Growth and Characterization of PrBiTe Crystals

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INTRODUCTION

A major problem in modern technology is the volume of transistors and computers chips that are currently being used, more specifically the wires in these devices. Alternatives to the current wires are high-mobility materials. High-mobility materials can be used for many applications in these devices by utilizing their low resistivity and small Joule heating. A known type of high-mobility material is Dirac materials, whose band dispersion is linear in contrast to a quadratic dispersion in normal materials.

In this project, we grew a new Dirac material PrBiTe, whose linear band dispersion is confirmed by the band structure calculation. The crystalline structure and stoichiometric composition were investigated via X-ray diffraction and energy dispersive X-ray spectroscopy, indicating high crystallinity and precise stoichiometry. Preliminary transport measurements reveal linear magnetoresistivity, and seemingly the coexistence between light and heavier electrons confirming the Dirac nature of the compound. The resistivity measured at T = 300 K shows a low value of 10.25 mΩ cm, which could indeed be useful as a low resistivity material for interconnects.

METHODS

- The crystals were grown through the flux growth method.
  - The metals are dissolved in an excess of bismuth flux at 1050°C.
  - This mixture is then cooled down to 800°C.
  - The flux is then separated by a filter in order to obtain the crystals.
- The identity and ratio of the elements present in the crystal was found using the energy-dispersive X-ray spectroscopy (EDS) technique, in which the sample is exposed to an electron beam and measuring the energy of the x-rays emitted. This allows to predict the composition of elements present in the sample.
- Electrical contacts made to the crystals using platinum wires and silver paste. The wiring configuration schematically shown in Figure 1.
- The electrical characterization of the crystal was performed using the physical property measurement system (PPMS) at temperature ranging from 2 K to 300 K, and magnetic field from -9 T to 9 T.

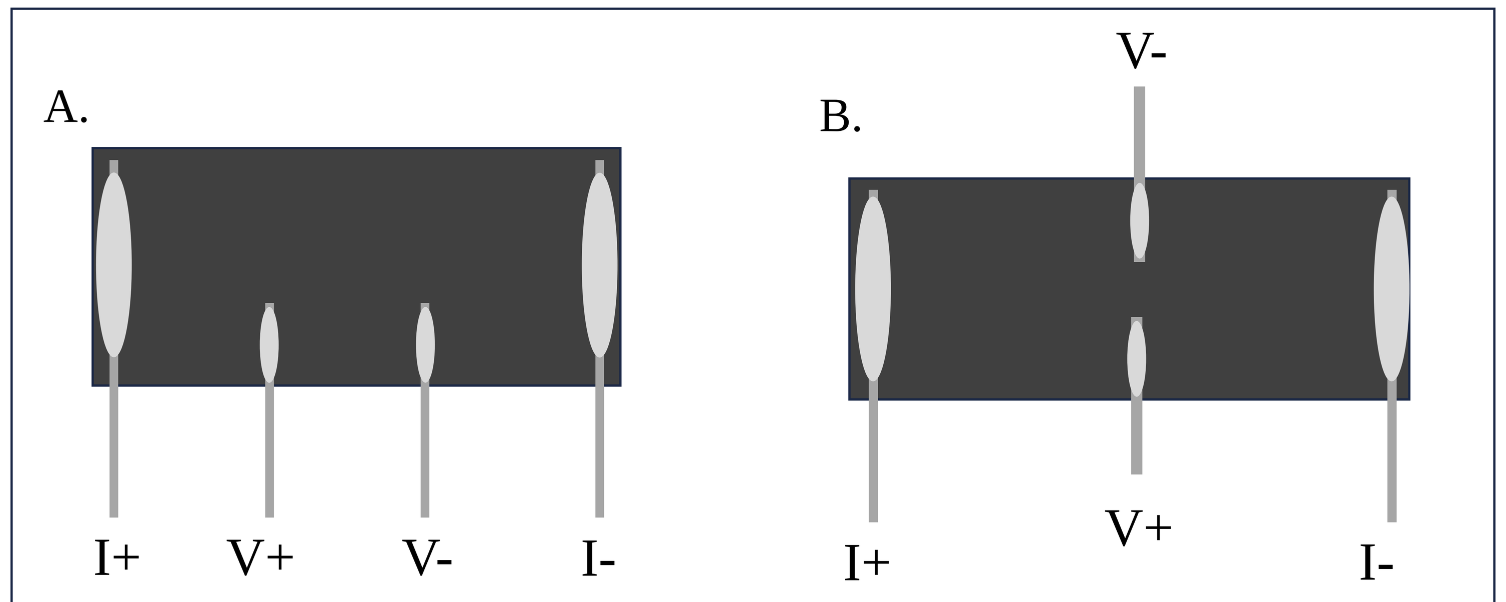

Figure 1: Schematic representation of electrical contacts made to the crystal for measuring A) longitudinal resistivity (ρ_{xx}), B) Hall resistivity (Transverse resistivity, ρ_{xy})

RESULTS

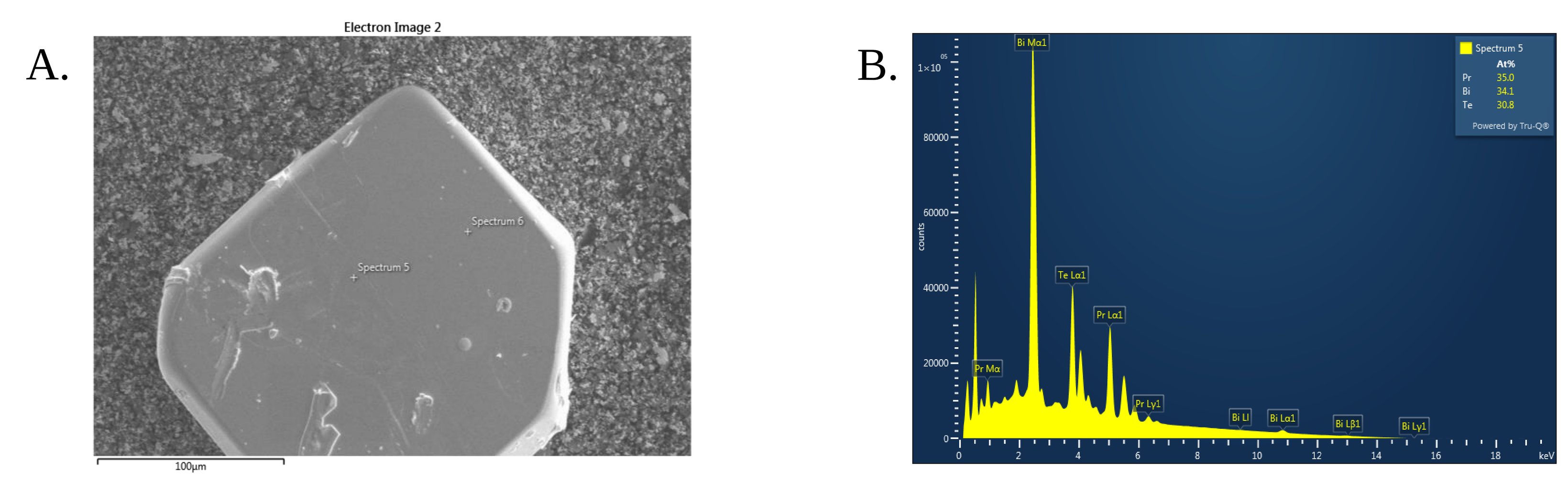

Figure 2: Energy dispersive X-ray spectroscopy (EDS) A): Image the single crystal when exposed to electron beam, B) Elemental mapping using EDS to understand the composition.

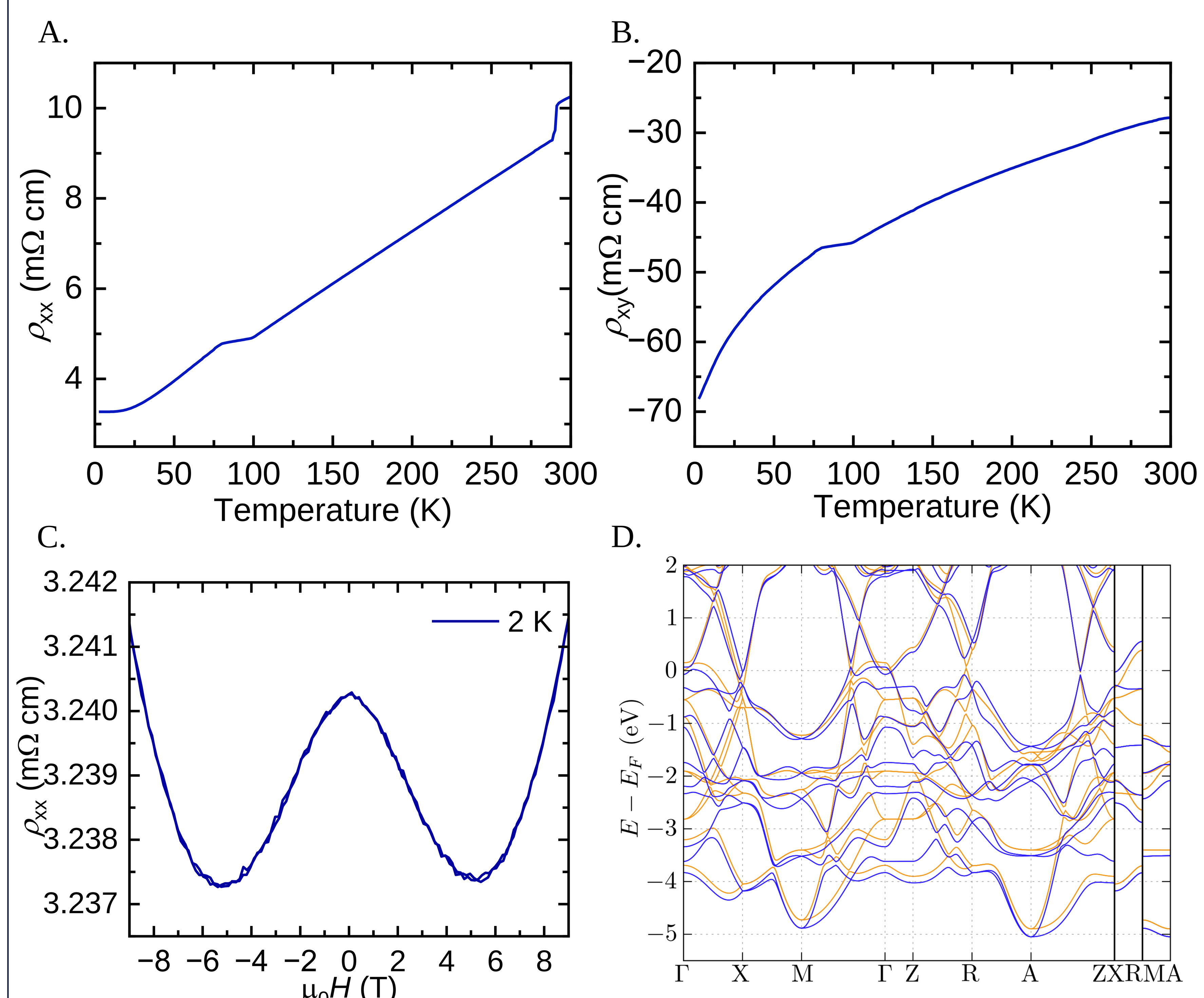

Figure 3: Electrical transport measurements A) Longitudinal resistivity as a function of temperature, B) Hall resistivity as a function of temperature, and C) Magnetoresistivity as a function of applied magnetic field along *c*-axis of the crystal D) Band structure analysis

RESULTS

Element	Pr	Bi	Te
Comoposition %	35.20	34.10	30.70
	35.10	34.20	30.70
	35.10	34.10	30.80
	35.00	34.10	30.80
	35.00	34.30	30.70
	34.80	34.30	30.80
	34.80	34.30	30.80
Average Composition	35.00	34.20	30.76
Empirical Formula	1.14	1.11	1.00

Table 1: Average composition calculated using EDS results and empirical formula of the crystal.

CONCLUSIONS

- Synthesized and characterized the bulk PrBiTe crystals using the flux growth method.
- The preliminary structural characterization using EDS found a 1.14:1.11:1.00 ratio (Table 1), which suggests an excess of Pr and Bi elements.
- The resistivity of the PrBiTe crsytal at T = 300 K is 10.25 mΩ cm (Figure 3a).
- The dimensions of the crystals are small, bigger crystals will need to grown for future experiments.
- Band structure analysis shows linear dispersion near Fermi-level, indicating that it is likely to be a dirac material
- There may be temperature calibration issues that would affect the plots in Figure 3.

FUTURE DIRECTIONS

- We need to understand the exact crystal structure using single crystal X-ray diffraction.
- Characterizing the magnetic properties of the crystals using the magnetic property measurement system (MPMS).
- Analyze the electrical transport measurements and magnetization to extract possible topological effects.

REFERENCES

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