Structural properties of ultra-thin Bi_2Te_3 topological insulator on GaAs(100)

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Molecular Beam Epitaxy (MBE) has been successfully used in the production of high structural quality chalcogenide materials in different substrates. However, one of the difficulties of growing bismuth telluride compared to the usual binary compounds is to maintain the correct 2:3 stoichiometry and usually requires the use of independent effusion sources containing pure Bi and Te and additional Te sources.

In this work, we investigate the properties of ultra-thin bismuth telluride layers, with thickness bellow 8 nm, grown by MBE directly on in-situ deoxidized GaAs(001) substrates, from a single Bi_2Te_3 source. Another single Te effusion cell was used to control the stoichiometry and to protect the sample surface after growth with a Te cap layer for ex-situ characterization.

The structural and optical properties of the obtained samples were investigated by high resolution x-ray diffraction (HRXRD), atomic force microscopy (AFM), scanning electron microscopy (SEM) and Raman spectroscopy. Their topological insulator properties were investigated by angle resolved photoelectron spectroscopy (ARPES).

AFM and SEM images of samples without the capping layer show an island like growth mode in the initial growth stages. Samples with nominal thickness bellow1 nm show an incomplete layer with flat, disconnected structures with partly hexagonal shape. On the other hand, 5 nm thick samples display plateaus and terraces with triangular shape and 1.07 nm mean step height difference. HRXRD indicate highly oriented epitaxial growth with the presence of only (0 0 3n) reflections. Raman spectroscopy of the thinner sample (1nm) shows, besides the classical active phonon modes of Bi_2Te_3, a structure near $75cm^{-1}$, which has already been observed for nanoplates.

The ARPES results for the 5 nm thick sample indicate dispersion similar to previous measurements on thick films and bulk single crystals. The linearly-dispersive Dirac-like bands are consistent with topologically protected surface states, with the Dirac point located at approximately 0.480 eV and a velocity of 3.5×10^5 m/s. For the incomplete layer growth sample, there is a shift of the Dirac point to shallower binding energies by approximately 0.150 eV and characteristic surface states although visible, cannot be easily identified due to increased disorder and/or finite thickness.