Electronic Supplementary Material (ESI) for Nanoscale

Supplementary Information

Metal-Insulator Transition in Variably Doped $(Bi_{1-x}Sb_x)_2Se_3$ Nanosheets

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Evidence of multi-band transport in doped $(Bi_{1-x}Sb_x)_2Se_3$ nanosheets in Hall effect data

In un-doped Bi_2Se_3 nanosheet, due the high bulk carrier density ($>10^{19}/cm^3$) from Se vacancies, the transport is dominated by the bulk carriers and Hall resistance shows a nearly perfect linear relationship with perpendicular magnetic field, B (solid black line, Figure S1). The extracted Hall slope, $R_H=R_{xy}/B$, from linear fitting of $R_{xy}(B)$ is expected to relate to the bulk carrier density $n_b = -1/(eR_H)$. However, as Sb doping reduces the bulk carrier density and conductivity contribution, the effect of surface states conduction in topological insulators is expected to be readily observable through non-linear Hall slope data. [1, 2] In a two band transport system, the R_{xy} is given by [2]

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$$R_{xy}(B)=-(B/e)[(n_s\mu_s^2+n_b\mu_b^2)+B^2\mu_s^2\mu_b^2(n_s+n_b)]/[(n_s\mu_s+n_b\mu_b)^2+B^2\mu_s^2\mu_b^2(n_s+n_b)^2] \quad (1)$$

where n_s, μ_s and n_b, μ_b represent the carrier density and mobility for the surface and bulk channel. Eq. 1 approaches the asymptotic behavior $R_{xy}/B(\infty)= -(1/e)(n_s+n_b)^{-1}$ in the strong field limit, and approaches $R_{xy}/B(0)= -(1/e)(n_s\mu_s^2+n_b\mu_b^2)/(n_s\mu_s+n_b\mu_b)^2$ in the small field limit. If $\mu_b \neq \mu_s$, then one has a field dependent R_{xy}/B and the field Hall slope is larger than the high field slope: $|R_{xy}/B(0)| > R_{xy}/B(\infty)$. This effect was indeed observed in our doped $(Bi_{1-x}Sb_x)_2Se_3$ nanosheet samples. Figure S1 A compares the R_{xy} data for a pure sample and a $(Bi_{1-x}Sb_x)_2Se_3$ nanosheet sample with x~0.17. The non-linear R_{xy}(B) data in doped sample is illustrated by the linear extrapolations of high field data not passing origin (dashed lines). The difference in Hall effect between un-doped and doped samples is further highlighted in plotting R_{xy}/B vs. in Figure S1B. In contrast to the constant Hall slope for un-doped sample, the magnitude of R_{xy}/B gradually decreases and approaches a constant value at high B, as Eq.1 predicts.

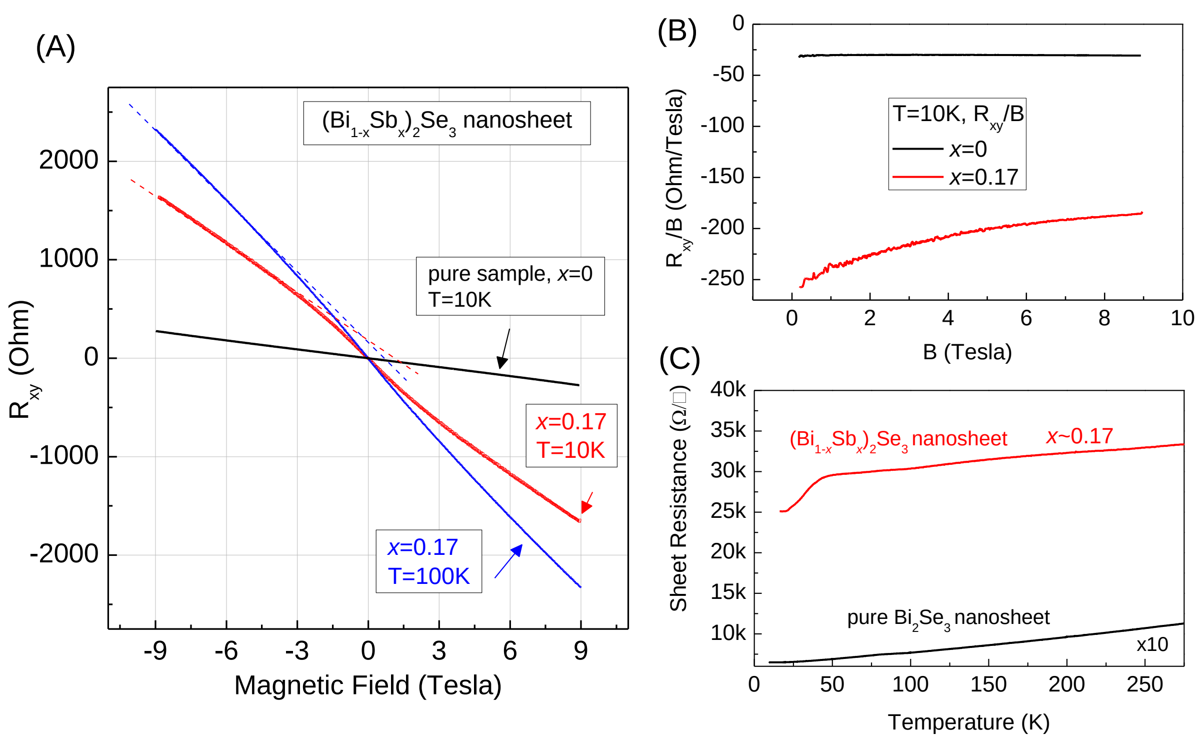

Fig. S1. (A) Field dependent Hall resistance for pure Bi_2Se_3 nanosheet and $(Bi_{1-x}Sb_x)_2Se_3$ nanosheet with x=0.17 at various temperatures, to show the nonlinear R_{xy} vs B in doped sample. (B) The Hall slope R_{xy}/B plotted as a function of B for pure and doped samples, highlighting the constant slope in pure sample vs. a B-dependent slope in doped sample. The non-linear R_{xy} vs B in doped sample is attributed to the increased contribution from the surface states channel in a two band (bulk plus surface) transport system. (C) Sheet resistance vs. temperature for the two $(Bi_{1-x}Sb_x)_2Se_3$ nanosheet samples in (A) and (B).

REFERENCES

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