Type of presentation: Oral

MS-5-O-2730 Initial Growth Behavior of ZnO Nanomaterials on Various 2-D Layered Materials

Jo J.[2], Oh H.[1], Kim M.[2], Yi G. C.[1]

[1]Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Korea., [2]Department of Materials Science and Engineering, Seoul National University, Seoul 151-744, Korea.

Email of the presenting author: jjhjjh0218@snu.ac.kr

Atomically thin layered crystals isolated by mechanical exfoliation method have exhibited new physical properties and provided novel applications. Moreover, hybrid structures of these 2-dimensional (2-D) layered materials with semiconductor thin films and nanostructures offer additional functionalities, such as flexibility and transferability, thereby greatly extending the applicability to the fabrication of electronic and optoelectronic devices [1,2]. Accordingly, many efforts have focused on nanomaterials growth using 2-D materials as substrates. In order to fabricate such nanomaterials with desired shapes and physical properties, however, the study on the initial growth mechanisms, such as nucleation, nuclei growth, and orientational relationship with substrate, should be accompanied in detail.

Here, we report on the initial growth behavior of nanomaterials on various 2-D layered materials, including graphene, *h*-BN, and MoS_2. “Direct growth and imaging” method was used to image nanomaterials at the early growth stages to avoid unintentional damages arising from conventional transmission electron microscopy (TEM) sample preparation processes, as described in Fig. 1 [3]. In this method, electron-beam transparent 2-D layered materials were exploited as supporting layers for TEM measurements as well as substrates for nanomaterial growth. After 2-D layered materials were transferred onto a TEM grid by mechanical exfoliation, ZnO nanomaterials were grown directly on these 2-D materials by metal-organic chemical vapor deposition and TEM measurements were conducted.

Using this method, we could clearly observe the growth behavior of ZnO nanomaterials on 2-D layered materials. At the initial stage of growth, ZnO clusters, a few tens of nanometer in size, were sparsely observed, and diffraction peaks from ZnO were rarely obtained (Fig. 2). However, they showed different growth behavior as the growth proceeded. Whereas rectangular-shaped and randomly grown nanomaterials were grown on *h*-BN and MoS_2, respectively, only hexagonal-shaped nanomaterials grown along typical [0001] direction were observed on graphene (Fig. 3). Disordered diffraction patterns of ZnO in the insets of Figs. 3a and c suggest that each nanomaterial grew with different growth directions and in-plane orientations on *h*-BN and MoS_2. In addition, dispersive patterns from ZnO in the inset of Fig. 3b indicate no epitaxial relationship with graphene. We believe that this study will lay down the building block for fundamental understanding of the effect of substrates on material growth by bottom-up approach.

[1] K. Chung et al. Science, 330, 655 (2010)
[2] D. I. Son et al. Nat. Nanotechnol. 7, 465 (2012)
[3] J. Jo et al. Advan. Mater. (2014) (online published)

Acknowledgement: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (NRF 2013034238), and the Ministry of Science, ICT & Future Planning (2013K1A3A1A32035597).

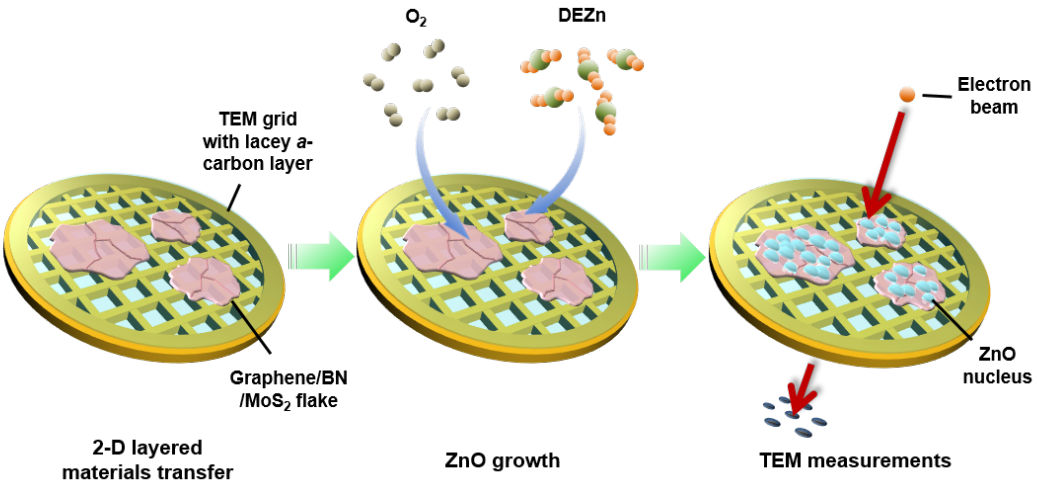

Fig. 1: Schematic diagram of the experimental technique for growing ZnO nanomaterials on 2-D layered materials and performing TEM measurements. 2-D materials were transferred onto a TEM grid by mechanical exfoliation. Afterward, ZnO nanomaterials were grown directly on these 2-D materials by metal-organic chemical vapor deposition and observed by TEM.

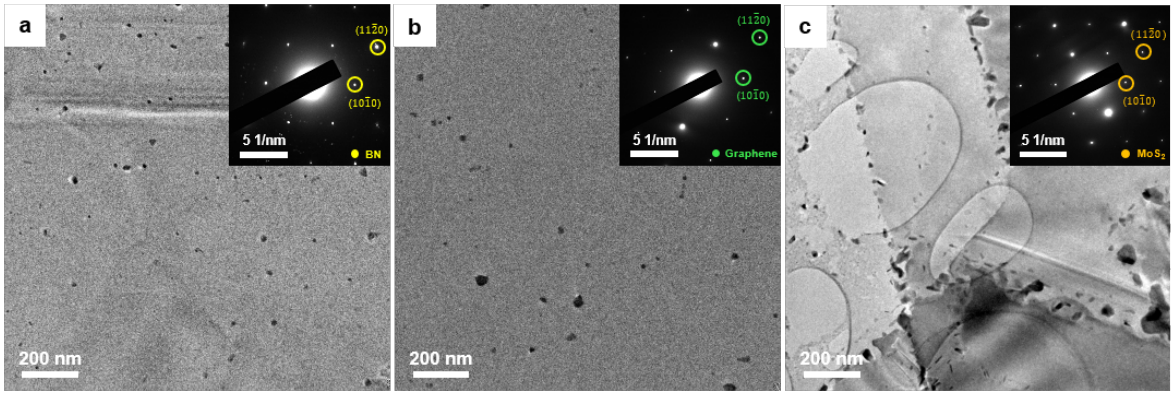

Fig. 2: Initial stage of ZnO nanomaterials growth on various 2-D layered materials. Bright-field images were obtained for ZnO grown on (a) h-BN, (b) graphene, and (c) MoS2 for 2 min, and the insets represent their corresponding SAED patterns. ZnO clusters with a size of a few tens of nanometer were sparsely observed. A 4.15-μm-diameter aperture was used.

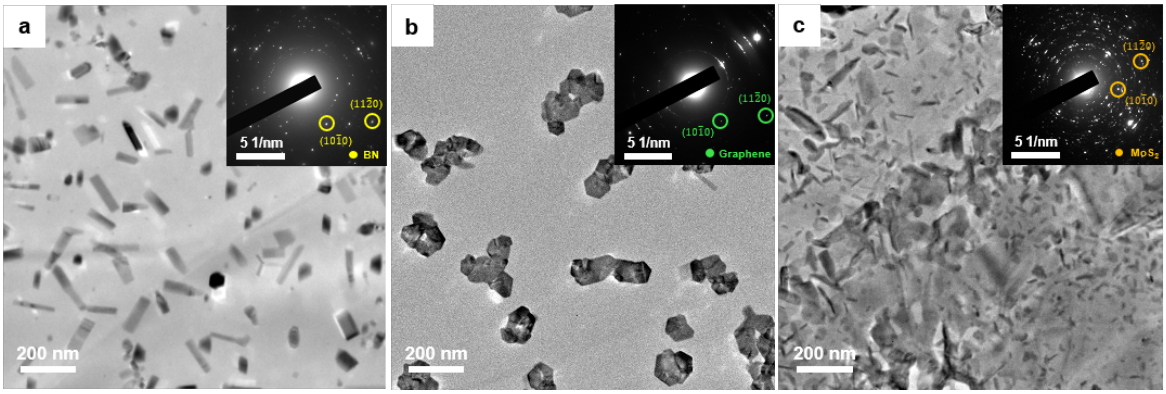

Fig. 3: Morphology of ZnO nanomaterials grown on various 2-D layered materials. Bright-field images were obtained for ZnO grown on (a) h-BN, (b) graphene, and (c) MoS2 for 15 min, and the insets represent their corresponding SAED patterns. These images show different growth behavior of ZnO on different 2-D materials. A 4.15-μm-diameter aperture was used.