# Fabrication of 2D Graphene Devices for Low Temperature Transport Measurement


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## Principal Investigator(s): Kenji Yasuda
## User(s): Benjamin Byrd, Lujin Min, Zhen Yang

*Affiliation(s): School of Applied and Engineering Physics, Department of Physics, Cornell University*



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*Contact: kenji.yasuda@cornell.edu, db923@cornell.edu, lm936@cornell.edu, zy467@cornell.edu*

*Website: sites.google.com/view/kenjiyasuda*


*Primary CNF Tools Used: Heidelberg MLA 150, Zeiss Supra SEM, Nabity Nanometer Pattern Generator System (NPGS), SC4500 Odd/Even-Hour Evaporator, Oxford PlasmaLab 80+ RIE System (Oxford 81)Lithography System, Zeiss Ultra SEM, SC4500 Even-hour Evaporator, AJA Sputter 1.*


## Abstract:

It can be said that many of the most exotic correlated many body states can be found in the phase diagram of magic angle twisted bilayer graphene (MATBG), including unconventional superconductivity [1] and the quantum anomalous hall effect (QAHE) [2]. In order to study the now broad range of emerging 2D materials, these devices must undergo a careful sample preparation and fabrication procedure. We report the successful fabrication and measurement of a variety of graphene based devices, including some twisted bilayer graphene (TBG).


## Summary of Research:

By measuring the longitudinal and hall resistance of a material we can probe the most important aspects of its electronic properties. In a dual-gated hall bar device architecture, with the instruments available in our lab, it is possible to measure these two resistances versus a versatile 4D phase space of carrier density, electric displacement field, out of plane magnetic field, and temperature. We can search for and define interesting phenomena within this phase space, as well as characterize their properties. In this report we present data from two different TBG devices.

Before fabrication can be done, our samples must be stacked into the correct device architecture. A schematic of this device structure can be seen in Figure 1a. In short, we have a top and bottom graphite gate along with two pieces of hBN to act as the dielectric, with a middle device layer. An image of a TBG device in the middle of the stacking procedure can be seen in Fig 1b. Additionally, we can characterize the moiré pattern formed by the twisted bilayer graphene using an atomic force microscopy technique (AFM), torsional force microscopy (TFM), during this step as shown in Fig 1c.

Once the stacking procedure is complete we fabricate the resulting device into a hall bar shape and make electrical contacts. Figure 2a shows the device coated in Polymethyl methacrylate (PMMA), patterned into a hall bar shape with electron beam lithography (EBL). Figure 2b shows the final result after etching the device into a hall bar, followed by another round of EBL as well as metal deposition. Finally, the device can be installed onto our sample holder, wirebonded, and installed onto our low temperature probe for transport measurements, as seen in Fig 2c.

Figure 3 shows the longitudinal resistance measurement for two different devices at a temperature of 1.5K. Fig 3a shows the landau fan diagram of the TBG sample which is detailed in Fig 1 and 2.The full filling peak is very well developed and some landau fan features can be observed, including some coming from the full filling. However, the integer peaks are blurred, likely due to being far from the magic angle and the device angle not being homogeneous. Fig 3b shows the landau fan for another TBG device. This one seems to have many different peaks and landau levels. It is not clear whether these peaks correspond to the integer peaks, full filling from twist angle inhomogeneity, or hBN alignment in the device. None-the-less, low noise transport data resolving clearly the features of both devices are able to be taken.

## Conclusions and Future Steps:

We have been able to implement a complete fabrication procedure in order to perform low temperature transport measurements on our devices. With these fabrication and measurement methods well established we are planning to expand our sample fabrication to a variety of materials and device structures in the search for interesting correlated and symmetry breaking phenomena.

## References:


[1] Y. Cao, V. Fatemi, S. Fang, K. Watanabe, T. Taniguchi, E. Kaxiras, and P. Jarillo-Herrero, Unconventional superconductivity in magic-angle graphene superlattices, Nature 556, 43 (2018).

[2] M. Serlin, C. L. Tschirhart, H. Polshyn, Y. Zhang, J. Zhu, K. Watanabe, T. Taniguchi, L. Balents, and A. F. Young, Intrinsic quantized anomalous Hall effect in a moiré heterostructure, Science 367, 900 (2020).


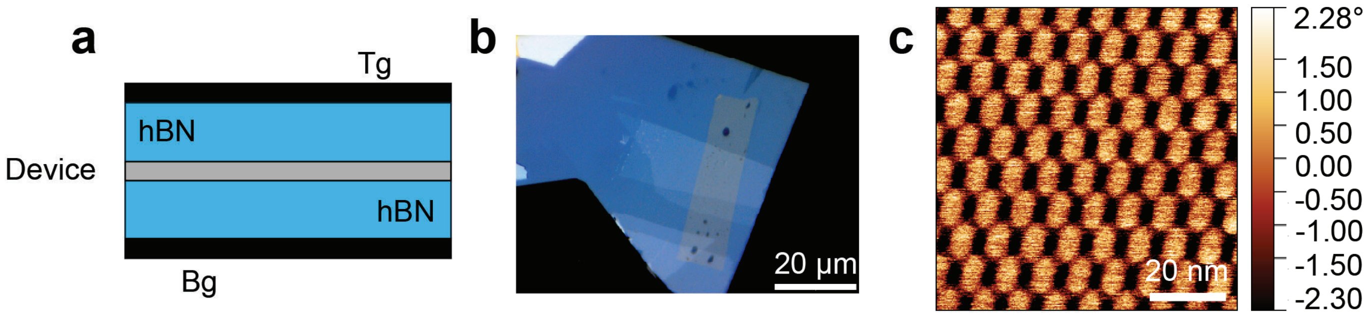


*Figure 1: a. Device structure, including two graphite gates, hBN as the dielectric, and the device layer. b. Optical images of a partially stacked device. Scale bar - 20 μm. c. TFM-phase image of the moiré pattern formed by the twisted graphene layers. Scale bar - 20 nm.*

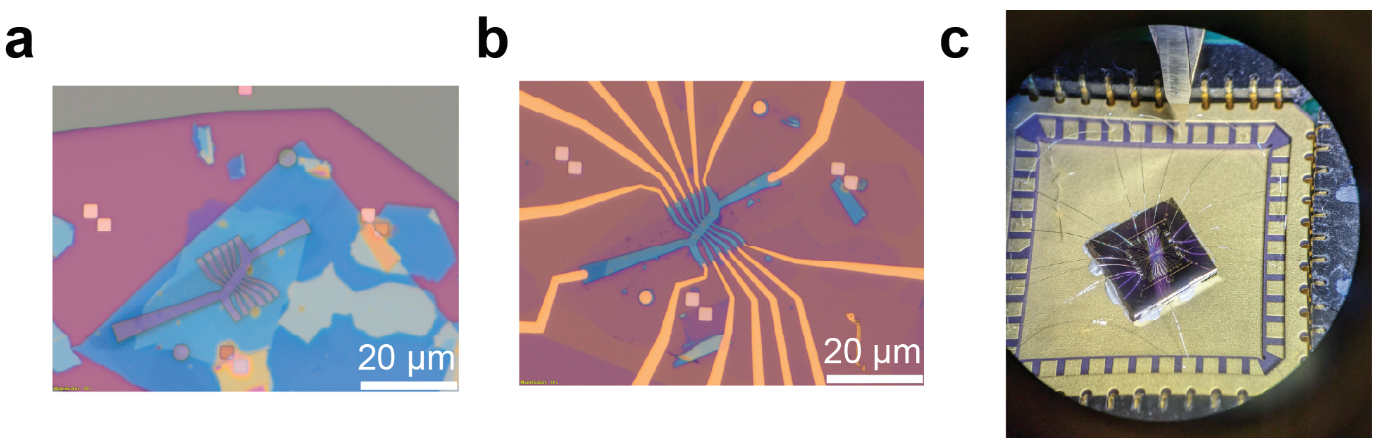


*Figure 2: a. Optical image of the device after the shape defining EBL. b. Optical image of the device showing the electrical contacts defined using EBL. c. Image of the sample installed onto our sample holder with the pads being wirebonded for electrical contact.*

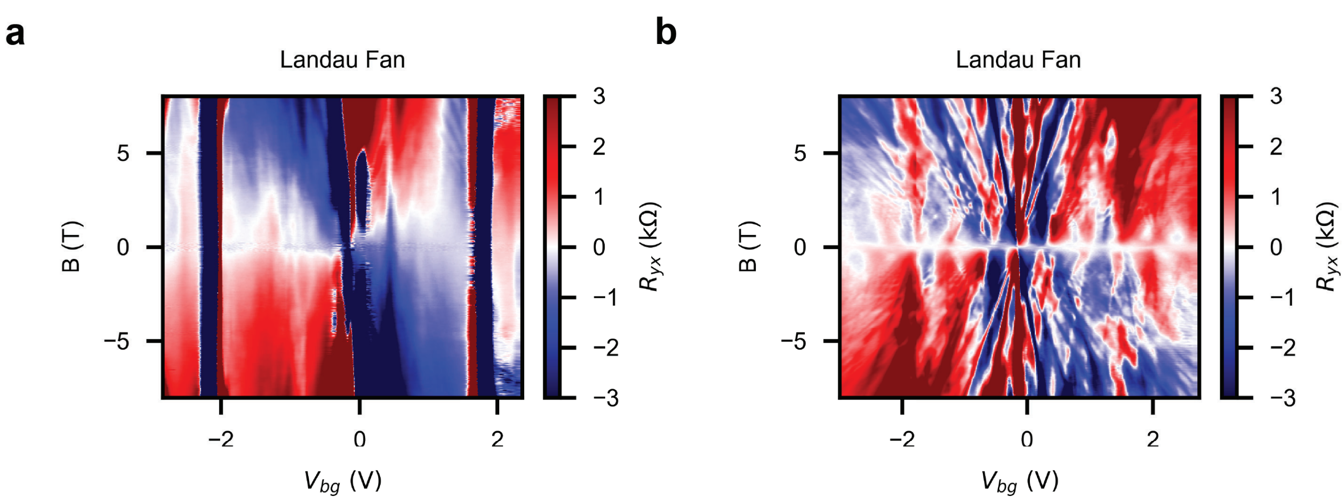


*Figure 3: a. Ryx measured versus Vbg and B of a TBG device. b. Ryx measured versus Vbg and B of a different TBG device. Both are taken at 1.5K.*