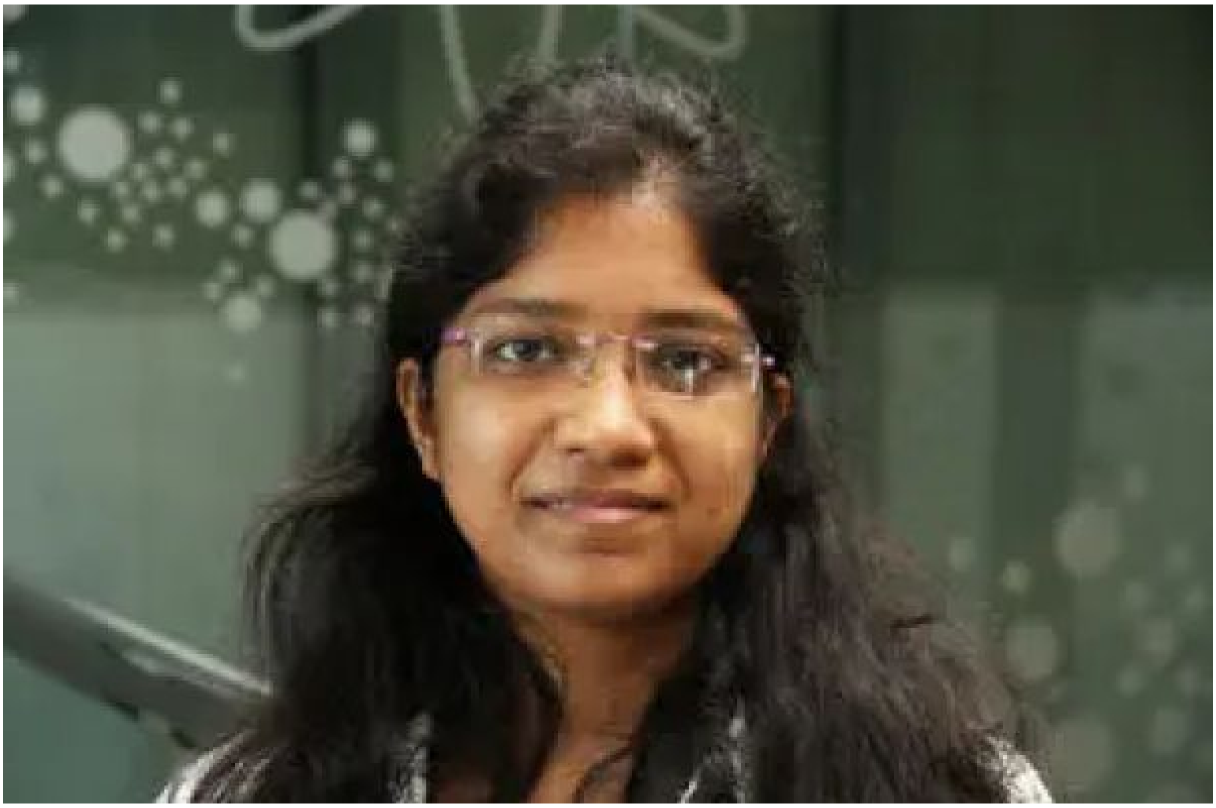

Phd Thesis Defense: Strain-Induced Buckling in Suspended Graphene-hBN and Ferroelectric Moire Domains in Twisted hBN

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10:00
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This thesis investigates the mechanical and electrostatic behaviour of van der Waals heterostructures based on graphene and hexagonal boron nitride (hBN). The work is centred on two related questions: how fabrication-induced strain affects suspended graphene-hBN devices, and how scanning-probe measurements can be used to study moire domains in twisted hBN. The first part of the thesis focuses on suspended graphene-hBN heterostructures. These devices were fabricated by dry transfer onto pre-patterned trenches, followed by suspension release using supercritical CO2 drying. After release, the suspended stacks did not remain flat, but instead developed smooth out of-plane buckled profiles.

Atomic force microscopy measurements show that this buckling is consistent with built-in compressive strain introduced during fabrication. Thermal-expansion mismatch, transfer-induced stress, and clamping at the contacts are all likely to contribute to the final mechanical state. Electrical measurements under gate bias further show that electrostatic loading softens the upward-buckled configuration and can drive a snap-through transition into a downward-buckled state. In the present devices, this transition is observed from the up state to the down state, while controlled switching back to the up state is not demonstrated. The second part of the thesis studies sliding ferroelectricity in marginally twisted hBN. In these devices, the small relative twist between the hBN layers produces a reconstructed moire pattern formed by alternating stacking domains. Kelvin probe force microscopy was used to measure the local electrostatic response of these domains. Bias-dependent measurements show that the two domain types have distinct Kelvin- null positions, with an untwisted hBN reference region lying approximately between them. The comparison between first- and second-harmonic responses supports the interpretation that the observed domain contrast is mainly governed by local contact-potential differences rather than by purely capacitive variations. The KPFM domain image is also analysed as a real-space map of the reconstructed moire network. Representative domain centres are extracted from the image and used to quantify the local moire geometry. This analysis provides a moire-scale description of local wavelength, effective twist variation, and network disorder. These quantities are interpreted as geometrical descriptors of the reconstructed domain pattern, not as direct measurements of atomic-scale strain. Overall, this thesis shows that strain, electrostatics, and interfacial polarisation are central to the behaviour of graphene-hBN and twisted-hBN heterostructures. The suspended graphene-hBN devices demonstrate how residual strain controls mechanical stability and electrostatic actuation, while the twisted-hBN measurements show how KPFM can be used to study moire domains. Together, these results provide a basis for future studies of strain-controlled nanomechanics and electrostatic domain mapping in two-dimensional materials.

Thesis Director: Prof. Dr. Adrian Bachtold

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