【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Mathematical and physical sciences)

Title of Project : Explorations of Novel Quantum Phenomena in Topological Insulators and Superconductors

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Research Area : Physics
Keyword : Semiconductor

【Purpose and Background of the Research】

Topological insulators are an emerging class of materials that host a new quantum-mechanical state of matter where an insulating bulk state supports an intrinsically metallic surface state whose existence is protected by a nontrivial topological structure of the Hilbert space. Intriguingly, the resulting metallic surface state is helically spin polarized and consist of massless *Dirac fermions*. Those peculiar properties of the surface state are expected to give rise to various novel quantum phenomena. An even more exotic state of matter is a topological superconductor, which is predicted to bear exotic quasiparticles called *Majorana fermions* that are their own antiparticles. Currently their realization in condensed matter is of significant interest because of their novelty as well as the potential for topological quantum computation.

In this project, we explore novel quantum phenomena associated with those novel quantum states of matter to extend our understanding of quantum mechanics in condensed matter.

【Research Methods】

The Principal Investigator's group has been leading the materials developments and transport measurements of topological insulators and superconductors in the past few years. Building on the expertise we have gained so far, we will further improve the techniques to grow high-quality bulk single crystals and epitaxial thin films of those materials, and elucidate their fundamental properties through precision measurements made at very low temperatures in high magnetic fields.

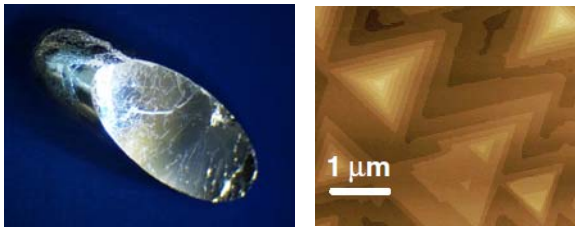

Figure 1 Bulk single crystal (left) and epitaxial thin film (right) of a topological insulator.

【Expected Research Achievements and Scientific Significance】

This project will clarify the following outstanding issues regarding topological insulators and superconductors, which will advance our understanding of the roles of topology in quantum mechanics and establish the new concept of *topological quantum phenomena*:

1) Consequences of helically spin polarized surface states of topological insulators, in particular the novel spin-charge coupling and the half-integer quantum Hall effect

2) Superconducting proximity effects in the surface states of topological insulators, in particular the Majorana zero-mode expected to appear in the vortex core of the proximity-induced 2D topological superconductivity

3) Topological magnetoelectric effect, which allows one to induce electric polarization via magnetic field in a quantized manner

4) Nature of the superconducting states in candidate materials of 3D time-reversal-invariant topological superconductors, which are expected to host helical Majorana fermions on the surface and yield an unconventional current-phase relationship in a Josephson junction

【Publications Relevant to the Project】

・A. A. Taskin, S. Sasaki, K. Segawa, and Y. Ando, Manifestation of Topological Protection in Transport Properties of Epitaxial Bi_2Se_3 Thin Films, Phys. Rev. Lett. 109, 066803 (2012).
・S. Sasaki, M. Kriener, K. Segawa, K. Yada, Y. Tanaka, M. Sato, and Y. Ando, Topological Superconductivity in $Cu_xBi_2Se_3$, Phys. Rev. Lett. 107, 217001 (2011).

【Term of Project】 FY2013-2017

【Budget Allocation】 171,700 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.sanken.osaka-u.ac.jp/labs/fmc/