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ScienceDirect

Physics Procedia 81 (2016) 37 – 40

Physics Procedia

28th International Symposium on Superconductivity, ISS 2015, November 16-18, 2015, Tokyo, Japan

Effect of Pr Additions to Li-doped Bi2212 Bulk Superconductors Sintered at Low Temperature

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Abstract

The physical properties study of the $Bi_2Sr_2CaCu_2O_y$ (Bi2212) ceramics samples sintered at low temperature has been carried out by measurement of electrical resistance and powder X-ray diffraction (XRD). The effects of Pr doping on the formation process of the Bi2212 phase, and its structural and superconducting features were studied. The samples were prepared by a solid-state reaction method from oxides and carbonate powders. The samples with nominal composition $Bi_{2.12}Sr_{1.90}Ca_{1.02}Cu_{1.96}Li_{0.15}Cl_{0.15}O_y$ added with praseodymium oxide (Pr_2O_3) were sintered in air at 710°C. The Pr_2O_3 addition ranging between 0.1mass% and 1.2mass% promotes the formation of the Bi2212 phase in low temperature synthesis. The full-width at half maximum (FWHM) value of the (200) and (00<u>10</u>) XRD peaks is slightly decreasing in the samples for low level doping and reaches a minimum around 0.6mass%. The maximum zero resistance temperature (T_c) is observed at 82.5K for the sample with 0.6mass% Pr_2O_3 addition by sintering even at 710°C, which is about 150°C lower than that of the non-added Bi2212 phase.

Keywords: Low temperature synthesis; Bi2212 bulk superconductor; $LiClO_4$ and Pr_2O_3 addition; Zero resistance

1. Introduction

The $Bi_2Sr_2CaCu_2O_y$ (Bi2212) superconductor is known to be one of the most stable compounds among the copper oxide-based high-T_c superconductors. In the last 25 years, chemical substitution and/or addition to the Bi2212 superconductors has been widely studied, because it is expected to improve its superconducting properties and to

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doi:10.1016/j.phpro.2016.04.016

influence its formation processes. It has been revealed that the addition of some elements, Li, Cl and Pr to Bi2212 system enhances Bi2212 phase formation and superconducting properties [1-6]. In general, lower temperature synthesis is desirable for commercial production of this important material. Noro et al. [2] reported that the X-ray diffraction (XRD) pattern of $Bi_{2.12}Sr_{1.90}Ca_{1.02}Cu_{1.96}Li_{0.15}Cl_{0.15}O_y$ compounds sintered at 720°C shows the predominance of the Bi2212 phase. Then, the zero resistance of the sample is observed at 78K. Aloysius et al. [6] reported that the critical current density (J_c) and the zero resistance temperature (T_c) of the (Bi, Pb)-2212 system is highly enhanced upon the addition of Pr. However, no further studies have yet been made to clarify the effect of Pr addition on the physical properties of Bi2212 bulk samples sintered at low temperature. In this work, we study the effect of Pr additions on the T_c and the full-width at half maximum (FWHM) values of the (200) and (00<u>10</u>) XRD peaks for Bi2212 bulk samples sintered at low temperature, in comparison with that of non-added sample.

2. Experimental

The Bi2212 bulk samples were prepared by a conventional solid-state reaction with a nominal composition of $Bi_{2.12}Sr_{1.90}Ca_{1.02}Cu_{1.96}Li_{0.15}Cl_{0.15}O_y$ [7]. Raw materials of $SrCO_3$ (99.9%), $CaCO_3$ (99.9%) and CuO(99.9%) were mixed and calcined twice at 950°C for 20h in air. After grinding, the calcined powder was mixed with Bi_2O_3 (99.9%), $LiClO_4$ (98.0%) and various amounts of Pr_2O_3 (99.9%). The mixtures were pelletized using a cylindrical die of 13mm diameter under a force of 30 kN. The Pr added samples were sintered at T_s=710°C for 100h in air. The sintering temperatures of other samples were described later. Finally, the samples were annealed at 700°C for 20h and rapidly quenched in liquid nitrogen, to ensure optimum value of the oxygen concentration. All the products were examined at room temperature by powder XRD using Cu-Kα radiation (Rigaku Ultima IV). The measurements were carried out with the θ-2θ scanning method in the range of 2θ = 20-65°. The chemical compositions of the sample were measured by wavelength-dispersive X-ray fluorescence spectrometry (WDXRF; Rigaku ZSX-Primus III). The electrical resistance R was measured by a standard DC four-probe method at temperatures between 50 and 290K.

3. Results and discussion

3.1. Effect of $LiClO_4$ and Pr_2O_3 addition

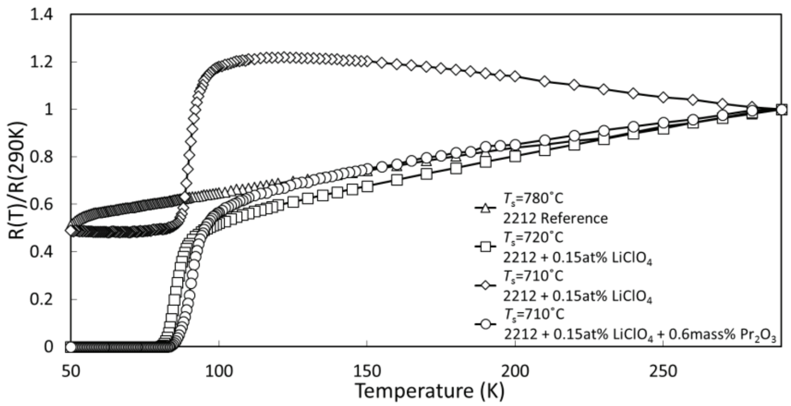

Fig. 1. Temperature dependence of the normalized resistance R(T)/R(290K) for 0.15at% $LiClO_4$ and 0.6mass% Pr_2O_3 added sample sintered at 710°C, 0.15at% $LiClO_4$ added samples sintered at 710 and 720°C, and reference (non-added) sample sintered at 780°C.

A comparison of the R-T behavior of $LiClO_4$ and Pr_2O_3 added sample, $LiClO_4$ added sample and non-added sample is shown in Fig. 1. The T_c (R=0) value is 82.5K for $LiClO_4$ and Pr_2O_3 added sample sintered at T_s=710°C. In addition, the T_c value is 78K for $LiClO_4$ added sample sintered at T_s=720°C. On the other hand, zero resistance is not observed above 50K and the resistance variation is found to be non-metallic from room temperature down to