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ANNEALING STUDIES OF α-IRRADIATED BI-SR-CA-CU-O SUPERCONDUCTORS

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Abstract:

Polycrystalline samples of $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212) and $Bi_{1.84}Pb_{0.34}Sr_{1.91}Ca_{2.03}Cu_{3.06}O_{10+x}$ (Bi-2223) superconductors irradiated with 40 MeV α-particles at various doses have been annealed in oxygen and air. Irradiated Bi-2212 samples have been annealed at 450°C and Bi-2223 samples have been annealed at 500°C as well as at high temperature (850°C). At lower dose of irradiation, Tc of Bi-2212 samples has decreased after annealing. In case of Bi-2223, there has been partial recovery by annealing at low temperature. But, annealing at high temperature has been detrimental.

Key Words : Annealing, α-irradiated Bi-2212, Bi-2223.

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1. Introduction

The process of annealing is very vital in radiation damage. Defects and disorder induced by irradiation get ordered by annealing. In the field of superconductivity, it helps in partial recovery of Tc as well as resistivity. Normally, for annealing of irradiated samples, they are brought to around two third of the melting point of the sample and cooled slowly for ordering. In case of high Tc superconductors, annealing studies open a new dimension as defects and disorder play a great role in superconductivity. Often, defects change carrier concentration in the conducting CuO_2 layer. Thus, for example, the oxygen excess compared to the stoichiometric content in these systems control Tc. Bi-2212 is vulnerable to absorb excess oxygen to relieve the stress in Bi-O bond, whereas in (Bi,Pb)-2223, this stress is partially relieved by doping of larger Pb^{2+} in Bi-site [1]. Hence, it does not absorb excess oxygen. The excess oxygen in Bi-2212 gets knocked out by α-irradiation, and the knock-out increases monotonically with dose, which we had earlier observed [2]. On the other hand, in case of Bi-2223, there is no knock-out of oxygen by α-irradiation [3]. These have reflections on the annealing conditions.

In this paper, we have investigated the annealing of α-irradiated Bi-2212 and (Bi,Pb)-2223 in oxygen and air respectively.

2. Experimental Details

Polycrystalline samples of Bi-2212 and (Bi,Pb)-2223 were prepared by usual solid state reaction [4,5]. They were characterised by powder XRD and observed to be of single phase. Their Tc's were 73K and 112K respectively obtained from resistivity measurements by four-probe technique at a constant current of 1mA.

Irradiation was carried out with 40 MeV α-particles at various doses from 1×10^{15} to $1 \times 10^{16} \alpha/cm^2$ at room temperature. There was generally decrease in Tc and increase in resistivity. Irradiated Bi-2212 samples were annealed in Oxygen at 450^0C, as the irradiated samples were found to be of lower oxygen content and the oxygen absorption takes place at this temperature. Irradiated Bi-2223 samples were annealed in air at 850^0C and 500^0C to see the effect of annealing at high and low temperature. In all cases, the annealed samples were brought to room temperature from annealing temperature by cooling slowly at the rate of $10^0C/hr$. We have annealed Bi-2223 samples irradiated with $1x10^{15}$ and $2x10^{15}\alpha/cm^2$ at high temperature and the sample irradiated with the highest dose at lower temperature. In case of Bi-2212, we have annealed the samples irradiated with $2x10^{15}\alpha/cm^2$ and with the highest dose to see the effect of oxygen annealing. Annealed samples were characterised by XRD as earlier. Their Tc and resistivities were measured like the unirradiated samples.

3. Results and Discussions

Tc and room temperature resistivity values of the annealed samples of Bi-2223 are given in table-1 and table-2 as compared to the corresponding irradiated and unirradiated samples.

Table-1. Result of Bi-2223 annealed at High temperature (850^0C)

Sample	Tc(K)	ρ(mΩ-cm)
unirradiated	112	3.117
Dose:$1x10^{15}$ α/cm^2	111	7.325
Annealed	75	10.940
Dose:$2x10^{15}$ α/cm^2	108	8.112
Annealed	74	11.460

Table-2. Results of Bi-2223 annealed at low temperature (500^0C)

Sample	Tc(K)	ρ(mΩ-cm)
unirradiated	112	3.117
Dose:$1x10^{16}$ α/cm^2	44	141.5
Annealed	89	31.3

It is seen that there is no recovery of Tc and resistance for the samples annealed at high temperature (at 850^0C). Rather, Tc(R=0) decreases compared to that of the irradiated sample. Tc onset remains nearly same, but there is a broad hump noticed (Fig.1). X-ray diffraction revealed amorphisation (Fig.2). Perhaps, weak links between grains get destroyed by annealing at high temperature. In the case of low temperature annealing at 500^0C for the sample at highest dose, there is partial recovery of Tc and resistivity for the sample annealed at 500^0C (Fig.3).

Annealing of defects occurs at the low temperature employed. The temperature employed (500^0C) is essential for the activation energy for mobility of the defects caused by irradiation. But, high temperature causes increase of defects, rather than lowering due to further creation of defects. After annealing them further at lower temperature also, there was no recovery. We are freshly irradiating samples at doses, of 1×10^{15} and $2 \times 10^{15} \alpha/cm^2$ to carry out annealing at lower temperature for recovery. The sample at highest dose was not annealed at high temperature, for we believe that, it will cause deterioration like the other samples.

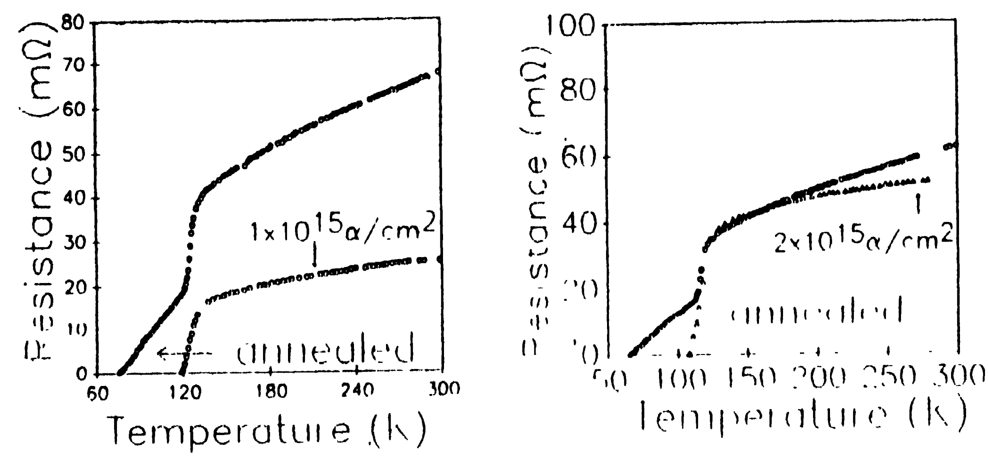

Fig. 1. **Resistances of Bi-2223- irradiated at 1×10^{15} and $2 \times 10^{15} \alpha/cm^2$ and annealed at high temperature.**

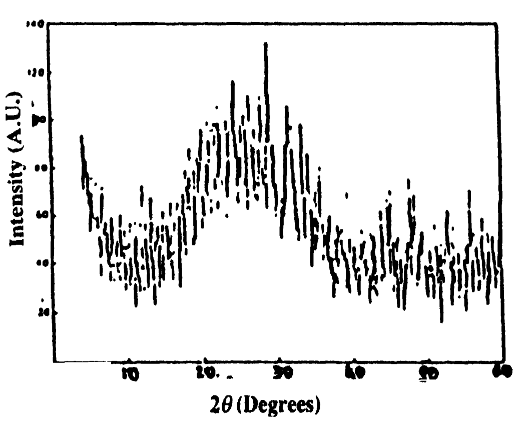

Fig. 2. X-ray Diffraction Patterns of Bi-2223 annealed after irradiation at high temperature.

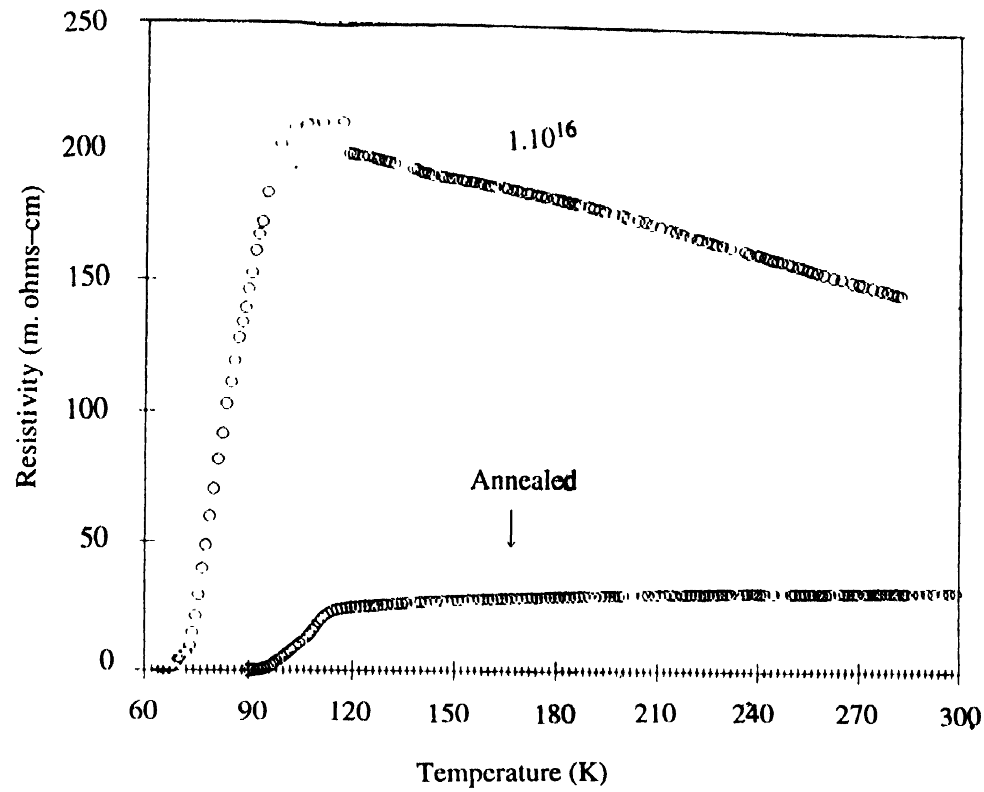

Fig. 3. Resistivity of Bi-2223 irradiated at highest dose and annealed at low temperature.

In case of Bi-2212, the unirradiated sample was in the overdoped region of the bell-shaped curve of Tc versus oxygen [6] (excess oxygen =0.2). α-irradiation caused partial knock-out of oxygen (excess oxygen =0.14), whereby its Tc increased. Hence, annealing in oxygen caused lowering of Tc as oxygen content is higher. Of course, there has been lowering of resistivity due to annealing, as it is seen in table-3. For the sample irradiated at highest dose, almost entire excess oxygen was knocked out and the sample became non-superconductor. Hence, annealing in oxygen caused increase of oxygen content and it became superconductor with Tc~46K. Table-3 gives Tc and room temperature resistivity of the irradiated as well as annealed samples of Bi-2212 as compared to unirradiated sample.

Table 3. Results of annealing of Bi-2212

Sample	Tc (K)	ρ (mΩ cm)
Unirradiated	73.1	3.966
$2\times10^{15}\alpha/cm^2$	74.3	17.281
Annealed	64.9	5.884
$1\times10^{16}\alpha/cm^2$	Non Sc	324.74
Annealed	46.45	25.241

4. Conclusions

We have investigated the annealing of α-irradiated Bi-2212 in oxygen at 450^0C and Bi-2223 at high and low temperatures. It is seen that, in case of Bi-2212, annealing in oxygen recovers superconductivity for the sample irradiated at highest dose, where, oxygen content is minimum, whereas in case of the sample irradiated at lower dose ($2\times10^{15}\alpha/cm^2$), Tc decreases after annealing in oxygen. In case of Bi-2223, oxygen knock-out is not significant during irradiation and hence, annealing in air is sufficient. Annealing at low temperature is effective in partial recovery of Tc, whereas annealing at high temperature is detrimental.

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