Unraveling Strain and Deformation in Two-Dimensional Materials via Multi-dimensional Electron Microscopy

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Two-dimensional (2D) materials and their heterostructures have emerged as key components for innovative applications and exhibit unique properties distinct from bulk materials. Understanding the behavior of strain and deformation in 2D materials is crucial for their potential device applications and offers valuable insights into precisely engineering nano-scale strain in these layered materials. Utilizing nanobeam four-dimensional scanning transmission electron microscopy (4D-STEM), here, we introduce novel approaches to investigate both in-plane and out-of-plane strain and deformation in 2D materials. Our findings reveal a new mechanism of strain relaxation in 2D materials through the formation of out-of-plane ripples. Additionally, we uncover how 2D materials employ long-range lattice rotation and confined nanoscale uniaxial strain to compensate for lattice mismatch, and we elucidate different stacking orders in van der Waals heterostructures mediated by interlayer strain effects.

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