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ScienceDirect
Physica C 460–462 (2007) 1192–1193
PHYSICA C
www.elsevier.com/locate/physc

Enhancement of pinning in cerium doped $Y_{(1-x)}Ce_xBa_2Cu_3O_7$ HTSC

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Available online 12 April 2007

Abstract

To test the pinning force in high-temperature superconductors with minor doping, the $Y_{(1-x)}Ce_xBa_2Cu_3O_7$ system has been synthesized. Temperature dependence of magnetization has been determined. The difference of diamagnetic responses M(zfc) − M(fc) is non-monotonic. It has a peak at a concentration value $x = 0.0156$, which corresponds to the most probable distance between cerium ions equal to eight lattice constants in the a–b plane and close to the diameter of vortices.

Keywords: HTSC; YBCO; Ce doped; Flux pinning

1. Introduction

The critical current of high-temperature superconductors depends on pinning of the magnetic flux. There exist several methods of the pinning enhancement in HTSC. The effect of chemical substitution on the properties of high-temperature superconductors has been widely investigated. Substitution of rare earth atoms for yttrium ones has been investigated usually at high concentrations. For a better understanding of pinning in HTSC, the influence of small concentrations of doping atoms should be considered. In particular, we have studied the $Y_{(1-x)}$-$RE_xBa_2Cu_3O_7$ systems, where RE is the rare earth elements, which either do not form the 123 structure (e.g. Ce that is more stable in a tetravalent state and does not form the superconducting 123 structure [1]) or form it very hard. The present paper reports the preparation method and magnetic measurements of the $Y_{(1-x)}Ce_xBa_2Cu_3O_7$ compounds with $x = 1/n^2$, where $n = 2, 3, 4, 5, 6, 7, 8, 9, 10, \infty$ is the average distance between Ce atoms in units of a lattice constant in the a–b plane (Fig. 1).

2. Experimental

$Y_{(1-x)}Ce_xBa_2Cu_3O_7$ samples with $x = 0.25$, 0.11, 0.0625, 0.04, 0.0278, 0.0204, 0.0156, 0.0123, 0.01 and 0 were prepared by the standard solid-state reaction technique. Y_2O_3, CeO_2, $BaCO_3$ and CuO, each of 99.99% purity, were used as precursors. The mixtures were pressed into pellets. The pellets were annealed in air atmosphere at 930 °C for 160 h with seven intermediate grindings. X-ray diffraction measurements on the samples with $x = 0.25$, 0.11 and 0.0625, were performed. The relative intensities of the foreign phase ($BaCeO_3$) peaks were equal to 36%, 15% and 5%, respectively. A solubility level of Ce was estimated by the linear extrapolation of $BaCeO_3$ peaks intensities. In the 123 structure it appeared equal to 2.4 at.%.

Temperature dependence of magnetization $M(T)$ was obtained with a vibrating sample magnetometer. The specimens were cylinders with a height and diameter of about 5 mm and 0.5 mm, respectively. The magnetic field of 100 Oe was applied parallel to the axis of symmetry of the cylindrical samples. Magnetic measurements were

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doi:10.1016/j.physc.2007.04.046

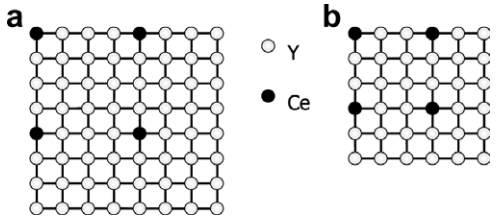

Fig. 1. A perfect lattice in the plane of rare earth elements in the 123 structure for $n = 4$ (a) and $n = 3$ (b).

performed under the zero-field-cooled (zfc) and field-cooled (fc) conditions.

3. Results and discussion

Typical temperature dependences of magnetization $M(T)$ obtained in the zero-field-cooled (zfc) and field-cooled (fc) regimes are shown in Fig. 2. As is known, the pinning potential is proportional to the difference of diamagnetic responses $dM = M(\text{fc}) - M(\text{zfc})$. Fig. 3 shows the difference dM as a function of n ($x = 1/n^2$). This dependence has a peak at $n = 8$ ($x = 0.0156$), which corresponds to the average distance between cerium ions of about eight units of a lattice constant in the a–b plane (30 Å).

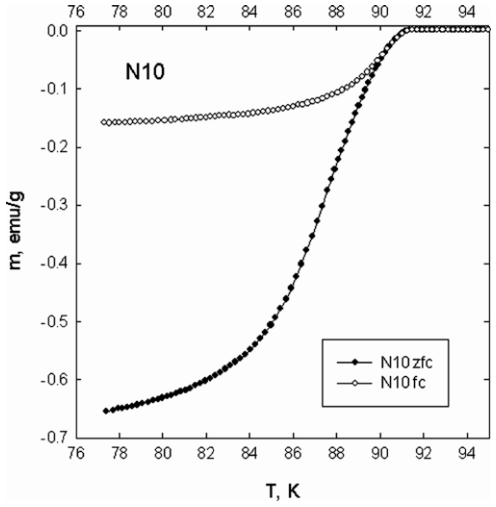

Fig. 2. Temperature dependence of magnetization $M(T)$ of sample $Y_{0.99}Ce_{0.01}Ba_2Cu_3O_7$ measured under zero-field-cooled (zfc) and field-cooled (fc) conditions.

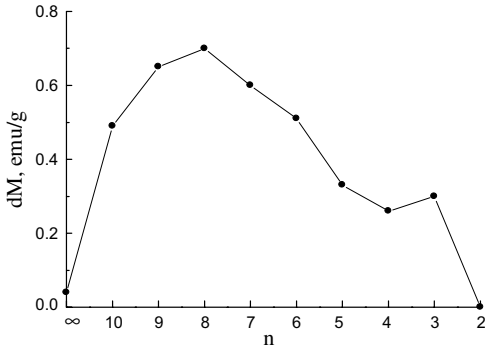

Fig. 3. The dependence of $dM = M(\text{fc}) - M(\text{zfc})$ at 77.4 K versus cerium content, $x = 1/n^2$.

The coherence length ξ in YBCO lies within the region of 10–30 Å [2]. Thus, the experimental data obtained demonstrate that the intragrain pinning in HTSC with the 123 structure is maximal when the most probable distance between pinning centers is equal to $\sim 2\xi$, i.e. to the vortex diameter.

Acknowledgments

This study was supported by the Quantum Macrophysics Program of RAS No. 3.4, the Integration Program of SB RAS 3.4, the Lavrent'ev Competition of Young Scientist, Projects SB RAS No. 52.

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