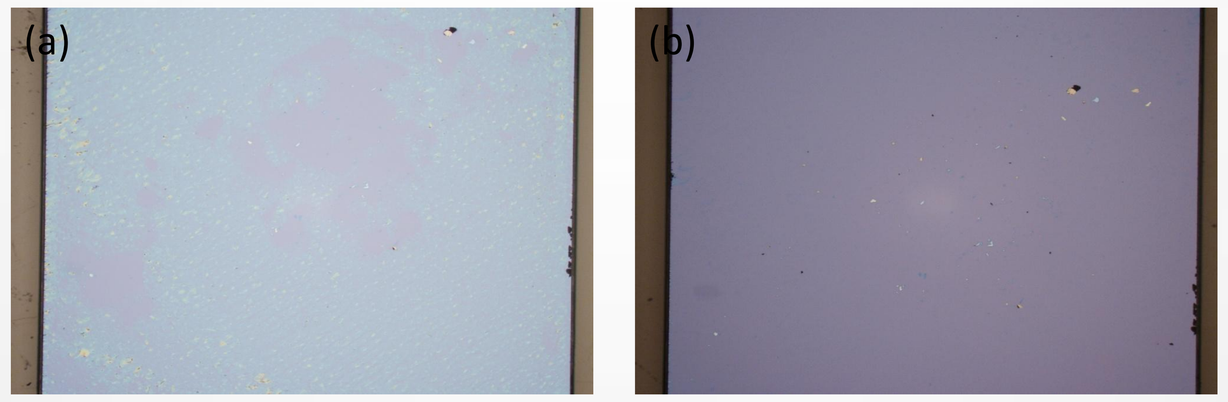

Fig 5: A chip before (a) and after (b) baking. Notice the large amount of tape residue that is cleaned by the baking process.

•The surface of the chips were scanned for graphene deposits using an optical microscope, then coated in e-beam resist.
•e-beam lithography was used to pattern alignment marks and to pattern the final contacts.

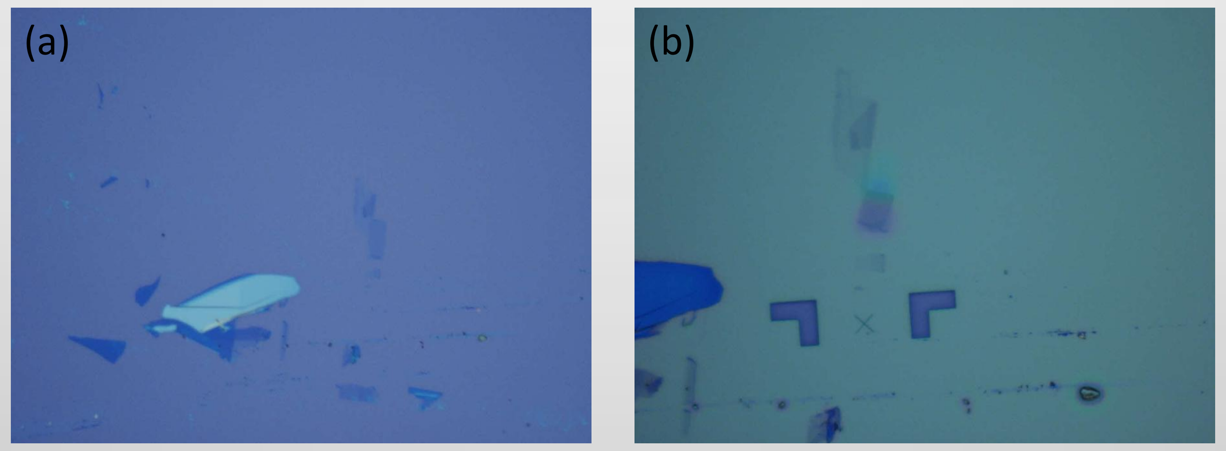

Fig 6: A small piece of graphene, before (a) and after (b) being coated in e-beam resist. The second image also shows the alignment marks used to locate the flakes in an SEM and accurately draw the leads.

•Thermal evaporation and sputtering were both used to deposit electrical leads (5nm Ti / 50 nm Al) for measurements.

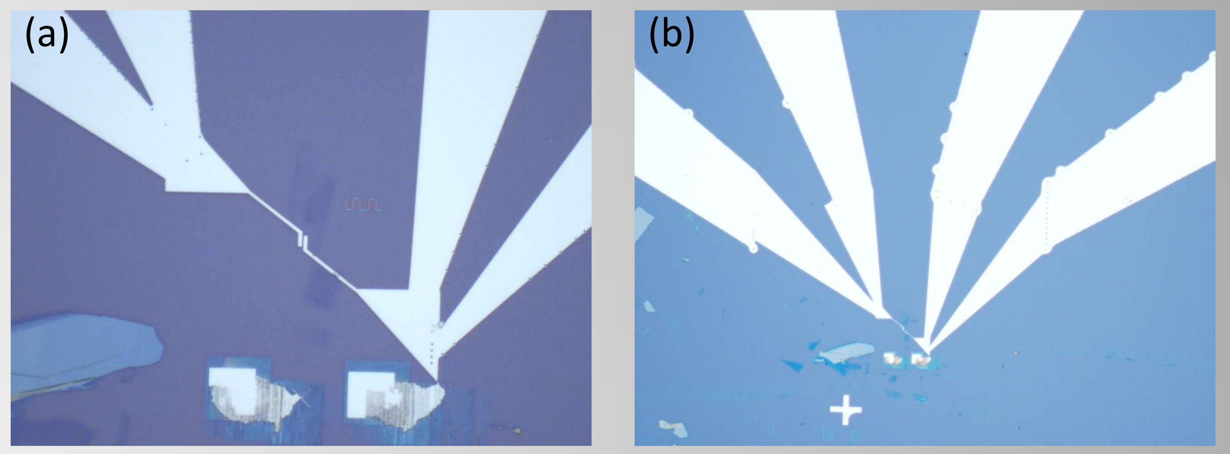

Fig 7: The graphene sample from Figure 6, now with metal contacts on the graphene at (a) 100x zoom and (b) 20x zoom.

Results and Conclusions

•We fabricated devices with graphene, however the contact resistance was too high to measure supercurrent in any device
•Sputtering metal contacts, rather than thermally evaporating, reduced contact resistance; however, even this resistance was too high to have a working device. The high temperatures required to evaporate titanium created impurities in the aluminum.

Future Work

Future work could include the further exploration of these methods, in hopes of creating a working device. To create such a device, the contact resistance must be reduced. Other research groups have used e-beam evaporation to create contacts, which may have contributed to their lower contact resistances. Another proposed change is to bake the device a second time after lithography and before sputtering or evaporation. The exposed edges of graphene may be covered in a residue layer after developing the pattern.

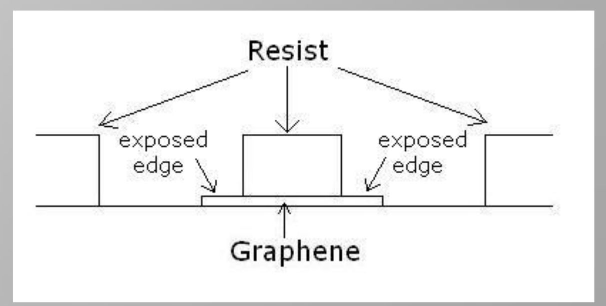

Fig 8: During lithography, the edges of the graphene sample are exposed to chemicals, the residue of which could affect contact resistance