

Activity Report for MERIT Long-Term Overseas Dispatch

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I stayed for research activities from April 12th to June 30th 2015 in Bulk Superconductivity Group (BSG), which is part of Division C (Materials and Mechanics) of the Department of Engineering in University of Cambridge in United Kingdom. This group under the supervision of Professor David Cardwell is working to apply high temperature superconductors.

Problems of my research

The theme of my doctoral thesis is “Enhancement of functionality of REBa₂Cu₃O_y (REBCO; RE = rare earth elements) superconducting bulk magnets”, which I have engaged in since I was an undergraduate. Since REBCO bulks can trap high magnetic fields by flowing superconducting current, they can be applied as strong superconducting magnets, and the enhancement of their critical current densities (J_c) and the increase in their sizes are necessary in order to achieve higher trapped fields. I have established the methods of controlling chemical composition of superconducting matrix and introducing novel flux pinning centers, resulting in improvement of J_c properties in small sample pieces. However, the most important factor for superconducting bulk magnets is trapped fields. I did not have technique of measuring trapped fields at first hand, and so I could only estimate them based on J_c values of small sample pieces. That is why I could not reveal the effect of these methods on the trapped fields.

My motivations for research in BSG

Professor Cardwell is one of the prominent researchers in Europe who works on superconductivity, and BSG is famous for breaking the world record for the value of trapped fields. They are also good at synthesis of high-quality bulks, and so I was interested in integrating my research based on solid state chemistry and their excellent techniques of growth of bulks. I joined this long-term overseas dispatch with following three motivations; (i) synthesis of larger bulks with controlled chemical composition, (ii) learning of the way to measure trapped fields at 77 K and below 60 K, and (iii) analysis of temperature dependence of field trapping properties for samples I prepared in Japan.

BSG's advantages

Only three students are now researching on REBCO bulks in my group, while all the researchers are engaged in this theme in BSG. They have borne much fruit at an unrivaled speed, resulting that Professor Cardwell is called a “paper maker.”

For one thing, there are a wide range of themes about REBCO bulks in BSG such as synthesis,

physical properties evaluation, application to equipment, and so on. Subdivision of themes makes research more effective. Researchers who are engaged in preparing samples can know through discussion in the group what type of samples are on demand for application. When some machinery, instrument and equipment are out of order, Mr. Dennis, a technical officer, can fix them immediately. Furthermore, people who major in mechanics assemble equipment they need. For example, they build up the one for measuring trapped fields at liquid nitrogen temperature, which possesses no fewer than nineteen Hall probes. Our group cannot imitate them because all of us belong to department of applied chemistry. BSG is domestically doing what is called “joint research between different fields” in MERIT.

In addition, the scale of research is large. For instance, it takes ~30 minutes to mix ~10 g of powder materials with mortar and pestle in our group. On the other hand, they mix up to 200 g of powders for two hours using an automatic mixing machine, resulting in increase in the mixture’s homogeneity. There are so many new electrical furnaces for sintering samples. They also kindly purchased a material powder which I needed. I was totally impressed with this excellent research environment.

My research in BSG

Unfortunately, I could not start my research until the end of April because all the electrical furnaces were full. However, I could observe the research of the other theme in BSG during this term. It was a good opportunity because I could understand for the first time how the equipment related to my research is developed.

From the end of April, I started my experiment supervised by Dr. Shi, a senior research associate. As for (i), the basic methods of preparing bulks in BSG were almost the same as ours, but they kindly taught me many keys to success in growth of large single-grain bulks. I could finally success in fabricating four kinds of larger samples (~25 mm ϕ after growth). I also prepared the graded RE-binary-mixed bulk which I had planned to synthesize for two years. I will evaluate their properties in the University of Tokyo.

As for (ii) and (iii), I could not be allowed to use the equipment for measuring trapped fields at lower temperatures because it consumes so much expensive liquid helium. On the other hand, they let me use the one at liquid nitrogen temperature (77 K) for many times. The high-low relation of trapped fields for the samples I prepared in the University of Tokyo was different from my expectation. I had expected that RE-mixed bulks which showed higher J_c would show a great field trapping property, but its trapped field was lowest among them. It was suggested that RE distributions were inhomogeneous in this sample. I will clarify this reason through magnetic measurement of small pieces cut from it.

Professor Cardwell was so busy that I could rarely meet him, but he kindly came once to listen to my presentation in the group meeting. He advised me that my talk was good and I should not be nervous in future, which made me confident in myself.

Communication with foreign students

Not only in BSG but also in the whole of University of Cambridge, there were many students and staffs who were from China, Taiwan and Hong Kong, and so I listened to Chinese rather than English during my stay. I think this situation is owing to the promotion of overseas studies in those countries. On the other hand, I could rarely meet Japanese researchers. It was probably due to the low rate of Japanese students studying abroad.

Of course, I also enjoyed the communication with students from various countries both in the department and in the accommodation. Since I had had few opportunities to speak English in Japan, it was difficult for me to cut into the discussion for the first time. However, every students kindly listened to my English, and so finally I could speak it at my ease. I think this stay was very meaningful because I could understand cultures and creeds of various countries as well as because I could study in BSG.

Acknowledgements

I would like to express my gratitude to all the members of BSG, especially Professor David Cardwell, Dr. Yunhua Shi, and Mr. Anthony Dennis. I am also deeply grateful to Professor Kohji Kishio, Professor Jun-ichi Shimoyama, and MERIT program for giving me this great opportunity.

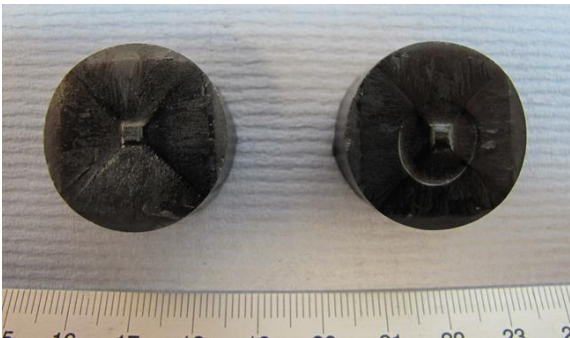


Fig. 1 Top views of samples

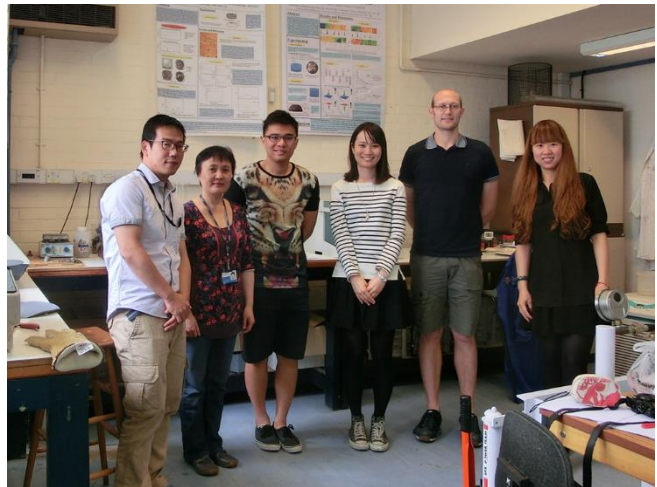


Fig. 2 Members in BSG