Citation of the 2015 (the 3rd) Nishina Asia Award

"The first experimental realization of the quantum anomalous Hall effect" by Dr. He, Ke

When a magnetic field is applied to a semiconductor or metal, a transverse electric field appears in the direction perpendicular to both the electric current and the magnetic field. This phenomenon is the well-known Hall effect. In many magnetic materials the Hall effect is observed without applying a magnetic field, as the internal field due to spontaneous magnetization plays the part of an applied field. This is called the "anomalous Hall effect". Another spectacular manifestation of the Hall effect is the "quantum Hall effect" observed in a two-dimensional electron system under a strong magnetic field, where the Hall conductivity is quantized to integer multiples of e^2/h. This year's award is for the discovery of the "quantum anomalous Hall effect", in which the anomalous Hall effect is quantized. In other words, the phenomenon can be viewed as the quantum Hall effect in the absence of an external magnetic field. The quantum anomalous effect, which involves dissipationless current in a zero magnetic field, is expected to play a crucial role for low-energy-consumption electronic device applications.

The quantum anomalous Hall effect was theoretically predicted in 1988. In spite of extensive efforts worldwide, the predicted effect defied experimental verification. Since 2009, Dr. Ke He and his collaborators have carried out systematic studies of material preparation and characterization of a class of material called "topological insulators", in order to realize experimentally the quantum anomalous Hall effect. Armed with his expertise in thin-film growth by molecular beam epitaxy (MBE), angle-resolved photoemission spectroscopy and scanning tunneling microscopy, Dr. He played a crucial role in the band-engineering and MBE growth of topological insulator samples toward the experimental realization of the quantum anomalous Hall effect. He managed to prepare a series of Bi_2Se_3 thin films of well-controlled composition, thickness and quality, with which he successfully demonstrated the evolution, with the number of atomic layers, of the electronic structure of the two-dimensional surface state of the topological insulator. Through this study, Dr. He and his colleagues clarified the relationships between magnetism, band structure and topological properties in magnetic topological insulators, and accumulated the know-how for tuning the materials parameters for the discovery of the quantum anomalous Hall effect.

In 2013, the quantum anomalous Hall effect was finally observed experimentally in thin films of Cr-doped $(Bi_xSb_{1-x})_2Te_3$ topological insulators by Dr. He and his collaborators. Growth of such four-element thin films, with fine-tuning of materials

parameters for the observation of the quantum anomalous Hall effect, was by far the most difficult part of the research program. Therefore, the contributions of Dr. He were crucial for the successful observation of the quantized anomalous Hall effect. This discovery not only settled the 25-year-long search for the quantum Hall effect without magnetic fields, but also opened the door for many other novel quantum phenomena associated with topological insulator materials. This work represents one of the most important experimental breakthroughs of condensed matter physics in recent years. It is remarkable that this Asian research group has made such an important breakthrough, leading the rapidly developing research field of topological materials. Dr. He played the most crucial role in this outstanding achievement and is well qualified as a recipient of the Nishina Asia Award.

References

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