THE IMPROVEMENT OF THE SUPER CONDUCTING PROPERTIES OF THE $YBa_2Cu_3O_{7-\delta}$ COMPOUNDS BY NEUTRONS IRRADIATION

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The effect of the increase of the critical temperature T_c by the irradiation of the Y123 samples with small doses of fast neutrons has been investigated by the temperature dependence of resistance and by EPR studies. The results indicated that T_c and EPR signals of all specimens increased with growth of irradiation doses. Meanwhile all three-lattice parameters decreased. These results are explained in terms of redistribution of the oxygen, which promotes the intensification of the interaction between Cu^{2+} ions and the improvement of super conducting properties of the specimens.

1. INTRODUCTION

The irradiation of some materials with small doses of radiation stimulated some processes, which result in the improvement of the crystal structure. This phenomenon is attributed to the decrease of defects by the recombination of the interstitial atoms with the vacancies [1,2]. In such case neutrons act like billiards. This is known as the effect of small doses in semiconductor physics and later was applied to high temperature superconductors.

In reference [3] it was found that the irradiation of the $Yba_2Cu_3O_{7-\delta}$ and $Pb_xBi_{1-x}Ca_2Sr_2Cu_3O_{10}$ samples with small doses of fast neutrons resulted in the increase of the critical temperature by ΔT_c =3.9K for the former system and by ΔT_c=5.8K for the latter system. It was attributed to reduction of the number of defects in the Cu-O chains.

It was reported [4] that the magnetism associated with the Cu-O units plays an important role in the super conducting properties of HTSC. Observation of the EPR signal in the cuprite superconductors was expected because the majority of copper ions are in the divalent state, as nuclear magnetic resonance, neutron scattering, photoemission and muon resonance studies have indicated it. HTSC cuprites and their insulating AFM parent compounds have been subjects of numerous EPR investigations in view of the possibility of direct access to the static and dynamic properties of the intrinsic Cu^{2+} ions. EPR signals of the superconductor compounds were attributed to the interaction between these ions [4].

Authors [5] investigated the effect of the fast neutron irradiation on the critical current density (J_c) and microstructure characteristics of highly textured YBCO bulks prepared by the powder melting process (PMP). Five similar samples were irradiated by fast neutrons with different fluents, from $5,1\times10^{16}$ to 6×10^{17}n/cm^2. The results indicated that the critical temperature (T_c) of (PMP) specimens decreased insignificantly after irradiation with fluents up to 6.1×10^{17}n/cm^2, and the J_c values increased monotonically with radiation doses.

It was reported [6], that the critical temperature enhancement was detected in the same compound by the gamma irradiation at the nitrogen boiling temperature. This experiment was held in our laboratory.

In this report we investigate the effect of small doses in the HTSC cuprites by the temperature dependence on the resistance and by the EPR measurements for several samples before and after irradiation with small doses of fast neutron irradiation.

2. EXPERIMENT

$YBa_2Cu_3O_{7-\delta}$ (Y123) ceramic samples were prepared using the solid-state reaction method. The powders were mixed and sintered in air three times and afterwards the materials were annealed in the flowing oxygen. Samples were identified by XRD measurements and Rietveld refinement, which showed that they were single phase with a high degree of orthorombicity.

We have taken four Y123 samples with different T_c. We have measured their critical temperatures from the dependence of the resistivity versus the temperature by the ordinary four contacts method (which were made of silver paste), and also the EPR signals before and after the irradiation. We have detected the super conducting transition temperature (T_c) by the middle point of the transition.

We have measured the EPR signals from the powders of the samples at the room temperature. We have taken the exactly same masses for the corresponding powders of the samples before and after irradiation.

The fast neutrons held the irradiation of the samples in the horizontal tunnel of the reactor at the temperature about 340K. The slow neutrons were cutted by a filter of the cadmium. Each specimen was irradiated once. The first N1 specimen was irradiated with three fluents of 10^{11}n/cm^2, 10^{12}n/cm^2 and 10^{13}n/cm^2. The second specimen N2 was irradiated with two fluents of 10^{11}n/cm^2 and 10^{12}n/cm^2. The third N3 and fourth N4 specimens were irradiated with one fluent

fluent of 10^{12}n/cm^2. For the fourth N4 specimen we have performed the Rietveld refinement before and after the irradiation.

3. RESULTS AND DISCUSSIONS

The dependence of the resistance versus temperature for the specimen N1 is shown on fig.1. We observed the increase of the T_c with growth of irradiation fluents, which is accompanied by a decrease of the resistance transition width.

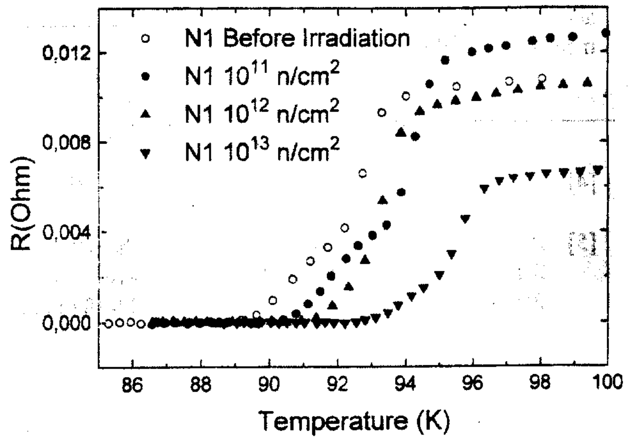

Fig.1. The temperature dependence of the resistance for the sample N1 before and after the irradiation for different fluent.

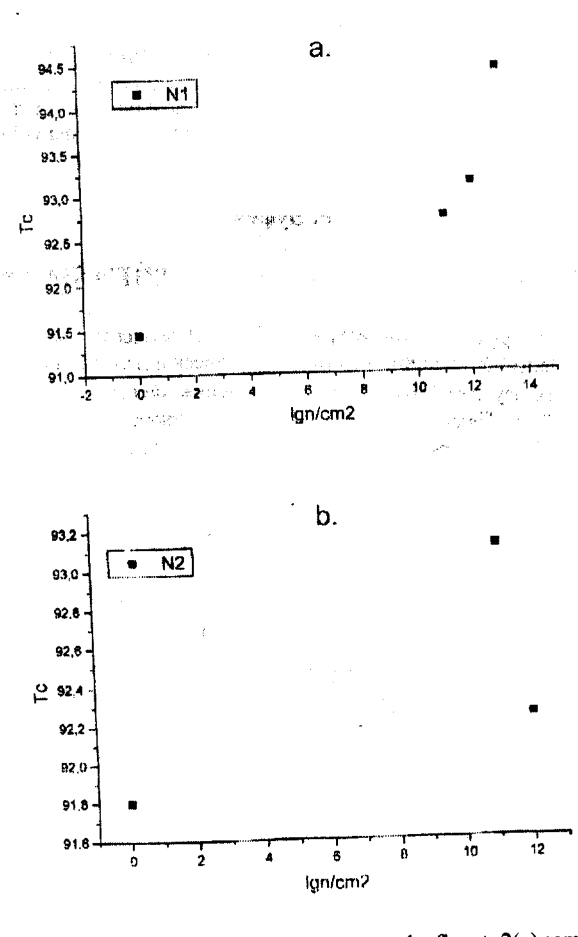

Fig2. The critical temperature versus the fluent: 2(a) sample N1, 2(b) sample N2.

Fig.2 (a) shows that for specimen N1 before the irradiation T_c was 91.44K and after the irradiation with fluents 10^{11}n/cm^2, 10^{12}n/cm^2 and 10^{13}n/cm^2 was 92.19K, 93.19K and 94.43K respectively. Fig.2 (b) shows that for the sample N2 the T_c was 91.79K before the irradiation and after the irradiation with the fluent 10^{11}n/cm^2 it increased to 93.12K but with the fluent 10^{12}n/cm^2 it decreased to 92.24K. From comparison of T_c's for specimens N1 and N2, we can see that the T_c of the specimen N1 increases up to 10^{13}n/cm^2, whereas for the specimen N2, the T_c decreases between the fluents of 10^{11}n/cm^2 and 10^{12}n/cm^2. We have also found that for the specimen N3 before the irradiation T_c was 90.02K and after the irradiation with the fluent 10^{12}n/cm^2 T_c became 91.34K. Regarding the sample N4 before the irradiation its T_c had been 90.04K and after the irradiation with the fluent 10^{12}n/cm^2 T_c became 91.34K. Fig.3 shows the EPR spectra for the N1 and N3 specimens. For both of them the EPR signal increased after the irradiation with the fluent 10^{12}n/cm^2 with respect to the EPR signal before irradiation.

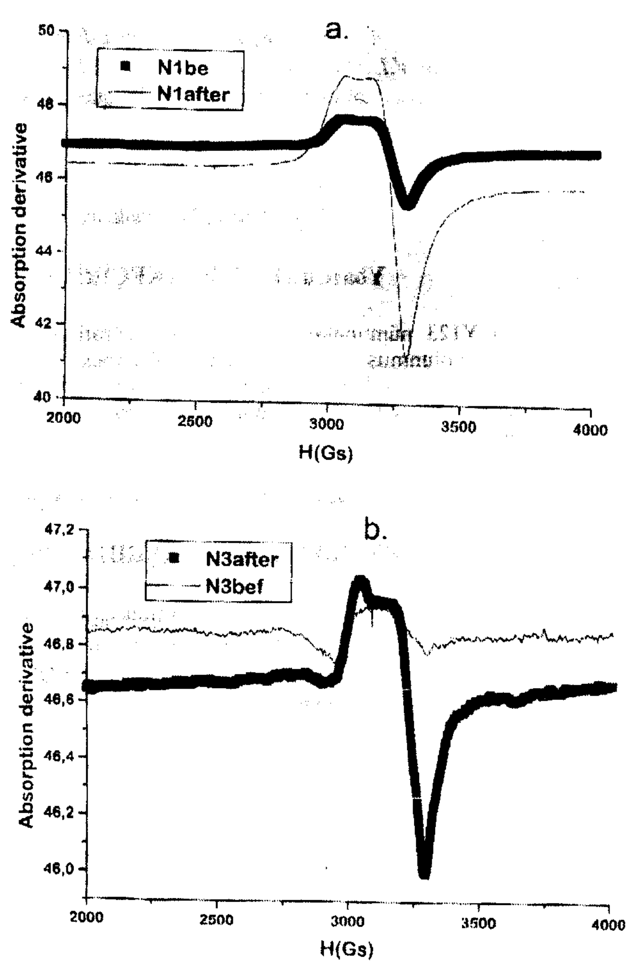

Fig.3. EPR spectra before and after the irradiation: 3(a) sample N1, 3(b) sample N3.

We have also calculated the lattice parameters for the specimen N4 before and after the irradiation with the fluent 10^{12}n/cm^2. The lattice parameters that we have obtained are as follows:

(a=3.82506⇒b=3.88615⇒c=11.67384⇒) before the irradiation and

(a=3.82486⇒b=3.88459⇒c=11.67069⇒) after the irradiation.

So, the reduction of the lattice parameters confirms that the superconducting properties are improved after the irradiation.

These results suggest a correlation between the increase of T_c and the EPR intensity and decrease of the lattice parameters after fast neutron irradiation. We suppose, that small doses of fast neutrons cause the recombination effect of the interstitial atoms with the vacancies. This effect mainly concerns the oxygen atoms, because of their lightness. We think that this process improves the crystal lattice, orders of the conducting planes and Cu-O chains, reduces the lattice parameters and increases T_c.

We suppose that the reduction of the lattice parameters (or in the other words the compression of the elementary cell) provokes the reduction of the distance between Cu^{2+} ions and therefore the reinforcement of the interaction between them. We assume that this reinforcement is the reason of the rise of the EPR signal and the critical temperature and generally the improvement of the super conducting properties of the compound by small doses of the neutrons irradiation.

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$Yba_2Cu_3O_{7-\delta}$ İFRATKEÇİRİCİSİNİN XASSƏLƏRİNİN YAXŞILAŞDIRILMASI

Məqalə Y123 nümunələrini kiçik dozalı sürətli neytronlarla şüalandırdıqdan sonra T_c kritik temperaturunun artmasının tədqiqinə həsr olunmuşdur. Nümunələrin EPR spektri və müqavimətin temperatur asılılığı öyrənilmişdir. Tədqiqatlar göstərir ki, şüalanma dozası artdıqda nümunələrdə T_c və EPR siqnalı artır. Bu zaman həm də qəfəs parametrlərinin kiçilməsi müşahidə olunur. Alınmış nəticələr oksigen atomlarının yenidən paylanması və bununla da Cu^{2+} ionları arasında qarşılıqlı təsirin güclənməsi ilə izah olunmuşdur.

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УЛУЧШЕНИЕ СВЕРХПРОВОДЯЩИХ СВОЙСТВ $YBa_2Cu_3O_{7-\delta}$ПОСЛЕ ОБЛУЧЕНИЯ НЕЙТРОНАМИ

В работе изложены результаты исследования эффекта увеличения критической температуры T_c Y123 образцов после облучения малыми дозами быстрых нейтронов. Изучены ЭПР-спектры и зависимости сопротивления от критической температуры. Результаты показали, что T_c и ЭПР сигналы всех изучаемых образцов растут с увеличением дозы облучения. Наблюдается также уменьшение параметров кристаллической решётки. Полученные результаты объясняются перераспределением атомов кислорода, что в свою очередь вызывает усиление взаимодействия между ионами Cu^{2+} и улучшение сверхпроводящих свойств образцов.

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