Topological crystalline insulators

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Topological crystalline insulators (TCIs) exhibit the electronic properties characteristic for solid state systems with topologically protected Dirac-like metallic surface states crossing the bulk semiconductor band gap. In contrast to topological insulators (TIs), in the TCIs the topological protection is warranted not by time-reversal symmetry but by specific crystalline symmetries (e.g. mirror planes). Right after the first theoretical proposals [1,2], the TCI states have been experimentally observed in n-$Pb_{1-x}Sn_xSe$ [3], p-SnTe [4], and p-$Pb_{1-x}Sn_xTe$ [5]. All these materials are IV-VI narrow-gap semiconductors exhibiting the inverted band structure ordering and well known for their thermoelectric and infrared optoelectronic applications. The TCIs constitute a new class of quantum topological materials offering crystal quality superior to the known TIs as well as new ways of controlling topological states by applying perturbations lowering crystalline symmetry.

The experimental investigations of the surface electronic structure by angle- and spin-resolved photoemission spectroscopy methods as well as electrical magneto-conductivity studies will be presented for $Pb_{1-x}Sn_xSe$ ($x \leq 0.3$) bulk monocrystals [3]. $Pb_{1-x}Sn_xSe$ as well as $Pb_{1-x}Sn_xTe$ are IV-VI semiconductor substitutional alloys undergoing a band inversion at a specific tin content, x_c, and temperature, T_C. For $x > x_c$ the topologically trivial band ordering observed in PbSe and PbTe is replaced by the inverted one (SnTe-like). In the inverted band structure regime we found in the photoemission spectra clear signatures of Dirac-like topological in-gap states centered in the vicinity of four X points of the (001) surface Brillouin zone. In the $Pb_{0.77}Sn_{0.23}Se$ monocrystal we observed additionally a temperature-driven topological phase transition from a trivial insulator to a TCI (below the inversion point $T_C \approx 150K$). The spin-resolved ARPES experiments revealed a characteristic double-vortical spin polarization texture around the X point in the TCI phase of PbSnTe [5] and PbSnSe [6]. All the key ARPES experimental observations agree well with model tight-binding band structure calculations taking into account the influence of strong relativistic effects on the band structure of IV-VI semiconductors [3,6].

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