

## The effect of sintering in different atmospheres on superconductivity parameters of YBCO

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**Abstract:**  $\text{YBa}_2\text{Cu}_3\text{O}_7$  (Y123) is a superconductor material discovered in 1987 and its transition temperature is above the liquid nitrogen temperature. It is known that superconductor samples produced by the solid-state reaction route are very often sintered in air atmosphere. However, in the presented work, Y123 was prepared by the same technique using a sintering ambient composed of a mixture of oxygen and argon gases for the first time. Critical current densities of the samples were calculated using results of magnetization measurements. It was obtained from magnetization analysis that all the samples exhibited superconductor character. It was also observed that the sample sintered in the 50% oxygen and 50% argon atmosphere showed the highest critical current density.

**Key words:** High- $T_c$  superconductor, sintered Y123, critical current density

### 1. Introduction

It has been discovered that a number of elements (Nb, Ca, Pb, etc.) and compounds (NbN,  $\text{MgB}_2$ , FeSe, etc.) have exhibited superconducting behavior since the discovery of superconductivity [1]. One of these alloys is the YBCO superconductor that was discovered in 1987 [2]. Although YBCO superconductors with different phases have been produced [3–6],  $\text{YBa}_2\text{Cu}_3\text{O}_7$  (Y123) is the phase to which the most attention was paid. The transition temperature of Y123 is about 92 K [7]. As the transition temperature of this phase is above the liquid nitrogen temperature, these types of superconductors are called high temperature superconductors and working with these superconductors has advantages due to their low-cost production and applicability.

Quite a number of studies have been performed to improve the superconducting parameters of Y123. One of these reported works was on Y123 produced by the pyrophoric reaction process. Y123 superconducting material was sintered in argon, air, and oxygen atmospheres and the highest critical current density was calculated for the sample sintered in argon atmosphere [8]. In another study, Al-doped Y123 superconducting material annealed in argon ambient was produced by the top-seeded melt-growth technique. In this study, the peak effect was observed in critical current density curves at the lowest concentration of Al for the standard oxygenation method and at the highest concentration of Al for annealing in argon [9]. It was seen from both studies that heat treatment in different atmospheres had effects on superconducting parameters and especially on the critical current density. In a previous study, the critical current values of  $\text{Y}_3\text{Ba}_5\text{Cu}_8\text{O}_{18}$  (Y358) sintered in oxygen and argon ambient were also reported [10].

Y123 was produced by the solid-state reaction technique in the current study. During the production

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process, a certain mixture of argon and oxygen gases was used as the sintering atmosphere for the first time. Influences of sintering atmosphere on the superconducting parameters of Y123 were investigated.

## 2. Materials and methods

The Y123 superconductor was produced using  $Y_2O_3$ ,  $BaCO_3$ , and  $CuO$  powders by the solid-state reaction technique. The production details are as follows:  $Y_2O_3$ ,  $BaCO_3$ , and  $CuO$  powders were ground for 1 h at stoichiometric ratios. The ground powders were calcined at 840 °C for 24 h inside an  $Al_2O_3$  crucible. After the calcination process, reground powders were weighed to 1 g and compacted in diameters of 12 mm under approximately 220 bar pressure. The prepared samples were then sintered in a cylindrical furnace for 24 h at 930 °C and oxygen gas (600 mL/min) was introduced into the furnace during the growth process. This sample was labeled as S100 by assuming that the 600 mL/min ratio is 100%. A similar procedure was applied only changing the gas flow ratios (300 mL/min oxygen + 300 mL/min argon) and this sample was labeled as S50. In the last step of the production process, at the same temperature and time, the sample was sintered by pumping the argon gas into the chamber at a 600 mL/min ratio. This sample was labeled as S0. A standard oxygenation process was applied to all the samples at 500 °C after sintering treatment.

X-ray diffractometer measurements of the samples were carried out with a Rikagu D/Max III C model instrument using  $CuK_\alpha$  peaks ( $\lambda = 1.5418 \text{ \AA}$ , 40 kV, 30 mA). The  $2\theta$  range of 20° to 60° was scanned in steps of 0.02°. Magnetization measurements of the samples were performed by the VSM module of Quantum Design PPMS at 20 K. The measurements were taken by preparing samples in 2.5 mm × 2.5 mm × 1.5 mm ( $a = b \neq c$ ) dimensions and applying the magnetic field along the  $c$  axis. The critical current densities  $J_c$  ( $A/cm^2$ ) (Eq. (1)) were obtained using the Bean model where  $\Delta M$  was extracted from the M-H hysteresis curve created by VSM.

$$J_c = \frac{20 \Delta M}{a(1 - \frac{a}{3b})} \quad (1)$$

## 3. Results and discussion

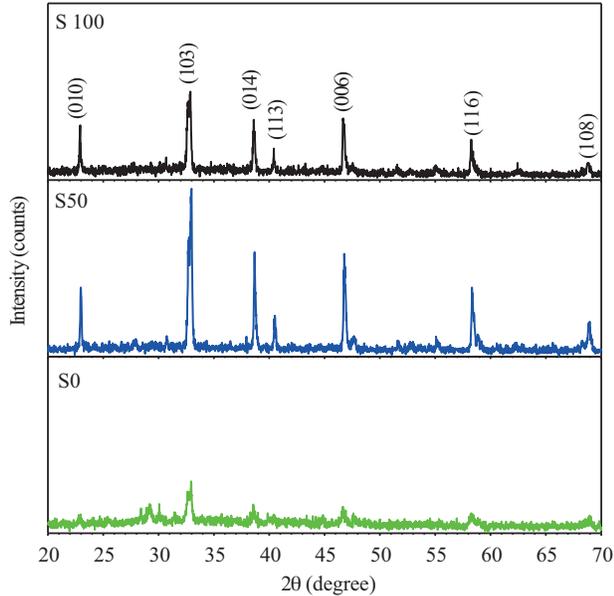
Figure 1 shows the X-ray patterns of the samples. The hkl indices of the characteristic peaks of the Y123 superconductor were marked as seen in the figure. When the figure is investigated, it is seen that all three of the samples have these characteristic peaks. It can be said that the alignment of sample S50 sintered in 50%  $O_2$ -50% argon atmosphere is better than that of the others. Some superconducting parameters of the produced samples of S0, S50, and S100 were determined and are given in the Table. As seen from the table, the lattice parameters a, b, and c are in good agreement with the standard values.

**Table.** Some superconductivity parameters of produced samples.

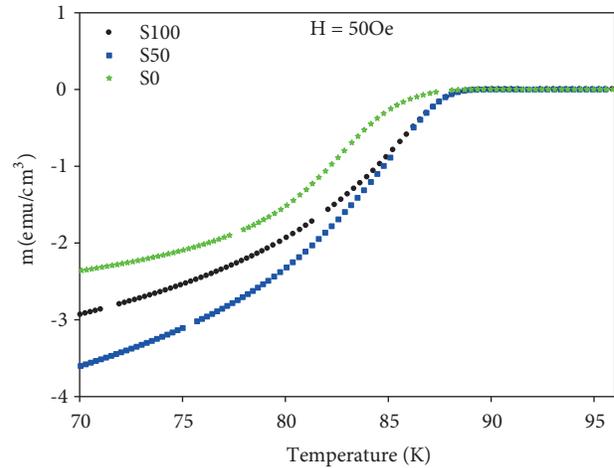
Parameters	S0	S50	S100
a (Å)	3819	3811	3796
b (Å)	3890	3875	4013
c (Å)	11,651	11,648	11,617
$T_c$ (K)	85	88	88
$J_c(0)$ ( $A/cm^2$ )	9489	14,287	12,817
$J_{c,max}$ ( $A/cm^2$ )	12,571	17,751	15,156

Figure 2 represents the change in magnetization of the samples with temperature at 50 Oe. The transition temperature of the superconducting material can indirectly be found using this curve. Figure 2 shows us that

S100 and S50 have transition temperatures of about 88 K while S0 exhibits a transition temperature of about 85 K. Although the samples were oxygenated, the absence of the oxygen in the sintering atmosphere slightly reduces the transition temperature.

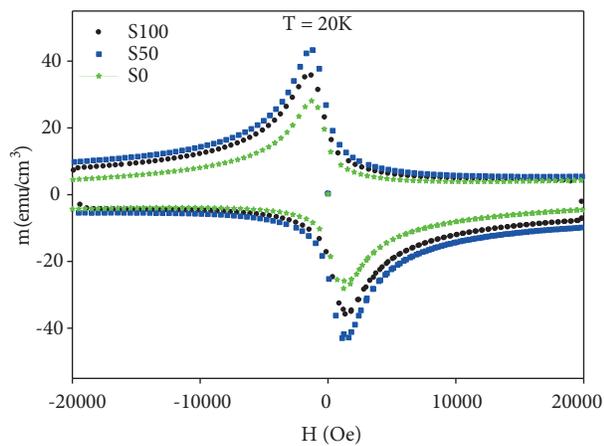


**Figure 1.** The XRD patterns of Y123 samples.

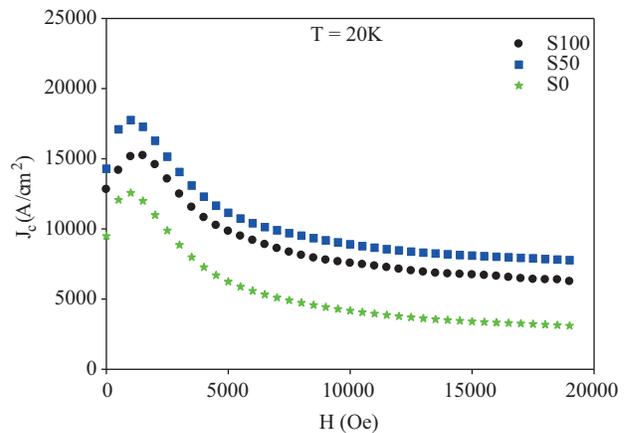


**Figure 2.** Moment-temperature variation of Y123 samples at 50 Oe.

Figure 3 shows the curves of magnetization versus magnetic field. As all three samples show the diamagnetic character, it can be concluded that each sample can show the Meissner effect. When the curves are investigated, the areas under the curves or the energy they store seem to be different. Hence, the calculated critical current density curves also are different (Figure 4). It was seen that the highest critical current density belongs to the sample sintered in 50% O<sub>2</sub> and 50% Ar (S50) atmosphere. This behavior can be explained by the fact that samples sintered in argon atmosphere have higher densification, as shown by Pathak et al.



**Figure 3.** Magnetization hysteresis loops for Y123 samples at 20 K.



**Figure 4.** Critical current density as a function of the applied field extracted from experimental magnetization curves for Y123 samples.

[8]. In addition, they showed that the sintering atmosphere can be correlated with weak-link behavior. In the current study, the sintering atmosphere of S50 may decrease the weak-link behavior and hence cause an increase in the critical current density. However, though S0 was sintered in 100% argon atmosphere,  $J_c$  does not show significantly higher values compared to the other samples (S100 and S0). This could be related to the oxygen dependence of the superconducting materials. The absence of oxygen causes a decrease in  $J_c$  values that is associated with the decrease in transition temperature in Figure 2. It can be concluded that from all the results presented in the current study S50 exhibits the best superconducting parameters as compared with other samples sintered in different atmospheres. Therefore, the experimental measurements revealed that a 50% oxygen and 50% argon sintering atmosphere is the most suitable balance for Y123 sample production.

### Acknowledgment

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