CRYSTAL CELL PARAMETERS BEHAVIOR OF GAMMA IRRADIATED YBCO CERAMIC.

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ABSTRACT: X -ray diffraction technique was employed to experimentally determinate the changes in the cell parameters of $YBa_2Cu_3O_{7-\delta}$ samples exposed to de action of Co^{60} gamma irradiation (1.33 and 1.17 MeV) at room temperature. The a, b, and c parameters and both the cell volume and orthorhombicity were graphically presented as a function of de exposure doses. A singular behavior of these parameters with the dose increment was observed. The results are compared with the values reported for the optimal $YBa_2Cu_3O_7$ structure and with some experimental galvanomagnetic measurements. Some ideas about the mechanisms, which take place in the observed behaviors, are discussed.

RESUMEN: Utilizando la técnica de difracción de rayos X se determinaron los cambios operados sobre los parámetros de la red de la estructura cristalina de cerámicas superconductoras masivas de $YBa_2Cu_3O_{7-\delta}$ cuando estas son irradiadas a temperatura ambiente con diferentes dosis de rayos gamma de 1.33 y 1.17 MeV producidas por una fuente de Co^{60}. Los parámetros de la red cristalina del material y otros afines fueron relacionados con la dosis de exposición observándose un comportamiento singular. Se hace un análisis comparativo entre estos resultados y los parámetros estructurales reportados en la literatura como óptimos y con los datos aportados por la medición de las propiedades galvanomagnéticas. Son presentados los posibles mecanismos que intervienen en los comportamientos observados.

INTRODUCTION.

In several works published about the interaction of the Co^{60} gamma radiation with the high temperature superconductors and particularly with the $YBa_2Cu_3O_{7-\delta}$ (YBCO) [1-4], the authors refer to the ability of this radiation to stimulate certain ordering of the structure, improving this way the superconducting properties within certain threshold doses.

The authors generally associate this behavior exclusively to the changes in the oxygen thermodynamic equilibrium of the target, in spite of the fact that the energy of the utilized gamma rays is higher than the displacement threshold energy of any of the atoms involved in the structure.

The structural reordering stimulated by the irradiation appears fundamentally based on the completing of the oxygen chains and the indispensable vacancy positions. The increase of the irradiation doses over a certain level is able to overdope with defects the structures (for example, vacancy excess) with the consequent deterioration of the superconducting properties.

The results of the structural analysis by x-ray diffraction (XRD) carried out to YBCO ceramic samples exposed to the Co^{60} gamma ray (1.17 and 1.33 MeV) action at room temperature are shown in the current paper

EXPERIMENTAL.

YBCO samples were prepared by solid state reaction method. Irradiation experiment was performed in a Co^{60} gamma chamber, model PX-γ-30 with a source calibrated to a power dose of 1.216 $Gy \cdot s^{-1}$. The diffraction patterns were obtained on a Philips (PW 1710) diffractometer. The programs DICVOL91 and LSUCRE for the refinement of the cell parameters were employed. All irradiation process and the XRD measurements took place at room temperature.

RESULTS AND DISCUSSION

The dose dependence of the experimentally calculated cell parameters for one representative sample is shown in figure 1. There the values corresponding to the $YBa_2Cu_3O_7$ cell parameter obtained from [5] have been represented by dashed lines. Taking these values like the ideals for YBCO structure, it could be observed that the experimental values, corresponding to the sample without irradiation, are placed under the optimum.
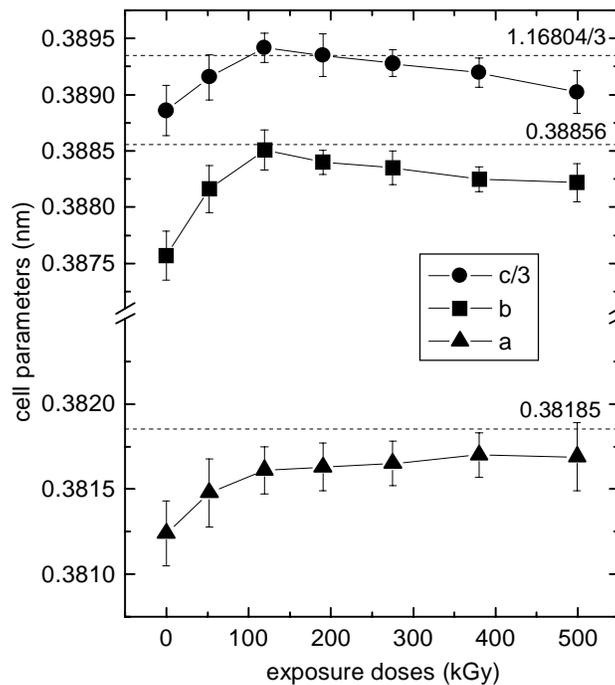

Figure 1. Dose dependence of the experimentally obtained cell parameters of the YBCO samples. Dashed lines present the presupposed optimum values of cell parameters.

As additional information, the figure 2 shows how change with the irradiation doses both the elementary cell volume and the orthorhombicity of the structure for the same YBCO sample, staying the comparison with the presupposed optimum value.
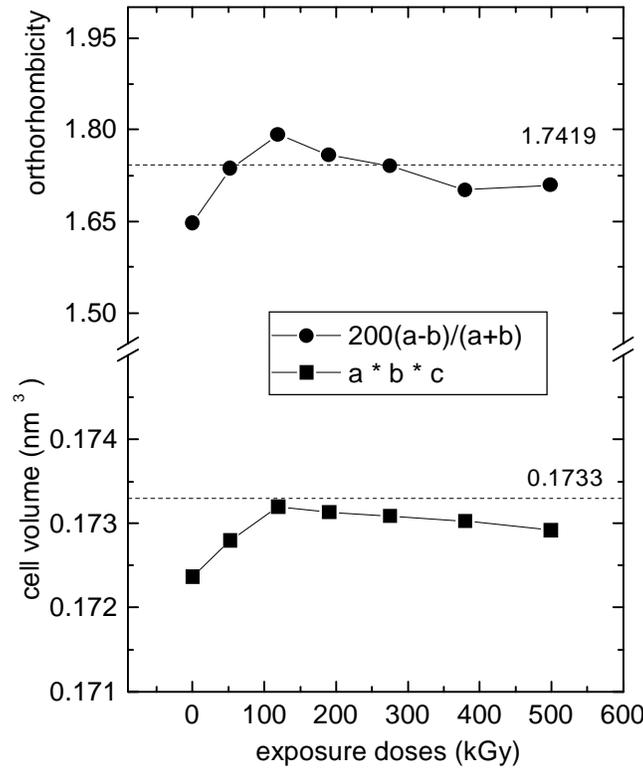

Figure 2. Elementary cell volume and orthorhombicity behaviors with γ irradiation doses. Dashed lines present the presupposed optimum values of cell volume and orthorhombicity.

The sample, that has just left the synthesis process, preserves certain disorder in its structure as a result of the treatments. For example, the oxygen vacancies, which in the ideal structure should be occupying only the O(5) positions in the Cu-O plane, now can occupy also some other different positions at the same time as these O(5) positions may be occupied by oxygen atoms. Other conversion or interstitial defects of other atoms are possible as well.

With the beginning of the irradiation process a singular behavior of the cell parameters is observed (see figure 1). The a, b and c values displace in the direction of the optimum, reaching the maximal approach to the structure for which the superconducting properties are manifested more strongly at near 120 KGy.

This value of ~ 120 KGy is particularly singular because, for example, in [6] a maximum in the T_{on} with the dose dependence for YBCO and BSCCO samples is reported at ~ 100 KGy. In [4] upon irradiating thick films of YBCO a maximum in the dependence of T_c

with the dose at 120- 130 KGy also was observed.

The result shown in the figure 1, concerning with the existence of a dose for which the structural parameters approach to the optimum values corroborates the supposed ability of the Co^{60} gamma radiation, at low and medium dose, to facilitate the reordering of the oxygen atoms. These atoms have a lesser displacement threshold energy in YBCO structure (~ 10 eV according to [7]), therefore they evacuate the O(5) position toward the existent vacancies in O(4). This process leads to the crystal uniformity of the Cu-O chains. The ordering of the atoms of oxygen in the chains plays an important role in the control of the charge carrier concentration in the CuO_2 plane [8], which directly influences the value of T_c according to the BCS theory.

Reached the optimum structure, any dose increment leads to a defect overdoping that would negatively modify the structure.

If the irradiation resulting damage in the superconductor structure with the dose increment is only due to the change in the oxygen thermodynamical equilibrium, then would be expected for the vacancy overdoping a behavior like is observed in [9]. In that case, according to the change of the stoichiometrycal coefficient δ from 0 up to 1 takes place a phase transition from orthorhombic to tetragonal structure. Therefore, the parameters a and b reach to be equal to each other, the one which occurs for δ ~ 0.6, while c grows all the time. As it is appreciated in the figure 1, after the 120 KGy a and b preserve their tendency to the coincidence which would occur at higher doses, but the c parameter shows an inverse behavior concerning the observed in [9]. This result leads to the hypothesis that, in this interaction, important displacements of other atoms different to the oxygen take place.

SUMMARY.

The behavior of experimentally calculated cell parameters for Co^{60} gamma irradiated YBCO samples indicates the validity of the oxygen reordering at low and medium doses thesis. The better values for these structural parameters were obtained after irradiation with ~ 120 KGy. For higher doses the singular behavior of curves indicates that during the irradiation process should take place not only oxygen displacement but also displacements of other atoms species.

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