Report of MERIT (domestic) Internship

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【Implementation period】
1st June 2019 – 30th June 2019

【Host organization】
Strong Correlation Interface Research Group, Strong Correlation Physics Division, Center for Emergent Matter of Science (CEMS), RIKEN
（Senior Research Scientist : Dr. Kei Takahashi）

【Research theme】
Synthesis of the ferromagnetic topological semimetal Fe_3GeTe_2 thin films via molecular-beam epitaxy

【Contents of research】

Topological aspects and related physical properties in quantum matter are one of the most important topics in modern materials science. For example, the correlation between bandstructure topology and magnetism generates large anomalous Hall and magneto-optical effects, leading intensive research in recent years.

I participated in an internship at the Center for Emergent Matter Science (CEMS), RIKEN. The CEMS carries out cutting-edge materials science research toward the realization of harmonious sustainable society. One of the big projects in CEMS is realization of energy-loss free quantum circuits utilizing topological properties in matter. The most important feature of this center is that world-leading scientists gather and closely cooperate. In this internship, I collaborate with the Correlated Interface Research Group, Strong Correlation Physics Division (Group Director: Prof. Masashi Kawasaki) through the Quantum Phase Electronics Center (QPEC) in University of Tokyo.

I successfully synthesized a layered compound Fe_3GeTe_2 by molecular-beam epitaxy. Fe_3GeTe_2 is a ferromagnetic metal with a magnetic transition temperature ~200 K. An important feature is that Fe locates in honeycomb-type structure, which leads to Dirac-type electronic states. Combination between the ferromagnetism and strong spin-orbit coupling generates a large Berry phase (geometrical phase), then a large anomalous Hall effect has been reported in bulk single crystals. The thin film synthesis of this compound paves a way to fabricate various heterostructures and exploration of emergent electrical and optical properties.

The crystallinity and flatness of the Fe_3GeTe_2 thin films are characterized by X-ray diffraction (XRD) and atomic force microscopy, respectively. I found clear XRD peak patterns and smooth topography, indicating the successful high-quality film growth. Further, we measured electrical transport and magnetic properties by using Quantum Design Physical Property Measurement System (PPMS), Magnetic Property Measurement System (MPMS). The obtained properties are consistent with previous reports on bulk single crystals. In addition, I fabricated heterostructures with a typical three-dimensional topological insulator $(Bi,Sb)_2Te_3$ and discuss the interfacial magnetic states.

The successful synthesis of Fe_3GeTe_2 thin films leads to collaboration with Takahashi laboratory in Department of Applied Physics, University of Tokyo for investigation of optical properties. Exploration of such physical properties related to large Berry phase, other than the optical properties, has also been started.

【Acknowledgements】

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