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THE EFFECT OF THE IRRADIATION BY THE SMALL DOSES OF THE FAST NEUTRONS ON THE CRITICAL TEMPERATURE AND EPR SPECTRA OF THE $YBa_2Cu_3O_{7-\delta}$ HIGH TEMPERATURE SUPERCONDUCTORS

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The increase of the critical temperature T_c after the irradiation of the Y123 samples with the small doses of the fast neutrons has been investigated and the measurements of the EPR spectra were held. The results indicated that T_c and EPR signal of all specimens increased after irradiation up to 10^{13}n/cm^2. These results are explained in terms of reordering of oxygen, caused by two different concurrence processes, which promotes charge ordering in the superconducting CuO_2 planes.

INTRODUCTION

The irradiation with the small doses of some materials stimulates the processes, after which the crystal structure improves. The reason of this phenomenon is in the decrease of defects by the recombination of the interstitial atoms in the vacancies [1, 2]. Name of this phenomenon is known as the effect of the small doses in the semiconductor physics. It was logically supposed that the similar phenomena would be realized in the high temperature superconductors**.**

The workers [3] detected that the irradiation of the HTSC samples $YBa_2Cu_3O_{7-\delta}$ and $(Pb_xBi_{1-x})Ca_2Sr_2Cu_3O_{10}$ with the small doses of the fast neutrons causes the increase of the critical temperature by ΔT_c=3,9K for the first system and ΔT_c=5,8K for the second system. In this paper it was reported, that it occurs because of the improvement of the connections of the Cu-O chains and the crystal structure.

The value of the small doses was calculated according to the concentration of the own defects in the crystal. Effect of small doses is possible if the distribution of the electrical and crystal fields, which are forced by the irradiation, would cause the diffusion of the atoms to the crystal sites. If we suggest, that the concentration of the own defects is 10^{19} cm^{-3} and the creative energy of the free atom is ~25ev. When the neutrons have 2mev energy and the concussion area $2\cdot10^{-24}$cm^2[4] the so called small dose for the first system is 10^{15}n/cm^2 and 10^{16} n/cm^2 for the second system they have found out Tc reaches to its maximum value at $1.02\cdot10^{12}$n/cm^2 for the $YBa_2Cu_3O_{7-\delta}$ and $4.2\cdot10^{11}$n/cm^2 for the (Pb_XBi_{1-X}) $Ca_2Sr_2Cu_3O_{10}$.

A number of experimental studies on the magnetic properties of HTSC have been reported, which hinted that the magnetism associated with the Cu-O units plays an important role in their superconducting properties. Observation of the electron paramagnetic resonance in the cuprite’s superconductors is expected because the majority of copper ions are in divalent states, as has been indicated by nuclear magnetic resonance, neutron scattering, and photoemission and muon resonance studies. HTSC cuprites and their insulating AFM parent compounds have been the 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. However, afterwards it was inferred that many of the observed EPR signals were due to impurity phases and that no EPR signal corresponding to the bulk divalent copper ions could be detected even at temperatures well above the Neel temperature of the AFM materials. However, EPR studies of oxygen deficiency Y123 compounds were attributed to the paramagnetic chain fragments in the Cu(1) plane and further were analyzed in terms of bottleneck of Cu(1) magnetic moments through the CuO_2 planes [4].

Authors [5] have investigated the effect of fast neutron irradiation on critical density (j_c) and microstructure characteristics of highly textured YBCO bulks prepared by powder melting process (PMP). Five similar samples were irradiated by fast neutrons with different fluencies, from $5,1\cdot10^{16}$ to $6\cdot10^{17}$n/cm^2. The results indicated that the critical temperature (T_c) of (PMP) specimens decreased insignificantly after irradiation with fluencies up to $6,1\cdot10^{17}$n/cm^2, and the j_c values increased monotonously with radiation doses.

In this context we suppose that it would be interesting to investigate again the so called the effect of the small doses in the HTSC cuprites and additionally to measure the EPR signals for the corresponding samples before and after irradiation by the small doses of the fast neutrons irradiation.

EXPERIMENTAL

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

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

The EPR signals we have measured 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 in order to avoid the different EPR spectrums caused by the different masses of the same sample.

Each specimen was irradiated at once. The first N1 specimen was irradiated with three fluencies 10^{11}n/cm^2, 10^{12}n/cm^2, and 10^{13}n/cm^2. The second specimen was irradiated with two fluencies 10^{11}n/cm^2, and 10^{12}n/cm^2. The third N3 and fourth N4 specimens were irradiated with one fluency 10^{12}n/cm^2.

RESULTS AND DISCUSSIONS

According to our measurements the effect of the increase of the critical temperature was confirmed. For specimen N1 before irradiation the T_c was 91,44K, and after irradiation with fluency 10^{11}n/cm^2 was increased to 92,73K, after irradiation with fluency 10^{12}n/cm^2 the T_c was found to be 93,19, and at 10^{13}n/cm^2 the T_c was 94,43K.

Fig.1. shows that as critical temperature is increased the width of the superconducting transition becomes narrower.

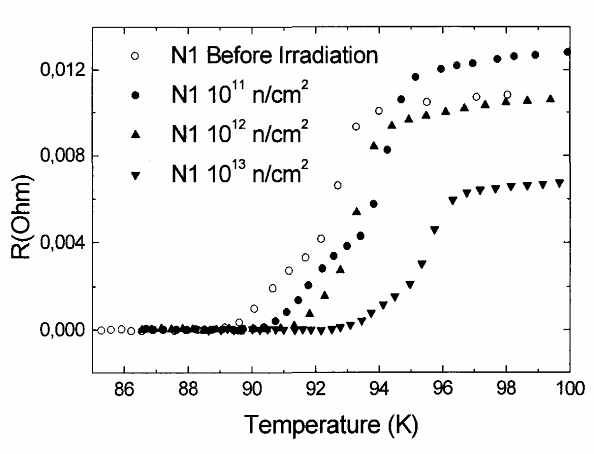

Fig.1.
Change of the critical temperature of the N1 specimen after irradiation with different fluencies.

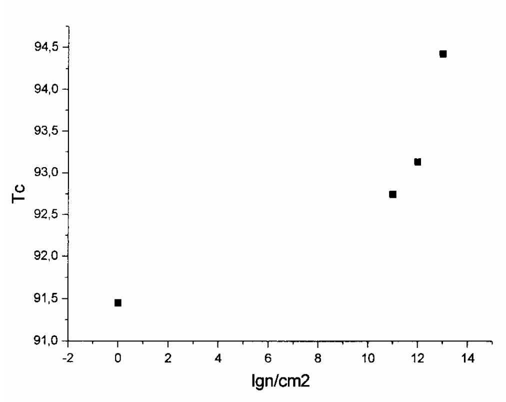

Fig.2.
Critical temperature versus irradiation fluencies for the sample N1.

For sample N2 we have obtained such results, before irradiation T_c=91,79K, with fluency 10^{11}n/cm^2 T_c=93,12K and with fluency 10^{12}n/cm^2 T_c=91,24K. For the specimen N3 before irradiation T_c=90,02K and with fluency 10^{12}n/cm^2 T_c=91,34K. As for N4 before irradiation T_c=90,04K and with fluency 10^{12}n/cm^2 T_c=91,34K. On the Fig.2 and Fig.3 we have the curves T_c versus the fluencies for the N1 and N2 specimens correspondingly. Fig.3 shows that T_c for the sample N2 at the fluency 10^{12}n/cm^2 is less than at the 10^{11}n/cm^2, but therewith for specimen N1 T_c is increased even up to the fluency 10^{13}n/cm^2. So for the N2 decrease of the Tc begins somewhere between 10^{11}n/cm^2 and 10^{12}n/cm^2.

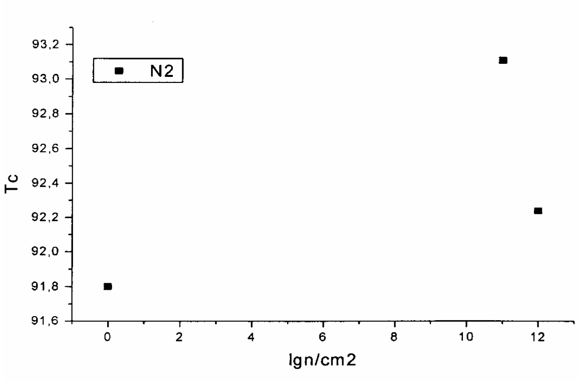

Fig.3.
Critical temperature versus irradiation fluencies for the sample N2

The EPR spectra for the N1 and N3 specimens are shown on figures 4 and 5. For both of them the EPR signal increased after irradiation with the fluency 10^{12}n/cm^2. In all cases the EPR line shape has not changed after irradiation.

these results support a possible correlation between the increase of T_c monitored by resistivity and the growth of the EPR intensity after fast neutron irradiation. There exist two concurence processes. First is the creation of the radiation defects and ionization of the lattice atoms. This process is caused by disorder in the conducting plane and Cu-O chains and decrease of T_c. Second is the diffusion of the oxygen stimulated by the electrical fields which are induced by the radiation defects. We think, that the second process improves the crystal lattice, orders the conducting planes and Cu-O chains and increases the T_c. Since at the doses 10^{11}-10^{13}n/cm^2 concentration of the radiation defects is four orders less than the concentration of the own defects, the second process is dominant. So this behaviour might be related to a redistribution of oxygen, most likely in basal planes, promoting charge ordering in the superconducting CuO_2 planes.

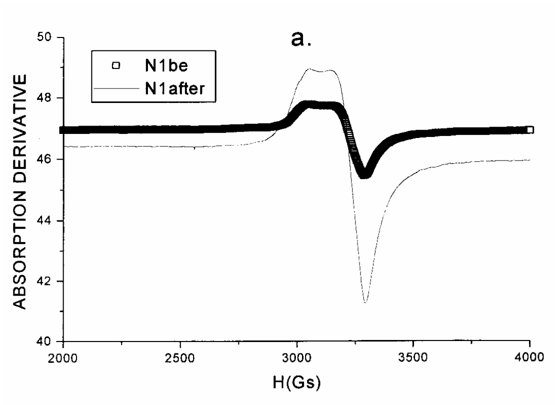

Fig.4.
EPR spectra for N1 specimen before and a irradiation.

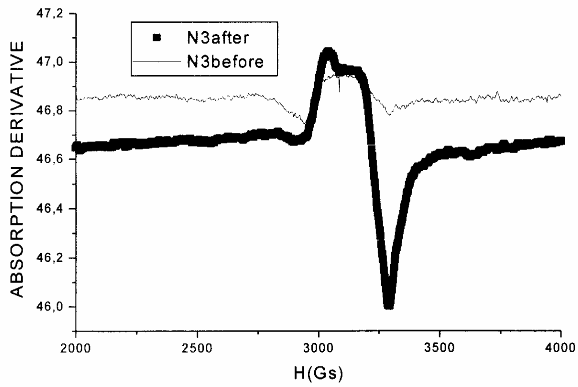

Fig.5.
EPR spectra for N3 specimen before and after irradiation

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KİÇİK DOZALI SÜRƏTLİ NEYTRONLARLA ŞÜALANDIRMANIN $YBa_2Cu_3O_{7-\delta}$ İFRAT KEÇİRİCİSİNİN KEÇİD TEMPERATURUNA VƏ EPR SPEKTRLƏRİNƏ TƏSİRİ

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Məqalə $YBa_2Cu_3O_{7-\delta}$ yüksək temperaturlu ifrat keçirici materialı kiçik dozalı sürətli neytronlarla şüalandırma nəticəsində T_c keçid temperaturunun və EPR spektrlərinin dəyişməsinin öyrənilməsinə həsr olunmuşdur. Neytron şüalanmasının dozası 10^{13}n/cm^2 -a qədər artdiqca keçid temperaturu da artır. Alinmış nəticələr ifrat keçirici CuO_2 təbəqəsində oksigen atomlarinin nizamının dəyişməsi ilə izah olunmuşdur

ВЛИЯНИЕ РАДИАЦИИ БЫСТРЫХ НЕЙТРОНОВ МАЛОЙ ДОЗЫ НА ТЕМПЕРАТУРУ СВЕРХПРОВОДЯЩЕГО ПЕРЕХОДА И ЭПР СПЕКТР ВТСП $YBa_2Cu_3O_{7-\delta}$

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Статья посвящена изучению влияния дозы облучения быстрыми нейтронами на критическую температуру и ЭПР-спектр высокотемпературных сверхпроводников $YBa_2Cu_3O_{7-\delta}$. Наблюдается увеличение T_c с увеличением дозы вплоть до 10^{13}n/cm^2. Данный результат ожидался из-за перестройки атомов кислорода в сверхпроводящей плоскости CuO_2 в результате двух конкурирующих процессов.

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