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Effects of x in $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ samples on c-lattice parameter, activation energy and its magnetic power constant

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Abstract

The $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ superconducting samples (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) which were prepared by solid-state reaction technique were studied to investigate the effect of x on c-lattice parameter, the activation energy, and the magnetic power constant of activation energy. c-Lattice parameters of the samples were calculated using XRD data and the activation energies of samples using the Arrhenius activation energy law were determined from the resistivity curves, obtained under six different magnetic fields up to 5 T in the range of temperature from 70 to 100 K steps by 0.25 K under zero cooling regime. The magnetic power constants of activation energies of the samples under different magnetic fields were calculated. The results showed that the value of c-lattice parameter is proportional to the size of ionic radius of atom, replaced by Yb in Yb123 structure. With increasing the x ratio, the activation energy and its magnetic power constant decreased and c-lattice parameter increased almost linearly. It is well known that when the magnetic field increases, activation energy of superconductor samples decreases. The control of activation energy of $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ sample using by x value and applied magnetic field can be useful in technical applications in superconductivity industry.

Keywords: Yb123; Gd123; Y123; RE123; (Yb,Gd)123; Activation energy; Magnetic power constant; Resistivity

1. Introduction

Since the discovery of $YBa_2Cu_3O_7$ (Y123) superconductors [1], well oriented bulk YBaCuO superconductors of which the critical current density (J_c) has approached to 10^5 A/cm^2 in zero magnetic field at 77 K [5] have been produced by many researchers [2–4]. In order to find an oxide superconductor with higher critical current density (J_c), some scientists [6,19] substituted almost all the rare-earth metals instead of yttrium (Y) in YBaCuO compound. It is known that rare-earth elements such as R = Gd, Nd, Yb, Sm, Eu, Dy, Ho, Er, etc. with the identical crystal structure can be replaced into Y site in Y123 structure. However, the difference in the ionic radii of R ions possibly introduces the differences in the electronic state in CuO_2 plane in Gd123 structure and affects the transition temperature T_c [7] and the temperature range of the transition (ΔT_c) from normal state to superconductivity. One of the origins of the changing ΔT_c is the activation energy that is the pinning potential barrier in the structure of superconductor, and it is well described by the thermally activated flux flow (TAFF) [8].

In this paper, we have studied the measurement of the broadening of resistive transitions due to thermally activated flux motion under the different magnetic fields in six samples of nominal composition $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0). Thanks to the measured resistive transition under various applied magnetic fields, the effect of the x ratio on activation energy and its magnetic power constant was well described by using TAFF model. In addition, the effect of x on the c-lattice parameter was examined. Although numerous studies have been undertaken on Yb123 and Gd123, no studies on the effect of x on the activation energy of $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ polycrystalline samples have been reported.

2. Experimental

The polycrystalline $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ ((Yb,Gd)123) samples were produced by solid-state reaction method for the six different x values. After stoichiometric mixtures of Yb_2O_3, Gd_2O_3 $BaCO_3$ and CuO for each compo-

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sition of x were thoroughly ground and calcined at 900 °C in air for 10 h, the mixtures were ground again, and pressed into a pellet form with 13 mm diameter under 250 MPa pressure, and then the samples for $x = 0$, 0.2, 0.4, 0.6, 0.8 and 1, respectively, were sintered at 890 °C for 24 h in air. Finally, all the samples together were subjected to oxygenation process at 400 °C for 2 h, followed to 300 °C at the rate of 1 °C/min under the flowing of oxygen and then they were cooled to the room temperatures in air. Samples were cut into bar-shape with identical dimensions with the size of 1.5 mm × 2.0 mm × 6.0 mm. The sintering and oxygenation temperatures of the samples were obtained from the differential thermal analysis (DTA) model NETZSCH1.

X-ray diffraction (XRD) studies were carried out in Rigaku D/Max-IIIC polycrystal diffractometer with Cu Kα X-ray radiation. The rate of the scan and the 2θ step scan mode were fixed to 5°/min and 0.02°, respectively. The data were collected over 2θ range from 20° to 60°.

The standard four-probe resistivity of samples were measured by using a physical properties measurement system (Quantum Design PPMS system) under various magnetic fields such as 0–5 T in the zero field cooling regime (ZFC). In order to remove the trapped magnetic field inside the samples, a 0.1 T magnetic field was applied for a short time at 100 K and then decreased to zero field before ZFC regime.

3. Results and discussions

In order to see the solid-state phase transformation and determine the process temperatures, DTA measurements were performed for all samples. Fig. 1 shows the results of DTA analysis for samples. It is clearly seen that an exothermic peak at around 300–400 °C and two endothermic peaks at around 793 and 970 °C were observed for all samples. It is believed that the peak at around 300–400 °C corresponds to the oxygen absorption and releasing temperature. It also can be seen that the peak intensity and the size for the samples with higher x value were decreasing. The endothermic peaks correspond to the formation of liquid phase to form superconductivity and the peritectic temperature of $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$. Consequently, from Fig. 1, the optimal sintering temperature for all the samples was chosen to be 890 °C.

The X-ray diffraction patterns of the samples were shown in Fig. 2. It was observed from the patterns that the samples were grown as a polycrystalline structure and there is no preferential orientation in the whole sample and the peaks observed are belong to typical polycrystalline Y123 phase. The peak of the $BaCuO_2$ was seen in very low intensity only at sample of $x = 0.0$. The c-lattice parameter and its error were calculated for each sample using least square refinement method. The variation of c-lattice parameter versus x is shown in Fig. 3. The c-lattice parameter value of the sample $x = 1.0$, Gd123, is found to be 11.694 Å which is in good agreement with reported values that is theoretically 11.707 Å in Ref. [9] and also is experi-

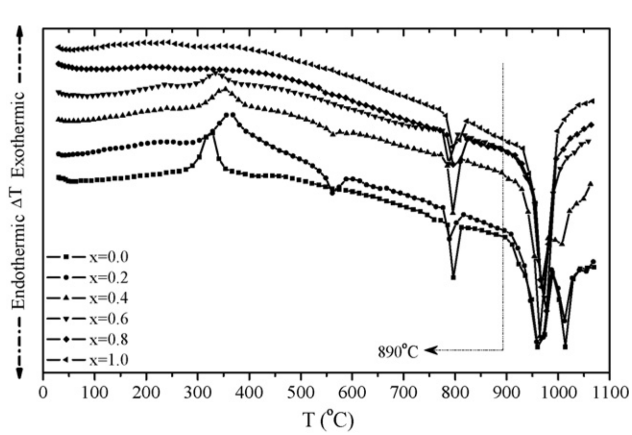

Fig. 1. DTA curves of samples $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$.

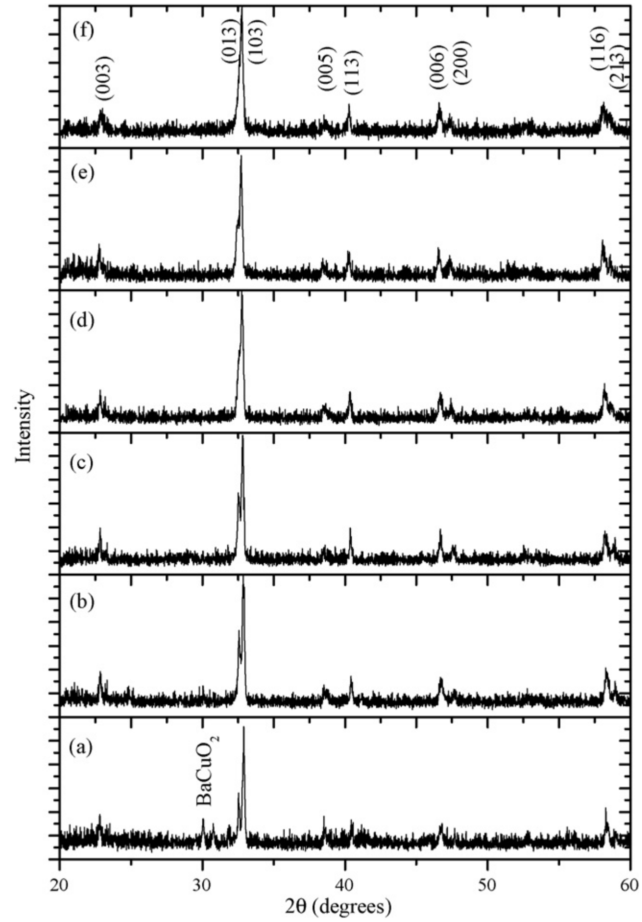

Fig. 2. XRD patterns for the nominal compositions of $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ with (a) $x = 0.0$, (b) $x = 0.2$, (c) $x = 0.4$, (d) $x = 0.6$, (e) $x = 0.8$ and (f) $x = 1.0$ polycrystalline samples.

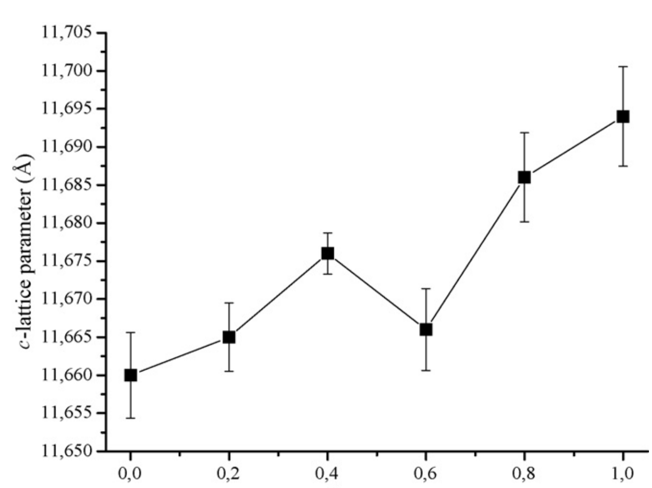

Fig. 3. c-Lattice lattice parameter of the samples vs. x in $Yb_{1-x}Gd_xBa_2Cu_3O_{7-y}$ superconductor samples.