

# Nonvolatile Switching of Magnetism via Gate-Induced Sliding in Tetralayer Graphene

**CNF Project Number: 3125-23**

**Principal Investigator(s): Kenji Yasuda**

**User(s): Daniel Brandon, Lujin Min, Yiwen Ai, Kyle Nadel, Peter Golemis, Akshat Gandhi, Zhen Yang**

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

*Primary Source(s) of Research Funding: Lab Start-up Fund, Department of Energy*

*Contact: [kenji.yasuda@cornell.edu](mailto:kenji.yasuda@cornell.edu), [db923@cornell.edu](mailto:db923@cornell.edu)*

*Research Group Website: <https://sites.google.com/view/kenjiyasuda>*

*Primary CNF Tools Used: Heidelberg MLA 150, Zeiss Supra SEM, Nabity Nanometer Pattern*

*Generator System (NPGS), Angstrom Load lock E-beam Evaporator, Oxford PlasmaLab 80+ RIE System (Oxford 81)*

## Abstract:

Within multilayered 2D van der Waals systems the stacking degree of freedom is an important parameter which often directly controls the electronic properties of the material. This is especially relevant in multilayered graphene systems, where the metastable rhombohedral stacking order has been reported to host exotic electronic states which are absent in the more commonly found Bernal stacking arrangement. In this work, we will show the ability to in situ control the stacking order via electrostatic gating and therefore switch the ferromagnetism found uniquely in the rhombohedral stacking order on and off [1].

## Summary of Research:

When multiple layers of graphene are stacked together, the way in which they are stacked controls the electronic structure. The Bernal stacking order (ABAB), is most commonly found and does not host any exotic correlated states. However, the rhombohedral stacking order (ABCA) instead hosts a variety of exotic phases including a correlation driven quarter metal state which hosts an anomalous Hall effect. The favorability of the stacking order can be controlled via doping and displacement field, which can be independently controlled via electrostatic gating in a dual gated architecture.

In nonmagnetic conductive material, the Hall resistance,  $R_{yx}$ , varies linearly with respect to the field, named the ordinary Hall effect (OHE). In ferromagnets, which host finite magnetic moment at zero field, an additional contribution occurs even at zero magnetic field, dubbed the anomalous Hall effect (AHE). In certain graphene systems, like rhombohedral stacked graphene, this

uniquely correlation and valley driven AHE can be observed under certain conditions. We fabricate Hall bar devices of multilayered graphene devices, where we can switch the dominant stacking structure between rhombohedral and Bernal thus switching on and off this AHE.

First, we fabricate multiple Hall bar devices, shown in Figure 1. These devices undergo a stacking procedure which allows us to utilize a dual-gated architecture for control over both doping and displacement field, before fabrication to define the main channel and voltage probes. By flowing current along the main channel and measuring the voltage on either side of the channel, we can accurately measure the Hall resistance.

We first confirm the structural switching of our devices by measuring the longitudinal resistance,  $R_{xx}$ , versus doping as controlled by the top and bottom gates at almost zero displacement field in Figure 2. As the doping is tuned to and from the most negative corner, a clear difference between the forward and backward directions is observed. This hysteretic behavior is a sign of the structural transition between the rhombohedral and Bernal favored states, which are shown in Figure 2.

Now with a clear hysteretic signal between the rhombohedral and Bernal structures, we can measure the Hall resistance on either side of the transition. As can be seen in Figure 3, the rhombohedral side reveals a clear nonzero  $R_{yx}$  contribution even at zero magnetic field which is absent on the Bernal side. This contribution flips sign as the field is applied, revealing magnetic hysteresis, a signature of ferromagnetism

## Conclusions and Future Steps:

In this work we have shown the ability to control the stacking order of few layer graphene via a sliding transition between the rhombohedral and Bernal stacking orders tuned electrostatically. Along with this structural sliding transition, we reveal the ability to turn on and off the magnetic state found only in the rhombohedral structure. In the future we hope to expand this structural

control of correlated phases to the other states reported in this structure, such as chiral superconductivity [2].

## References:

- [1] D. Brandon et al., Nonvolatile Switching of Magnetism via Gate-Induced Sliding in Tetralayer Graphene, arXiv: 2510.00220
- [2] T. Han et al., Signatures of Chiral Superconductivity in Rhombohedral Graphene, Nature 643, 654 (2025).

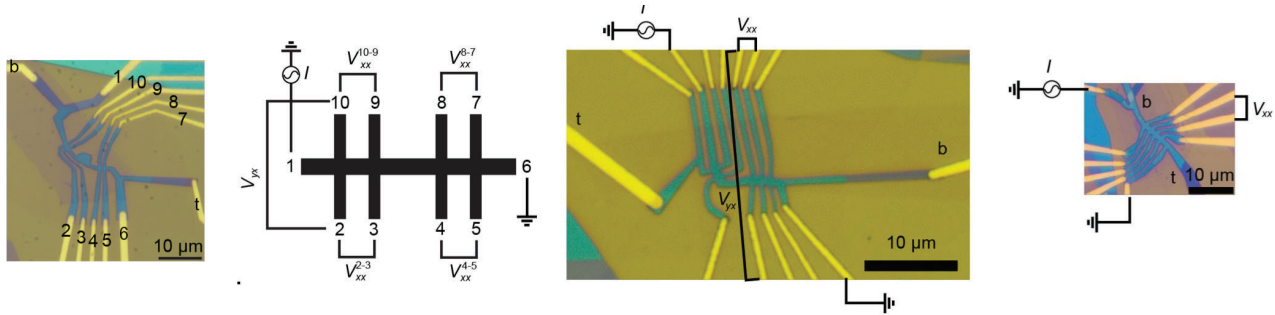


Figure 1: Left - Optical image of device 1, which is measured in Figures 2 and 3. Middle Left - Measurement configuration of device 1. Middle Right - Optical image and configuration of device 2. Right - Optical image and configuration of device 3.

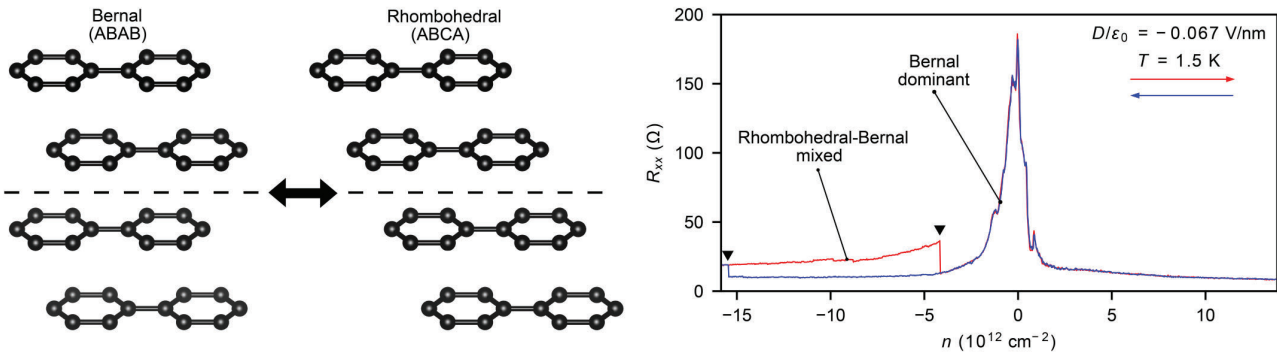


Figure 2: Left - Stacking structure of Bernal and rhombohedral tetralayer graphene respectively. Right - Longitudinal resistance measured versus doping in the forward (red) and backward (blue) directions. A clear difference is observed.

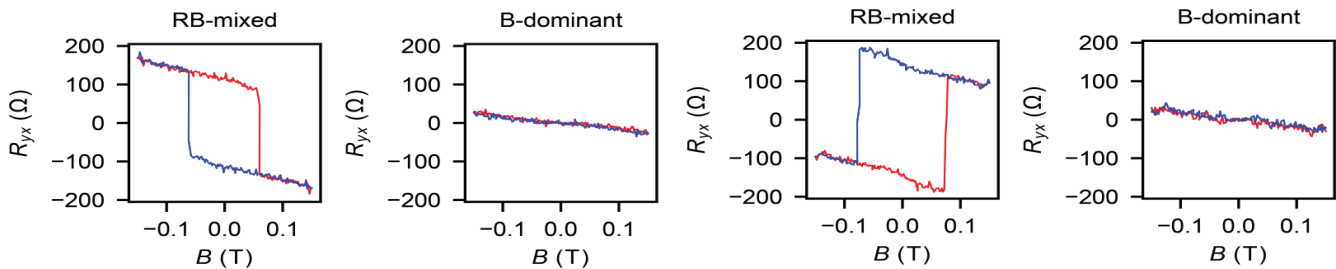


Figure 3: Left and Middle Right - Hall resistance versus magnetic field measured in the rhombohedral-Bernal state.. A clear hysteresis is observed. Middle Left and Right - Hall resistance versus magnetic field measured in the Bernal-dominant state. Only the ordinary Hall effect is seen.