Project No : 2008ICC-PROJECT-05

Improvements and magnetic field heat-treatment of new superconducting wires and ferromagnetic materials

Yanwei Ma (IEE, Chinese Academy of Science, Chine)
Satoshi Awaji (HFLSM, IMR, Tohoku University, Japan)

Through the support from the International Cooperation Project between China and Japan, 5 persons, including 3 staffs and one student from Chinese team have visited HFLSM for collaboration work. Thanks to the project, we have made some great progresses in developing high perform MgB_2 and pnictide superconductors, as well as improving the properties of new materials by using high field heat treatment equipments. Detailed achievements are listed below:

1. Significant improvement of critical current densities in MgB_2 tapes by the chemical doping method

Based on the mechanism analysis of nano-C and SiC powder doping, we studied the co-doping effect of nano-C and SiC powder to MgB_2 tapes by using some organic dopants such as Phthalocyanine, acetone, $C_9H_{11}NO$ and so on. It's found that the critical current density under high-field MgB_2 has been effectively increased compared to those of C or SiC doping. At the same time, the optimal sintering temperature was decreased to 800^{o}C. The large amounts of grain boundaries as well as the effective C substitutions are thought as the main reasons. For example, a significant J_c improvement at both 4.2K and 20K has been achieved in MgB_2 tapes using $C_9H_{11}NO$ as dopant. $C_9H_{11}NO$ doping will cause a small depression in T_c, while the J_c and H_{c2} values are strongly enhanced. The highest J_c was obtained in $C_9H_{11}NO$-doped sample sintered at 800°C, which was 3.7×10^4A/cm^2 at 4.2K, 10T. This is the highest J_c values in MgB_2 tapes using carbohydrates as doping materials. Moreover, at 20K, 5T, a transport J_c value as high as 1.9×10^4A/cm^2 is observed, suggesting that MgB_2 are promising for practical applications. Besides the improvement of grain linkages, the clearly enhanced H_{c2} is thought as the main reason for the prominent J_c performance in field in $C_9H_{11}NO$ doped MgB_2 samples.

2. Breakthrough of large transport critical currents achieved in new iron-based superconducting wires and tapes

The 122-type iron-based superconductors, such as SrKFeAs, have a low sintering temperature and a simple structure, no oxygen element containing. We successfully fabricated SrKFeAs superconducting wires using PIT method and studied it's properties in 2009. It's found that the transition temperature of these wires were around 35 K, while the upper critical field were over 140 T, indicating a very promising practical application of these wires. In October, 2009, we obtained a high transport critical currents (up to 40 A) in Iron-based superconducting wires using a four-probe method. This is the highest transport I_c obtained in Iron-based superconducting wires. It is a breakthrough progress and has significant meaning from the application point.

3. Improved properties in several function materials under magnetic fields

Using magnetic field heat treatment process, magnetism and ferroelectricity at room temperature were simultaneously improved in $BiFeO_3$ materials. This is the first report on this phenomenon in the word. The possible enhancement mechanism may be the greater magnetic anisotropy induced by magnetic field annealing, or the magnetic structure was further modulated by the magnetic field based on the small size effect on magnetism.

By the way, we found that magnetic field processing leads to the formation of γ-Fe_2O_3 phases in the microspheres when a magnetic field of 12 T was applied during the annealing of amorphous α-Fe_2O_3 microspheres, and the field-treated microspheres exhibit typical room-temperature ferromagnetic behavior, whereas non-field-heated sample presents paramagnetism. The improvement in magnetic properties is considered to be a result of magnetic field-induced transformation from α-Fe_2O_3 to γ-Fe_2O_3.

Related paper published in 2009-2010

1. Lei Wang, Yanpeng Qi, Dongliang Wang, Xianping Zhang, Zhaoshun Gao, Zhiyu Zhang, Yanwei Ma, Satoshi Awaji, Gen Nishijima, and Kazuo Watanabe, " Large transport critical currents of powder-in-tube $Sr_{0.6}K_{0.4}Fe_2As_2$ / Ag superconducting wires and tapes", *Physica C* 470 (2010) 183-186.
2. Xianping Zhang, Dongliang Wang, Zhaoshun Gao, Lei Wang, Yanpeng Qi, Zhiyu Zhang,Yanwei Ma, Satoshi Awaji, Gen Nishijima, Kazuo Watanabe, Eric Mossang, Xavier Chaud, "A special carbohydrate $C_9H_{11}NO$ doping to improve the Jc-B properties of MgB_2 tapes", *Supercond. Sci. Technol.* 23 (2010) 025024.
3. Xianping Zhang, Yanwei Ma, Dongliang Wang, Zhaoshun Gao, Lei Wang, Yanpeng Qi Satoshi Awaji, Kazuo Watanabe, and Dongning Zheng, Co-Doping Effect of Nanoscale C and SiC on MgB_2 Superconductor, *IEEE Transactions on Applied Superconductivity*, 19 (2009) 2694.
4. Xianping Zhang, Yanwei Ma, Dongliang Wang, Zhaoshun Gao, Lei Wang, Yanpeng Qi, Satoshi Awaji, Kazuo Watanabe, Eric Mossang, "Phthalocyanine doping to improve critical current densities of MgB_2 tapes", *Supercond. Sci. Technol.* 22 (2009) 045019.
5. Dongliang Wang, Xianping Zhang, Zhaoshun Gao, Lei Wang, Yanwei Ma, Satoshi Awaji, Gen Nishijima, Kazuo Watanabe, E. Mossang, Effect of processing temperature on the superconducting properties of acetone doped MgB_2 tapes, *Physica C* 469 (2009) 23-26.
6. Dongliang Wang, Yanwei Ma, Zhaoshun Gao, Xianping Zhang, Lei Wang, Eric Mossang, Gen Nishijima, Satoshi Awaji, and KazuoWatanabe, Enhancement of the High-Field Jc properties of MgB_2/Fe Tapes by Acetone Doping, *J Supercond Nov Magn*, 22 (2009) 671–676.
7. Wang Junhong, Wang Lei, Yu Peng, Wang Dongliang, Ma Yanwei, Watanabe Kazuo, Magnetic field-induced ferromagnetism in iron oxide microspheres, J. Magn. Magn. Mater., 321 (2009) 3411.