Magneto-resistance Up to 60 Tesla in Topological Insulator Bi_2Te_3 Thin Films

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Introduction

The magneto-resistance (MR) of metals can be strongly affected by the details of the Fermi surface geometry and character of electron-electron (e-e) interactions and therefore gives valuable insight into the physics dominating the conductivity. Linear MR happens in only special systems, such as polycrystalline materials with open Fermi surfaces, Dirac materials where all the Fermions can be collapsed into the lowest Landau level, and in inhomogeneous materials where the mobility fluctuations play an important role. Linear MR up to 15 T have also been observed in topological insulators (TI) recently, and suggested to be associated with the Landau level splitting of the Dirac cone. On the other hand, gate dependence studies indicated that the linear MR might be due to bulk channel rather than surface states. Here, we study MR of Bi_2Te_3 thin films in high magnetic fields up to 60 T and explain the result by weak anti-localization (WAL) effect and Hikami-Larkin-Nagaoka theory.

Experimental

The Bi_2Te_3 films were grown by pulsed laser deposition at CINT. X-ray diffraction and energy dispersive x-ray spectroscopy showed uniform film of high crystal quality without impurity phase. The high field Hall effect and MR measurements were carried out at low temperatures using the short pulse field facility at NHMFL at LANL. The MR and Hall data were measured by applying low DC current in Hall bar geometry. Both magnetic field and current were reversed to symmetrize the data and eliminate parasitic voltages induced by fast changing magnetic field.

Results and Discussion

The Hall resistance shows a linear dependence on the magnetic field (**Figure a**). The slope implies that the majority charge carriers are electrons with a concentration ~ 2×10^{19} cm^{-3}. The MR as a function of magnetic field is shown in **Figure (b)**, and show sharp dips at low fields, suggesting the WAL effect. The linear MR does not saturate in high magnetic fields up to 60 T.

Previous works in TI systems attributed the linear MR to Abrikosov's "quantum linear MR" mechanism. We estimate in our system, the magnetic field has to be more than ~ 500 T to reach the quantum limit region, so this mechanism does not apply in our case. Another quantum model based on assumption of material inhomogeneity can also be ruled out, because our film samples show very uniform structure and only n-type behavior.

The coexistence of a sharp dip at low fields and linear-like MR at high fields suggests the possibility that both are associated with the WAL effect. Our data can be well described by a quasi-particle model, the Hikami-Larkin-Nagaoka equation, without considering strong/non-trivial electron-electron interaction. To obtain a good fit to the experimental data, the elastic scattering time should be longer than the spin-orbit scattering time, and this is possible in topological insulators where spin-orbit interaction is very strong.

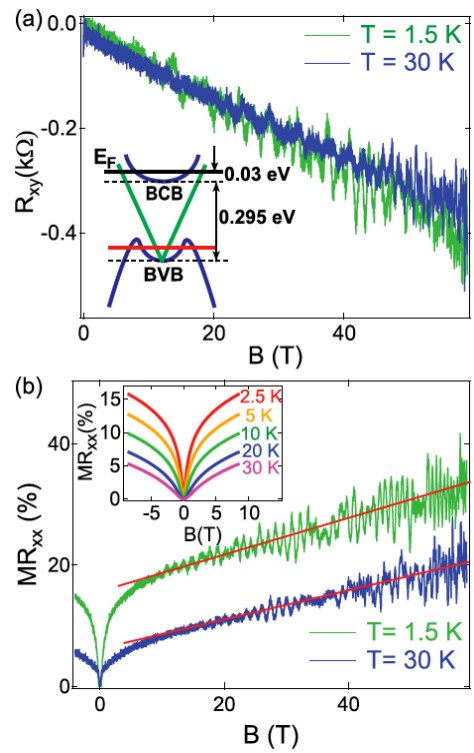

Figure. (a) Hall resistance vs B. Inset: a schematic of Bi_2Te_3 band structure. **(b)** MR vs B at 1.5 and 30 K. Inset: curves in lower B taken at different temperatures.

Conclusions

The non-saturating linear-like MR in TI Bi_2Te_3 thin films (up to 60 T) can be well understood as the WAL phenomena described by Hikami-Larkin-Nagaoka theory.

References

[1] S. X. Zhang *et al*., App. Phys. Lett. **101**, 202403 (2012).