Growth of atomically thin hexagonal boron nitride on Ni foils by molecular beam epitaxy

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Hexagonal boron nitride (h-BN) has recently been the subject of an intense, ongoing research effort. This has in large part been driven by the suitability of h-BN for integration into heterostructures with other 2-dimensional materials, such as graphene [1]. We report the synthesis of h-BN on polycrystalline Ni foils by molecular beam epitaxy (MBE) using elemental B and N sources. The precise control over growth conditions, such as substrate temperature, and precursor flux offered by MBE, make it a valuable tool for fundamental studies of h-BN growth. In this study, samples were synthesized at substrate temperatures 730°C and 835°C over 3 to 5 hours. The presence of high quality h-BN film on the Ni foil substrate was first confirmed using Raman spectroscopy, which revealed a sharp, symmetric peak at 1365 cm^{-1} (Figure 1). This peak originates from the E_{2g}-symmetric, doubly degenerate, in-plane optical phonons of h-BN [2]. The surface morphology resulting from this growth procedure was evaluated using atomic force microscopy (AFM), which also allowed the continuity of the atomically thin h-BN films to be confirmed. Figure 2 depicts an AFM height scan of h-BN on top of Ni foil. In addition to the topographic features of the underlying Ni foil (such as terraces and step edges), a cellular array of linear features is easily discernible which we identify as wrinkles in the h-BN film (shown by arrows in Figure 2). The ubiquity of the wrinkle structure in numerous AFM scans, together with the uninterrupted observation of the h-BN Raman signal, offer strong evidence of continuous h-BN film. Synchrotron-based x-ray reflectivity (XRR) was employed to estimate the thickness of the grown films which was revealed to be about 0.9 nm. Using shorter duration growths we were able to gain insight into the nucleation and growth behavior of h-BN. Figure 3 presents an electron micrograph of h-BN prior to the formation of a closed film. Spots with prominent contrast at the approximate geometric centers of the islands are clearly observed, which suggest the h-BN nucleated heterogeneously. We also observed that the morphology of h-BN islands evolved from ramified "star"-shaped to much larger compact triangles with increasing substrate temperature.

References

[1] C.R. Dean et al., Nat. Nanotechnol. 5 (2010) 722.
[2] S. Reich et al., Phys. Rev. B 71 (2005) 205201.

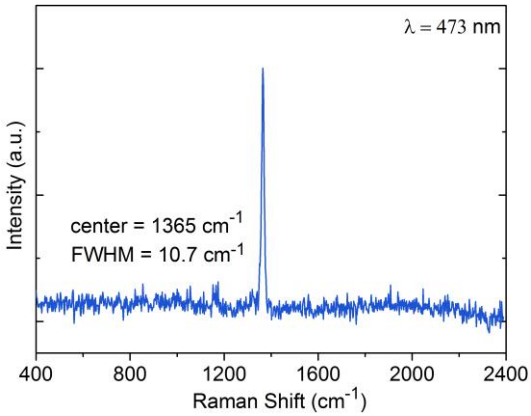

Figure 1: Raman spectrum collected from a continuous h-BN film synthesized at 730°C over 5 hours. The Ni substrate background signal is subtracted.

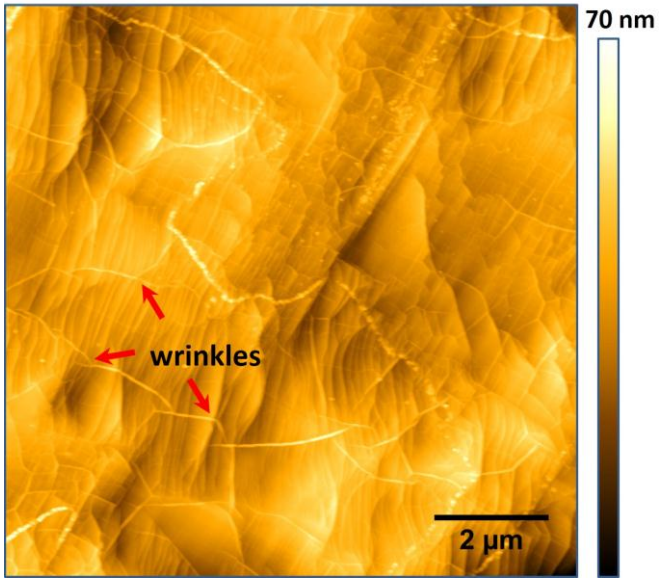

Figure 2: AFM height scan of a continuous h-BN film grown on Ni (730 °C, 5 h). The arrows show wrinkles which typically protrude ~5nm out of the plane of the film.

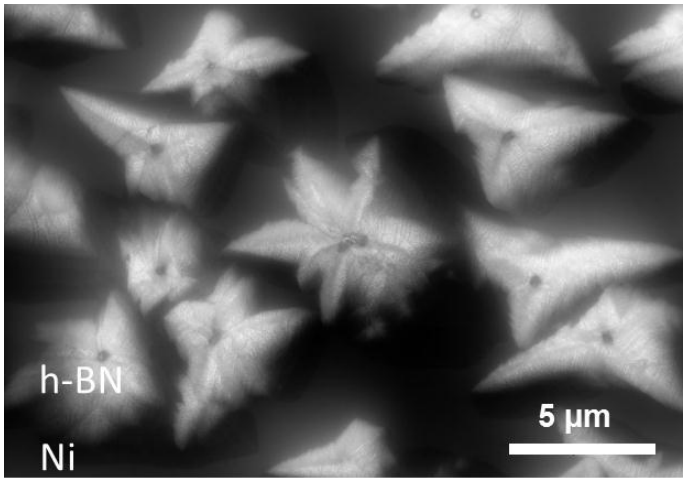

Figure 3: SEM micrograph of h-BN before covering the entire Ni surface (735°C 3 h). Spots with high contrast are typically observed in the center of the h-BN islands.