Thin-Suspended 2D Heterostructures: Facile, Versatile and Deterministic Transfer Assembly

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We report a deterministic 2D material (2DM) transfer method to assemble any-stacking-order heterostructures incorporating suspended ultra-thin 2D materials, such as monolayer graphene (MLG) and bilayer graphene (BLG). The transfer procedure uses a nitrocellulose micro-stamp which improves the imaging and alignment of 2DMs during the process, can dry pick-up naked crystals (graphene, MoS_2, and hBN) directly from a SiO_2 substrate, and precisely transfer them on substrates or trenches. Optical and Raman data show that no significant defect is introduced upon transfer, even in suspended MLG and BLG. The areas transferred range up 600 μm^2 on substrate. High-yield transfer of suspended ultra-thin 2DM does not require critical point drying for areas up to 15 μm^2 and suspension heights down to 160 nm. To demonstrate the method's capabilities, we assembled on-substrate and suspended optical cavities tuning BLG's Raman scattering intensity (proportional to light absorption) by factors of 19 and 4, respectively. This versatile and facile fabrication of heterostructures incorporating suspended 2DMs is likely to accelerate research in twistronics, straintronics, and nano-opto-electro-mechanical systems (NOEMS).

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FIGURES

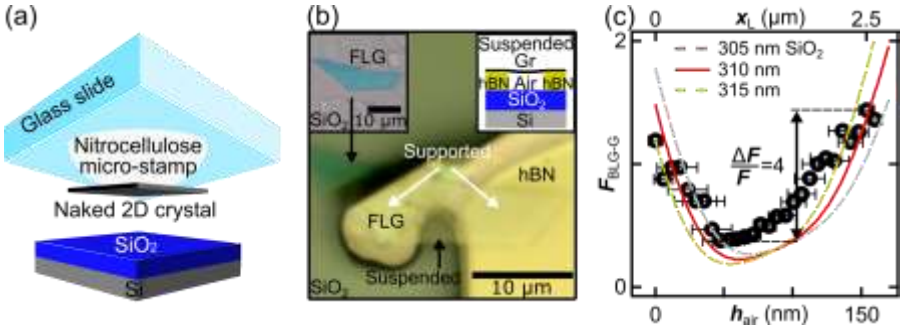

Figure: 2DM Deterministic transfer based on nitrocellulose micro-stamp. (a) Schematics of transfer method. (b) Top-view optical image of a thin-suspended-graphene/Air/SiO2/Si heterostructure. Inset: Left, optical image of graphene crystal before transfer. Right, structure geometry. (c) Tuning Raman scattering intensity (Raman factor, F_{BLG}) as a function of varying air-spacer thickness (h_{air}).