Characterizing topological insulators: transport measurements and capacitance probe design

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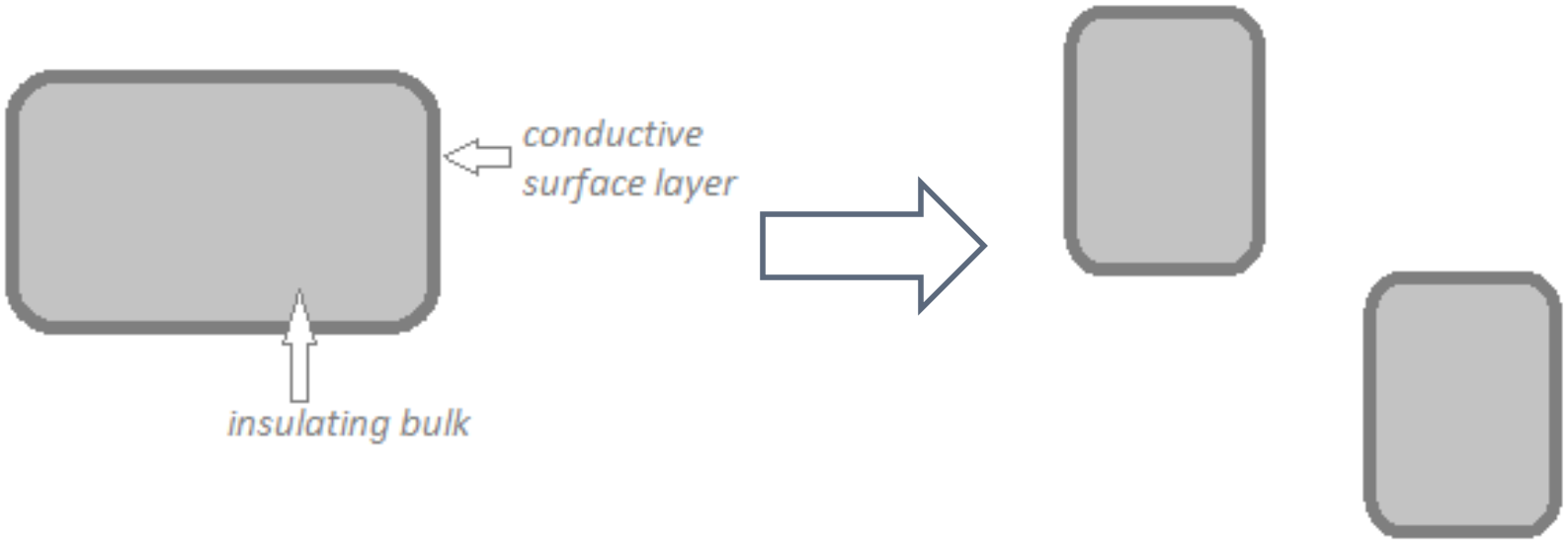
1. What is a topological insulator?

2. Four-probe resistance measurements

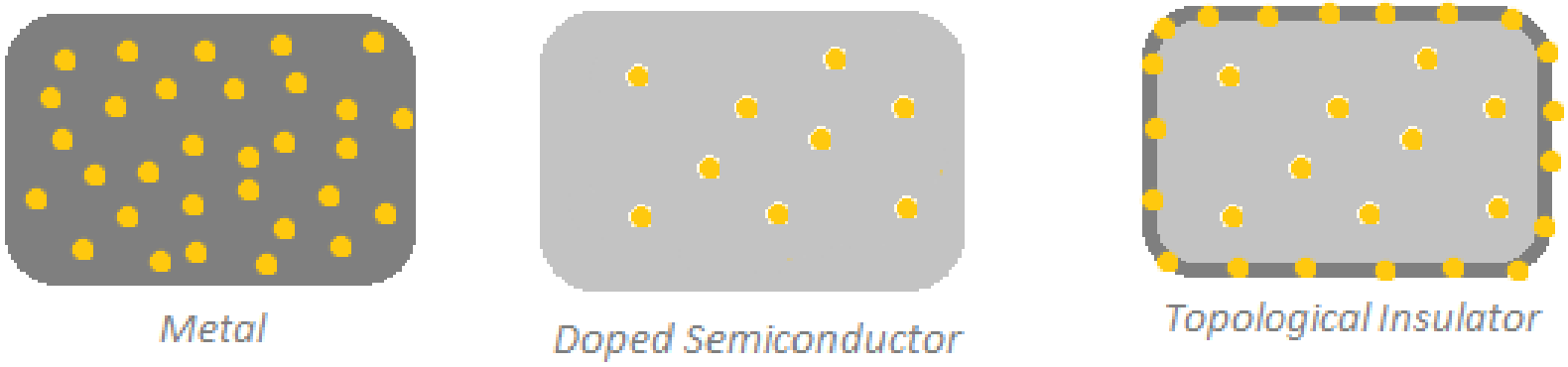
3. Probe design

Topological insulators (TIs)

- As T → 0: electrically insulating bulk; electrically conducting surface
- Has a topologically protected surface



Topological insulators



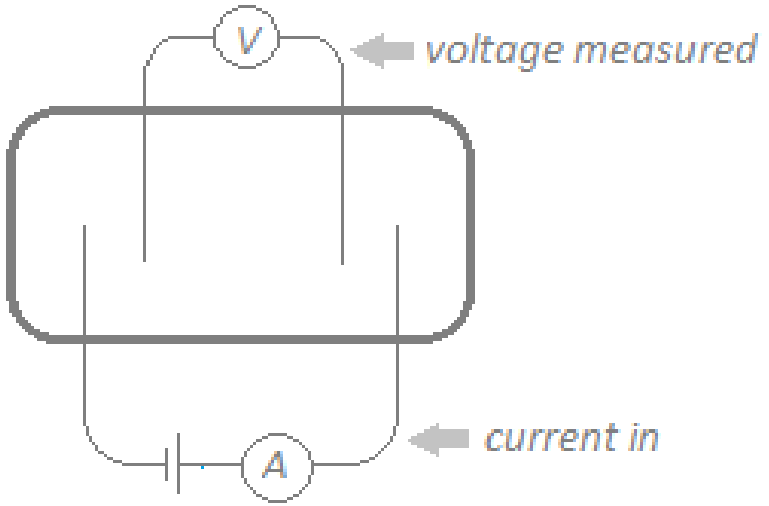
Carrier Density of Selected Materials

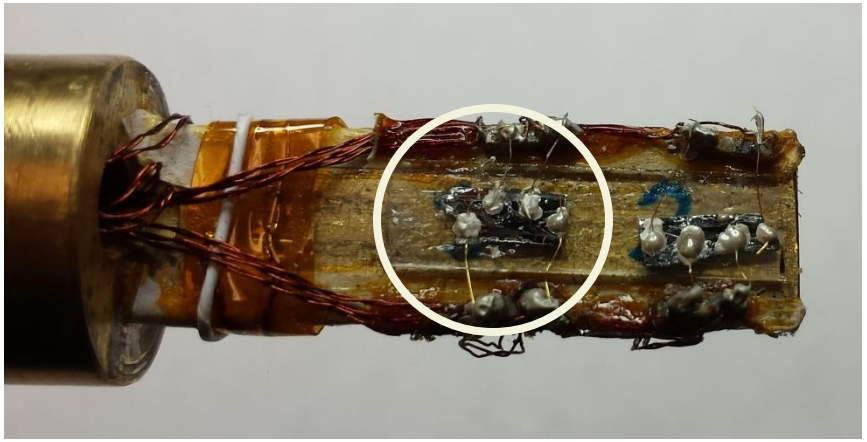
	Metal[1]	Si: Doped Semiconductor[1]	Bi_2Se_3: Tl[2]
Carrier density (e^-/cm^3)	~10^{23}	~10^{15}	~10^{17}

1. J. Singleton. *Band Theory and Electronic Properties of Solids*
2. D. Kim, et. al. *Surface conduction of topological Dirac electrons in bulk insulating Bi_2Se_3*

Four-probe resistance measurements

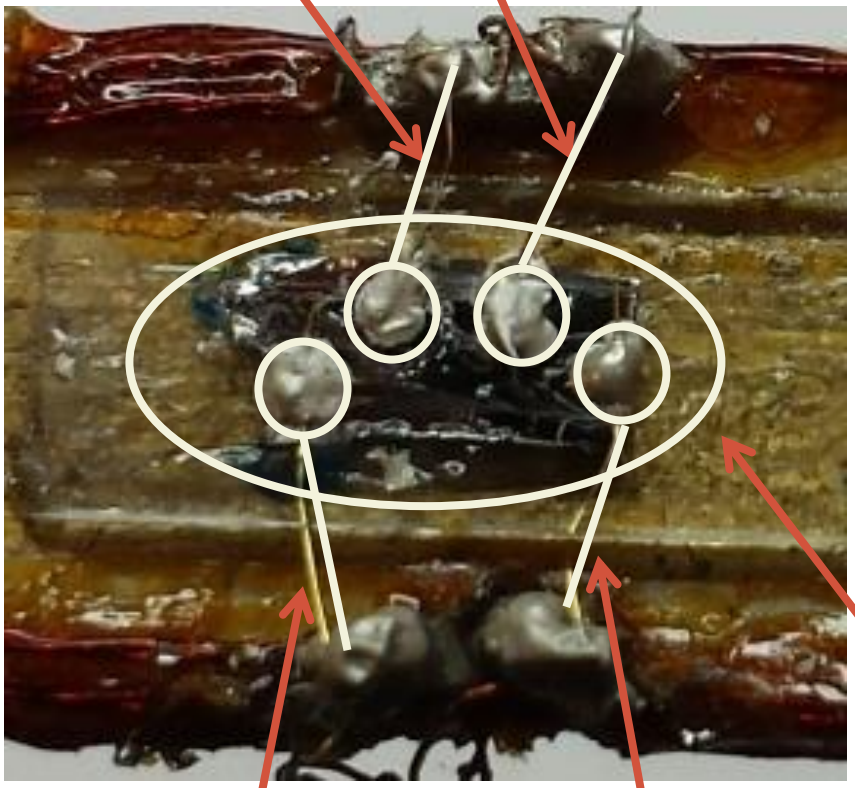
- Test resistance as a function of temperature to determine properties of the material
- Material tested was Bi_2Te_2Se (BTS), a TI
- Decrease error in resistance by removing internal resistance effects of current source and wires
- Comparison to two-probe measurement

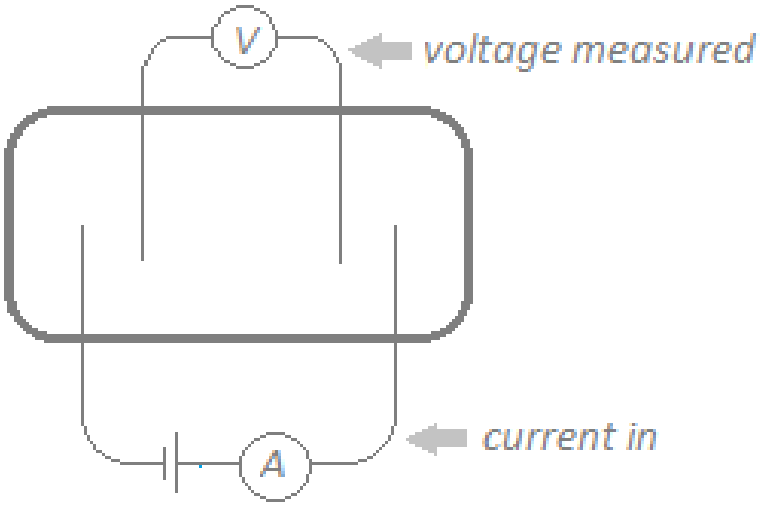




Four-probe resistance measurements

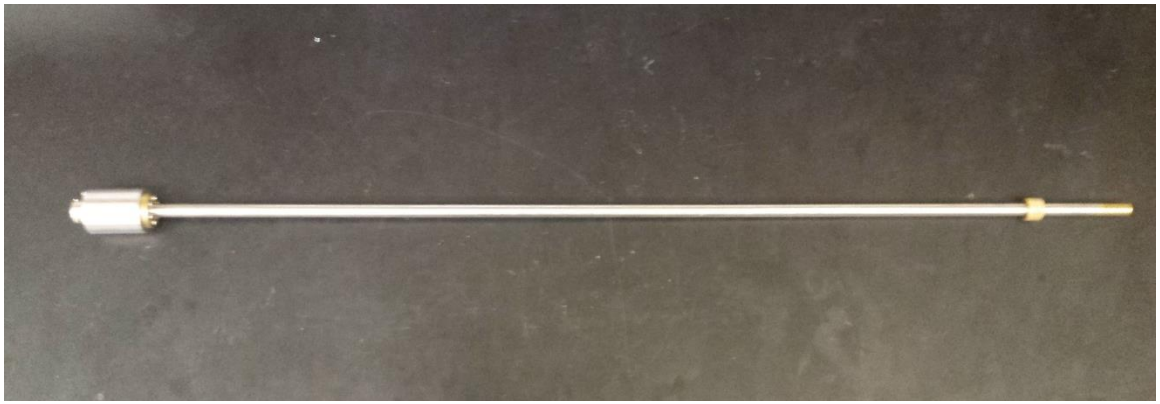
- Voltage measured

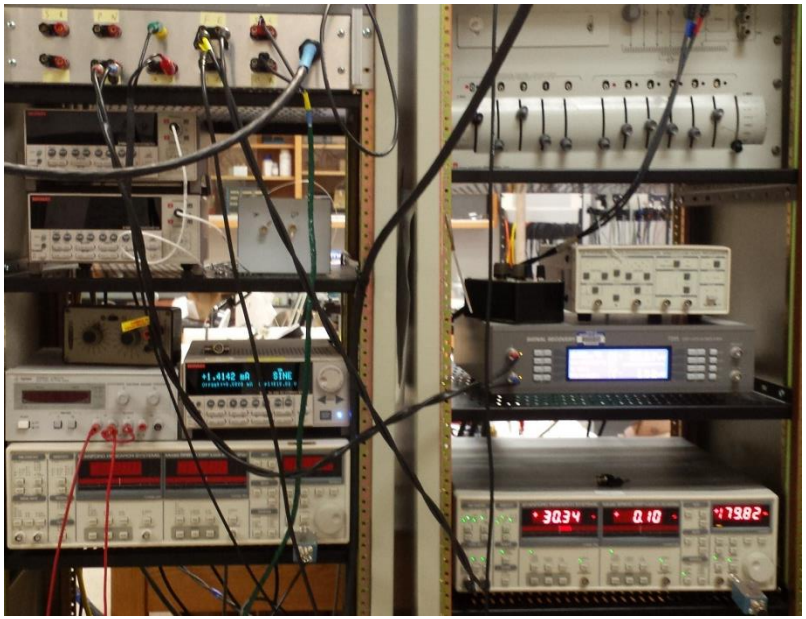




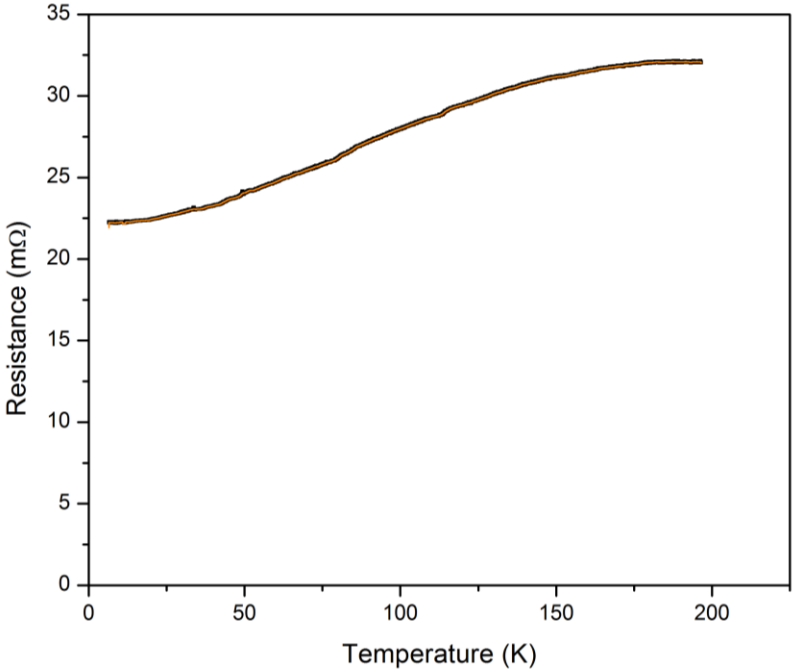
- Sample
- Current in

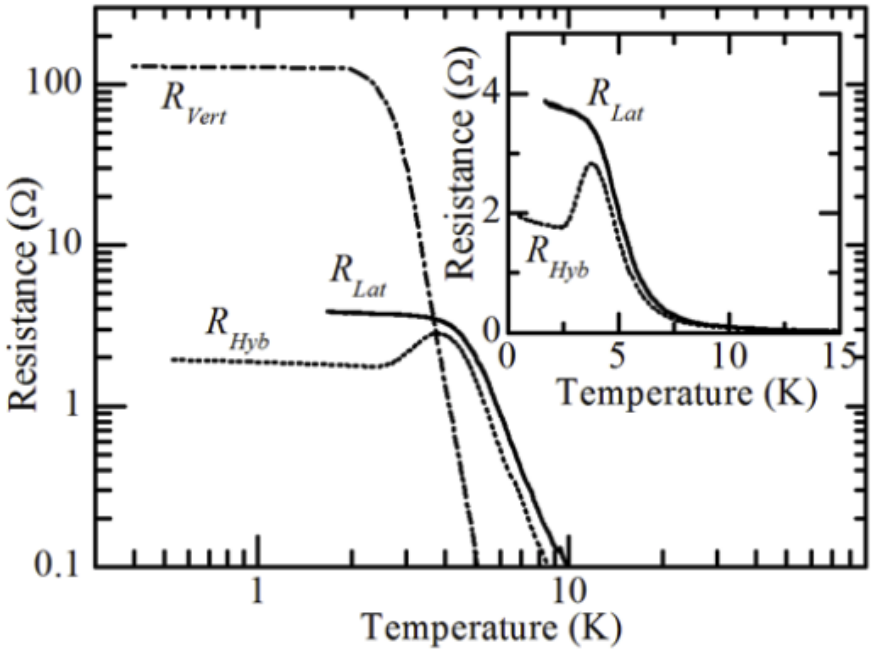
Four-probe resistance measurements





Four-probe resistance measurements

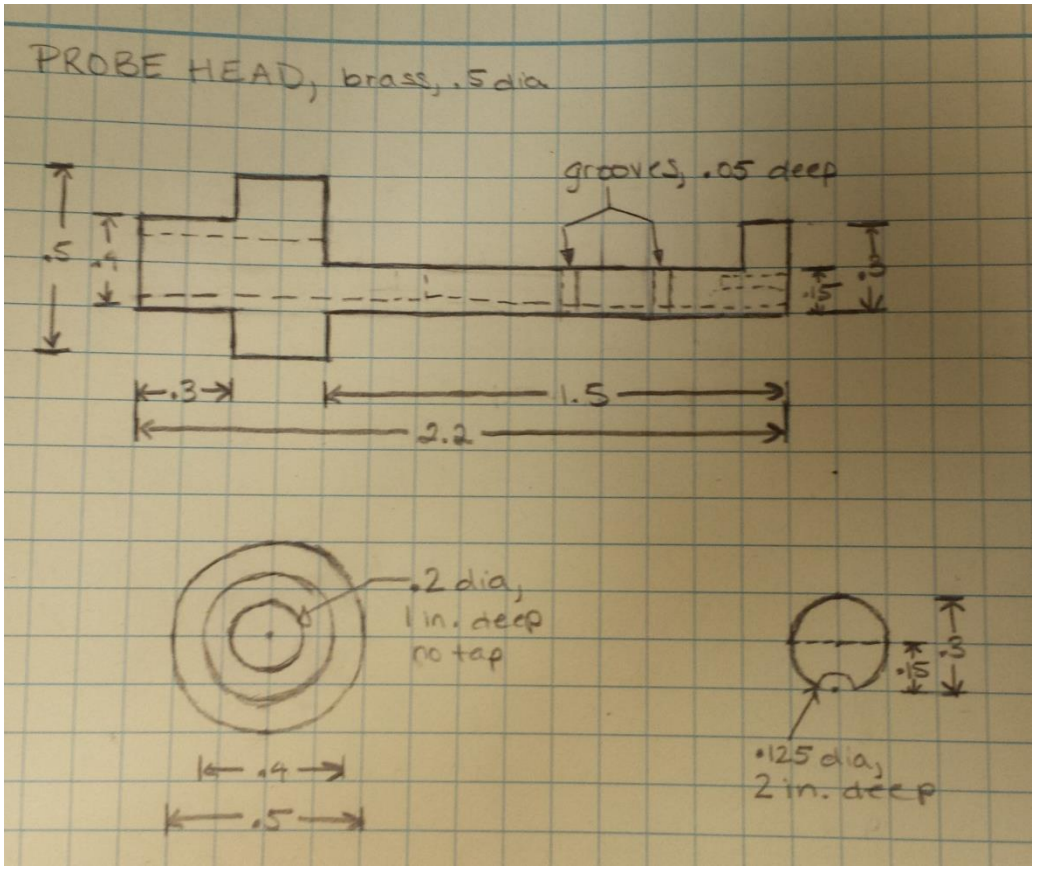




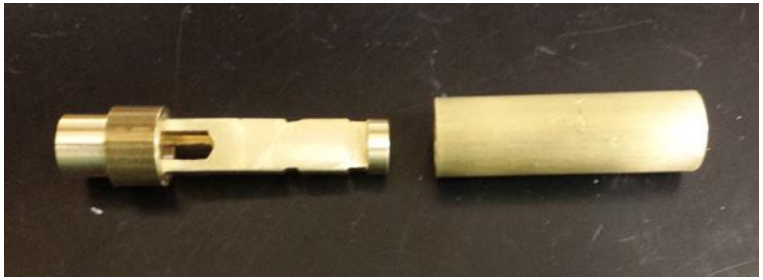
- Heating of sample of Bi_2Te_2Se
- Metallic behavior – comparison to expected TI behavior
- Capacitance?

Figure: S. Wolgast et al, “Discovery of the First True Three-Dimensional Topological Insulator: Samarium Hexaboride”, arXiv: 1211.5104 (2012)

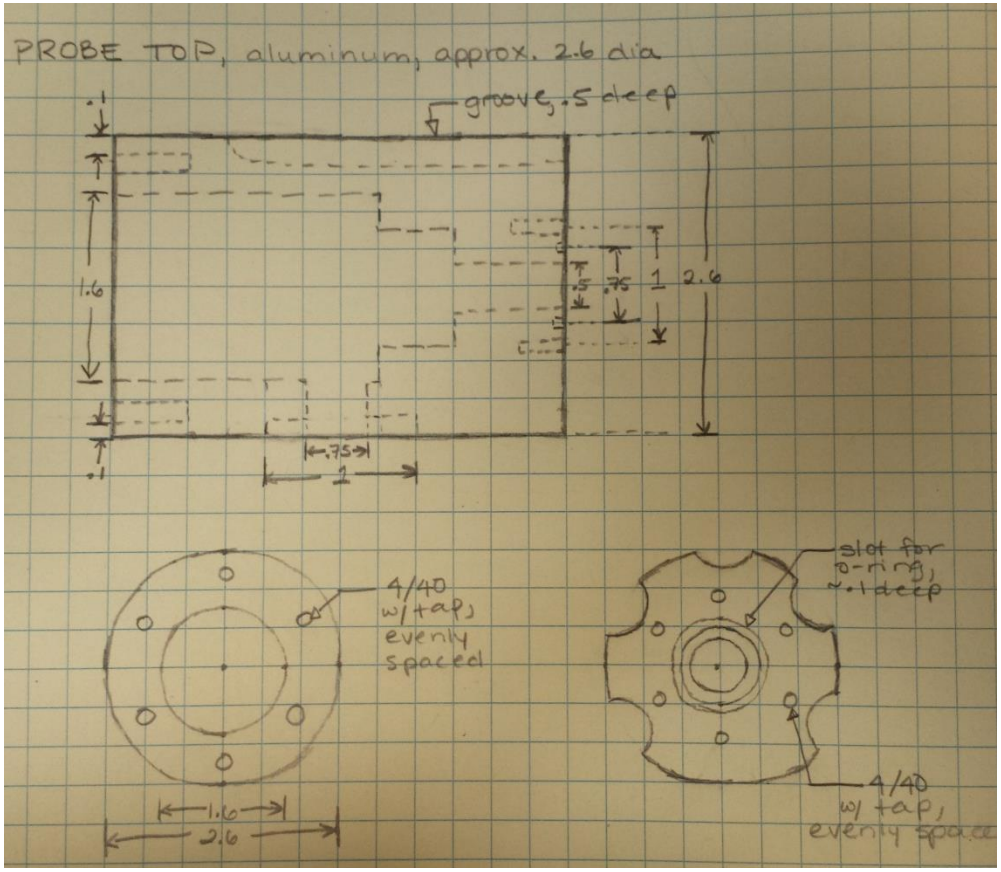
Probe design: brass head & cap



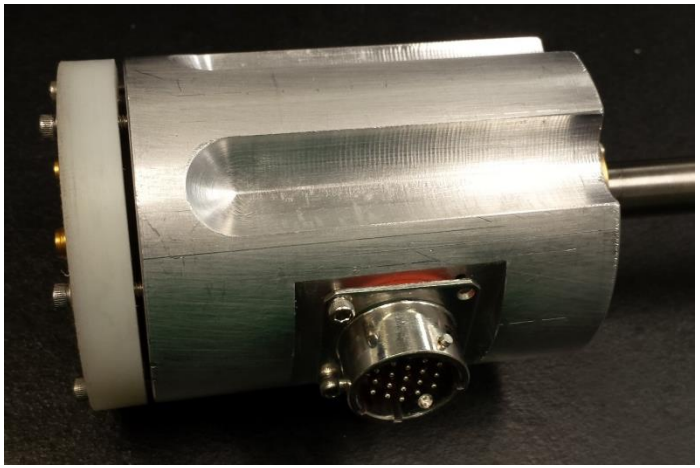
- Challenges:
  - Flat surface for mounting sample
  - Grooves for wires



Probe design: aluminum head

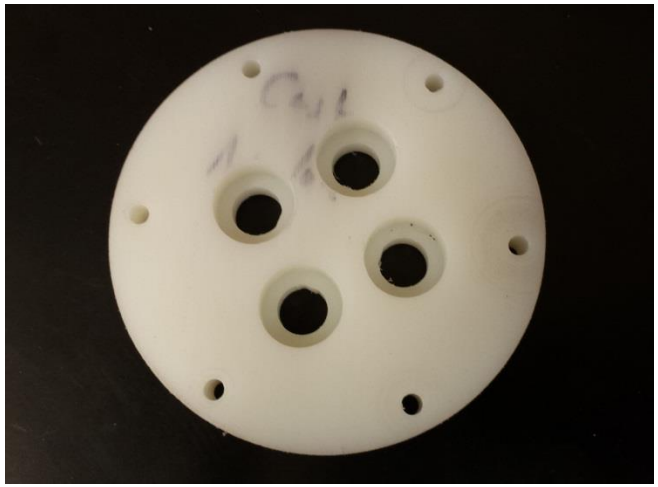


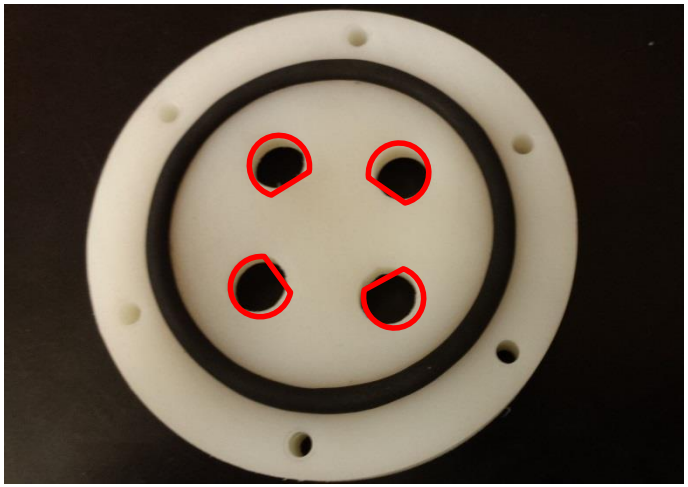
- Challenges:
  - Location of connector
  - Weight (grooves)



Probe design: nylon cap

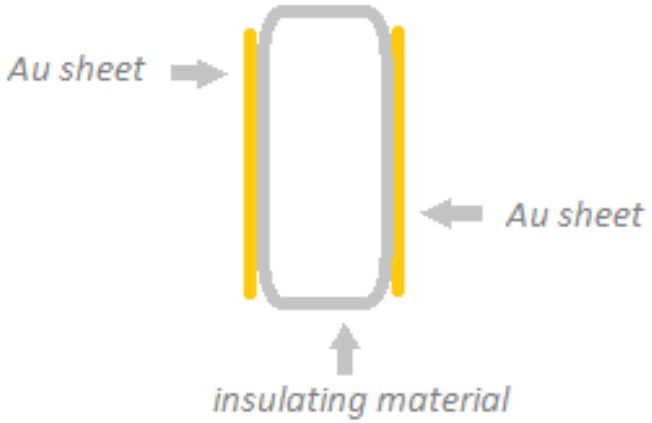
- Most complex part of probe
- Made by machine shop
  - D-shaped holes
  - Coaxial cables

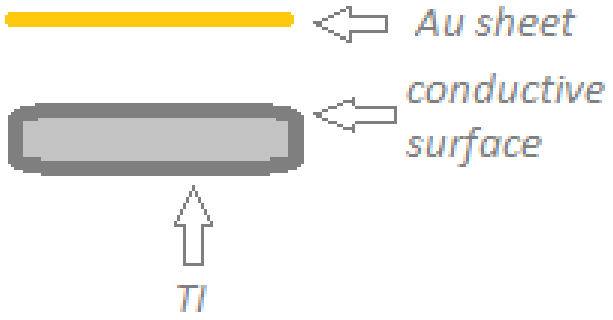




Probe design: complete!

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

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