Report of MERIT Long-Term Oversea Dispatch

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This document reports my MERIT long-term oversea dispatch in Max Planck Institute for Solid State Research (Stuttgart, Germany, Fig. 1) from March 11th 2019 to September 11th 2019. During the dispatch I synthesized crystals and thin films of iridates to realize materials with Dirac electrons, an exotic energy structure of conduction electrons in materials.

Fig. 1. Max Planck Institute for Solid State Research.

Research Topic and Background

Dirac electron system is a group of materials whose conduction carriers have a linear energy dispersion. One of famous examples of Dirac electron systems is graphene. Dirac electron systems show extremely higher mobility of their carriers than other ordinary materials, which attracts both scientific and applicational interest. Recently it is also interested as an example of topological materials.

Perovskite-type iridates $A\mathrm{IrO_3}$ (A = Sr, Ca) are candidates of line node semimetals, a kind of Dirac electron systems [1]. It is also known that these materials host relatively large electron correlation effects and turn from a semimetal to an insulator by lowering dimensionality [2]. Therefore, perovskite-type iridates will provide a unique playground to investigate interplays of Dirac electron and correlation.

However, synthesis of high-quality samples of perovskite-type iridates is difficult since the perovskite-type phase is metastable at ambient pressure for both $\mathrm{SrIrO_3}$ and $\mathrm{CaIrO_3}$. No early research on perovskite-type iridates reported transport properties specific for Dirac electron systems before a recent observation of high-mobility carriers in single crystals of $\mathrm{CaIrO_3}$ [3]. I have researched on these materials by making thin film samples. In this dispatch, I also tried high-pressure synthesis of bulk samples in addition to thin film synthesis to realize high-quality samples.

Method of Research

I worked on synthesis of perovskite-type iridates $\mathrm{SrIrO_3}$ and $\mathrm{CaIrO_3}$ by two-way methods:

high-pressure synthesis of bulk and epitaxial film growth by pulsed laser deposition. In bulk synthesis I tried to make single crystalline samples of both $SrIrO_3$ and $CaIrO_3$. In thin film synthesis I optimized substrate and conditions for growth of $SrIrO_3$, which has smaller distortions of crystal structure from cubic perovskite and therefore is supposed to be more advantageous for thin films.

Results of Research

I successfully synthesized single crystalline samples for both $SrIrO_3$ and $CaIrO_3$. About 150 μm-size single crystals of $SrIrO_3$ were obtained (Fig. 2). There was no previous report on single crystal growth of perovskite-type $SrIrO_3$. Therefore, this will be the first realization of perovskite $SrIrO_3$ single crystals. However, electric conductivity measurement of such small crystals was difficult, and evaluation of transport properties remains to be a future task. For $CaIrO_3$ I obtained about 300 μm-size crystals and measured resistivity, which showed signatures of weak localization of carriers at low temperature, different from the previous work on single crystal $CaIrO_3$. To find a cause of this difference is next problem.

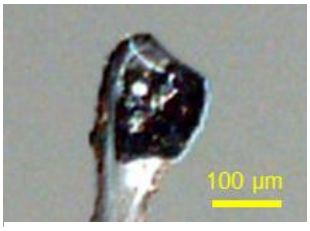

Fig. 2. Single crystal of perovskite-type $SrIrO_3$.

Substrate and growth conditions of $SrIrO_3$ thin film were reoptimized. However, carrier mobility of films was not so improved from the previous samples. It is still unclear whether lower mobility of $SrIrO_3$ comes from some technical problems or a character of $SrIrO_3$ itself, which is future problem to solve.

Conclusion

This oversea dispatch was six month-long, longer than MERIT standard. The long period of the dispatch enabled me to try sample synthesis, which needs long-term research, by two methods, which was very precious experience for me. I successfully grew single crystalline samples and clarified some future problems in research. Therefore, I conclude that the dispatch was a very productive activity for both my research experience and progress.

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