

Electrical Transport in Graphene Heterostructures

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Primary CNF Tools Used: Heidelberg DWL 2000, Photolithography Spinners, GCA AutoStep 200 DSW i-line Wafer Stepper, E-Beam Lithography Spinners, Zeiss Supra SEM, Nabyt Nanometer Pattern Generator System, Oxford 81/82 Etcher, SC4500 Even/Odd, Oxford ALD Flexal

Abstract:

Graphene heterostructures continue to provide myriad opportunities for researching new strongly correlated and topological physics. We fabricate three different types of graphene heterostructure, to facilitate study of this physics. We will examine magic-angle twisted bilayer graphene in close proximity to few-layer graphene, an electronic double-layer of bilayer graphene separated by thin boron nitride, and rhombohedral stacked graphene. Each of these configurations is host to unique phenomena to be surveyed using low temperature electrical transport measurements. Imperative to our ability to process these graphene heterostructures into electronic devices which can be measured in a dilution refrigerator are a variety of tools available to us through the Cornell nano-scale science and technology facility.

Summary of Research:

We are conducting low temperature electrical transport measurements on three different categories of graphene heterostructures, magic-angle twisted bilayer graphene, insulated graphene bilayers, and rhombohedral-stacked graphene.

The pairing mechanism of superconductivity in magic-angle twisted bilayer graphene remains unclear, whether it be a conventional phonon-mediated pairing or a more exotic unconventional pairing. Previous work has used bilayer graphene in close proximity to but insulated from magic angle twisted bilayer graphene to tune the strength of the Coulomb interaction, thereby tuning the superconducting phase[3]. We will use multilayer graphene to further investigate the effect of Coulomb screening on magic angle twisted bilayer graphene. Figure 1 shows a graphene heterostructure device, intended to be used for this purpose.

Using bi-layer graphene separated by a thin piece of boron nitride, an exciton condensate phase has previously been demonstrated[2]. We have fabricated bi-layer graphene heterostructure devices to analyze this. Figure 2 shows a graphene heterostructure device for studying exciton condensation in a graphene bi-layer heterostructure. To prevent the formation of PN junctions between differently doped graphene bi-layers, we used the Oxford ALD Flexal to deposit an Al_2O_3 thin film on top of the graphene heterostructure, and then evaporated additional metal electrodes, to dope the graphene contacts.

Rhombohedral-stacked graphene's unique electronic properties promote the role of electron-electron interactions, giving rise to topological and strongly correlated quantum phases[4, 1]. These phases are not yet fully understood, but could have a variety of applications in future electronics. We have fabricated few-layer Rhombohedral-stacked graphene heterostructures and performed low temperature electronic transport measurements on them. A rhombohedral-stacked graphene heterostructure device is shown in Figure 3.

Crucial to our work studying graphene heterostructures has been the Cornell nano-scale science and technology facility. All of our graphene heterostructure devices use a similar nano fabrication procedure, which is carried out entirely within the Cornell nano-scale science and technology facility's clean room. First, a completed graphene/boron nitride heterostructure is deposited onto a silicon substrate outside the clean room, using transfer techniques standard to van der Waals heterostructure assembly[5]. Alignment markers are evaporated onto this substrate in the clean room before deposition, they are patterned using a quartz photomask prepared with the Heidelberg DWL200, and then exposed using the

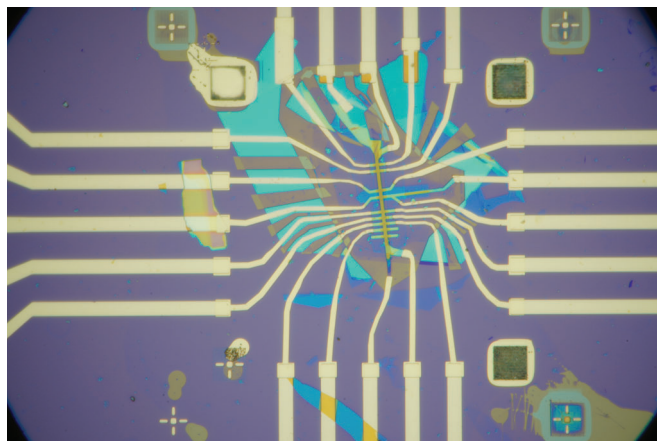


Figure 1: A graphene heterostructure device consisting of magic-angle twisted bilayer graphene in close proximity to few-layer graphene. The heterostructure has been etched into a Hall bar geometry using clean room tools.

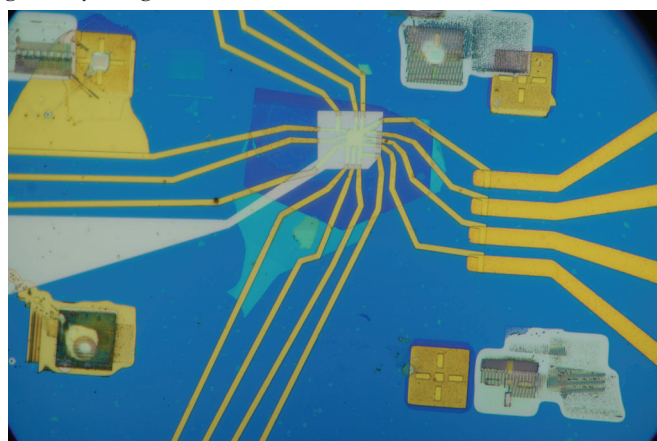


Figure 2: An electronic double layer device made with bilayer graphene separated by thin boron nitride. Al_2O_3 has been deposited on top of it, and gold has been evaporated to dope the graphene contacts.



A rhombohedral-stacked multilayer graphene heterostructure which has been etched into a Hall bar geometry using nanofabrication facilities.

GCA AutoStep 200 DSW i-line wafer stepper. Using the E-Beam lithography spinners, PMMA A4-950 is spun onto the sample, and then the graphene/boron nitride heterostructure is patterned into an appropriate electrical geometry using successive electron beam lithography steps with the Zeiss Supra SEM and Nabity Nanometer Pattern Generator system and etching steps with the Oxford 81/82 Etchers, wherein O_2 and CHF_3 plasmas are used to etch. When the graphene/ BN heterostructure has been patterned appropriately, the SC4500 Even/Odd-Hour evaporators are used to deposit chromium,

palladium, onto the silicon substrate and create metal electrodes. To aid with lift-off after metal evaporation, layers of PMMA A4-495 and A4-950 are used, or M2-950.

Conclusions and Future Steps:

Our work studying magic-angle twisted bilayer graphene in close proximity to few-layer graphene, an electronic double-layer of bilayer graphene separated by thin boron nitride, and rhombohedral stacked graphene probes topological and strongly correlated physics. We have carried out measurements of completed rhombohedral stacked graphene heterostructure devices, but have not yet done so on the other two configurations of graphene device we have fabricated. Future work will include electrical measurements of these configurations, and further assemblage of graphene devices to improve measurement quality and certainty. The Cornell nano-scale science and technology facility provides access to tools essential to our continued research.

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