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Fascinating current density features of noble metal doped $YBa_2Cu_3O_{7-\delta}$ (YBCO) Superconducting materials

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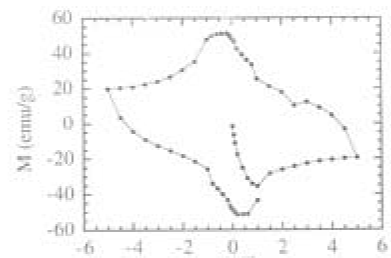
ABSTRACT

$YBa_2Cu_3O_{7-\delta}$
(YBCO)



The aligned YBa2Cu3O7-δ(YBCO) superconducting materials were prepared by unique annealing method on a Gold foil. The structural and other properties of these superconducting materials have been studied i.e. X-ray diffraction, Scanning Electron Micrograph Magnetization and resistivity measurements. The study shows that the change in the Gold doping concentration in these superconducting materials from 0.1 to 3% affected the transition temperature range from 89K to 94K and the critical current density noticeably. The current density measured from the M-H curve is 2 × 104 Acm-2 by Bean Model. Densification and elongated alignment ≈200 µm longs are observed in these materials.

Keywords: Superconductivity; Aligned grains; Magnetization; Au doping; Critical current density

INTRODUCTION

Extensive research on the composite materials is goining on, spanning nearly three decades but there is still a lack of consistencies. Therefore it is important to further research to be conducted to resolve inconsistencies. The various attempt has been made to study the doped $YBa_2Cu_3O_{7-\delta}$ (YBCO) in bulk form high-temperature superconductor with the noble metals, viz Platinum (Pt), Gold (Au), Silver(Ag)[1–11] and Cu of YBCO is replaced by these noble metals. these metals are the same in the periodic table of Cu. Many groups have made composite materials by using Gold (Au).[2,4,5,7,11,12]

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Gold does not exhibit this property, so that Y-Ba-Cu-0 / Au composites should not exhibit this effect. Silver acting as a channel for the diffusion of oxygen into Y-Ba-Cu-0 . could be responsible for nucleating the larger grains observed in cold-pressed Y-Ba-Cu-0 / Ag composites but Y-Ba-Cu-0/Au composites produce grains of much smaller size .

In the low doping of silver in the YBCO, silver plays as an oxygen stabilizer, the critical density enhances in the order of magnitude, the Tc remains unchanged. As the Ag content increases to above 20%, Tc starts to drop, some Ag atoms occupy the Cu-1 and Cu-2 site in this material. and give rise to a modification of weak link profile which causes an increase in current carrying capacity.[1,5] Silver (Ag) plays an important role to promote the kinetic of oxygenation during the growth of YBCO thin film. The advantages of silver doping may be related to its ability in the enhancement of the critical current density and grain growth.[13]

Gold (Au) doped YBCO, the c axis lattice parameter expanded to without changing the oxygenation. The weakening of intergranular link as the concentration of Gold(Au) is above 3%..[1,4,14] Platinum plays as a nucleation center during the melt processing of platinum doped YBCO. The concentration of platinum in the range of 0.5-1 % wt enhanced the critical density 18× 10^3 Acm^{-2} at 77K.[15–17]

EXPERIMENTAL DETAILS

The preparation of the samples $YBa_2Cu_3O_{7-\delta}$ (YBCO) was carried out by Yttrium Oxide (Y_2O_3), Barium Carbonate ($BaCO_3$), Copper Oxide (CuO) in the correct stoichiometric ratio and heated the mixture with using two intermediate grindings.

After pouring the mixture in, to clean die, and hydraulic pressure is used to press in to make pellet form (dia.10mm, thickness 2.5 mm) by using a pressure of 154.4MPa. The pellets were then placed on the Gold foil with a dimension of 2.5× 2.5× 0.1 mm^3 and annealed in the oxygen.

The pellets were heated at different temperature at different time duration i.e.the first pellets were heated at 650 ºC at 2 ºC per minute for 2hours, heated to 950 ºC at 5 ºC per minute for 2hours, then heated at 1020 ºC at 5 ºC per minute held at 1020 ºC for 2hours, now cooled to 1010 ºC at 10^0 C per minute, held at 1010^0 C for 30 minutes and cooled to 950 ºC at 1 º C per minute, held at 950 ºC for 2 hours, cooled to 450 ºC at 1 ºC per minute held at 1020 ºC for 30 minutes and then furnace cooled to room temperature (Sample B). For a few samples, the final annealing temperature was increased to 1030 ºC at 5 º C per minute held at 1030 ºC for 1 hour, cooled to 1020 ºC at 10 ºC for 2 hours (sample C). Other procedure same for Sample B. For comparison, the parent's pellets (annealed the oxygen flow at 950 ºC) Sample A was also studied.

RESULT & DISCUSSION

CuKα radiation was used in X-ray diffraction. All the samples were found to form single phase material and indexes exactly in the same manner as that of the parent orthorhombic YBCO compound. Except for the position 001 peak is shifted reflecting in the change in the lattice parameter. The 006 peak in the X-ray pattern shifted to lower 2θ values due to the incorporation of Gold foil on the Samples B and Sample C while the 020 nearly and 200 peaks remain stationary as shown in Fig. 1.

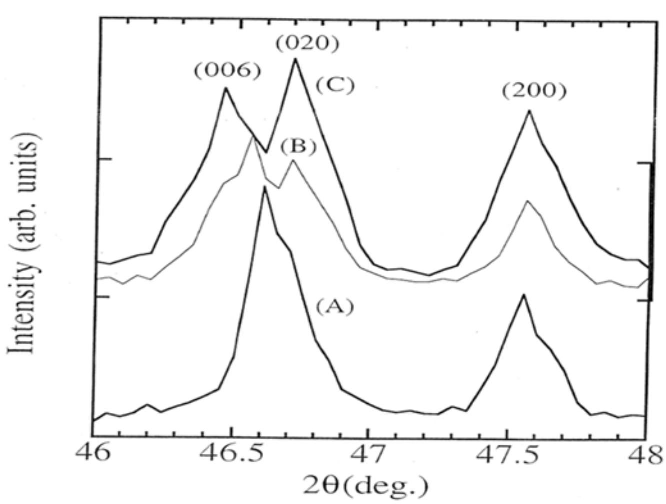

Figure 1 X-ray diffraction pattern of Sample A, Sample B, Sample C of YBCO compound

The melting behaviour of YBCO pallets during the annealing on the platinum[1] and Gold foil is significantly different from that the alumina.[18] The pellets on platinum and Gold foil always retained their shapes in spite of being heated close to melting temperature (1030 ºC). Alumina decomposed and melted.

The elemental composition of all samples was determined by Electron Probe Micro Analysis (EPMA) revealing the atomic ration of 1:2:3 for Y, Ba, Cu in the samples. The Gold concentration of 0.5 to 1 % at sample B and 2 to 3% in sample C was present and mainly confined to the grain boundaries.

The Scanning Electron Micrograph of the samples shows that all are highly densified.[19] The polycrystalline microstructure of sintered materials is absent. The density of the pellets was 93% of the theoretical density of YBCO. In the case of parent material sample A have 76% and sample B shows 85% of the theoretical density of YBCO.[20] As the temperature of 1020 ºC the Gold fills the grain boundaries and attract the YBCO grains closer together and this is seen in the EDXS investigation. In the vicinity of the Gold near the interface long 200 μm maligned grains of YBCO can be seen in Fig. 2. Due to this important nature of Gold, Gold crucibleis is most suitable for growing the big crystal of YBCO.[21]

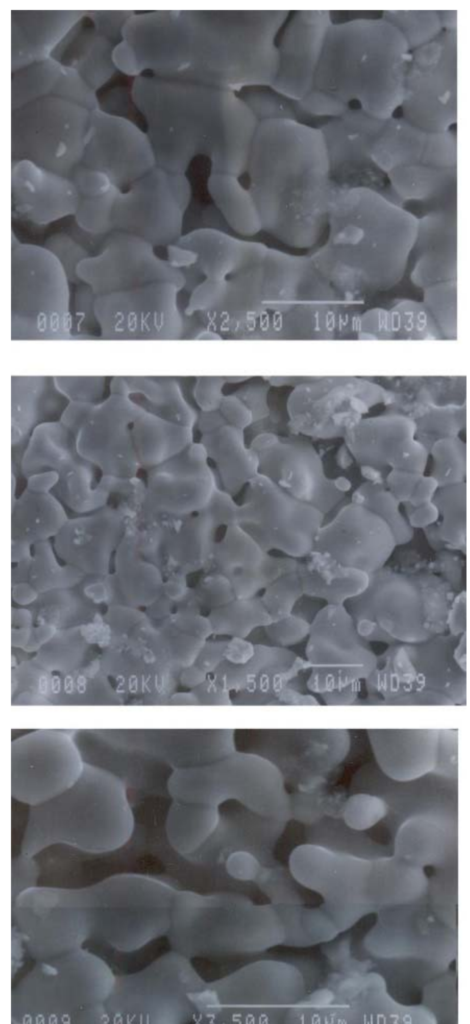

Figure 2. Aligned grain of YBCO observed in sample annealed on Gold foil at 1020 ºC temperature for 2h.

Four point resistivity measurement was made in a closed cycle cryostat as shown in Figure 3.

The superconducting transition temperature Tc increases due to an increase of Gold concentration. The dense Sample C shows Tc≈ 94K higher than both the grain oriented Sample B Tc≈ 92K and parent Sample A Tc ≈89K. The same evidence was found by DC susceptibility measurement.

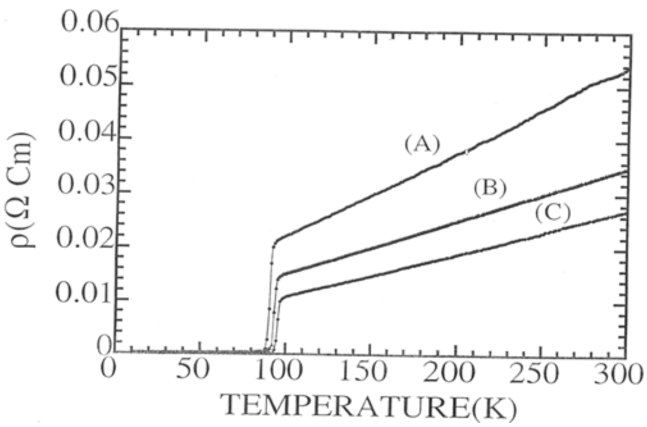

Figure 3. Resistivity versus temperature of Sample A parent Sample, grain-oriented Sample B, highly densified Sample C.

The DC susceptibility as a function of temperature was measured using DC magnetometer.[22] The sample was cooled in zero fields. The susceptibility of these materials are shown in Fig 4 where a sharp superconducting transition at 94.4K is evident for dense Sample C and Sample B and A show Tc≈ 92K, Tc ≈90 K also.

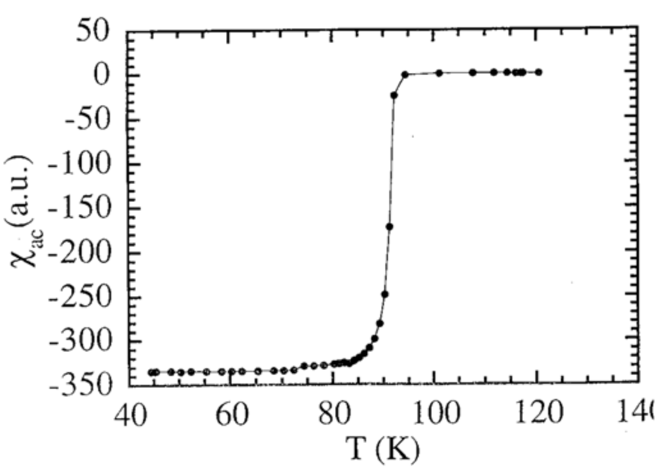

Figure 4 Dc susceptibility of the densified sample annealed on Gold foil 1030 ºC for 1h

The magnetization as a function of magnetic field intensity was measured using a SQUID magnetometer. A plot of magnetization as a function of the c-axis magnetic field is shown in Figure 5, The magnetization shows a sharp minimum load at 1.8KG followed by an approach to saturation.[23] The magnetization curve is similar to that obtained by other workers in single crystal YBCO. The Jc of these samples was calculated by Bean model[16] and it was found that the Jc increases from 4 $\times 10^3$ to 2$\times$ 10^4 Acm^{-2} towards going for densification samples.

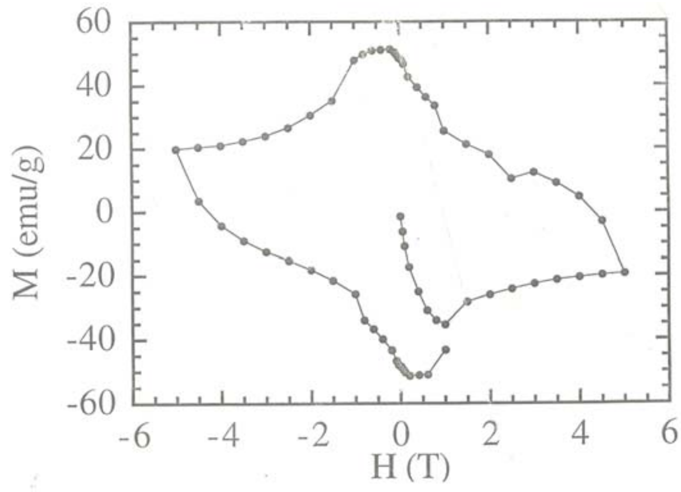

Figure 5. M versus H for the densified Sample annealed on Gold foil at 1030^0 C at 1h

Conclusion

Herein this report describe a new process for the preparation of the Gold dense YBCO, superconductor. The increase of c-axis parameter of the YBCO unit cell is correlated with systematic increases in the Tc value as measured in a transport experiment of the material.

Due to this process, the morphology of the sample is changed, annealed at 1020 ºC for two hours and the crystallites are oriented. Gold has increased the melting point of the YBCO and filled the grain boundaries of the YBCO when it was annealed at 1030 ºC for one hour. this causes an increase in the densification as well as the critical current density of the material**.**

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