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# Topological crystalline insulator states in $Pb_{1-x}Sn_xSe$

**T. Story**

*Institute of Physics, Polish Academy of Sciences, Warsaw, Poland*

Topological crystalline insulators (TCIs) constitute a new class of quantum materials recently proposed theoretically [1,2]. These materials exhibit the electronic properties characteristic for topological insulators with topologically protected Dirac-like metallic surface states crossing the bulk semiconductor band gap. In contrast to canonical topological insulators in the TCIs the topological protection is warranted not by time-reversal symmetry but by specific crystalline symmetries. The TCIs enrich the spectrum of electronic topological materials and provide new ways of controlling topological states, e.g., by applying perturbations lowering crystalline symmetry. The first material that has been theoretically identified as the TCI is SnTe [2]. Experimentally, the TCI states have been observed so far in n-$Pb_{1-x}Sn_xSe$ [3], p-SnTe [4], and p-$Pb_{1-x}Sn_xTe$ [5]. These are IV-VI narrow-gap semiconductors exhibiting the inverted band structure ordering and well known for their thermoelectric and infrared optoelectronic applications.

Our recent results will be presented on growth of bulk monocrystals by self-selecting vapor growth method, surface electronic structure investigations by angle-resolved photoemission spectroscopy (ARPES), and magneto-transport studies of $Pb_{1-x}Sn_xSe$ ($x \leq 0.3$) [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 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 ARPES spectra clear signatures of Dirac-like topological in-gap states centered in the vicinity of the X point 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 (for temperatures below the inversion point $T_C \approx 150$ K). Our spin-resolved ARPES experiments enabled us to reveal a characteristic double-vortical spin polarization texture around the X point in the TCI phase of $Pb_{0.73}Sn_{0.27}Se$. All the key ARPES experimental observations agree well with model tight-binding band structure calculations taking into account strong relativistic effects [6].

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[1] L. Fu, Phys. Rev. Lett. **106**, 106802 (2011).
[2] T.H. Hsieh, H. Lin, J. Liu, W. Duan, A. Bansil, L. Fu, Nature Commun. **3**, 982 (2012).
[3] P. Dziawa, B.J. Kowalski, K. Dybko et al., Nature Materials **11**, 1023 (2012).
[4] Y. Tanaka, Z. Ren, T. Sato et al., Nature Physics **8**, 800 (2012).
[5] S.-Y. Xu, C. Liu, N. Alidoust et al., Nature Commun. **3**, 1192 (2012).
[6] B.M. Wojek, R. Buczko, S. Safaei et al, Phys. Rev. **B 87**, 115106 (2013).