Planar Tunneling Spectroscopy of Samarium Hexaboride(SmB_6)

Building Block for Topological Quantum Computer

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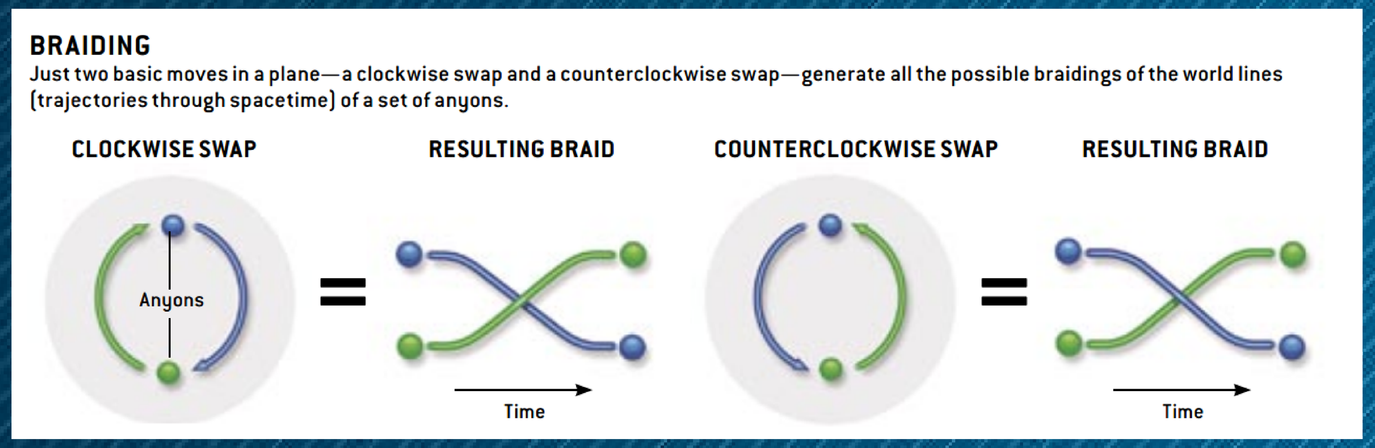
Introduction

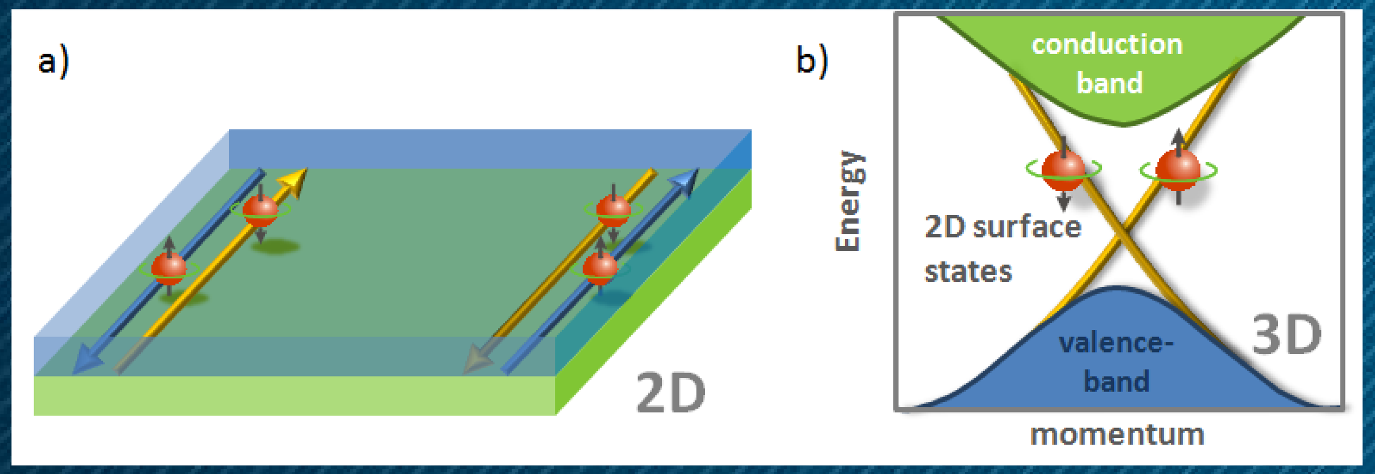
- Quantum computers(QC) perform calculations using qubits, superpositions of 0 and 1.
- Difficulties: Qubits are extremely fragile and easily cause errors.
- Topological QC: Uses the topology of qubits' worldlines to create braidings stable for outside disturbance.
- Optimal qubits candidate: nonabelian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



▲ The worldlines of anyons form different topology, which is stable under disturbance

Basic Theories

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

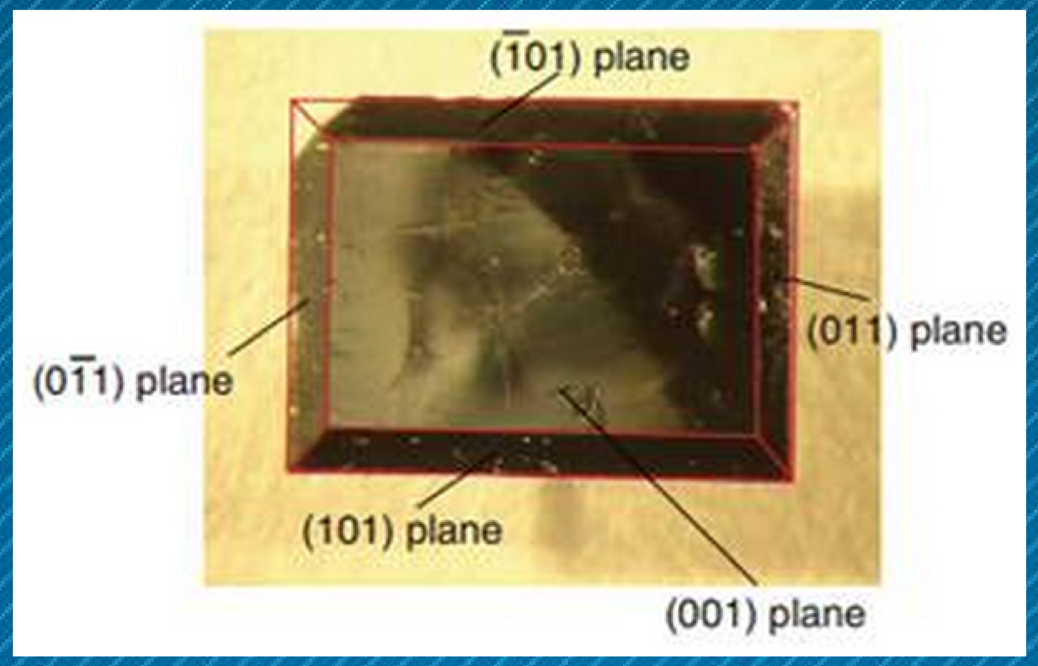


▲ How electrons travel between conduction band and valence band via surface states. Its shape is linear in 3D (left).

- ***Planar tunneling spectroscopy(PTS)*** **is sensitive to material's surface property.**

Objectives

- SmB_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, plannar tunnling can possibly detect bulk porperty such as Fano resonace.



▲ SmB6 crystal, different surface has different indeices as well as surface properties. (Image from *First observed 2D Fermi surfaces in Kondo insulator SmB6*, Science 346, 1208 (2014) DOI: 10.1126/science.1250366)

Methods & Experiments

1. (Normal environment) Sample polishing and cleaning.
2. (Vacuum) Ion beam etching/cleaning.
3. (Vacuum) Sputtering of aluminum & Plasam 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. tempearture/ conductance vs. bias.

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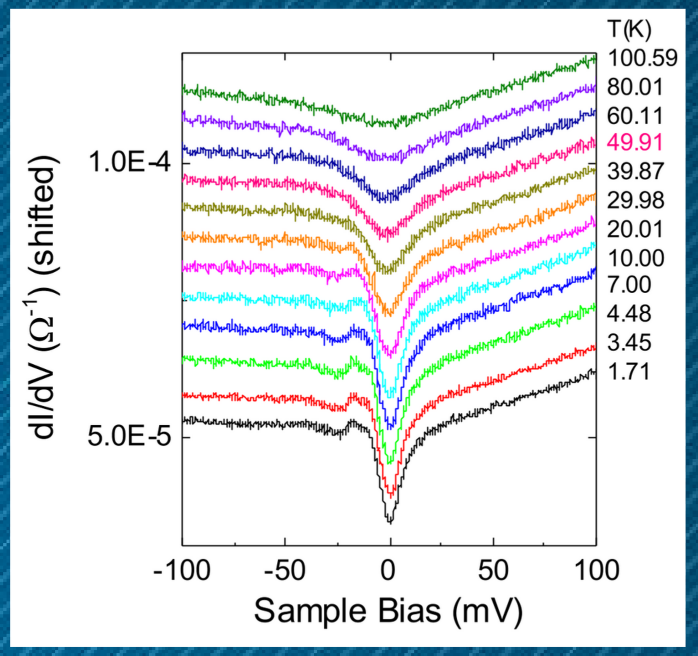
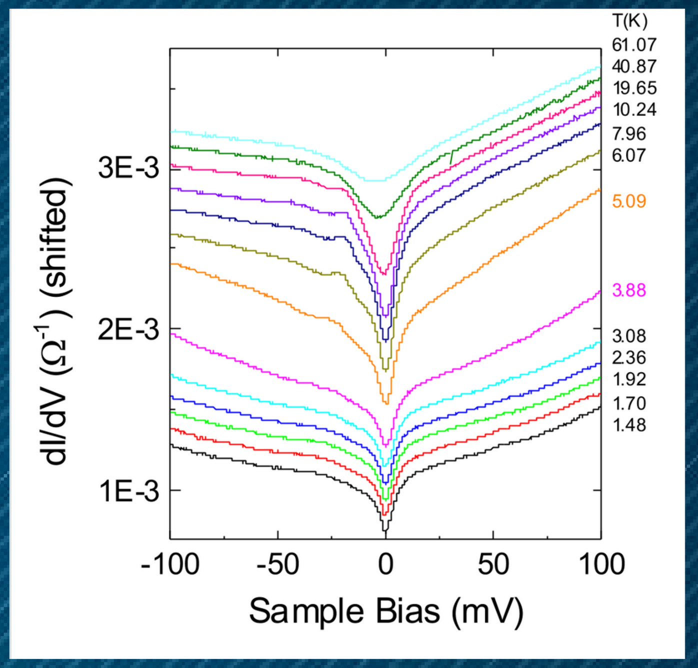
Results

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



▲ Tunneling spectra for (001) surfaces from 4K to 100K, -300mV to 300mV



▲ Tunneling spectrum for (011) surface from 4K to 60K, -300mV to 300mV

Conclusions

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

References

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[5] Li & Chen, *Two-dimensional Fermi surfaces in Kondo Insulator SmB6* (Science 346, 1208 (2014)DOI: 10.1126/science.1250366)