Spatially-controlled epitaxy of h-BN/graphene heterostructures via defect-engineering using focused He ion beam

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Van der Waals (vdW) heterostructures combining 2D materials such as graphene and hexagonal boron nitride (h-BN) have a great prospect for the realization of atomically thin devices with tailored properties [1]. To achieve a high density, bottom-up integration, the synthesis of such heterostructures via vdW epitaxy is a promising alternative to mechanical transfer, which is problematic in terms of scaling and reproducibility. Nevertheless, due to the weak bonding between 2D crystals, vdW epitaxy is sensitive to various surface defects, usually leading to uncontrolled nucleation and thus non-uniform growth of polycrystalline material [2]. Hence, the control over nucleation location is one of the key challenges to achieve scalable and high-quality fabrication of 2D heterostructures. In this contribution, we report on the use of focused ion beam (FIB) within a He ion microscope [3] as a novel tool to deliberately create atomic scale defects in graphene on SiC(0001), which act as nucleation sites for h-BN grown via molecular beam epitaxy (see Fig. 1a,b). Thereby, we demonstrate a mask-less, selective-area growth of h-BN/graphene heterostacks (see Fig. 1c), in which nucleation yield and crystal quality of h-BN is controlled by the ion beam parameters used for the defect formation. Importantly, the epitaxially grown h-BN exhibits electron tunneling characteristics comparable to those of h-BN flakes exfoliated from high-quality bulk crystals [4] (see Fig. 1d). Our results open a new pathway for the scalable fabrication of not only h-BN/graphene systems, but also of other vdW heterostructures composed of layered materials such as transition metal dichalcogenides.

References

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Figures

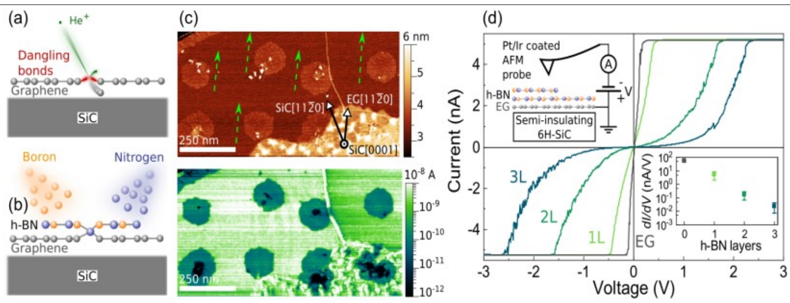

Figure 1: (a,b) Process schematics: (a) Deterministic placement of defects via He FIB in graphene (EG) fabricated on SiC by surface graphitization; (b) h-BN growth with nucleation taking place at FIB-defects. (c) Atomic force microscopy height (top) and conductive (bottom) images of epitaxially aligned h-BN islands on graphene patterned with 10000 He ions per defect; (d) Vertical transport in h-BN tunnel barriers, with I-V curves shown for single (1L), bi- (2L) and tri-layer (3L) thick h-BN. The insets show the measurement configuration (upper left), and the tunnel conductance (lower right).