Classical Linear Magnetoresistance in Polycrystalline InSb

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Abstract

Polycrystalline Indium antimonide exhibits a linear magnetoresistance which is qualitatively similar to the magnetoresistance of lightly doped, single-crystal InSb at low temperatures. Unlike the single-crystal case, magnetoresistance in polycrystalline InSb is a purely classical effect. The irregular current paths found in polycrystalline InSb force current into unfavorable alignments with an applied voltage, resulting in linear magnetoresistance. Recent measurements established this effect in polycrystals up to 350 K. [1] The results contained in this paper extend the magnetoresistance measurements up to the melting point of InSb at 800 K. Linear magnetoresistance is observed over the whole range from 350 K to 800 K, and in fact increases as the temperature increases.

1 Introduction

The linear magnetoresistance of polycrystalline InSb is due to its inhomogeneous structure. In order to prepare the polycrystals, pure single-crystal InSb is ground into a fine powder, with an average grain size of 10-20 μm. These grains are then formed into a polycrystal with droplets of Sb along the grain boundaries serving as the inhomogeneities. These inhomogeneities cause the current paths in the polycrystal to misalign with an applied voltage. This misalignment is at the root of the observed linear magnetoresistance in InSb. Another consequence of large inhomogeneities in a semiconductor is that under high magnetic fields, the magnetoresistance is proportional not to the mobility, but to the spread of mobilities in a sample.[2] This helps to explain the observed increase in magnetoresistance as a function of temperature.

2 Methods

The successful execution of this project required the construction of two devices, one great and one small. In order to attach leads to the polycrystals conducting Ti/Au pads must be deposited. In order to make this process streamlined and uniform, a simple mask was designed that allows the deposition of 5 top leads and 2 side leads each on 3 separate crystals. The crystals are recessed into ‘pockets’ in order to keep them stationary during the evaporation.

The greater design challenge came in the form of a heated sample stage capable of reaching 800 K. This sample stage had to maintian a temperature stable enough for measurements, yet be immersed in a helium-3 refrigerator in order to access the high magnetic field therein. These two constraints necessitated mounting the sample stage inside a vacuum can in order to minimize thermal leakage from the stage.

3 Results

The magnetoresistance of polycrystalline InSb continues to be linear above 350 K up to the melting point at 800 K. Figure 1 shows the percentage deviation from the zero-field resistance as a function of magnetic field for several temperatures. The magnetoresistance continues to increase with T throughout the temperature range, indicating that the physics behind the magnetoresistance between 350 K and 800 K is likely the same as the physics between 200 K and 350 K.

References

[1] Jingshi Hu and T. F. Rosenbaum. Classical and quantum routes to linear magnetoresistance. *Nature Materials*, 2008.

[2] M. M. Parish and P. B. Littlewood. Non-saturating magnetoresistance in heavily disordered semiconductors. *Nature*, 2003.