The Kaleidoscope of Graphene Applications: From Bio to Quantum

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Graphene's exceptional properties have opened unprecedented opportunities across diverse fields. This presentation will showcase our recent results in biological sensing, nanomechanics, and quantum device applications.

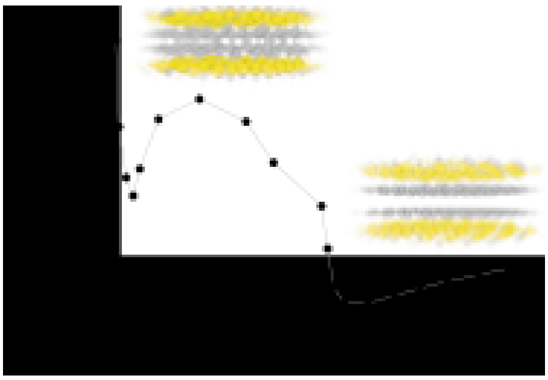
Biosensing Applications [1]: The increasing prevalence of antibiotic-resistant pathogens and infectious diseases demands rapid, sensitive diagnostic platforms. A paradigm-shifting approach is demonstrated using thermal scanning probe lithography (tSPL) for multiplexed biofunctionalization of graphene field-effect transistor (FET) sensors. This scalable method enables spatially selective immobilization of different bioreceptors with sub-20 nm precision, achieving massively parallel pathogen detection on a single chip. These antibody- and aptamer-modified graphene FET sensors demonstrate ultra-sensitive detection of SARS-CoV-2 spike proteins at 3 aM concentrations and identification of just 10 infectious virus particles per milliliter.

Diamene [2]: Using the modulated nanoindentation (MoNI) method, Å-indentation measurements are performed, and they reveal that epitaxial graphene on SiC exhibits transverse stiffness superior to bulk diamond and undergoes reversible sp^2-to-sp^3 phase transitions into diamene under pressure (Fig. 1). The role of nitrogen is also revealed.

New Law of Friction [3]: Understanding interfacial interactions between graphene and its substrate is fundamental to controlling electronic and mechanical properties. A method to measure the usually inaccessible interfacial shear modulus is developed and measurements allow to establish its reciprocal relationship with friction forces, providing predictive control over sliding behaviour in 2D materials.

Spontaneous emergence of straintronics effects and striped stacking domains in untwisted three-layer epitaxial graphene [4]: Self-organized emergence of ABA and ABC stacking domains in three-layer epitaxial graphene is revealed. The domains assemble naturally into controllable nanometer-scale stripes extending for microns, without the need of mechanical twisting and alignment (Fig.1). The size and geometry of the observed stacking domains depend on the interplay between strain and shape of the three-layer regions. These findings indicate the possibility of controlling the desired shape and periodicity of the domains through pre-growth patterning of the SiC substrate. Isolated, stripe-shaped ABA/ABC domains pave the way for new potential applications in quantum electronics.

[1] Wright et al. Nanoscale 16 (42), 19620-19632 (2024)
[2] Gao et al. Nature nanotechnology 13 (2), 133-138 (2018)
[3] Rejhon et al. Nature Nanotechnology 17 (12), 1280-1287 (2022)
[4] Rejhon et al. PNAS 121 (50), (2024) e2408496121



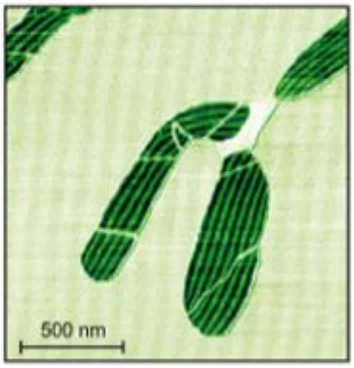


Figure 1: LEFT: Two-layer graphene sandwiched between SiC and undergoing a graphene-diamene phase transition. RIGHT: Self-organized emergence of ABA and ABC striped domains in three-layer epitaxial graphene.