SUPERCONDUCTING AND TRANSPORT PROPERTIES OF FeF_2 ADDED $YBa_2Cu_3O_{7-\delta}$ SUPERCONDUCTOR

Kong Wei[1], Kong Ing[2] and R. Abd-Shukor[2]

[1]School of Applied Science and Foundation, Kuala Lumpur Infrastructure University College, Unipark Suria, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia.

[2]School of Applied Physics, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia.

Introduction

The $YBa_2Cu_3O_{7-\delta}$ (YBCO) superconductors have been studied extensively for its various practical applications. It is necessary to obtain high transport critical current density (J_c) of this compound. Several methods have been employed to enhance the superconducting and transport properties, including rare earth elements substitutions and magnetic impurities additions. A strong interaction between flux line network and magnetic texture can be expected if the magnetic impurities have the same order magnitude with the flux line network [1]. The increase in Fe substitution at Cu sites resulted in the decrease the superconducting transition temperature of YBCO [2-5]. The reduction in T_c was also observed in Zn-doped and Co-doped YBCO [5-6]. The Fe_2O_3 nanoparticles deposited on YBCO thin film also lowered the T_c and J_c [7]. The T_c of nano Al_2O_3-added YBCO remained almost unchanged while the J_c and J_c-B behavior was remarkably improved with 0.01 wt.% of nano Al_2O_3 [8]. Magnetic impurities generally suppress the superconductivity. In this work, we study the effect of FeF_2 additions in YBCO on the superconducting and transport properties.

Experimental

The $YBa_2Cu_3O_{7-\delta}$ superconductor powders were prepared by solid state reaction of high purity Y_2O_3, BaO and CuO powders. The mixed oxides powders were ground and followed by sintering in air at 900 ºC 24 hours. FeF_2 was added to the YBCO powders with amounts of 0.01 to 0.10 wt.%. Powders were then pressed into pellets with 13 mm diameter and 2 mm thickness and sintered at 900 ºC 24 hours. Pure YBCO pellet was prepared for comparison. Because FeF_2 is anhydrous, the mixing and preparation was done in helium gas environment.

The electrical resistance-temperature measurements were carried out by the four-point probe technique in conjunction with a CTI cryogenics closed-cycle refrigerator. The transport critical current density was measured on bar-shaped samples at 77 K using the 1 μV/cm criterion.

A vibrating sample magnetometer (VSM) by Model VSM LDJ 9600 was used to measure the magnetization loop at 77 K with the magnetic field parallel to the c axis of the specimen. The measurements were carried out in a maximum external field of 12 kOe. The XRD patterns of the samples were recorded using a Siemens D 5000 diffractometer with CuK_α radiation.

Result and Discussion

The lattice parameters of the pure YBCO are a = 3.822 Å, b = 3.885 Å and c = 11.672 Å. All of the FeF_2-added samples showed no systematic variation in the lattice parameters with respect to the pure sample. This result indicates that FeF_2 most probably does not enter the YBCO crystal structure. Figure 1 shows the curves of electrical resistance versus temperature for pure and FeF_2-added samples. Figure 2 shows the curve of critical current density versus the amount of FeF_2 additions. The temperature where the resistance begins to show a sudden drop ($T_{c\text{-}onset}$), the zero resistance temperature ($T_{c\text{-}zero}$), transition width (ΔT_c) and critical current density (J_c) were shown in Table 1.

Table 1 The transition temperature and transport properties of pure and added samples.

x (wt.%)	$T_{c\text{-}onset}$ (K)	$T_{c\text{-}zero}$ (K)	ΔT_c (K)	J_c (mA/cm^2)
0	88	80	8	7
0.01	92	86	6	16
0.03	92	87	5	950
0.05	89	81	8	711
0.07	88	78	10	625
0.10	88	77	11	420

Sample added with 0.03 wt.% FeF_2 shows the highest T_c and J_c. A small amount of magnetic particles optimized the superconducting and current carrying

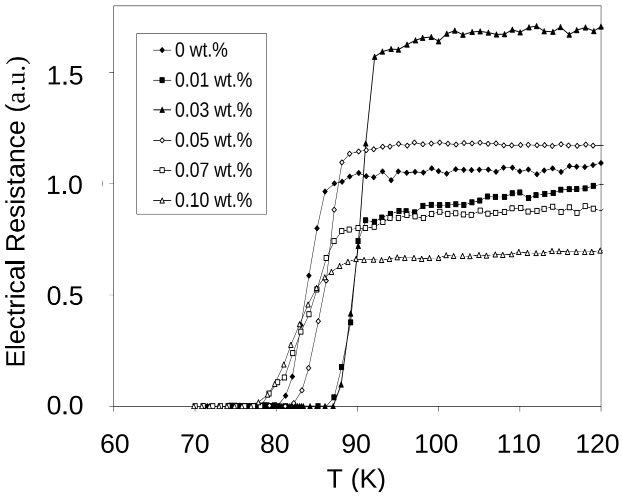

Fig. 1 Electrical resistance versus temperature curves for pure and FeF_2-added samples.

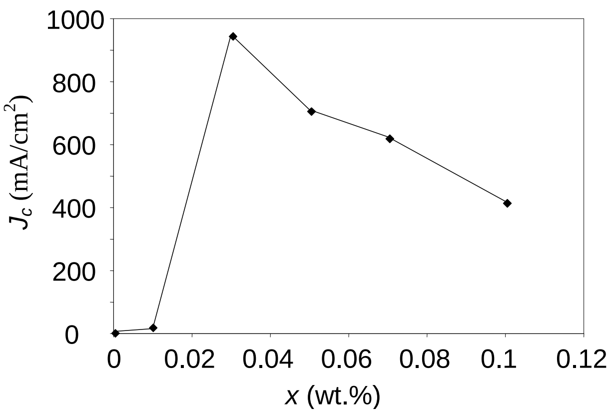

Fig. 2 Critical current density (J_c) versus amount of FeF_2 additions.

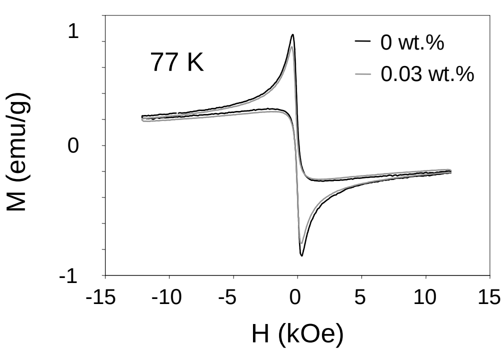

Fig. 3 Magnetization hysteresis loops at 77 K for pure and 0.03 wt.% FeF_2-added samples.

properties of bulk YBCO. The excessive addition of FeF_2 (> 0.03 wt.%) suppressed the T_c and J_c. However, all the added samples still showed an enhanced J_c at 77 K compared to the pure sample. Figure 3 shows the magnetization hysteresis loops at 77 K for pure and 0.03 wt.% FeF_2-added samples. The samples showed a normal state magnetization at 300 K. At 77 K, both samples exhibited a significant perfect diamagnetism curves. The additions of FeF_2 as magnetic impurities do not affect the diamagnetic behavior of YBCO at low temperature.

Conclusion

FeF_2 as a magnetic impurity in small amounts does not affect the electric and magnetic properties of superconductors YBCO. In contrast, a small amount of FeF_2 improved the superconducting and transport properties of YBCO. Excessive FeF_2 addition leads to a degradation in T_c and J_c.

References

1. Lyuksyutov, I. F. and Naugle, D. G. Frozen Flux Superconductors. *Proc. of SPIE*, **4058** (1999) 376-386.
2. Yao, X., Oka, A., Izumi, T. and Shiohara, Y. Crystal Growth and Superconductivity of Fe-doped YBCO Single Crystals. *Physica C*, **339** (2000) 99-105.
3. Alfred-Duplan, C., Marfaing, J., Vacquier, G., Benlhachemi, A., Musso, J. and Gavarri, J. R. Sintering Effects in Superconducting Fe-based YBCO Composites: Simulation of Electrical Resistances at Low Temperature. *Mater. Sci. Eng. B*, **39** (1996) 1-7.
4. Hasan, M. K. and Kouvel, J. S. Changes in Vortex Pinning Produces by Fe Doping of Polycrytalline YBCO. *Physica C*, **355** (2001) 307-311.
5. Licci, F. and Raffo, L. Interplay of Electronic and Structural Features in Zn- and Fe-doped YBCO. *Supercond. Sci. Technol.*, **8** (1995) 245-251.
6. Liu, L., Dong, C., Zhang, J. and Li. J. The Microstructure study of Co-doped YBCO System. *Physica C*, **377** (2002) 348-356.
7. Wang, J., Tsai, C. F., Naugle, D. G and Wang, H. Microstructural and Pinning Properties of $YBa_2Cu_3O_{7-\delta}$ Thin Film Doped with Magnetic Nanoparticles. *Proc. of ESNF*, **7** (2009).
8. Moutalibi, N. and M'chirgui, A. Improved Flux Pinning Behavior in Bulk YBCO Achieved by Nano-Alumina Addition. *J. Appl. Phys.*, **97** (2008) 012284-1-012284-6.