Clean assembly of van der Waals heterostructures using silicon nitride membranes

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Abstract

Heterostructures of van der Waals materials can be used to create a wide range of electronic devices; however, they require extreme cleanliness to achieve high performance[1]. Current fabrication methods are polymer-assisted, and they restrict the fabrication process to low temperatures and ambient pressure or low vacuum which allows for sources of contamination to be present in heterostructures limiting the useful device area[2].This work presents a novel heterostructure fabrication method based on polymer-free silicon nitride membranes. This fabrication method is both quicker than conventional polymer-based methods and straightforward to use. The elimination of polymers from the assembly process produces heterostructures without interlayer contamination. This allows the realization of high-quality interfaces and devices with strong optoelectronic and electronic behaviour due to increased homogeneity across the whole heterostructure area.
This technique also removes the limitations of polymer techniques allowing samples to be fabricated at temperatures of up to 600 °C, in organic solvents and in ultra-high vacuum.

References

[1] Mayorov, A. S. et al. Micrometre-scale ballistic transport in encapsulated graphene at room temperature. Nano Lett. 11, 2396–2399 (2011)
[2] Frisenda, R. et al. Recent progress in the assembly of nanodevices and van der Waals heterostructures by deterministic placement of 2D materials. Chem. Soc. Rev. 47, 53–68 (2018).
[3] Wang, W. et al. Clean assembly of van der Waals heterostructures using silicon nitride membranes. Nat Electron 6, 981–990 (2023).

Figures

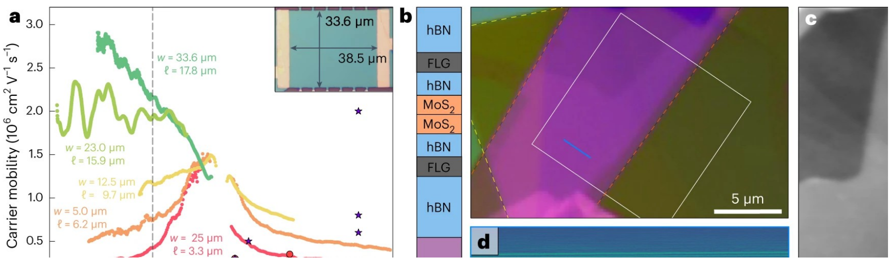

Figure 1: a, Carrier mobility at 4 K for five graphene devices. Purple stars correspond to samples fabricated at Manchester University and red circles by other groups. **b**,**c**, Optical (**b**) and AFM micrographs (**c**) of an eight-layer stack assembled in air with SiNx Membranes. Layer sequence is shown on the left. No bubbles are present **d**, Cross-sectional HAADF-STEM image showing the cross section of the device at the location marked with the blue line in **b**.

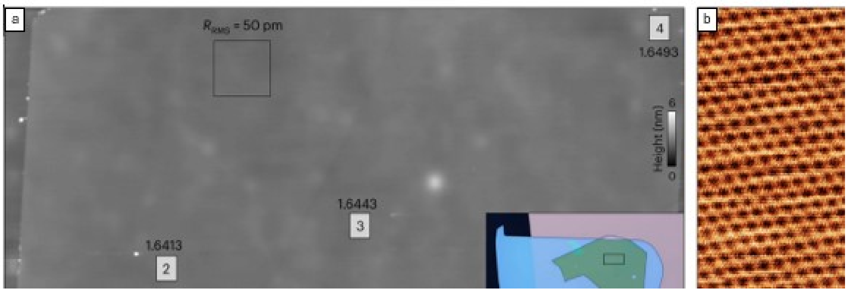

Figure 2: a, AFM topography map of a twisted-graphene monolayer/bilayer heterostructure placed on a bulk hBN crystal fabricated in UHV. Numbers give the x component of the moiré period. **b,** Example of c-AFM micrograph collected from the sample shown in e and used for the moiré period analysis.