ARPES studies of (111)-oriented (Pb,Sn)Se, a topological crystalline insulator

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A defining property of topological insulators such as Bi_2Se_3 is the presence of gapless surface states, where the absence of a gap is 'topologically protected' by time reversal symmetry. Recently it was realized that this concept can be generalized and extended to other forms of symmetry. For the case of point-group symmetries, this gives rise to the new class of 'topological crystalline insulators' (TCI) [1]. To date mirror-symmetry protected TCI surface states have been experimentally observed on the (100) faces of $Pb_{1-x}Sn_xSe$ [2], $Pb_{1-x}Sn_xTe$ [3], and SnTe [4]. Though not available as natural cleavage planes, the study of different surface orientations is attractive due to the fundamental importance of crystalline symmetry in the TCI phase. We present angle-resolved photoemission spectroscopy (ARPES) measurements of the surface states on in-situ grown (111) oriented films of $Pb_{1-x}Sn_xSe$ [5], a three-dimensional topological crystalline insulator.

The film growth was performed with a hot wall epitaxy method at the I3 and I4 beam lines at the MAX-lab synchrotron facility. This allowed for extensive ARPES characterization of the surface electronic states without ever leaving ultra high vacuum. Extensive *ex-situ* characterization confirmed the success of these sample growths in terms of composition and structural quality. In contrast to the surface states observed on the (100) face, on the (111) face the Dirac-like surface states are well separated and noninteracting, located at the time reversal invariant momenta $\overline{\Gamma}$ and $\overline{M}$ in the surface Brillouin zone. We observe a topological phase transition within the temperature range 100-300K, and with spin resolved ARPES confirm that the topological states possess helical spin texture. Our observations are well captured by a tight binding model, and provide experimental support for the existing body of theoretical work studying the role of surface orientations in TCI materials [6].

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