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The influence of gamma irradiation on superconductivity of $YBa_2Cu_3O_{7-x}$.

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Abstract

We have studied the effects of gamma irradiation up to 600 Gy on the superconducting properties of $YBa_2Cu_3O_{7-x}$ ceramic. A low decrease of the transition temperature and enhancement of critical magnetization current density was found after irradiation.

1. Introduction

It has been reported that some physical properties of high-T_c oxide superconductor are effected by the irradiation of high-energy particles such as neutron, electron, ion and photon [1-5] studies on radiation effect of high-T_c materials are principally concerned with transition temperature Tc and critical current density Jc. To achieve high values of J_c it is fundamental importance to introduce pinning centres for flux lines into the superconductor. Sufficiently high value of J_c have been found only in thin films or in single crystals [6,7]. An appreciable change in the superconducting transition temperature and critical current density was observed in Y-Ba-Cu-O ceramics irradiated by electrons with energy up to 10 MeV [2,8]. It is, therefore, expected that gamma irradiation also effects the superconducting properties of this ceramic. But some previous results indicate that these ones are influenced only little by gamma irradiation up to total dose 8 MGy [9,10]. In this paper, the change of superconducting properties by gamma irradiation is studied in sintered $YBa_2Cu_3O_{7-x}$.

2. Experimental

The sample of nominal composition $YBa_2Cu_3O_{7-x}$ was prepared by citrate sol gel process using the autocatalytic decomposition of Y, Ba, Cu citrates [12]. The calcinated powder was synthesized at 950 °C for 20 hours in flow O_2, then pressed into the pellet (in diameter 10 mm, 6 t), sintered at 980 °C for 20 hours in flow O_2 and finally oxidized at 500 °C for 22 hours in flow O_2. From pellet were cut experimental samples with the same shape. These samples were then irradiated by various doses of ^{60}Co gamma-ray radiation with photon energy 1.33 MeV at dose 155.4 R/min. The used radiation doses were 5, 25, 125 and 600 Gy.

The transition to the superconducting state was studied by the measuring of temperature dependence of AC susceptibility in temperature range 77-110 K at 5 Oe. The AC susceptibility was measured by mutual inductance bridge of Hartshorn type.

The hysteresis magnetic properties were examined by measuring of magnetization by vibrating sample magnetometer in temperature range 4.2-100 K and magnetic field up to the 6 T.

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3. Results and Discussion

The sample was characterized by x-ray powder diffraction as single phase $YBa_2Cu_3O_{7-x}$ with the transition temperature T_c = 88.5 K.

The temperature dependencies of the magnetic AC susceptibility are shown on Figure 1. After the gamma irradiation AC susceptibility shows a slight change of transition temperature T_c (onset of AC susceptibility). The T_c gradually decreases from 88.5 K to 87 K after irradiation up to 600 Gy. But the character of transition to the superconducting state is rather changed after irradiation. The curve for unirradiated sample shows some steps, which are gradually removed after irradiation and transition is become sharper. These steps can be attributed to the distribution of the regions with a slight different T_c, which is caused by the displacement of oxygen ions in the chain sites. Although the x-ray diffraction spectrum before irradiation demonstrates that the sample is almost single phase, it has to be assumed that there are inhomogeneities in the sample. Thus during gamma irradiation some oxygen atoms could get more energy and jump to correct lattice sites making the structure of the material more ordered than before irradiation. On the other hand Shiraishi [5] mentioned that the gamma irradiation is also expected to form an amorphous film along the interface of crystallite as well as the grain boundary. This fact decreases the transition temperature T_c too and its dose dependence is effected by microstructure in the specimen. It was found that dose for the change of critical temperature is expected to be higher for the high - quality sample.

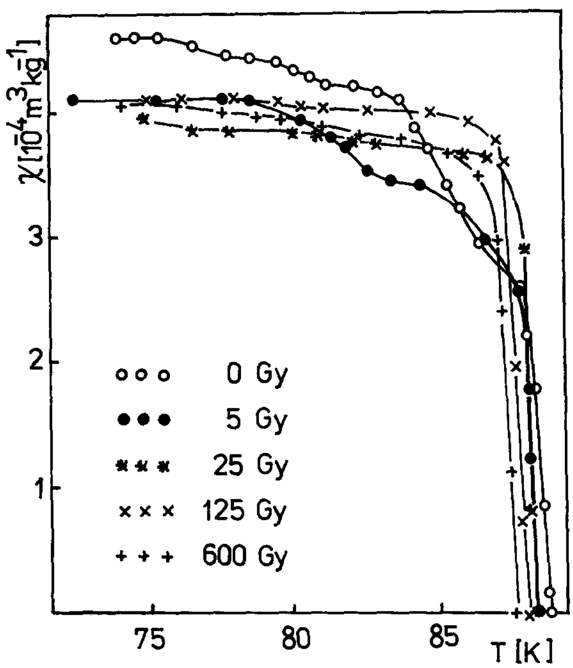

Fig. 1

The temperature dependence of AC susceptibility at 0.5 mT.

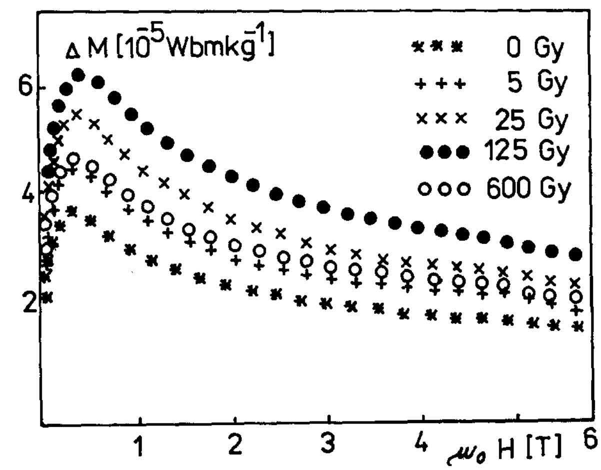

Fig. 2

The field dependence of magnetization hysteresis delta M at 4.2 K

In Figure 2 is shown the field dependence of the magnetization hysteresis delta M for unirradiated and irradiated up to 600 Gy at 4.2 K. Delta M is taken as full difference in the magnetization from M-H hysteresis loops at the given magnetic field. The magnetization hysteresis delta M increases by the gamma irradiation for all doses at these ranges of magnetic field. This suggests that the gamma irradiation-induced defects act as pinning centres. The maximum enhancement of delta M by factor 1.6 at 1 T and 4.2 T is reached for irradiation by 125 Gy. There is the interesting fact that the enhancement of delta M after irradiation by 600 Gy is smaller than for 125 Gy. This may be due to the decrease of its critical temperature by the irradiation.

The influence of irradiation on the intragrain critical current density can be evaluated from hysteresis loops.The width of hysteresis loop delta M is proportional to the corresponding critical current J_c at

		DOSE [Gy]			
	T[K]	5	25	125	600
J_c^{irr}/J_c^{unirr}	4.2	1.14	1.39	1.60	1.16
	77.0	1.23	1.05	1.39	1.53

Table 1.

The influence of irradiation on intragrain critical current measured at 4.2 K and 77 K in magnetic field 1 T.

given magnetic field. However, an accurate determination of the absolute values of J_c is difficult for samples because of the exact information in the

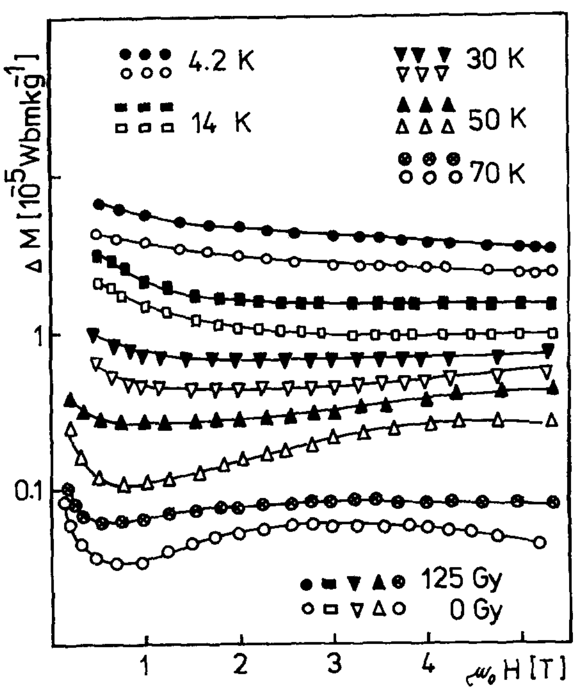

Fig.3

Magnetic field dependence of magnetization hysteresis at 1 T.

size and shape of grains. So we made only the comparison of the width of the hysteresis loops delta M before and after gamma iradiation, that is proportional J_c^{irr}/J_c^{unirr}. This comparison of the influence of irradiation for our samples is shown in table 1 for temperatures 4.2 K and 77 K. The obtained enhancement of J_c by gamma irradiation are not so expressive as for electron and neutron irradiation [4,13]. The effect of gamma irradiation is less efficient because of high penetration of gamma rays into the sample, in contrast electrons, the damage is more uniform. But the atomic displacements can take place by radiation of electrons produced by

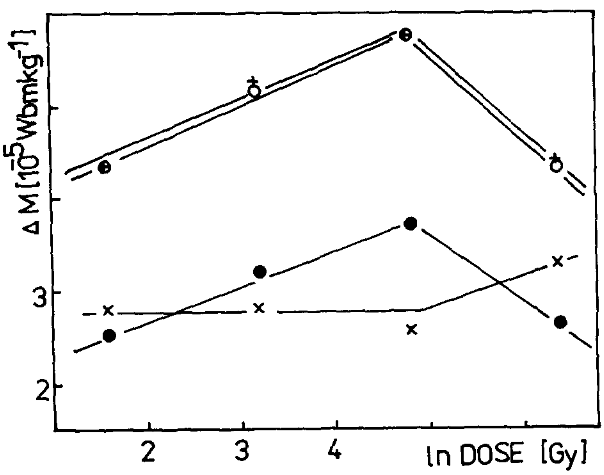

Fig.4

The magnetization hysteresis delta M at 1 T versus total dose after irradiation (+), after two months (o), after five months (*) and after five months and subsequent oxidation (x) of the material.

Compton process at gamma irradiation.

In Figure 3 is shown the magnetic field dependence of the magnetization hysteresis delta M for unirradiated and gamma irradiated by 125 Gy samples for some different temperatures. We can see that for higher temperatures delta M increases slightly with magnetic field and shows more or less pronounced maximum. This maximum can be found is magnetization hysteresis curves and is known as "fish-like behaviour". It has been suggested that these features might be caused by oxygen disordering or oxygen deficient regions within the sample [11] This "fish-like behaviour" of delta M is rather depressed at low magnetic field by gamma irradiation. This fact suggests that structure is become more ordered by rearrangement of oxygen atoms after irradiation. The dependence of the enhancement of delta M on temperature and magnetic field reflects the nature of the pinning centres induced by gamma irradiation. These pinning centres are more effective at higher temperatures and lower magnetic field than those existing before irradiation.

We measured the time stability of J_c enhancement too. The measurements were made after two months, after five month and after five month with subsequent oxidation at 500 °C in O_2 for 22 hours.

The result of this experiments are shown in Figure 4. No changes in delta M were registered after two months. The decrease of delta M after five months is indicated but character ofits dependence is the same as for the first measurements. The next oxidation irradiated samples at 450 °C in O_2 for 24 hours shows only small changes of delta M with dose up to 125 Gy. These results indicate, that by irradiation introduced pinning centres are partly recovered in time, and the absolute recovering takes place after subsequent oxidation. The values of delta M are even lower after five month and subsequent oxidation than those for as prepared sample.

In conclusion, slightly decreasing of the superconducting transition temperature by ^{60}Co gamma ray irradiation was observed in $YBa_2Cu_3O_{7-x}$ ceramic. The steps in temperature dependence of AC susceptibility near transition to superconductivity state are removed after irradiation by making the structure of the samples more ordered probable by rearrangement of oxygen atoms. Critical current density increase after irradiation by factor 1.6 for 125 Gy dose. It was suggested that by irradiation induced pinning centres are more effective at higher temperatures and lower magnetic fields. The another oxidation causes the removing by irradiation induced pinning centres and those existing before irradiation too.

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