Transport property measurements of superconducting wires and tapes and growth of some novel materials in magnetic fields

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1. Background and purpose of proposed research period (12 point times)

Taking into account the close ties between two teams in both countries, the possibility to cooperate and exchange knowledge and practical experience may lead to produce some outstanding results and make both teams competitive in the fields of superconducting materials. Based on this consideration, Prof. Watanabe invited me as a guest professor to stay in IMR for over one month, from 20 Feb. to 31 March, 2010.

2. Proposed plan (12 point times)

The recent discoveries of superconductivity in $LaFeAsO_{1-x}F_x$ (La-1111) and related compounds, with a highest T_c of ~55 K, stimulate worldwide interest in the iron-based system. Based on the potential applications, superconductors typically require stabilization using a normal metal cladding for reasons of electrical, thermal, and mechanical protection and, in general, need to be drawn into fine fibers. In 2008, our group (at IEE, CAS) first fabricated iron pnictide wires by the powder-in-tube method (PIT). A new class of high-T_c iron pnictide composite wires, such as $LaFeAsO_{1-x}F_x$, $SmFeAsO_{1-x}F_x$ and $Sr_{1-x}K_xFeAs$, has been obtained by the in-situ PIT technique. Our work explicitly proves the feasibility of processing pnictide superconductors into a composite wire form which is useful for potential applications.

In order to evaluate these new Fe-based wires and tapes, it is necessary to measure the J_c and the irreversibility field of the samples, which is quite important for us to know whether pnictide is appropriate for potential applications. We expected that transport measurements in higher fields on pnictide samples would provide additional useful information for understanding the weak-link behavior of pnictides.

In addition, one effective method of aligning grains is to apply a large magnetic field during phase formation or sintering. Magnetic field induced texture in superconducting materials results from the anisotropy in the paramagnetic susceptibility. In this sense, growth of some new materials such as $BiFeO_3$ or MgB_2 samples under magnetic fields will be performed, in order to evaluate a magnetic field effects. On the other hand, if an X-ray diffraction experiment can be easily carried out in a high magnetic field, much useful information on the crystal structure change in fields will be obtained directly, and this seems to be important to gain profound understanding of the origin of the structural transition of iron pnictides. These considerations motivate me to investigate their structural transition behavior utilizing a low temperature X-ray diffraction apparatus in high magnetic fields.

3. Results and discussions(12 point times)

During my staying, I have done a lot of research work with the great help from the staffs at HFLSM, as listed below: i) By utilizing the High Field Low Temperature XRD apparatus, I performed the x-ray diffraction measurements for new iron based 122 type superconductor powders over a wide temperature range (room temperature ~RT to 10 K) and in fields up to 5 T, which might enable us to gain profound understanding of the origin of the superconductivity of HTS. ii) In order to characterize transport properties of iron pnictide and MgB_2 wire and tapes, I have carried out the Ic measurements by using the novel 18T CSM magnet. iii) At the same time, I have also performed the high field heat treatments for some new magnetic materials, by using the 10T CSM magnet system. Some positive results are listed below, which will be published soon.

(i) Having measured transport Ic values of Nd_2O_3 doped MgB_2 tapes with different doping levels. It is found that compared to the undoped tapes, the critical current density J_c of the doped samples was effectively improved in high magnetic fields, as shown in Figure 1. In the field of 10T and 12T, the J_c (4.2K) of 5 at.% doped samples reached 2.46×10^3 A/cm^2 and 5.27×10^2 A/cm^2, which was about twice and three times as high as the pure samples, respectively.

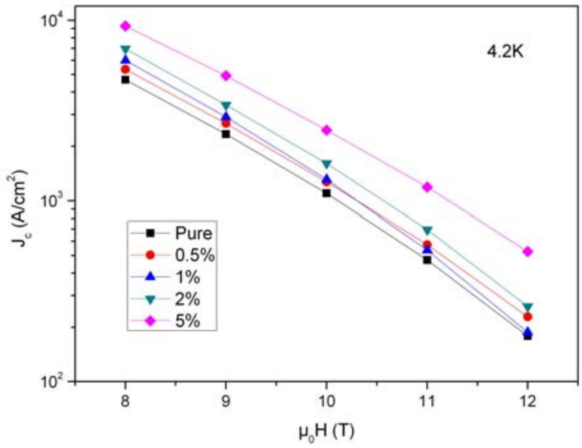

Fig. 1. Magnetic field dependent transport critical current density of pure and doped tapes at 4.2K. The applied field is parallel to the tape surface in the measurement.

(ii) Having also performed the I_c-B measurements for Ag-sheathed SmFeAsO (Sm-1111) superconducting tapes. Figure 2 presents the transport critical current density J_c as a function of field for $SmFeAsO_{0.8}F_{0.2}$ tapes synthesized at 900°C. Clearly, a transport J_c as high as ~2700 A/cm^2 at 4.2 K and self-field has been observed. In the high field region, the J_c is almost field independent, constant at ~180 A/cm^2. Although the transport critical current density J_c in the superconducting wires is limited by the weak links between grains, higher J_c values could be expected in pure and textured materials, which is the on-going research.

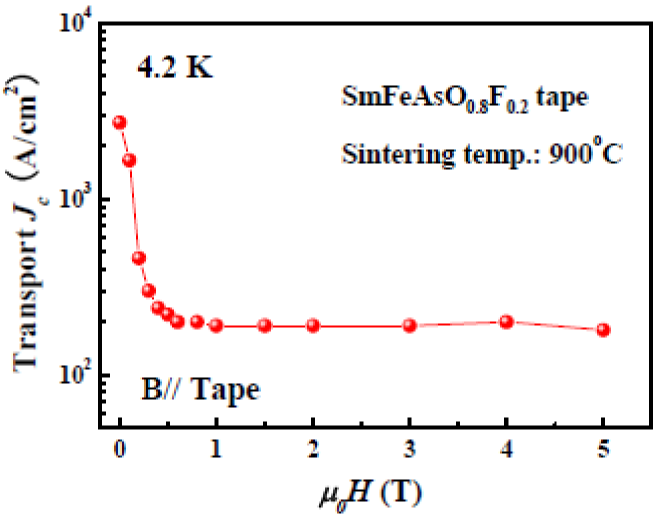

Fig. 2. Transport critical current density J_c at 4.2 K as a function of field for $SmFeAsO_{0.8}F_{0.2}$ tapes heat-treated at 900°C.

(iii) Having studied the effect of magnetic annealing on multiferroic properties of $BiFeO_3$ and $Bi_{0.8}La_{0.2}FeO_3$ ceramics. It was found that the ferroelectric and dielectric properties of BF and BLF ceramics were both enhanced greatly by magnetic annealing. When $BiFeO_3$ and $Bi_{0.8}La_{0.2}FeO_3$ were processed under a magnetic field of 10 T, the obtained remnant polarization and maximum spontaneous polarization values are about two times as large as that for the samples fabricated at 0T, and the relative dielectric constant were improved by 9.55% and 11.65% for BF and BLF ceramics, respectively.

4. Summary and perspective (12 point times)

Thanks to the support from the ICC-IMR, I came to IMR as a guest professor for cooperation work for over one month. Most importantly, we have obtained some very positive and important experimental results in developing MgB_2 and pnictide superconductors, as well as improving the properties of new materials by using high field heat treatment equipments. I expect I may have another chance in the future to visit the IMR again.