FUNDING PROGRAM FOR NEXT GENERATION WORLD-LEADING RESEARCHERS

Project Title: Creation of Innovative Devices Based on Topological Insulators	
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1. Background of research

A few years ago, a new quantum state of matter called “topological insulator” was discovered. Topological insulators are insulating in the bulk but possess intrinsically metallic surface, where electrons behave as “massless Dirac fermions” and carry electrical as well as spin currents with a high mobility. Because of such peculiar surface states, topological insulators are expected to play a key role in realizing innovative information devices. However, the actual topological-insulator materials discovered so far are poorly insulating in the bulk, hindering the studies and exploitations of the topological surface states.

2. Research objectives

There remain a lot to be understood in the topological surface states of those materials, and some of the outstanding issues are expected to lead to profound discoveries that may worth the Nobel Prize. In this project, we challenge such outstanding issues in topological insulators by taking advantage of our strength in materials synthesis, and help create innovative devices based on the fundamental understanding we gain for those materials.

3. Research characteristics (incl. originality and creativity)

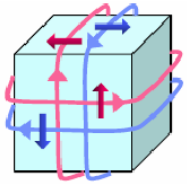
We aim at establishing the fundamental understanding of topological insulators by combing three vital components: explorations of new materials, syntheses of high-quality single crystals, and top-notch measurements of basic physical properties. At the same time, we will build the foundations of the their applications through our device research involving designing, fabrication, and characterization of prototype devices.

4. Anticipated effects and future applications of research

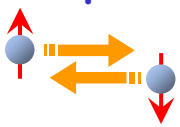
In the peculiar surface states of topological insulators, electrons can much more easily transport information and are much less susceptible to scattering by impurities compared to the electrons in ordinary materials. If those advantages are successfully implemented in the future ultra-low-power-consumption transistors or ultra-high-speed quantum computers, significant saving of energy in the area of information devices will be accomplished.

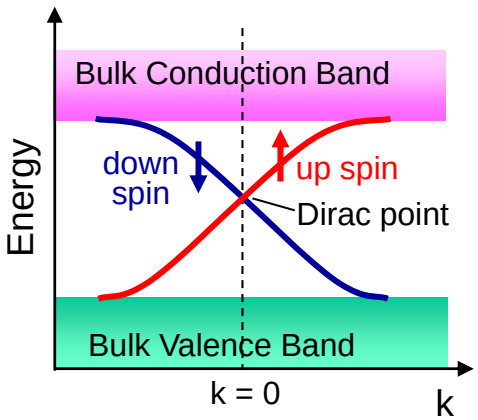
Novel Quantum Phenomena in Topological Insulators

- Spin-filtered Dirac fermions on the surface
- Dissipationless spin current



Pure Spin Current





- Axion electrodynamics involving the B·E cross term leads to novel magnetoelectric effects

Half-Integer Quantum Hall Effect

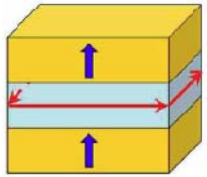
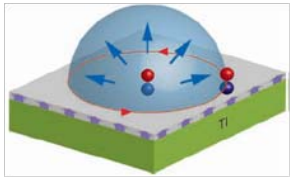
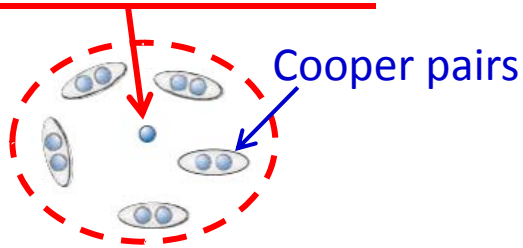


Image Monopole



Qubit of topological Quantum Computing

- Proximity superconductivity leads to Majorana Fermions



Novel Quantum Phenomena ⇒ Innovative Devices