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High quality topological insulator Bi_2Se_3 grown on h-BN using molecular beam epitaxy

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Topological insulator (TI) is a bulk-insulating material with topologically protected Dirac surface states in the band gap. In particular, Bi_2Se_3 attracted great attention as a model three-dimensional TI due to its simple electronic structure of the surface states in a relatively large band gap (~0.3 eV). However, experimental efforts using Bi_2Se_3 have been difficult due to the abundance of structural defects, which frequently results in the bulk conduction being dominant over the surface conduction in transport due to the bulk doping effects of the defect sites. One promising approach in avoiding this problem is to reduce the structural defects by heteroepitaxially grow Bi_2Se_3 on a substrate with a compatible lattice structure, while also preventing surface degradation by encapsulating the pristine interface between Bi_2Se_3 and the substrate in a clean growth environment. A particularly promising choice of substrate for the heteroepitaxial growth is hexagonal boron nitride (h-BN), which has the same two-dimensional (2D) van der Waals (vdW) layered structure and hexagonal lattice symmetry as Bi_2Se_3. Moreover, since h-BN is a dielectric insulator with a large bandgap energy of 5.97 eV and chemically inert surfaces, it is well suited as a substrate for high mobility electronic transport studies of vdW material systems. Here we report the heteroepitaxial growth and characterization of high quality topological insulator Bi_2Se_3 thin films prepared on h-BN layers. Especially, we used molecular beam epitaxy to achieve high quality TI thin films with extremely low defect concentrations and an ideal interface between the films and substrates. To optimize the morphology and microstructural quality of the films, a two-step growth was performed on h-BN layers transferred on transmission electron microscopy (TEM) compatible substrates. The resulting Bi_2Se_3 thin films were highly crystalline with atomically smooth terraces over a large area, and the Bi_2Se_3 and h-BN exhibited a clear heteroepitaxial relationship with an atomically abrupt and clean interface, as examined by high-resolution TEM. Magnetotransport characterizations revealed that this interface supports a high quality topological surface state devoid of bulk contribution, as evidenced by Hall, Shubnikov-de Haas, and weak anti-localization measurements. We believe that the experimental scheme demonstrated in this talk can serve as a promising method for the preparation of high quality TI thin films as well as many other heterostructures based on 2D vdW layered materials.

Keywords: Topological insulator, Bismuth selenide, Hexagonal boron nitride, Molecular beam epitaxy