2023 Intellectual Merit

DMR-2041972

Mixed-dimensional moiré systems of twisted graphitic thin films

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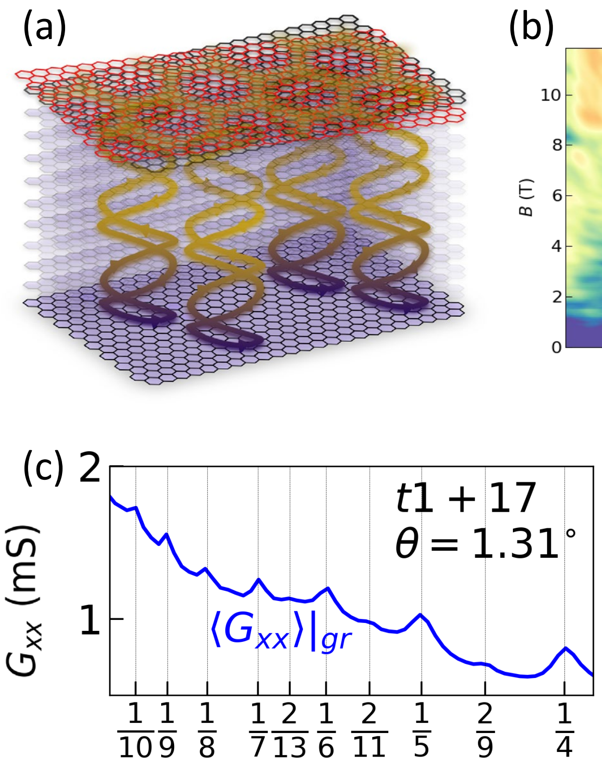
Twisting sheets of graphene atop one another creates a moiré superlattice that can generate a variety of exotic new quantum states. Prominent examples include unconventional superconductivity, ferromagnetism, and topological insulators. So far, work in this field has been limited to structures comprising just a few graphene sheets, as it is generally assumed that the moiré pattern formed at a single rotated interface cannot appreciably modify the properties of a bulk, three-dimensional crystal.

In our work (Nature 2023), we challenge this assumption and demonstrate that it is not always the case. In particular, we study a thin film of graphite with a single rotated sheet of graphene on top. We find that the moiré pattern formed at the surface of the material can hybridize with the entirety of the graphite bulk, creating a mixed-dimensional moiré material with coexisting two- and three-dimensional properties. Our work represents a new paradigm in the study of layered materials.



(a) Schematic of a mixed-dimensional moiré material of twisted graphene on graphite. (b) Landau fan diagram showing moiré surface physics. (c) Conductance oscillations in bulk graphite arising due to the surface moiré.

Adapted from D. Waters *et al.*, Nature **620**, 750-755 (2023)

Imaging graphene multilayers for education and outreach

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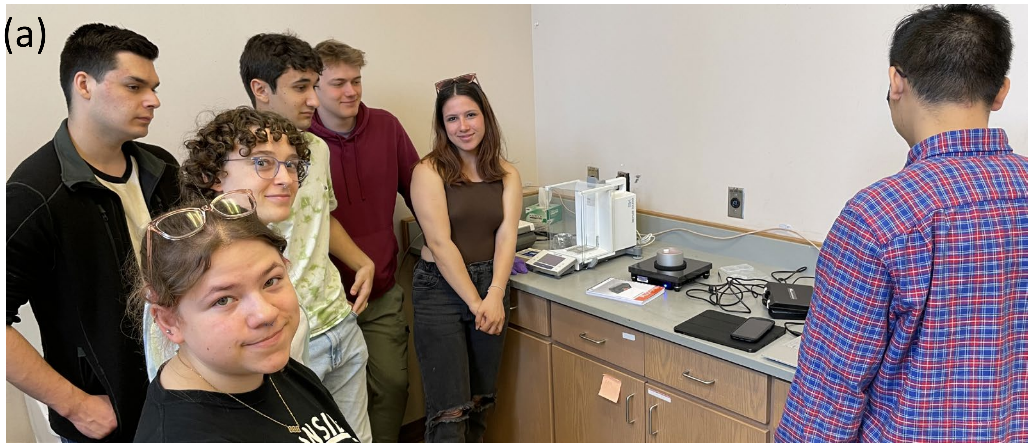
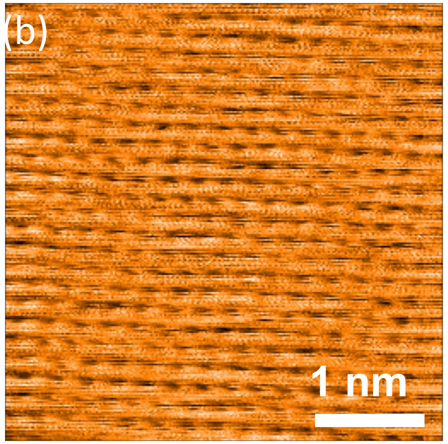
Layered two-dimensional materials offer exciting opportunities to spark the interest of future scientists and engineers. Since they are atomically thin, all of their constituent atoms reside at the surface of the material. Scanning tunneling microscopy (STM) is an ideal tool for visualizing the lattice-scale structure of these materials, as it can achieve atomic resolution of their surfaces.

This year, we developed a new laboratory module open to all freshman engineering students at the University of Washington. Our module is a tabletop STM that students can use to image the atomic structure of the surface of graphite. In doing so, students are introduced to the exciting world of van der Waals quantum materials. Although the module is meant to encourage students to major in Materials Science and Engineering, it has been used by students with interests spanning many disciplines of engineering.





(a) Photograph of undergraduate students performing the scanning tunneling microscopy lab module developed by the PI for the College of Engineering at UW. (b) Image of the atomic structure of the surface of graphite acquired in the STM lab module.