Characterizing topological insulators: transport measurements and capacitance probe design

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Physics REU 2014
1. What is a topological insulator?

2. Four-probe resistance measurements

3. Probe design
Topological insulators (TIs)

- As $T \to 0$: electrically insulating bulk; electrically conducting surface
- Has a topologically protected surface
Topological insulators

Carrier Density of Selected Materials

<table>
<thead>
<tr>
<th></th>
<th>Metal(^1)</th>
<th>Si: Doped Semiconductor(^1)</th>
<th>Bi(_2)Se(_3): TI(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier density</td>
<td>(~10^{23})</td>
<td>(~10^{15})</td>
<td>(~10^{17})</td>
</tr>
</tbody>
</table>

2. D. Kim, et. al. *Surface conduction of topological Dirac electrons in bulk insulating Bi\(_2\)Se\(_3\)*
Four-probe resistance measurements

- Test resistance as a function of temperature to determine properties of the material
- Material tested was Bi$_2$Te$_2$Se (BTS), a TI
- Decrease error in resistance by removing internal resistance effects of current source and wires
- Comparison to two-probe measurement
Four-probe resistance measurements

- Voltage measured
- Current in
- Sample
Four-probe resistance measurements
Four-probe resistance measurements

- Heating of sample of Bi$_2$Te$_2$Se
- Metallic behavior – comparison to expected TI behavior
- Capacitance?

Probe design: brass head & cap

- Challenges:
  - Flat surface for mounting sample
  - Grooves for wires

August 6, 2014
University of Michigan REU 2014
Probe design: aluminum head

- Challenges:
  - Location of connector
  - Weight (grooves)
Probe design: nylon cap

- Most complex part of probe
- Made by machine shop
  - D-shaped holes
  - Coaxial cables
Probe design: complete!
Using probe to study capacitance

- Test another property of TIs
- Resistance results show metallic behavior, but capacitance results may show something unique to TIs
- Versatile: dielectric constant of an insulator
- Future tests:
  - Quantum capacitance
  - Boundary between surface & bulk states
Acknowledgements

- University of Michigan
- National Science Foundation
- LSA Scientific Machine Shop
- Lu Li & group, especially Fan Yu