Irradiation effect on (Bi-Pb) 2223 superconductor

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The superconducting material with nominal composition $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ has been subjected to irradiation with 500 KeV argon ions at two doses 1×10^{17} and 2×10^{17} ions/cm^2. X-ray diffraction, resistivity and magnetic susceptibility examined before and after irradiation. T_c decreased after irradiation. This decrease could be explained to displacement of Bi-Pb.

1. Introduction

The influence of ionizing radiation on High-T_c superconductors is of interest from point of view of potential enhancement of superconducting characterization of thermal and radiation stability of high-T_c superconducting material [1–3]. Oxygen contents play an important change in T_c [4]. So oxygen changes with different environmental conditions, like temperature and pressure during annealing [4, 5] and later with irradiation [6–8]. Ruault *et al.* [8] report the irradiation disordering of oxygen in the Cu-O chain of the basal plane causes a structural transition from the orthorhombic to the tetragonal phase.

In the present work we study the effects of irradiation by argon ion on high-T_c $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ ceramic with X-ray diffraction, resistivity and magnetic susceptibility versus temperature.

2. Experimental procedures

A specimen with a nominal composition of $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ was prepared in the conventional manner using high purity powders of Bi_2O_3, PbO, $SrCO_3$, $CaCO_3$ and CuO the mixture were calcined at 810 °C for 19 hours in air. The calcined material was reground and pressed into pellet form. The pellet was sintered at 850 °C for 168 hours and annealed at 850 °C for 24 hours followed by furnace cooling to room temperature in air. The thickness of irradiated region typically had dimensions of 8 mm × 8 mm × 1.5 mm for irradiation energies of 500 KeV argon ions. X-ray diffraction of the specimen prepared was recorded in Philips-type 1700 powder diffractometer with CuK_α radiation. The X-ray diffraction patterns shows that the $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ is single phase having orthorhombic structure and the lattice constants are $a = b = 5.41$ Å and $c = 37.1$ Å.

The resistivity of the sample was measured by the standard dc four probe technique using Keithley 181 nanovoltmeter. Magnetic measurements were made with a SQUID magnetometer under 10 Oe field cooling and zero-field cooling processes. Irradiation was done with 500 KeV argon ions at doses of 1×10^{17} and 2×10^{17} ions/cm^2 to (Bi-Pb) 2223 dimensions of 8 mm × 8 mm × 1.5 mm. Details of the irradiation are given in literature [9, 10].

3. Results

3.1. X-ray diffraction

The X-ray diffraction pattern from the unirradiated specimens shows a pure $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ high-T_c phase, shown in Fig. 1a, which has orthorhombic structure with $c = 37.1$ Å and $a = b = 5.41$ Å. The lattice parameters obtained in the present work are in good agreement with those reported earlier [2–5]. X-ray of the irradiated specimen, (Fig. 1b, dose 1×10^{17} ions/cm^2) shows a slight decrease in the intensity and with increasing the irradiation doses to 2×10^{17} ions/cm^2 we observed more reduction in the intensity. The intensity of the characteristic lines are still identifiable above the background. The differences in intensities ratio before and after irradiation are clear and approximately 60%. The peak of (002) after irradiation change to broad and the peak of (008), (0010), (115), (0012), (119), (0014) and (1111) almost same in shape but less intensities after irradiation.

Matsui *et al.* [11] have observed that Bi-2212 film irradiated with 200 keV Neions decrease the intensity up to dose of 1×10^{13} ions/cm^2 and interpreted their observation in terms of a partial breakdown of the layered structure.

3.2. Resistivity

The temperature dependence of the resistivity for the $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ system is shown in Fig. 2. For comparison, the resistivity for unirradiated and irradiated, with different doses, specimens are shown in the same figure. The transition temperature T_c of unirradiated samples 108 K, in good agreement with published data [12, 13]. The sample irradiated at 1×10^{17} ions/cm^2 shows a reduction in T_c from 108 to 102 K which is remarkable clear. The single transition without changing the sharpness of the transition.

The specimen irradiated at high doses (1×10^{17} ions/cm^2) shows a gradually reduction in the T_c to 92 K

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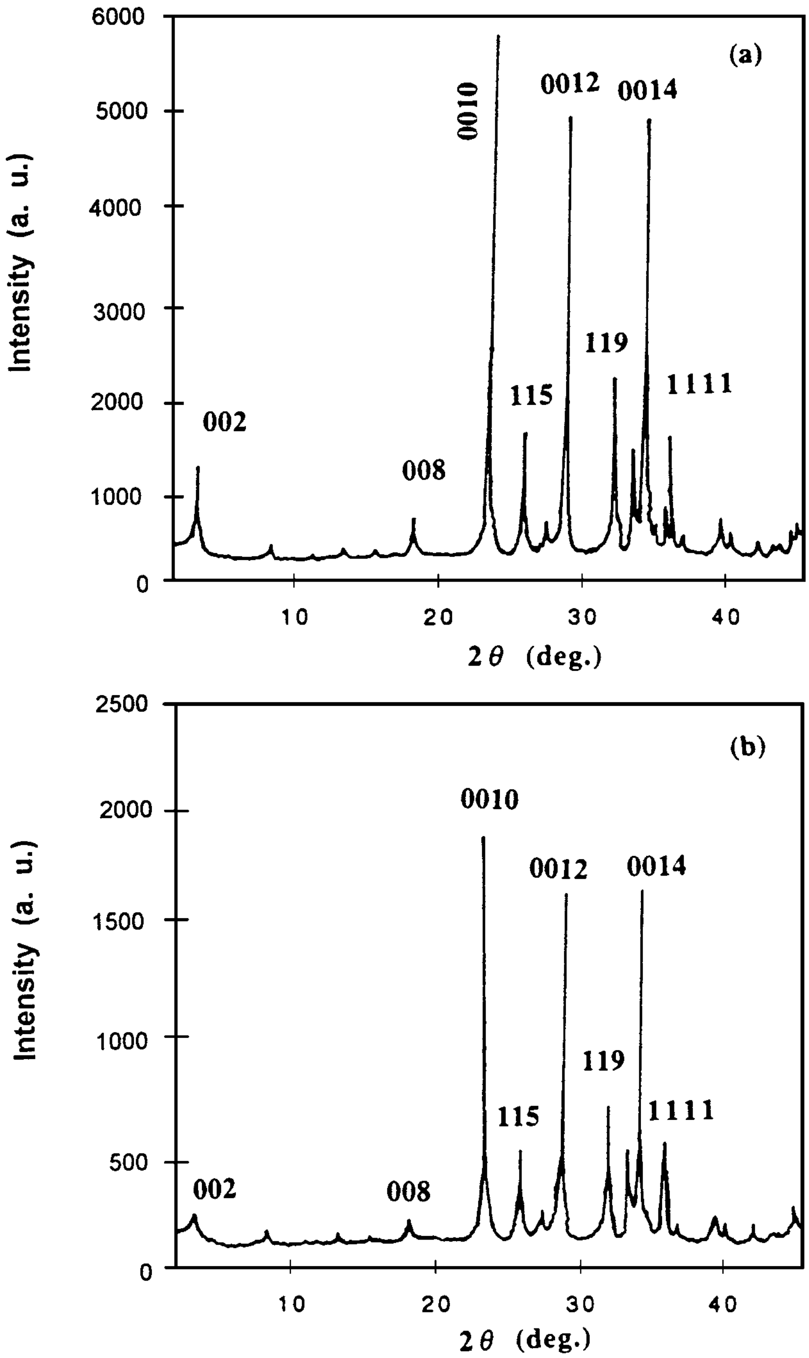

Figure 1 X-ray powder diffraction patterns for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$ with CuK_α (a) unirradiated, (b) irradiated (dose: 1×10^{17} ions/cm^2).

and the drop in the resistivity broadened than the unirradiated sample. Nagashima *et al.* [14] have observed the vanishing of superconductivity and non-metallic behavior at dose 7×10^{16} neutrons/cm^2.

To summarized the resistivity study we plot, Fig. 3, the change between the T_c and doses and that shows with increasing the dose by 1×10^{17} ions/cm^2 each time T_c will decrease.

3.3. Magnetic susceptibility

Magnetic measurement were made with a SQUID magnetometer. Fig. 4, shows the temperature dependence of magnetic susceptibility under 50 Oe field cooling and zero field cooling processes. T_c determined from the magnetic susceptibility measurements ($T_c \sim 106$ K) was a little lower than that determined by measuring the resistivity of the specimen. We have also observed a decrease in the magnetization after irradiation of (Bi-Pb) 2223. The magnetic susceptibility was 106 K before irradiation, has come down to 92 K after irradiation with dose 1×10^{17} ions/cm^2 and to 85 K with dose of 2×10^{17} ions/cm^2. This behavior can be explained by oxygen knock-out from (Bi-Pb) 2223. Allgeier and Schilling [15] does similar study in Bi-2212 and indicate that due to the change in oxygen content.

4. Discussion

In discussion we have demonstrated the change of X-ray, T_c and magnetic susceptibility with irradiation at

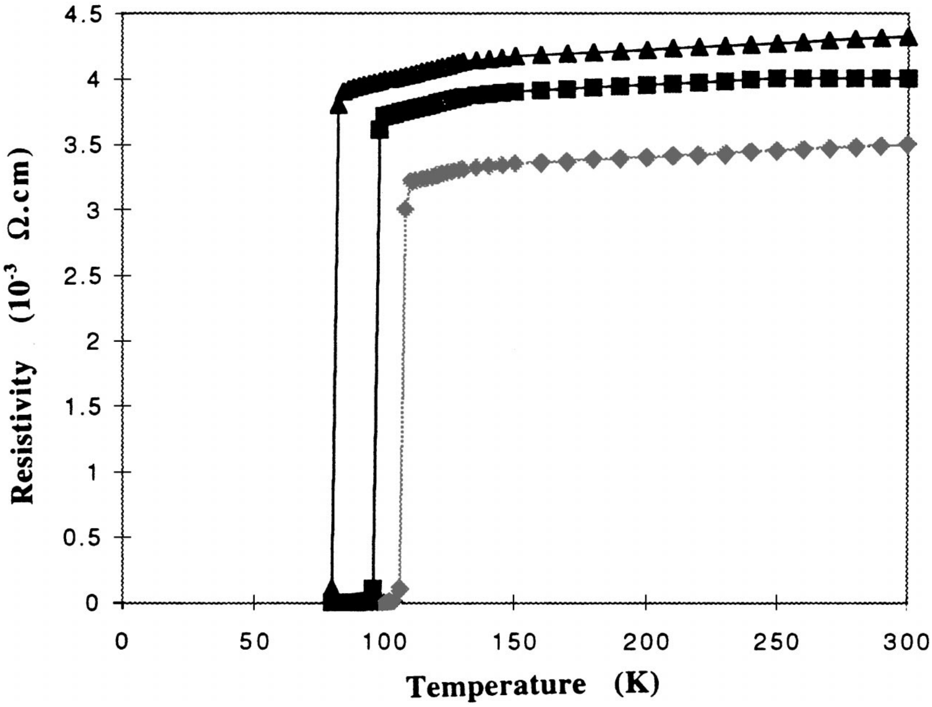

Figure 2 Variation of resistivity with temperature for $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_x$; (▲) unirradiated, (■) irradiated at dose 1×10^{17} ions/cm^2, (♦) irradiated at dose 2×10^{17} ions/cm^2.

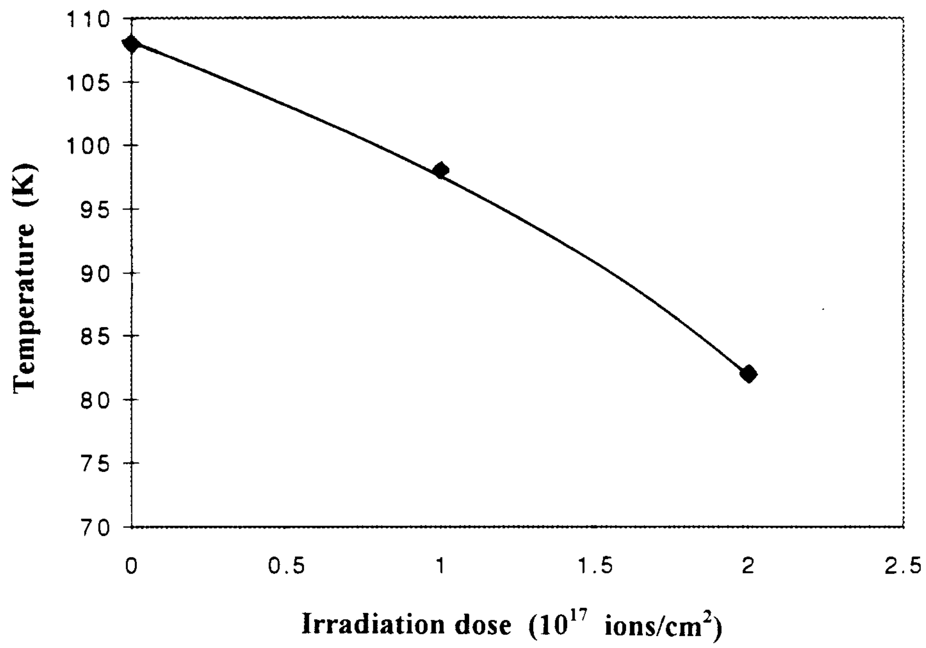

Figure 3 Variation of the critical temperature T_c with irradiation doses.

1×10^{17} and 2×10^{17} ions/cm^2. The change in oxygen content [5] and the Zn element like Bi and Pb can be easily displaced, as their ion-scattering cross-sections are larger than the ion-scattering cross-section of oxygen. So, the displacement of Bi and Pb which stop ion irradiation cause a local amorphization.

The change in the T_c in the specimen at doses 1×10^{17} and 2×10^{17} ions/cm^2 indicate a localization caused by irradiation-induced disordering. Clark *et al.* [16] think the change due to destroy weak-linking between grains, leaving the intrograin superconductivity intact.

5. Conclusion

With every new study of superconducting oxides, one would like to establish systematic in the variation of T_c with composition so that higher T_c's can be found and the physics involved can be better understood. So, we have irradiated (Bi-Pb) 2223 ceramics of T_c (R=O) 108 K and we found a decrease in T_c with irradiation which could be explained to displacement of Bi-Pb or to knock-out the oxygen by ion irradiation. Analysis of magnetic susceptibility shows a decrease in magnetization which can be attributed to the same cause.

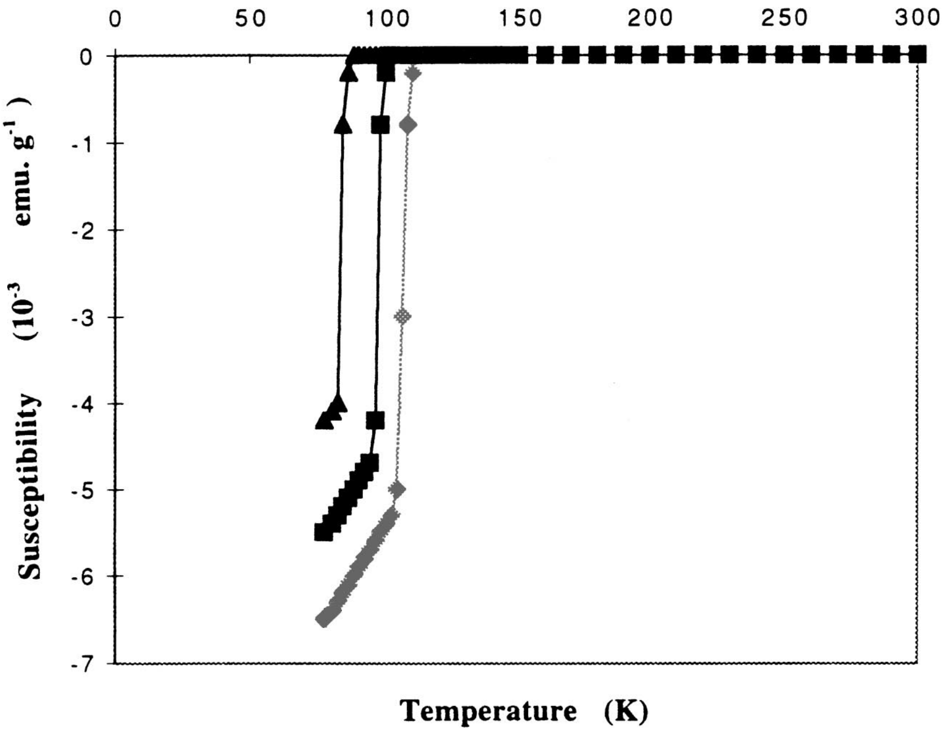

Figure 4 Variation of susceptibility with temperature.

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