MBE Growth and Properties of Bi_2Se_3/Sb_2Te_3 p-n-p-n Short-period Superlattices

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Three dimensional topological insulators (3D TIs) are materials that exhibit topologically protected surface states and an insulating bulk [1]. Of the common 3D TIs Bi_2Se_3 and Sb_2Te_3 and their associated alloys are considered most promising due to their band structure. Additionally, there are several experimental and theoretical properties that emerge when 3D TIs are combined with each other and with other materials in superlattices [2]. Many device applications for heterostructures of 3D TI materials are centered on p-n junctions. For example, p-n-p-n superlattices of TIs are theoretically predicted to exhibit novel phenomena such as spin currents [3]. Due to selenium vacancies Bi_2Se_3 bulk is typically n-type and due to anti-site defects, Sb_2Te_3 bulk is p-type. Thus, p-n-p-n short-period superlattices of these two materials present an excellent opportunity to explore these phenomena.
Here we present the growth and properties of p-n-p-n Bi_2Se_3/Sb_2Te_3 short-period superlattices. A series of superlattice samples, grown by molecular beam epitaxy (MBE) with varying thicknesses of both binary materials were characterized utilizing atomic force microscopy (AFM), high resolution x-ray diffraction (HR-XRD) and transport measurements. Using HR-XRD we observe the change in effective composition for the samples (Fig. 1). The HR-XRD superlattice peaks were used to extract the period of each sample. Field dependent hall resistance shows a change of carrier type from n-type to p-type with the transition taking place at around an effective composition of 42% Bi_2Se_3 (Fig. 2). Magneto-resistance measurements indicate the presence of weak anti-localization (WAL) cusp consistent with the presence of topological surface states.

[1] Y. Xia et al., Nat. Phys. 5, 398 (2009)
[2] Z. Chen et al., Nano letters 15, 6365 (2015)
[3] K.M. Masum-Habib et al., Phys. Rev. Lett. 114 176801 (2015)

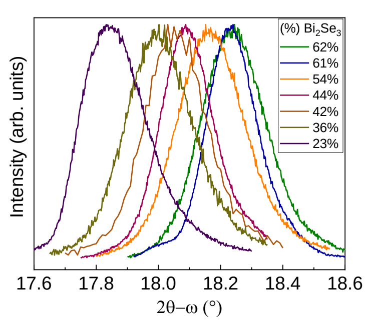

Fig. 1 XRD scans of the (006) zero-order superlattice peak of the samples.

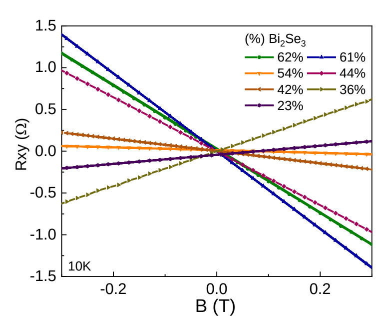

Fig. 2 Field dependent resistance at 10K of the samples with varying composition.

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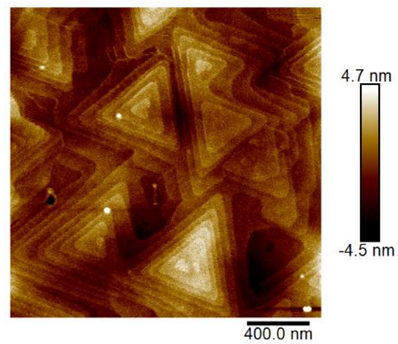

Fig. 3 Atomic Force Microscopy image of 4μm^2 of 44% Bi_2Se_3 superlattice sample.

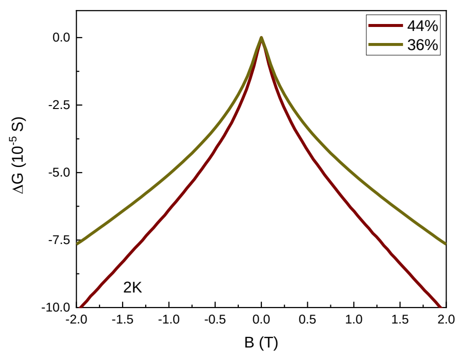

Fig. 4 Magnetoresistance measurements at 2K of p-type and n-type samples near the n- to p-type transition point, both showing weak anti-localization cusps.