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Low-Temperature Transport and Magnetoresistance in Bismuth Chalcogenide Topological Insulators

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Bismuth/antimony-based chalcogenides such as $\mathrm{Bi_2Te_3}$, $\mathrm{BiSbTe_3}$, and $\mathrm{Sb_2Te_3}$ serve as prototypical compounds where the interplay of strong spin-orbit coupling[1] and crystal symmetry gives rise to both thermoelectric efficiency and topologically non-trivial surface states.[2][3] In this study, high-quality single crystals of these materials were synthesized via a modified Bridgman technique and comprehensively characterized using X-ray diffraction (XRD), SEM, TEM, and EDS.[4] Rietveld refinement of XRD data reveals a systematic variation in lattice parameters, with $a = b$ ranging from 4.27 A^o in $\mathrm{Sb_2Te_3}$ to 4.38 A^o in $\mathrm{Bi_2Te_3}$, and a corresponding unit cell volume expansion from 482.05 A^{o3} to 508.5 A^{o3}, confirming successful isovalent doping and phase purity.

Temperature-dependent resistivity measurements (4K–300K) show metallic conduction in all samples, with clear Fermi liquid behavior below 50K. Fitting the low-temperature region to the expression $\rho = \rho_0 + AT^2$ yields coefficients a ranging from 9.0 * 10^{-5} to 20.5 * 10^{-5} $\mu\Omega$·cm/K^2, indicating enhanced electron-electron scattering in $\mathrm{Bi_2Te_3}$. Magnetoresistance (MR) measurements exhibit a prominent weak antilocalization (WAL) effect at low fields[5], which was quantitatively modeled using the Hikami–Larkin–Nagaoka (HLN) formalism. The α values, if around -0.5 to -1, confirm strong spin-orbit interaction with minimal magnetic scattering. Notably, $\mathrm{BiSbTe_3}$ displayed clear quantum oscillations resembling Shubnikov-de Haas behavior above 5T and a remarkably high MR of 140% at 2K and 9T, pointing to well-defined Fermi surfaces and high carrier mobility.

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