Morphological control over $(Bi_xIn_{1-x})_2Se_3$ grown on GaAs

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Bismuth chalcogenides, such as B_i2Se_3, have become increasingly popular materials to study as prototypical topological insulators (TIs). TI materials have a bulk band gap crossed by linear surface states that form a graphene-like Dirac cone. Plasmons excited in the TI surfaces states have been demonstrated to have exceptionally large mode indices and relatively long plasmon lifetimes[1], making them ideal candidates for sensing and waveguiding applications in the difficult-to-access THz regime. Bi_2Se_3 can be grown by van der Waals (vdW) epitaxy on a variety of substrates, yet previous studies have shown that film quality is limited by a disordered layer between the substrate and the film, leading to large trivial carrier densities and low mobility[2]. $(Bi_{1-x}In_x)_2Se_3$ (BIS) is an ideal material to use as a buffer layer as it shares the crystal structure, lattice constant, and vdW bonding of B_i2Se_3 but is a trivial band insulator for x>0.3. Major improvements in sheet density and mobility have already been reported for films grown using BIS buffer layers as compared to growths directly on sapphire[3], indicating that the Fermi energy is within the bulk band gap.

We are interested in growing Bi2Se3 films with BIS buffers on GaAs substrates to integrate TI materials with semiconductor optoelectronic structures. We find that the morphology for BIS grown on GaAs(001) is strongly dependent on selenium overpressure. At lower selenium fluxes rectangular needles form (Sample A), while at high selenium fluxes terraced hexagonal features are present (Sample C), as shown in the scanning electron microscopy images in Figure 1. All features are aligned along the (011) plane of the GaAs. At intermediate selenium fluxes (Sample B), the film is ultra-smooth. This is significant, because growth of TIs and related materials on sapphire usually exhibit spiral growth with either triangular or hexagonal domains, especially at these relatively large thicknesses (50nm). An ultra-smooth BIS buffer layer improves the quality of overgrown Bi_2Se_3. From x-ray diffraction measurements, we suspect that the hexagonal features seen at high selenium fluxes are self-assembled B_i2Se_3 nanostructures. By tuning the BIS growth conditions, we can exercise substantial control over the film morphology, despite the use of vdW epitaxy. Control over the buffer morphology will ultimately pave the way for unique TI devices.

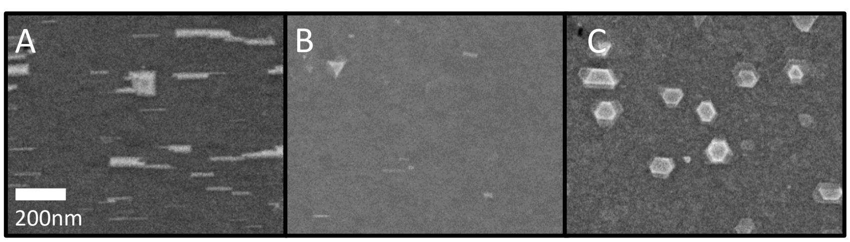

Figure 1: SEM images of 50nm BIS films grown on GaAs substrates. Selenium flux increases from left to right.

[1] T. P. Ginley, S. Law, *Adv. Opt. Mater.* **2018**, 1800113.
[2] Y. Wang, T. P. Ginley, C. Zhang, S. Law, *J. Vac. Sci. Technol. B* **2017**, *35*.
[3] Y. Wang, T. P. Ginley, S. Law, *J. Vac. Sci. Technol. B* **2018**, *36*.

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