Growth of Single Crystal Topological Insulators and Dirac Semimetals

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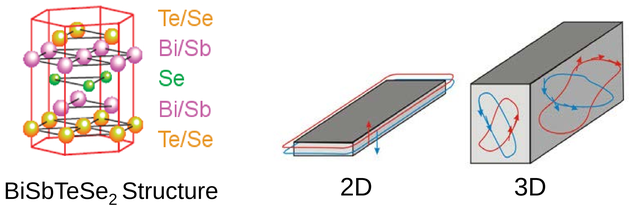
What is a topological insulator?

A topological insulator (TI) is a material that is insulating in its bulk, yet conductive on its surface.

- Conductivity of surface not affected by impurities
- Produces unfading spin currents



$BiSbTeSe_2$ Structure

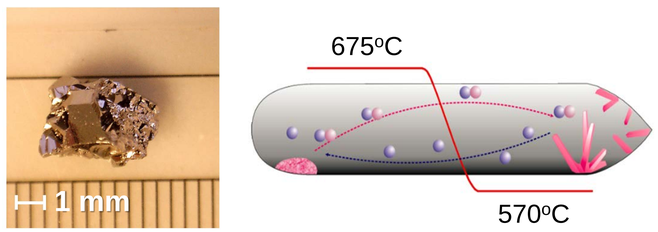
$BiSbTeSe_2$: a 3D TI

- Hypothesis: $BiSbTeSe_2$ (1:1:1:2 mole ratio) will have superior conductivity
- Problem: Different elemental vapor pressures produced compound with excess selenium
- Approach: Vary the concentration of Se to form $BiSbTeSe_2$

➢ Was the correct molecular structure formed?
➢ Does composition affect crystal structure and conductivity?

Cd_3As_2: a Dirac semimetal

- 3D analog to graphene
- High electron mobility
- Defects do not affect conductivity



Grown using thermal transport

Methodology

Prepare ampoule and load raw materials

Seal ampoule at high vacuum

Melt and anneal in furnace for 10 days

Results

Narrow peaks indicate single crystal was formed

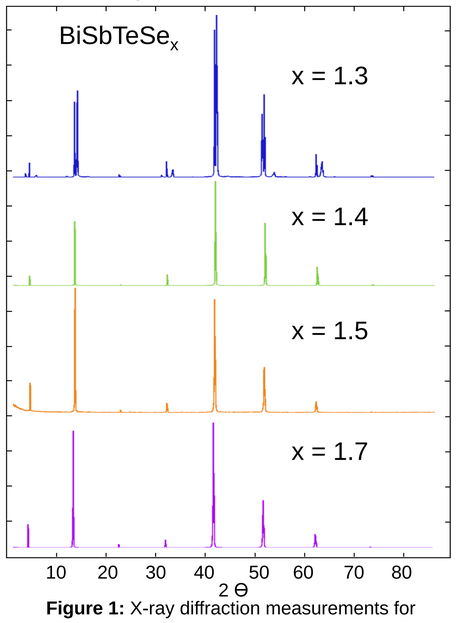


Figure 1: X-ray diffraction measurements for BSTS single crystals with varying amounts of Se

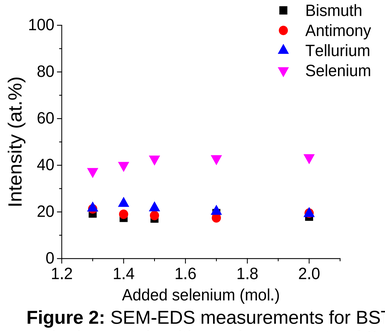


Figure 2: SEM-EDS measurements for BSTS single crystals with varying amounts of Se

Peaks match those of similarly structured compounds

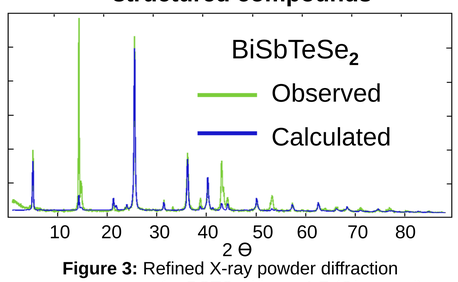


Figure 3: Refined X-ray powder diffraction measurements for BSTS with x = 1.7 (Observed) and similar rhombohedral compounds (Bi_2Se_2Te, Sb_2Te_2Se; Calculated)

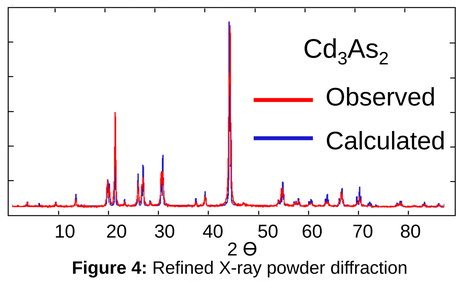


Figure 4: Refined X-ray powder diffraction measurements for Cd_3As_2 (Observed) and similarly structured compounds (Calculated)

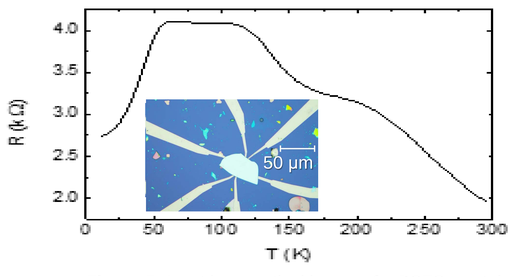
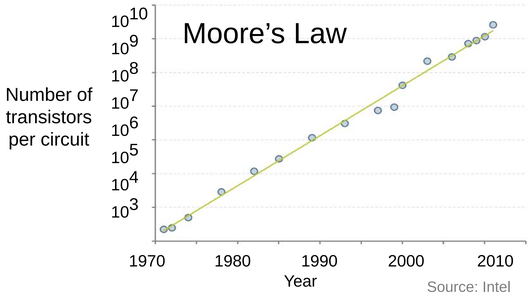
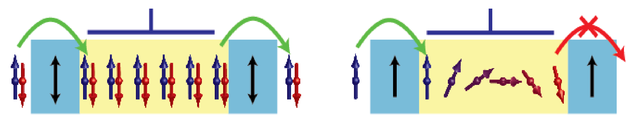


Figure 5: Inset is an optical image of a BSTS crystal (thickness ~60nm). Graph shows temperature dependence of electrical resistance

Possible Applications



Spintronics and quantum computing: use electron spin rather than charge to manage information



Next Steps

$BiSbTeSe_2$:

- Take resistance vs. magnetic field measurements for the BSTS sample to confirm topological insulator character
- Synthesize a $BiSbTeSe_2$ single crystal with the correct mole ratio and compare its conductivity to the crystals already grown

Cd_3As_2:

- Characterize the Cd_3As_2 sample and measure conductivity
- Refine the thermal transport method to grow larger Cd_3As_2 crystals

References / Acknowledgements

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