Surface Structure and Electronic Properties of Epitaxial Topological Crystalline Insulator Films

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Topological crystalline insulators (TCI) feature surface electronic states are protected by crystal symmetry. As a representative TCI, the structural and electronic properties of SnTe films grown on $SrTiO_3$(001) were investigated using scanning tunneling microscopy (STM), noncontact atomic force microscopy (NC-AFM), electron and x-ray diffraction, and density functional theory. Initially, SnTe (111) and (001) surfaces formed; however, the (001) surface dominated with increasing film thickness. The film grows domain-by-domain with the [011] direction of SnTe (001) islands rotated up to 7.5° with respect to $SrTiO_3$ [010]. Analysis of the diffraction data reveals a mosaic distribution of SnTe (001) domains. Complementary STM and NC-AFM experiments address the properties of the thicker films in real space. It is found that the growth mechanism induces a variety of defects on different length scales that affect the electronic properties, including: domain boundaries; dislocations at the domain boundaries that serve as periodic nucleation sites for pit growth; screw dislocations; and point defects. These features give rise to variations in the electronic structure of the surface states as evidenced in STM images by standing wave patterns and a non-uniform nanometer scale background superimposed on atomic scale images. Simultaneous force versus and tunneling current versus distance curves indicate that the tip is unusually close to the surface during STM imaging making the surface susceptible to tip-induced modification. The results indicate that both the growth process and the scanning probe tip are candidates to induce symmetry breaking defects in a controlled way to pattern the topological surface states which then eventually enable fabrication of devices.

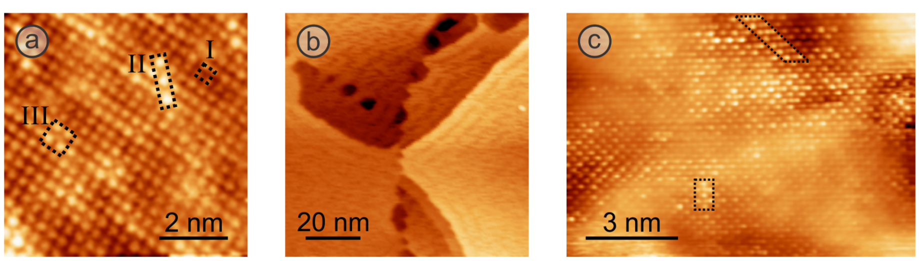

Figure 1: High-resolution STM images the SnTe film. a) Atomic resolution image with the boxes highlighting: I the surface unit cell; II a chain of brighter atoms; III atoms apparently displaced away from their lattice positions. b) A large-scale image showing standing wave patterns emanating from the step edges. c) Atomic resolution image showing a continuous variation in the background along with regions, surrounded by the dashed boxes where additional features within the unit cells become visible.

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