Controlled Synthesis of Heterostructures of 2D Materials

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Abstract

Two-dimensional (2D) crystals, such as graphene, hexagonal boron nitride, and a family of metal dichalcogenides, represent a new class of functional materials with a wealth of interesting physical and chemical properties. Going beyond homogeneous 2D crystals, heterostructures that combine different 2D materials in layer stacks or as several tightly interfaced components in a single, atomically thin membrane promise tunable properties and greatly extended functionality, and raise fundamental questions on interface formation, intermixing, strain, polarity, etc., in a new context at reduced dimensionality.

While initial studies on these systems rely on monolayer sheets isolated from layered bulk crystals, broader fundamental investigations and potential applications require reliable and scalable methods for fabricating and processing high-quality 2D heterostructures. I will discuss recent advances in understanding the synthesis and processing of heterostructures of 2D materials on metal substrates, derived primarily from real-time observations by surface electron microscopy complemented by high-resolution scanning probe microscopy and in-situ spectroscopy methods. Focusing on the integration of graphene [1] with hexagonal boron nitride [2], I will discuss pathways to the successful realization of key challenges in the controlled formation of heterostructures: atomically precise thickness and stacking control in superlattices [3] and the creation of atomically sharp line interfaces in heterogeneous single layer membranes [4]. Our combined findings establish a powerful toolset for the scalable fabrication of 2D heterostructures for research and applications.

References

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Figures

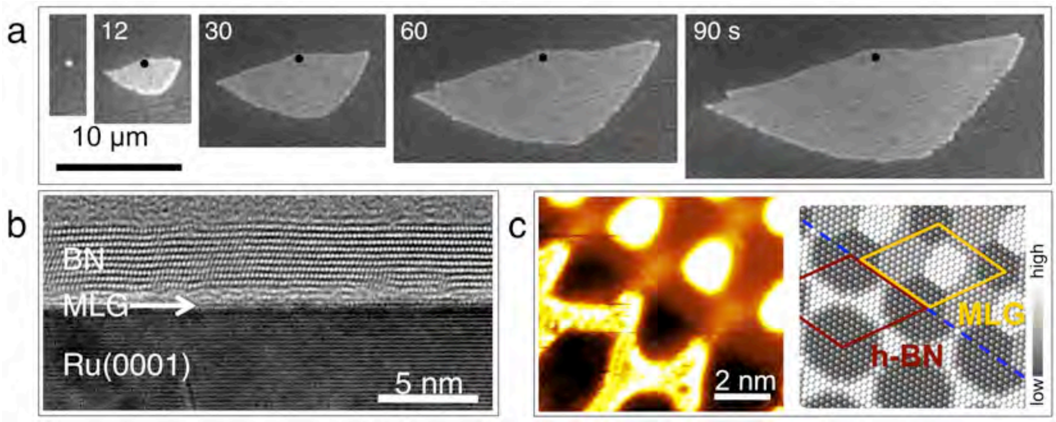

Fig. 1: 2D materials and their heterostructures.

a – Real-time microscopy of large-scale graphene growth on metals (refs. [1,2])

b – Thickness-controlled few-layer h-BN integrated with graphene (ref. [3])

c – Single layer graphene-boron nitride heterostructures with atomically sharp line interfaces (ref. [4]).