Molecular Beam Epitaxy of Hexagonal Boron Nitride on HOPG

Ping Wang[1], Eric Reid[1], David Arto Laleyan[1], Jiseok Gim[2], Qiannan Wen[1], Zhe Liu[1], Zhaohui Zhong[1], Mack Kira[1], Robert Hovden[2], and Zetian Mi[1, +]

[1]*Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI 48109, USA*

[2]*College of Engineering, Materials Science and Engineering, University of Michigan, Ann Arbor, MI 48109, USA*

As a member of the III-nitrides as well as the two-dimensional (2D) material families, hexagonal boron nitride (hBN) has received tremendous attention in recent years, and has emerged as a promising candidate for many applications, including deep ultraviolet (UV) and 2D optoelectronics, 2D transistors, and quantum emitters. In the 2D materials group, graphite, graphene, and hBN are lattice-matched to within 2% and exhibit complementary electronic properties, with hBN having a wide bandgap and graphene being a gap-less semimetal [1]. Multilayer hybrid heterostructures based on graphene and hBN have been intensively studied by stacking layers exfoliated from highly-ordered pyrolytic graphite (HOPG) and hBN crystals. To realize well-stacked vertical 2D heterostructures and to achieve scalable devices, epitaxial growth of such configuration would be highly beneficial [2].

In this context, we have investigated the epitaxy of hBN on HOPG utilizing ultra-high temperature molecular beam epitaxy (MBE) equipped with a plasma-assisted nitrogen source. We have demonstrated the formation of hBN quantum dots (QDs) and flakes at different growth conditions. The initial nucleation of hBN takes place primarily at the HOPG atomic steps, where the height fluctuation provides nucleation sites on low surface energy planes, whereas nucleation rarely formed on the bare terraces. Auger electron spectroscopy (AES) confirms the presence of boron and nitrogen elements from the QDs and flakes with a B/N ratio nearly 1, indicating both of the dot- and flake-like nanostructures are BN. Atomic force microscopy (AFM) shows that most of the flakes are 1 ML hBN with a thickness of 3.5 Å, while the QDs have lateral sizes ~5-10 nm and heights ~2-5 nm. Strong excitonic emission at ~215 nm has been observed using a 193 nm excitation laser at room temperature. A detailed study of the structural and optical properties of hBN quantum dots is currently in progress and will be reported.

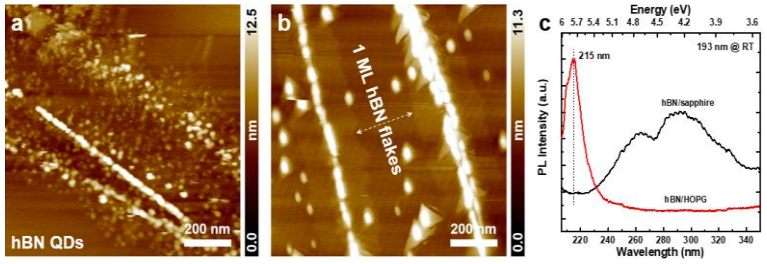

Figure 1. AFM images of hBN (a) QDs and (b) flakes. (c) PL spectrum of hBN grown on HOPG (red) and sapphire (black).

[1] C. R. Woods et al., Nat. Phys. **10**, 1–6 (2014).
[2] Y. J. Cho et al., Sci. Rep. **6**, 34474 (2016)

[+] Author for correspondence: ztmi@umich.edu