Unconventional Ferroelectricity in Graphene/hBN Moiré: Phenomenology, Mechanism, and Applications

X. Wang[1], Z. Zheng[1], S. H. Aronson[1], X. Yan[2], V. K. Sangwan[2], J.H. Qian[2], S. E. Liu[2], K. Watanabe[3], T. Taniguchi[3], S.Y. Xu[4], Q. Ma[5], M. C. Hersam[2], R. Ashoori[1], and P. Jarillo-Herrero[1]

[1]*Massachusetts Institute of Technology, Cambridge, MA, U.S.A.;* [2]*Northwestern University, Evanston, IL, U.S.A.;*
[3]*National Institute for Materials Science, Tsukuba, Ibaraki, Japan;*
[4]*Harvard University, Cambridge, MA, U.S.A.;* [5]*Boston College, Boston, MA, U.S.A.*

qiong.ma@bc.edu; pjarillo@mit.edu

2D van der waals materials, and in particular, moiré structures formed by 2D materials, offer a unique platform to study and engineer exotic condensed matter states. One example is the ferroelectricity found in Bernal bilayer graphene/ hBN moiré heterostructures, which is beyond the conventional understanding of ferroelectrics resulted from displacement of ions in insulators or semiconductors. Here, a metallic system hosts ferroelectricity, pointing to an unconventional mechanism while also hosting more exotic phenomena with diverse applications.

First, we study the origin of such unconventional ferroelectricity with combined transport and capacitance measurements. By comparing results from the two distinct probes, we reveal a localized and ordered electronic system in addition to the itinerant system corresponding to normal bilayer graphene. A direct correspondence is found between the alternating doping of the two systems and the state of the ferroelectric system. Second, we uncover an "electronic ratchet effect" resulted from the unique doping sequence, and find an infinite number of states that can be stabilized in the ratcheting regime. Third, such exceptional tunability, which is difficult or impossible to achieve in conventional ferroelectrics, can be applied to synaptic devices, enabling new functionality. In particular, we demonstrate tunable long term potentiation and depression curves with multiple switches and input specific adaptation capability.

References

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