Planar Tunneling Spectroscopy of Samarium Hexaboride (SmB\textsubscript{6})

Building Block for Topological Quantum Computer

Lunan Sun(1), Dae-Jeong Kim(2), Zachary Fisk(2), Laura H. Greene(1), Wan Kyu Park(1)

(1) University of Illinois at Urbana-Champaign, Urbana, USA (2) University of California-Irvine, Irvine, USA

Introduction

- Quantum computers (QC) perform calculations using qubits, superpositions of 0 and 1.
- Difficulties: Qubits are extremely fragile and easily cause errors.
- Topological QC: Uses the topology of qubits’ worldlines to create braidings stable for outside disturbance.
- Optimal qubits candidate: nonabelian anyons, which exist only in mathematical predictions so far.
- Ideal candidate for nonabelian anyons: Majorana bound states in topological insulators/superconductors.

Basic Theories

- Topological insulator is insulating in bulk while carrying a conducting metallic state on surface.
- The linear surface state links the conducting and covalent band.
- The surface state is topologically protected.

Objectives

- SmB\textsubscript{6}, a Kondo insulator, is predicted to carry topological surface state.
- Using planar tunneling, one can inspect the density of state (DoS) at low temperature (<10K).
- Also, planar tunneling can possibly detect bulk property such as Fano resonance.

Methods & Experiments

1. (Normal environment) Sample polishing and cleaning.
2. (Vacuum) Ion beam etching/cleaning.
3. (Vacuum) Sputtering of aluminum & Plasma Oxidation.
4. (Normal environment) Painting insulating strips.
5. (Vacuum) Depositing silver counter electrodes.
6. (Normal environment) Connecting leads and mounting to probe.
7. (Low temperature) Measuring junction conductance vs. temperature/conductance vs. bias.

Results

- Similar tunneling spectra are obtained from both (001)(left) and (011)(right) planes.
- Suppressed dip near zero-bias voltage is linear.
- Asymmetric background shape.
- The peaks at about -20mV does not behave monotonically with temperature.

Conclusions

- Intrinsic surface states are found in both (001) and (011) planes.
- Suppressed 0-bias dip is linear—agrees with the shape of surface state.
- Asymmetric background indicates the Fano resonance.

References

[3] Yee et al., Imaging the Kondo Insulating Gap on SmB\textsubscript{6}, 2013; arXiv:1308.1085v2
[5] Li & Chen, Two-dimensional Fermi surfaces in Kondo insulator SmB\textsubscript{6} (Science 346, 1208 (2014) DOI: 10.1126/science.1250366)