Abstract

Superconducting samples of type Bi\textsubscript{1.8}Pb\textsubscript{0.4}Sr\textsubscript{2}Ca\textsubscript{2}Cu\textsubscript{3}O\textsubscript{10+δ} added with nano-Ag, nano-ZnO and nano-Fe\textsubscript{2}O\textsubscript{3}, respectively, were prepared by a solid-state reaction technique. The concentrations of nano-materials were 0.0, 0.2, 0.4, 0.6, 1.0 and 1.5 wt. % of the sample total mass. The prepared samples were characterized using X-ray powder diffraction (XRD) and scanning electron microscopy (SEM) for phase analysis and microstructure examination. The elemental stoichiometric of the prepared samples was determined using energy dispersive X-ray (EDX) and particle induced X-ray emission (PIXE). The Oxygen-content of these samples was obtained using non Rutherford backscattering spectroscopy (RBS) at 3 MeV proton beam. XRD analysis indicated that (Bi, Pb)-2223 maintained its tetragonal structure even after different nano-materials addition. The volume fraction results indicated that nano-materials addition reduced the formation rate of the (Bi,Pb)-2223 phase and increased other secondary phases such (Bi,Pb)-2212 and 3321 phases. EDX showed the existence of nano-materials in spite of their absence in the X-ray pattern, indicating that they did not enter (Bi, Pb)-2223 structure but just occupied interstitial places among its grains. PIXE results showed elemental contents very close to the starting values. Moreover, RBS results indicated that the addition of nano-scale Ag and ZnO did not change the O-content of (Bi,Pb)-2223 phase while the addition of nano-Fe\textsubscript{2}O\textsubscript{3} reduced the oxygen mass percentage from 15.16% into 14.88%.

The electrical resistivity of the prepared samples was measured by the conventional four-probe technique in temperature range from room temperature down to the zero superconducting transition temperature T\textsubscript{0}. The electrical resistivity measurements indicated that T\textsubscript{c} for nano-Ag added samples increased from 110 to 112.8 K as x varied from 0.0 to 1.5 wt. %. The increase of T\textsubscript{c} was assigned to the improvement of weak links through grains. The variation of T\textsubscript{c} for nano-ZnO and nano-Fe\textsubscript{2}O\textsubscript{3} added samples showed a slight decreasing with x, with a retardation rate of 6.4% and 22.5 %, respectively.

The results of electrical resistivity, above T\textsubscript{c}, are discussed according to the excess conductivity model, showing the existence of four different regions, namely critical (cr), three-dimensional (3D), two-dimensional (2D) and short-wave (sw) regions. The zero-temperature coherence length, the effective layer thickness of the two dimensional system and the inter-layer coupling strength are estimated as a function of the substitution-content x. Furthermore, the thermodynamics critical field, lower critical magnetic field, upper critical magnetic field, critical current density and Fermi energy are calculated with the aid of Ginzburg number.

The transport critical current density was measured by four-probe technique at 77 K. It was found that the critical current density increased from 460 A/cm\textsuperscript{2} for the pure sample and reaches maximum values of 1014A/cm\textsubscript{2}, 805A/cm\textsubscript{2} and 480A/cm\textsubscript{2} with 0.6 wt.% nano-Ag, 0.4wt.% nano-ZnO and 0.2 wt. % nano-Fe\textsubscript{2}O\textsubscript{3}, respectively.