Electron Irradiation Controlled Bulk Conductivity of $Pb_{1-x}Sn_xSe$ Topological Crystalline Insulators

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The surface states of topological crystalline insulators [1-5] are topologically protected against disorder backscattering by specific crystalline symmetry as opposed to time-reversal symmetry protection in prototypical bismuth-based topological insulators. Both kinds of topological materials are characterized by helical Dirac-like linear energy dispersion superimposed onto band-gap of parent compound. It is extremely difficult to reveal the properties of these states in electrical transport, because they are obscured by highly conductive bulk states.

Here we report on high energy (2.5 MeV) electron irradiation study on the conductivity of bulk $Pb_{1-x}Sn_xSe$ (x=0.19 – 0.30) monocrystals. The electron irradiation induces Frenkel-type point defects in our crystals (interstitials and vacancies, presumably in both cation and anion sublattice). In effect, the samples being initially strongly n-type ($n \approx 2\text{-}4 * 10^{18}$ cm^{-3}) diminish their bulk carrier concentration during subsequent exposure to electron irradiation. It is even possible to fully convert the conductivity to p-type. During sequential irradiation process the resistivity increases by several orders of magnitude in consequence making topological surface states more favorable in electrical conduction. Indeed, when the concentration of bulk electrons or holes reaches the order of 10^{17} cm^{-3}, the clear cusp appears in low field magnetoconductance at helium temperatures. We have identified it with weak antilocalization effect of topological surface states. The proper analysis within Hikami-Larkin-Nagaoka model of quantum corrections to magnetoconductance revealed up to 8 coherent conducting channels. It is in accord with four equivalent Dirac cones on top surface and four on bottom surface. Both surfaces equally take part in electronic conduction because only these surfaces are perpendicular to magnetic field applied.

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