Stacking-Order Switching in Graphitic Polytypes

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Abstract

The distinct stacking arrangements of graphene layers—so-called graphitic polytypes—host a wide range of emergent quantum phenomena driven by interlayer coupling and symmetry breaking, including orbital magnetism, superconductivity, and fractional quantum Hall states. Recent work has revealed spontaneous electric polarization at room temperature in mixed-stacked tetra- and pentalayer graphene. Although tetra- and pentalayer graphene support three and six distinct stacking configurations, respectively, including the energetically most stable Bernal (ABA) and rhombohedral (ABC) polytypes, achieving local, reversible, and energy-efficient switching between these polytypes remains a central challenge. Here, we demonstrate deterministic and reversible switching between Bernal-stacked and rhombohedral tetralayer graphene with spatial resolution down to 30 nm in a Super-Lubricant Array of Polytypes (SLAP) device geometry, using shear forces of only a few nanonewtons and switching energies below 1 fJ. Conducting-probe force microscopy shows that stacking reconfiguration occurs via edge-nucleated solitons that spontaneously propagate across the structure, enabled by ultralow interfacial friction arising from an incommensurate superlubric interface and long-range elastic coupling. By engineering cavity geometries, we further achieve programmable elastic interactions between neighboring stacking domains, allowing control over their switching thresholds and trajectories. This slidetronic control of stacking order offers a route toward reconfigurable multiferroic and neuromorphic van der Waals devices.

References

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