LOSS OF THE TRANSITION TEMPERATURE DISTRIBUTION HOMOGENEITY WITHIN YBCO CERAMIC AFTER GAMMA IRRADIATION.

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Abstract. T_{on}, T_{off} and T_c behaviors as a function of depth for a superconductor material irradiated with Cs^{137} gamma source have been studied experimentally and by computer simulation techniques. After the irradiation the critical temperature of the material increased, observing that the most significant changes took place at zones of sample nearest to the gamma source. By simulation was found that the higher dose concentrations locate near the incident surface of the sample. Comparing this simulation with our experimental data we found a good coincidence. Our study indicates that the dose deposited about the incident surface is high enough in order to stimulate the processes that benefit the structure and therefore it improves the superconducting properties of the material. Moving into the sample bulk these processes become less effective due to the insufficient dose deposition.

Resumen. Se estudiaron experimentalmente y mediante técnicas de simulación los comportamientos de T_{on}, T_{off} y T_c en función de la profundidad en superconductores irradiados con una fuente gamma de Cs^{137}. Después de la irradiación se observó que la temperatura crítica del material creció, siendo más significativos los cambios en la región directamente expuesta a la fuente. Con ayuda de la simulación se encontró que la mayor densidad de dosis depositada en este caso se ubicaba precisamente en la zona de la cara de la muestra sobre la que incide la radiación. Comparando la simulación con los resultados experimentales se encontró una adecuada coincidencia. La dosis depositada en la región de la cara de incidencia de la radiación es lo suficientemente grande como para estimular los procesos de ordenamiento estructural que potencian el mejoramiento de algunas propiedades superconductoras. A medida que se profundiza en el volumen de la muestra esta deposición disminuye y por lo tanto los procesos mencionados son menos efectivos.

INTRODUCTION.

The papers dedicated to the study of gamma irradiation effects on the properties of the HTSC are characterized for the lack of coincidence in criterions and results. Some authors, as for example [1,2], have observed an improvement of the superconducting properties with dose increment, others as [3,4] report exactly the opposite and the rest have not found any dependence [5,6]. These contradictions have not been completely explained yet, some authors even attribute these behaviors to a "sample effect" [7].

The current paper shows the transition temperatures depth profiling for a YBCO superconductor material irradiated with Cs^{137} gamma rays and presents the arguments to relate this behavior with one of the sources of the above mentioned contradictions.

MATERIALS AND METHODS.

Four identical samples with a parallelogram shape from one superconducting $YBa_2Cu_3O_{7-\delta}$ pellet, synthesized by standard solid state reaction as reported elsewhere, were taken for the experiment. The single-phase structure of the pellet was previously tested by the X-rays diffraction analysis.

For all samples, the transition temperatures were measured using the “four probe method”, first placing the probes on the surface which later should be directly exposed to the radiation source and next on the opposite side.

Two of the samples were mechanically polished step by step to diminish its thickness and the transition temperatures of each new layer were measured by the same way. An approximate representation of the transition temperature distribution within the bulk material was obtained.

A quite homogeneous behavior in all the volume with T_{on} = 90.5 K, T_{off} =87.4 K, T_c = 88.9 K and the transition width of 3.1 K was observed. These results are in correspondence with the reported for the similar ceramic structure and non-stoichiometric coefficient.

The intact samples were placed within a glass container to preserve it from ambient conditions. The container was directly exposed to a Cs^{137} source calibrated to a power dose of $1x10^{-3}$ Gyh^{-1} until a 0.265 Gy exposition dose was reached.

RESULTS AND DISCUTION.

After irradiation, the distribution of the transition temperatures within the samples, measured following the explained above procedure, changed. Figure 1 shows the results of the after irradiation measurements for one representative sample.

Measurements made on the surface directly exposed to the source show an improvement of the superconducting properties. Its critical temperature increased in 2.24 K and the transition width decreased from 3.15 K to 1.44 K. The transition temperature values measured on the opposite surface practically did not change.

In general, as seen in figure 1, the critical temperature distribution after the irradiation process appears non-homogeneous in all material volume and the most significant changes take place at the zones nearest to the gamma source.

To prove the experimental results we have carried out a computer modeling of this irradiation process using the EGS4 program [8]. The real geometrical conditions were preserved in the simulation. Figure 2 represents the deposited dose distribution (in normalized percents) along a line that crosses the sample through their center in the direction of the incident radiation.

The higher concentration doses are located near the incident surface of the YBCO sample. The percent of deposited dose continuously decreases as the depth increases, reaching the minimum values at the opposite surface. Comparing this simulation with our experimental data we found a good coincidence. The dose at the front surface is high enough in order to stimulate the processes that benefit the structure (such as a reorganization of the vacancies) and therefore it improves the superconducting properties of the material [7]. Moving inside the material, these processes become less effective due to the insufficient dose deposition.

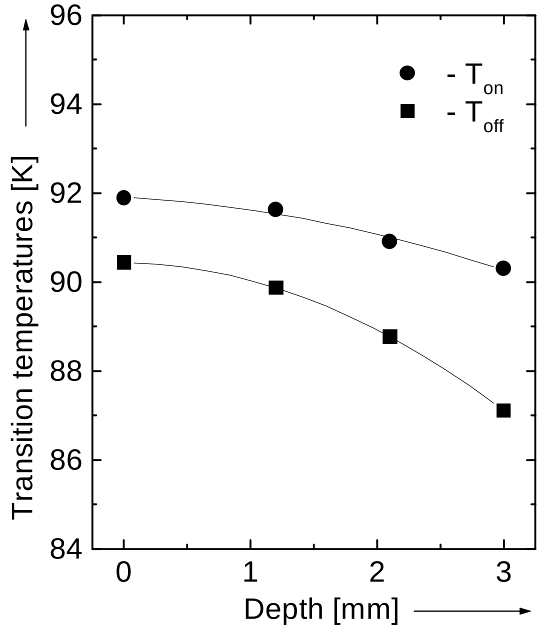

Figure 1. Depth dependence of the experimental determined transition temperatures in the irradiated sample. The curves are to guide the eye.

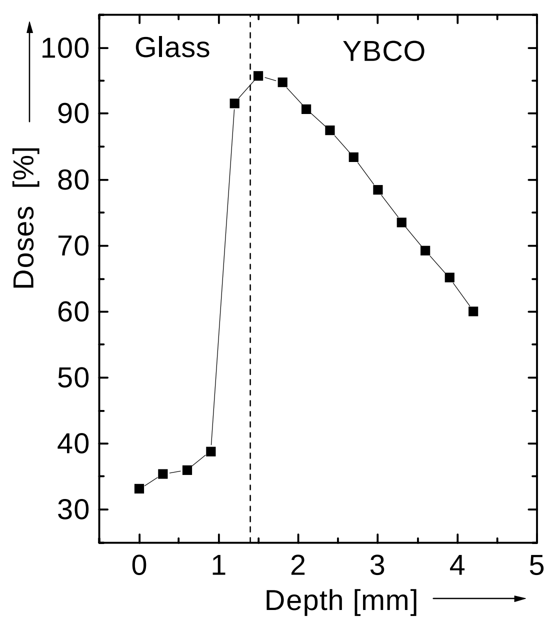

Figure 2. Depth dependence simulation of the deposited doses in the irradiated sample. The curve is to guide the eye.

This inhomogeneous spatial distribution of the doses and therefore of the critical temperature may be one of the possible sources of inconsistent results of irradiation studies.

If the energy of gamma ray increases, then this spatial dose distribution should change too and the maximum of the deposited doses shifts into the sample. In some cases it may occur that the deposited dose is less on the exposed surface than on the opposite one and the maximum is located inside the sample [9].

If the dose is great enough to overdope with defects an specific zone of the material, then the superconducting properties in this zone should be degraded, independently that in other zones these properties may be different due the different deposited doses.

CONCLUSIONS

The initial homogeneity of the spatial transition temperature distribution within the YBCO ceramic disappears after the irradiation with Cs^{137} gamma source. The values of these temperature parameters will depend of the local deposition irradiation doses, which may be sufficiently high in a given zone in order to influence in their structural organization, improving or affecting the local superconducting properties. These aspects are very important to take into account when measurements are carried out using the transport methods to avoid wrong interpretations of the results.

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