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Irreversibility Curve on $Y_{1-x}Lu_xBa_2Cu_3O_{7-\delta}$ (x=0.4, 0.5 and 0.6) superconducting

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Abstract. The irreversibility line in the H−T plane divides the irreversible and reversible behaviour of the magnetization which is of importance for the characterization of high T_c superconductors. In this work, we report the production of $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ (X=0.4, 0.5 and 0.6) superconducting system using the usual solid state reaction method. The irreversibility line H-T plane for the $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ polycrystalline sample was investigated. The curves of magnetization ZFC (cero field cooled)- FC (field cooled) were measured in magnetic fields between 100 Oe and 4000 Oe, and allowed to obtain the values for irreversibility and critical temperatures.

1. Introduction

The mixed state of high temperature superconductors (HTSC) reveals an unusual number of characteristic [1,3], within which we can denote the irreversibility temperature. In type II superconductors the magnetic irreversibility persists up to a well defined temperature limit that depends on the applied field as well as on certain thermodynamic properties of the superconductors [2]. This limit can most precisely be determined from ZFC and FC magnetization data as a function of temperature. The magnetic irreversibility in type II superconductors, originates starting from the movement of vortexes, those which consequently overcome the imprisonment forces. In the region magnetically reversible, the vortexes have enough energy and they can move freely, while to temperatures under T_{irr}, the mobility is restricted and the vortexes remain trapped in the pinning center.

The emergence of irreversibility in a system of superconducting grains is linked to the formation of structures, which are formed by frustrated coupled grains [4]. An arrangement of grains acts as a pinning center freezes locally topological degrees of freedom section of a vortex whose length is much smaller than the width of sample. Above T_{irr} the system is magnetically reversible due to thermal agitation. When temperature decreases below T_{irr}, enough so that many of the grains become coupled, strong irreversibility effects become visible in the magnetization curve.

Plotting the irreversibility data for a range of data in the (H,T), we can demarcate the irreversibility line $T_{irr}(H)$ of each sample. This line separates a region of high temperature magnetically reversible from another of low temperature magnetically irreversible, dividing the phase diagram H(T) in two different areas; one at high fields and temperatures where the magnetic properties are reversible and another region for low field and temperatures, where the magnetic properties are irreversible. Two main theoretical lines are used for the interpretation of the irreversibility line, one of which is that the vortexes are thermally actived. In this case, the reversible behaviour occurs when the flux-creep effects [5, 6] becoming dominant. The other line of reasoning suggests that associated whit T_{irr}, a phase transition occurs. In this line, we have the theories of lattice fusion of vortices (flux melting) [5, 6], glass superconductor (superconducting glass) [7] and glass of vortexes (vortex-glass) [8].

2. Experimental

Samples of $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ material, were synthesized by the standard solid state reaction recipe, from Aldrich precursor powders of Y_2O_3 (99.9%), Lu_2O_3 (99.99%), $BaCO_3$ (99.997%) and CuO (99.9%). Powders were mixed, grinded, palletized and calcined at temperature of 750 °C for 12 h. Then, material was regrind, pressed as circular disks and sintered at 900 °C for 36 h, with two intermediate pulverizations. Crystalline structure was studied by X-ray diffraction, with a nickel-filtered Cu-Kα radiation (λ=1.5406 Å) of a SIEMENS D5000 equipment.

3. Results and discussion

In figure 1 the XRD patterns of $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ are represented, being taken at room temperature. It is clear from figure 1 that all samples have the single phase with tetragonal RE:123 unit cell. Rietveld refinement was performed to determine the lattice parameters a= 3.8090 Å, b= 3.8770 Å y c= 11.6570 Å, whit symmetry of space group P4/mmm.

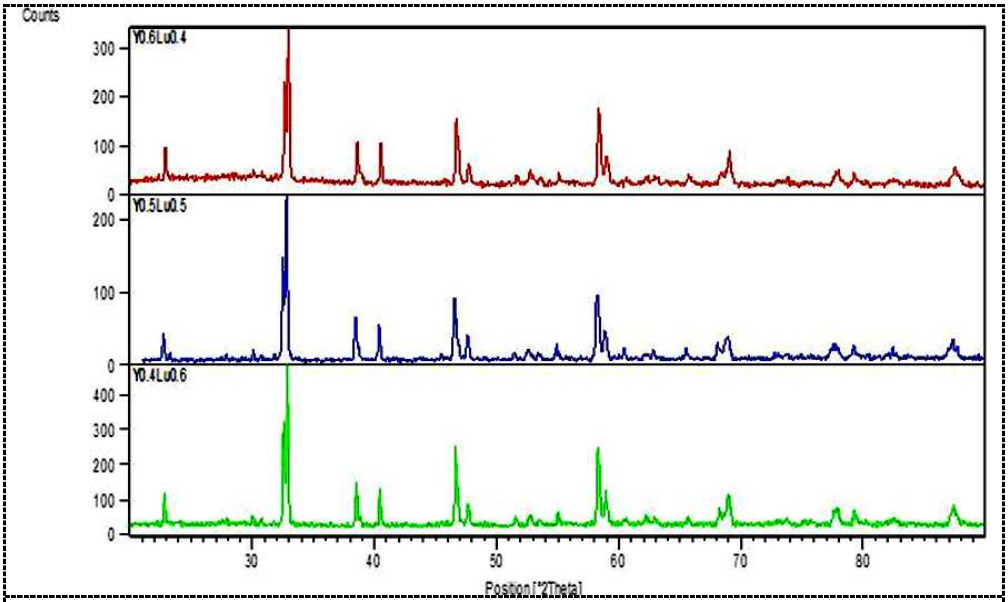

Figure 1. XDR patterns for $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ system

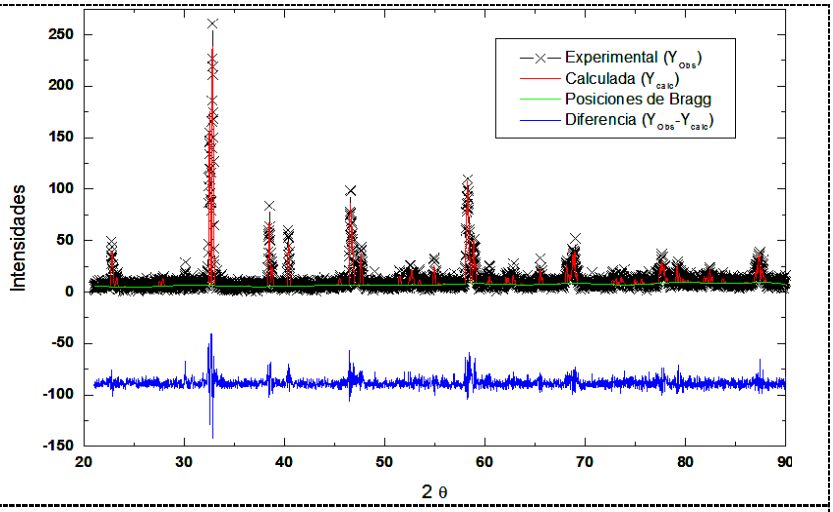

Figure 2. Rietveld refinement of sample $Y_{0.5}Lu_{0.5}Ba_2Cu_3O_{7-\delta}$ through the program General Structure Analysis System (GSAS)

By detecting secondary electrons and backscattered electrons are allowed to determine the morphological characteristics of the three samples, which were observed and analysed, at different magnifications: 2000X, 2500X y 5000X. Figure 3 shows the micrographs featuring homogeneous granularity including two zones (white and gray). The superconducting behaviour of the system $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$, was verified from measurements of magnetization, which is determined with critical temperatures ranging from 91.2 K ($Y_{0.6}Lu_{0.4}Ba_2Cu_3O_{7-\delta}$), 89.8 K ($Y_{0.4}Lu_{0.6}Ba_2Cu_3O_{7-\delta}$), and 90.2 K ($Y_{0.5}Lu_{0.5}Ba_2Cu_3O_{7-\delta}$). The T_c for these two samples was predicted by Skakle and West [9] and Anderson et al. [10], reporting temperatures lower than those obtained in this work. On the other hand, the critical temperatures obtained for the system are in close agreement with those predicted by other authors for CLBCO type system [11].

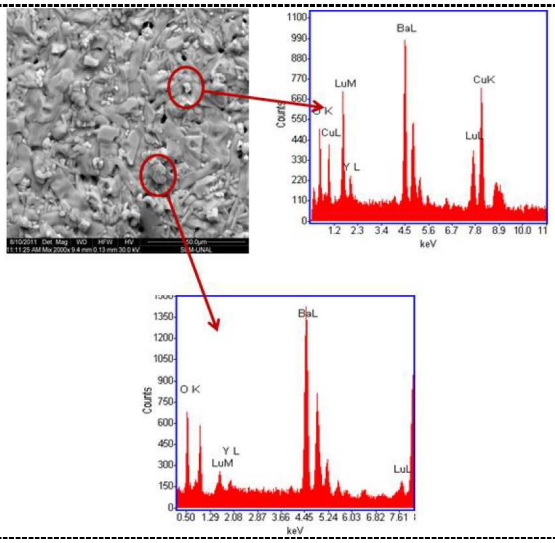

Figure 3. White and gray zone micrograph of the sample $Y_{0.5}Lu_{0.5}Ba_2Cu_3O_{7-\delta}$

The DC magnetization results for all $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ system are shown in figure 4. The transition temperature T_C for systems has defined as the onset of the diamagnetic transition. The transition temperature and irreversibility were obtained through from Zero Field Cooled (ZFC) and Field

Cooled (FC) magnetization data as a function of temperature. In figure 5 the curve ZFC-FC is shown for the $Y_{0.6}Lu_{0.4}Ba_2Cu_3O_{7-\delta}$ sample. In figure 6 we show the behaviour of temperature irreversibility for each of the samples with fields ranging from 100 Oe to 4000 Oe.

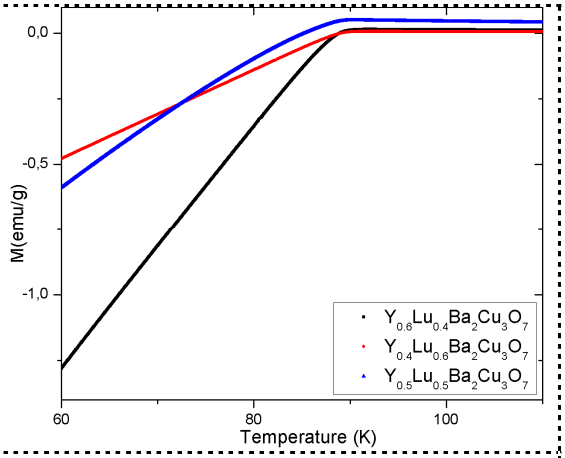

Figure 4. Magnetization result for all samples of the $Y_{1-x}Lu_xBa_2Cu_3O_{7-\delta}$ system.

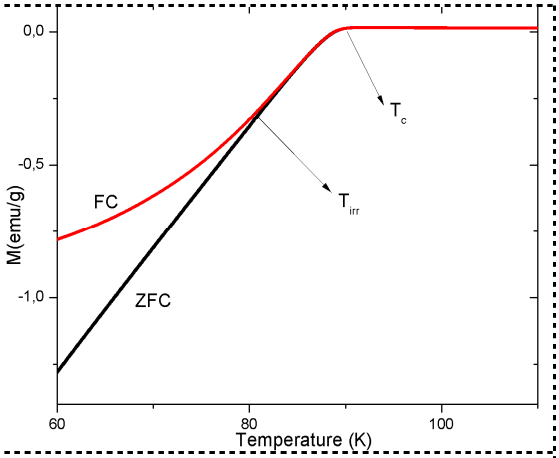

Figure 5. ZFC and FC magnetization by $Y_{0.6}Lu_{0.4}Ba_2Cu_3O_{7-\delta}$ sample.

Table 1. Structural results obtained from the Rietveld refinement method and critical temperature.

Sample	χ^2	a (Å)	b (Å)	c (Å)	T_C (K)
$Y_{0.6}Lu_{0.4}Ba_2Cu_3O_{7-\delta}$	1.183	3.813(9)	3.881(8)	11.678(7)	91.2
$Y_{0.4}Lu_{0.6}Ba_2Cu_3O_{7-\delta}$	1.348	3.814(3)	3.880(2)	11.671(7)	89.9
$Y_{0.5}Lu_{0.5}Ba_2Cu_3O_{7-\delta}$	1.527	3.813(1)	3.879(1)	11.684(1)	90.2

The results obtained by refinement (χ^2, structural parameters), as well as that T_C for the field but lower than they are in Table 1.

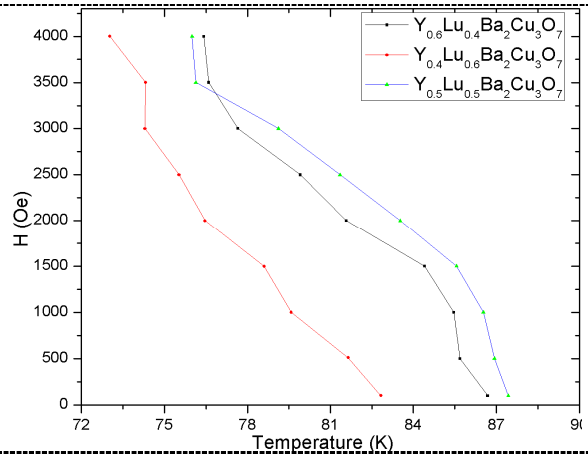

Figure 6. The magnetic irreversibility data of a $Y_{0.5}Lu_{0.5}Ba_2Cu_3O_{7-\delta}$ system

4. Conclusion

The superconducting behaviour of the $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ system was verified from measurements of magnetization, obtaining critical temperatures higher than those reports by Skakle and West [9] and Anderson et al. [10]. The obtained results allow concluding that in the $Y_{1-X}Lu_XBa_2Cu_3O_{7-\delta}$ system a characteristic bend of the Almeida–Thouless (AT) tendency is dominant for low fields and a bend Gabay–Toulouse (GT) behaviour for high magnetic fields. This feature of the irreversibility line has been reported as a characteristic of granular superconductors and it corroborates the topological effects of vortexes mentioned by several authors [14–16].

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