

BEHAVIOR OF THE IRREVERSIBILITY LINE IN THE NEW SUPERCONDUCTOR

$\text{Lu}_{3-x}\text{Gd}_x\text{Ba}_5\text{Cu}_8\text{O}_{18}$ FOR $x = 1.5$ AND $x = 2$

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COMPORTAMIENTO DE LA LÍNEA IRREVERSIBILIDAD EN EL NUEVO SUPERCONDUCTOR $\text{Lu}_{3-x}\text{Gd}_x\text{Ba}_5\text{Cu}_8\text{O}_{18}$ RARA $X = 1.5$ AND $X = 2$



ABSTRACT

The irreversibility properties of High-Tc superconductors are of major importance for technological applications. For example, a high irreversibility magnetic field is a more desirable quality for a superconductor (Viera, et al., 2001). The irreversibility line in the H-T plane is constituted by experimental points, which divides the irreversible and reversible behavior of the magnetization. The irreversibility lines for series of $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ polycrystalline samples with different doping were investigated. The samples were synthesized using the usual solid state reaction method. Curves of magnetization ZFC (Zero Field Cooled) FC (Field Cooled) for the system $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$, were measured in magnetic fields of the 100 to 2,000 Oe, and allowed to obtain the values for the irreversibility and critical temperatures. The data of irreversibility temperature allowed demarcating the irreversibility line, $T_{irr}(H)$. Two main lines are used for the interpretation of the irreversibility line: one of those which suppose that the vortexes are activated thermally and the other proposes that associated to T_{irr} (Irreversibility Temperature) a phase transition occurs. The irreversibility line is described by a power law. The obtained results allow concluding that in the system $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ a characteristic bend of the Almeida-Thouless (AT) tendency is dominant for low fields and a Gabay-Toulouse (GT) behavior for high magnetic fields.

KEYWORDS

Magnetization, Irreversibility Line, High Critical Temperature Superconductors, Method solid state reaction.

RESUMEN

Las propiedades de irreversibilidad de los superconductores de alta Tc son de gran importancia para las aplicaciones tecnológicas. Por ejemplo, un campo magnético de alta irreversibilidad es de una calidad más deseable para un superconductor (Viera, et al., 2001). La línea de irreversibilidad en el plano H-T está constituida por puntos experimentales, que divide el comportamiento irreversible y reversible de la magnetización. Se investigaron las líneas de irreversibilidad de la serie de muestras policristalinas $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ y $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ con diferente dopaje. Las muestras se sintetizaron utilizando el método de reacción de estado sólido usual. Se midieron curvas de magnetización ZFC (Zero campo enfriada) FC (campo enfriada) para el sistema de $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ y $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$, en los campos magnéticos de la 100 a 2000 Oe, y se dejaron para obtener los valores para la irreversibilidad y las temperaturas críticas. Los datos de temperatura de irreversibilidad permitidos para la demarcación de la línea de irreversibilidad: $T_{irr}(H)$. Dos líneas principales se utilizan para la interpretación de la línea de irreversibilidad: uno de los que suponen que los vórtices se activan térmicamente y el otro propone que, asociado a T_{irr} (irreversibilidad de temperatura), se produce una transición de fase. La línea de irreversibilidad es descrita por una ley de potencia. Los resultados obtenidos permiten concluir que en el sistema $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ y $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ una curva característica de la tendencia Almeida-Thouless (AT) es dominante para los campos de bajos y un comportamiento (GT) Gabay-Toulouse es para altos campos magnéticos.

PALABRAS CLAVE

Magnetización, Línea de Irreversibilidad, Superconductores de Alta Temperatura Crítica, Método de Reacción de Estado Sólido.

INTRODUCTION

The mixed state of the high temperature superconductors (HTSC) reveals an unusual number of characteristics (Roa-Rojas, *et al.*, 2000; Udomsamuthirun, *et al.*, 2010), within which we can denote the irreversibility temperature. In the 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 (Topal *et al.*, 2011). This limit can most precisely be determined from ZFC (Zero Field Cooled) and FC (Field Cooled) magnetization data as a function of temperature. The emergence of irreversibility in a system of superconducting grains is linked to the formation of structures, which are formed by frustrated coupled grains (Aliabadi, *et al.* 2009). 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} (Irreversibility Temperature) the system is magnetically reversible due to thermal agitation. When the 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 region of low temperature magnetically irreversible, divides 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 field and lower 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 vortices are thermally activated. In this case, the reversible behavior occurs when the flux-creep effects (Aliabadi, *et al.*, 2009; Tavana & Akhavan, 2010) becoming dominant. The other line of reasoning suggests that associated with T_{irr} , a phase transition occurs. In this line, we have the theories of lattice fusion of vortices (flux melting) (Aliabadi, *et al.*, 2009; Tavana & Akhavan, 2010), glass superconductor (superconducting glass) (Landinez-Tellez, *et al.*, 2008) and glass of vortices (vortex-glass) (Toby 2001).

RESULTS AND DISCUSSION

In Figure 1 the XRD patterns of the $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ are represented, being taken at room temperature. It is clear from Figure 1 that all samples are the single phase with tetragonal RE: 123 unit cell, and other crystallographic phases due to impurities in the samples do not exist. The lattice parameters $a = 3.8909 \text{ \AA}$, $b = 3.8291 \text{ \AA}$ and $c = 31.2090 \text{ \AA}$, with symmetry of space group P4/mmm. The superconducting behavior of the system $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ was verified from measurements of magnetization, which is determined with critical temperatures ranging from 65 K $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and 78 K $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$. The T_c (Critical Temperature) for these two samples was predicted by Skakle and West (Davor-Pavuna, *et al.*, 1992) and Anderson *et al.* (Yagi, *et al.*, 1991) reporting temperatures lower than those obtained in this work. On the other hand, the critical temperatures obtained for the system $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ are in close agreement with those predicted by other authors for Lu-Gd-Ba-Cu-O type system (Barros, *et al.*, 2004; Parra-Vargas, *et al.*, 2007; Parra-Vargas, *et al.*, 2009).

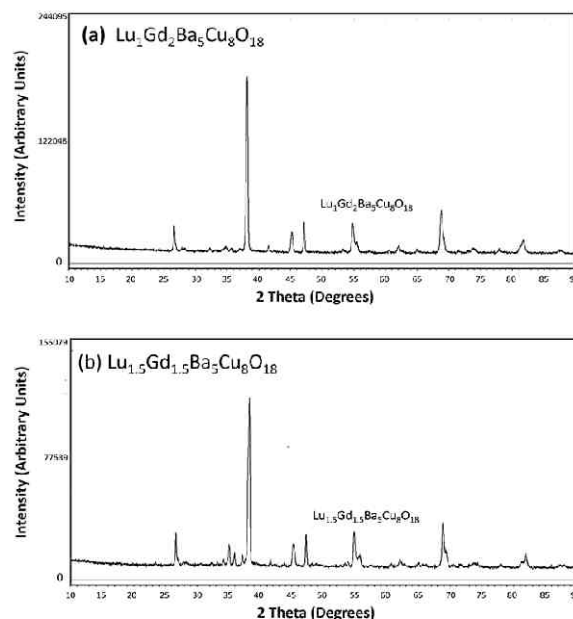


Figure 1. XRD patterns for $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ (a) and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ (b)

The DC magnetization results for all samples of the $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ system are shown in Figure 2. The transition temperature T_c for these systems has been defined as the onset of the diamagnetic transition (Barros, *et al.*, 2004; Parra-

Vargas, *et al.*, 2007; Parra-Vargas, *et al.*, 2009). The transition temperature and irreversibility were obtained through from Zero Field cooled (ZFC) and Field cooled (FC) magnetization data as a function of temperature

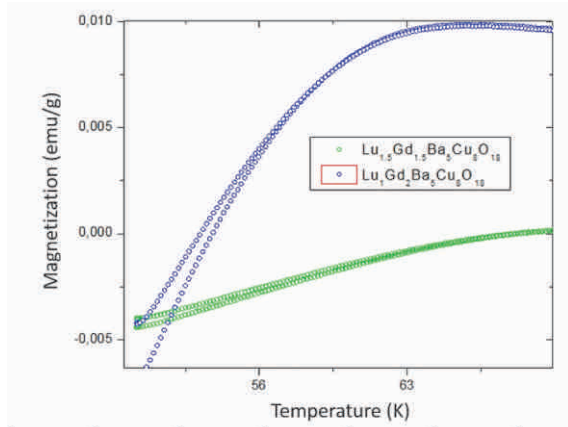


Figure 2. Magnetization results for all samples of the $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$

In Figure 3 and Figure 4 the curves Zero Field cooled ZFC and Field cooled FC is shown for $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ samples. The theoretical structural parameters for $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ are in Table 1 and Table 2, as well as that of T_c for the field but lower they results are in Table 3. The continuous lines through the low field data T_{irr} in Figure 5 are fitting of the Almeida-Thouless (AT) like lines (Viera, *et al.*, 2001; Barden & Stephen, 1965)

$$H = H_0^{AT} [1 - t^{AT}]^\alpha \text{ with } \left(\alpha = \frac{3}{2} \right)$$

where $t^{AT} = T_{irr}^{AT}(H)/T_{irr}^{AT}(0)$, H_0^{AT} and $T_{irr}^{AT}(0)$ are fitting parameters, which represent, respectively, the irreversibility field at zero temperature and the extrapolation of the $T_{irr}^{AT}(0)$ to zero field.

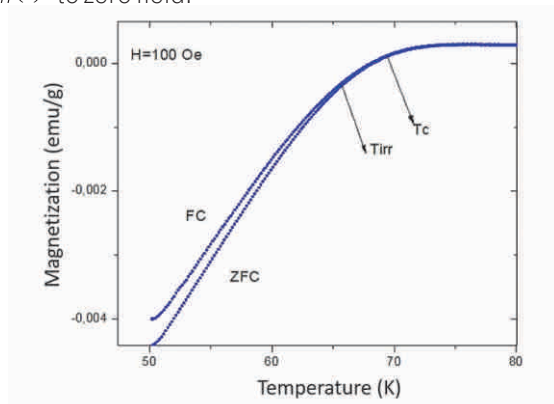


Figure 3. ZFC and FC magnetization by $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$

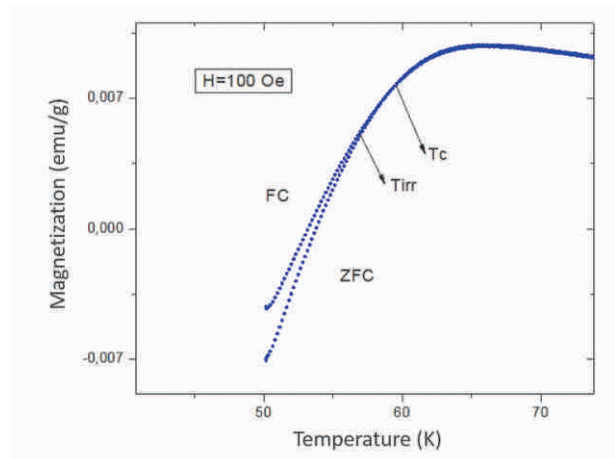


Figure 4. ZFC and FC magnetization by $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$

a(Å)	b(Å)	c(Å)		
3.890	3.829	31.399		
Ion	x(Å)	y(Å)	z(Å)	SOF
Lu(1)	0.49	0.49	0.00	0.5
Gd(1)	0.49	0.49	0.37	0.5
Ba(1)	0.49	0.49	0.12	1
Ba(2)	0.49	0.49	0.24	1
Ba(3)	0.50	0.51	0.61	1
Ba(4)	0.50	0.51	0.74	1
Ba(5)	0.49	0.49	0.87	1
Cu(1)	0.00	0.00	0.05	1
Cu(2)	0.00	0.00	0.18	1
Cu(3)	0.00	0.00	0.32	1
Cu(4)	0.00	0.00	0.43	1
Cu(5)	0.00	0.00	0.54	1
Cu(6)	0.00	0.00	0.67	1
Cu(7)	0.00	0.00	0.80	1
Cu(8)	0.00	0.00	0.93	1
O(1)	0.50	0.00	0.05	1
O(2)	0.00	0.50	0.50	1
O(3)	0.00	0.00	0.12	1
O(4)	0.00	0.51	0.18	1
O(5)	0.00	0.00	0.25	1
O(6)	0.00	0.50	0.32	1
O(7)	0.00	0.50	0.32	1
O(8)	0.00	0.00	0.93	1
O(9)	0.50	0.00	0.43	1
O(10)	0.51	0.00	0.54	1
O(11)	0.00	0.51	0.54	1
O(12)	0.00	0.00	0.61	1
O(13)	0.00	0.51	0.67	1
O(14)	0.00	0.51	0.74	1
O(15)	0.00	0.00	0.79	1
O(16)	0.00	0.50	0.86	1
O(17)	0.50	0.00	0.93	1
O(18)	0.00	0.50	0.93	1

Table 1. Structural theoretical model use for the samples from $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ $x=1.5$

a(Å)	b(Å)	c(Å)		
3.890	3.829	31.399		
Ion	x(Å)	y(Å)	z(Å)	SOF
Lu(1)	0.49	0.49	0.00	0.33/0.66
Gd(1)	0.49	0.49	0.37	0.66/0.33
Gd(2)	0.50	0.50	0.48	0.66/0.33
Ba(1)	0.49	0.49	0.12	1
Ba(2)	0.49	0.49	0.24	1
Ba(3)	0.50	0.51	0.61	1
Ba(4)	0.50	0.51	0.74	1
Ba(5)	0.49	0.49	0.87	1
Cu(1)	0.00	0.00	0.05	1
Cu(2)	0.00	0.00	0.18	1
Cu(3)	0.00	0.00	0.32	1
Cu(4)	0.00	0.00	0.43	1
Cu(5)	0.00	0.00	0.54	1
Cu(6)	0.00	0.00	0.67	1
Cu(7)	0.00	0.00	0.80	1
Cu(8)	0.00	0.00	0.93	1
O(1)	0.50	0.00	0.05	1
O(2)	0.00	0.50	0.50	1
O(3)	0.00	0.00	0.12	1
O(4)	0.00	0.51	0.18	1
O(5)	0.00	0.00	0.25	1
O(6)	0.00	0.50	0.32	1
O(7)	0.00	0.50	0.32	1
O(8)	0.00	0.00	0.93	1
O(9)	0.50	0.00	0.43	1
O(10)	0.51	0.00	0.54	1
O(11)	0.00	0.51	0.54	1
O(12)	0.00	0.00	0.61	1
O(13)	0.00	0.51	0.67	1
O(14)	0.00	0.51	0.74	1
O(15)	0.00	0.00	0.79	1
O(16)	0.00	0.50	0.86	1
O(17)	0.50	0.00	0.93	1
O(18)	0.00	0.50	0.93	1

Table 2. Structural theoretical model use for the samples from Lu₁Gd₂Ba₅Cu₈O₁₈x=2

Lu ₁ Gd ₂ Ba ₅ Cu ₈ O ₁₈	T _c	H _c	T _{irr}
	64.91	100	59.13
	64.83	200	60.93
	63.45	300	60.23
	63.27	400	60.19
	61.3	500	55.24
	61.06	600	57.09
	60.28	700	53.65
	60.14	800	53.63
	59.27	900	54.83
	58.08	1000	56.62
Lu _{1.5} Gd _{1.5} Ba ₅ Cu ₈ O ₁₈ x=1.5	T _c	H _c	T _{irr}
	70.62	100	69.2
	71.7	200	69.24
	72.15	300	68.17
	70.63	400	67.13
	70.12	500	65.08
	69.08	600	64.94
	69.48	700	62.9
	69.22	800	61.25
	69.85	900	60.93
	66.7	1000	59.83
	69.85	1500	58.46
	66.7	2000	57.72

Table 3. Irreversibility temperature T_{irr} and critical temperature T_c determined in the presence of magnetic field for the samples Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈ x=1.5 and Lu₁Gd₂Ba₅Cu₈O₁₈ x=2

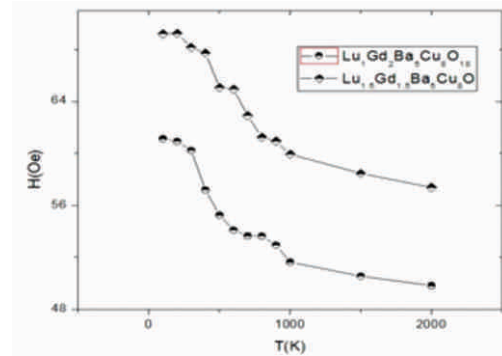


Figure 5. The magnetic irreversibility data Lu₁Gd₂Ba₅Cu₈O₁₈ and Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈

In the presence of high magnetic fields it presents the Gabay-Toulouse (GT) behavior type (Fischer, 1989)

$$H = H_0^{GT} [1 - t^{GT}]^\alpha \text{ with } \left(\alpha = \frac{1}{2} \right)$$


where $t^{GT} = T_{irr}^{AT}(H) / T_{irr}^{GT}(0)$, H_0^{GT} being the irreversibility field at $T=0$ and $T_{irr}^{GT}(0)$ is the extrapolation of the GT-like line to zero field (Peng, *et al.*, 1989; Gabay & Toulouse, 1981).

CONCLUSIONS

The production and characterization of the new superconducting materials Lu₁Gd₂Ba₅Cu₈O₁₈ and Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈ is reported. The compound Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈, becomes superconductor at a high temperature of 64.9 K y 70.6 K respectively, with applied fields until 2000 Oe. The structural ordering is in agreement with similar ones reported by other authors (Udomsamuthirun, *et al.*, 2010; Topal *et al.*, 2011) for the Y₃Ba₅Cu₈O₁₈ compound. Although the optimal Lu₁Gd₂Ba₅Cu₈O₁₈ and Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈ synthesis conditions are not yet known, it has been shown that the production of a novel superconductor system RE₃Ba₅Cu₈O₁₈, with substitutions of the Y with RE atoms, can be successfully made; it is worth to mention that RE₃ can be made with RE_{3-x}RE_{2x} combinations. The latest result can initiate a broad research field in superconductivity of high (Critical Temperature) T_c, which could add pivotal information for the understanding of the mechanism which gives rise to the superconductivity at high T_c.

The superconducting behavior of the system Lu₁Gd₂Ba₅Cu₈O₁₈ and Lu_{1.5}Gd_{1.5}Ba₅Cu₈O₁₈ was verified from measurements of magnetization, obtaining critical temperatures higher than those reports by Skakle

and West (Davor-Pavuna, *et al.*, 1992) and Anderson *et al.* (Yagi, *et al.*, 1991). The obtained results allow concluding that in the system $\text{Lu}_1\text{Gd}_2\text{Ba}_5\text{Cu}_8\text{O}_{18}$ and $\text{Lu}_{1.5}\text{Gd}_{1.5}\text{Ba}_5\text{Cu}_8\text{O}_{18}$ a characteristic bend of the Almeida-Thouless (AT) tendency is dominant for low fields and a bend Gabay-Toulouse (GT) behavior 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 (Larson & Von Dreele, 2000; Skakle, 1994; Anderson, *et al.*, 2003).

The REBCO family of superconductors has been shown to feature relatively high T_c . A recently introduced member of this family, RE358, has been argued to exhibit $T_c \geq 100$ K. Characterization of this phase has been the subject of some recent investigations. However, in the recently reported experiments, there are some discrepancies in distinguishing the RE358 from the RE123 phase. Our objective here has been to resolve such discrepancies conclusively. In doing so, we prepared samples in which both of the phases coexisted. We verified existence of both phases via X-ray diffraction experiment supplemented with standard theoretical X-ray diffraction. The observation that our results are in good agreement with one of the reported experiments, thus clearly identifying the characteristics of RE358 superconductors. 

BIBLIOGRAFÍA

- ALIABADI, A., AKHAVAN, F. Y. & AKHAVAN, M. 2009. A new Y-based HTSC with Tc above 100 K. *Physical C* 469, 20122014.
- ANDERSON, P. S., KIRK, C.A., SKAKLE, J. M. S. & WEST, A. R. 2003. Synthesis and characterization of $\text{La}_x\text{BaCu}_y\text{O}_{13+x}$ AND $\text{La}_x\text{BaCu}_{1-x}\text{MxO}_{13+x}$; M=Fe, Co, Ni, Zn J. *Solid State Chem.* 170 (1).
- ANDERSON, P. W. & KIM, Y. B. 1964. Hard Superconductivity; Theory of the Motion of Abrikosov Flux Lines *Review of Modern Physics*, (New York) 36 (1) 39.
- BARDEN, J & STEPHEN, M. J. 1965 Theory of the Motion of Vortices in Superconductors. *Phys. Rev.*1197.
- BARROS, F. M., VIEIRA, V.N. *et al.* 2004. Magnetoresistivity, fluctuation conductivity and magnetic irreversibility in the $\text{Y}_{0.95}\text{Pr}_{0.05}\text{Ba}_2\text{Cu}_3\text{O}_{7-\delta}$ compound: a case of split pairing transition *physical C* 408410 (632).
- DAVOR-PAVUNA, M. C. 1992. *Introduction to Superconductivity and High-Tc Materials*, World Scientific Publishing Co. Pte. Ltd.
- DE ALMEIDA, J. R. L. & THOULESS, D. J. 1978. Stability of the Sherrington-Kirkpatrick solution of a spin glass model. *J. Phys. A* 11 (983).
- FISCHER, M.P.A. 1989. Vortex-glass superconductivity: A possible new phase in bulk high-Tc oxides *Phys. Rev. Lett.* 62 (1415).
- GABAY, M. & TOULOUSE, G. 1981. Coexistence of Spin-Glass and Ferromagnetic Orderings *Phys. Rev. Lett.* 47 (201).
- LANDINEZ-TELLEZ, D. A., ROA-ROJAS, J., MARTINEZ BUITRAGO, D. & PARRA VARGAS, C. A. 2008. Producción y caracterización del material superconductor $\text{Yb}_{0.6}\text{Sm}_{0.4}\text{Ba}_2\text{Cu}_3\text{O}_7$. *Rev.Colomb. Fis.* 40(1), 101, 103.
- LARSON, A. C. & VON DREELE, R. B. 2000. *General Structure Analysis System*, Los Alamos National Laboratory Report LAUR, 86.
- PENG, J. L., KLAVINS, P. *et al.* 1989. Enhanced magnetoresistance in layered magnetic structures with antiferromagnetic interlayer exchange *Phys. Rev. B* 39 (9074).
- PARRA-VARGAS, C. A., LANDNEZ TELLEZ, D. A. & ROA-ROJAS, J. 2007. Determining superconducting parameters from analysis of magnetization fluctuation for $\text{CaLaBaCu}_3\text{O}_{7-\delta}$ superconductor *physical B* 398 (301).
- PARRA-VARGAS, C. A., PIMENTEL J. R., PUREUR, P., LANDINEZ TELLEZ, D. A. & ROA-ROJAS, J. 2009. Magnetization fluctuation analysis and superconducting parameters of $\text{La}_{0.5}\text{RE}_{0.5}\text{BaCaCu}_3\text{O}_{7-\delta}$ (RE=Y, Sm, Gd, Dy, Ho, Yb) superconductor *physical B* 404 (2766).
- ROA-ROJAS, J, MENEGOTTO COSTA, R, PUREUR, P. & PRIETO, P. Fluctuaciones en la magnetoconductividad de bajo campo en superconductores texturizados de $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ *Phys. Rev. B* 61. 12457.
- SKAKLE, J. M. S. & WEST, A. R. 1994. Superconducting $\text{La}_{1-x}\text{Ba}_{1.5+x-y}\text{Cu}_y\text{O}_z$ solid solutions I. Phase diagram, cation stoichiometry and Tc data *Physica C* 220 (187).
- TAVANA, A. & AKHAVAN, M. 2010. How Tc can go above 100 K in the YBCO family. *Eur. Phys. J. B.* 73, 7983.
- TOBY, B. H. 2001. EXPGUI, a graphical user interface for GSAS. *J. Appl. Crystallogr.* 34, 210213
- TOPAL, U. & AKDOGAN, M. 2011. Further increase of Tc in YBaCuO superconductors. *J. Supercond. Nov. Magn.* Doi:10.1007/s10948011129-1
- UDOMSAMUTHIRUN, P., KRUAEHONG, T., NILKAMJON, T. & RATRENG, S. 2010. The new superconductors of YBaCuO materials. *J. Supercond. Nov. Magn.* 23, 13771380.
- VIERIA, V.N & PUREUR, P.J. the effects of Sr and Ca on the magnetic irreversibility and fluctuation conductivity of ybco-123 2001. *Schaf, Physics C* 353-241.
- YAGI, T., DOMON, M., OKAJIMA, Y. & YAMAYA, K. 1991. Low-temperature crystal structure and superconductivity in $\text{La}_{2-x}\text{Ba}_x\text{CuO}_4$ *Physica C* 173. 453.