Thermoanalytical Study of the superconductor Compound $Y_{0.85}Ho_{0.15}Ba_2Cu_3O_7$

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Abstract

A ceramic superconductor compound $Y_{0.85}$ $Ho_{0.15}$ Ba_2 Cu_3 O_7 was prepared by solid state reaction method in our laboratory. The thermo analytical behavior of the prepared compound in the range 20-1000 ^{O}C has been studied using DTA technique. Use has been made of the equations of Avrami and Arrhenuis to determine the most significant parameters of our compound, where we have introduced the data extracted from the DTA spectrum of our compound into the two equations. The outputs from the equations included important parameters such as the growth rate (k), kinetic of transformation (n) and the activation energy Ea, which was found equal to 0.72 eV.

Introduction

The superconducting compound $YBa_2Cu_3O_6$ have been studied by many groups [1]. They reported that the superconducting phase was orthorhombic, but can be changed to tetragonal phase by substitution with a certain rare earth elements [2,3]. It was found that the phase transformation was related to the redistribution of oxygen atoms in the structure [4].

Many researchers studied the phase transformation and its parameter related to both nucleation and activation energy using Differential Thermal Analytical (DTA) technique [5].The analysis of the DTA spectrum was done by observing the evolved and absorbed heat with respect to a reference material that appears as an endothermic and exothermic peaks [6,7]. These peaks represent a thermal reaction that would happen in the material under study through the heat treatment from room temperature of 20 ^{O}C up to 1000 ^{O}C.

Details about the kinetic of transformation play great role in understanding the configuration structure of high temperature superconductor. Accordingly, we have carried out the present work. The main aim of this work was to study the kinetic of transformation as a result of the substitution of 15% of the weight of Y by Ho in the compound $YBa_2Cu_3O_6$.

Experimental Procedure

A ceramic sample of the compound $Y_{0.85}$ $Ho_{0.15}$ Ba_2 Cu_3O_7 was prepared using solid state reaction method. High purity powders of $[(Y_2O_3)_{0.85},(HO_2O_3)_{0.15}]$, $BaCO_3$ and CuO with the ratio 1: 2: 3 were mixed after milling, then calcined at an appropriate temperature to ensure decarbonation. Pressed disks of the calcined powder are then sintered, those produced ceramic sample were used for the determination of the properties of the superconducting phase of our compound.

Results and Discussion

The DTA spectrum of the superconductor $Y_{0.85}Ho_{0.15}$ Ba_2 Cu_3 O_7 is shown in Fig.(1). From this figure, it can be noticed that during the heating process there is an exothermic peak started at about 400 ^{O}C, up to 540 ^{O}C with a hump at about 475 ^{O}C. While in the range 570- 750 ^{O}C an endothermic peak took place with a hump at 600 ^{O}C and there is another endothermic peak in the range 930-985 ^{O}C with a hump at 960 ^{O}C.

In the cooling cycle there is a reversible exothermic peak in the range 975- 890 ^{O}C with a hump at 935 ^{O}C related to the last peak of the heating cycle. The appearance of this reversible peak at a temperature higher than 930 ^{O}C means that a phase transformation has taken place in this sample.

To investigate the kinetic of the transformation we applied the Avrami equation [8]:

$1- x = \exp(-kt^n)$.....(1)

Where x is the volume fraction transformation, k is a constant related to rate of growth, t is the time of reaction, and n is the kinetic of transformation.

Equation (1) may be written as:

$\ln (1-x) = -kt^n$,or

$\ln (1-x)^{-1} = kt^n$

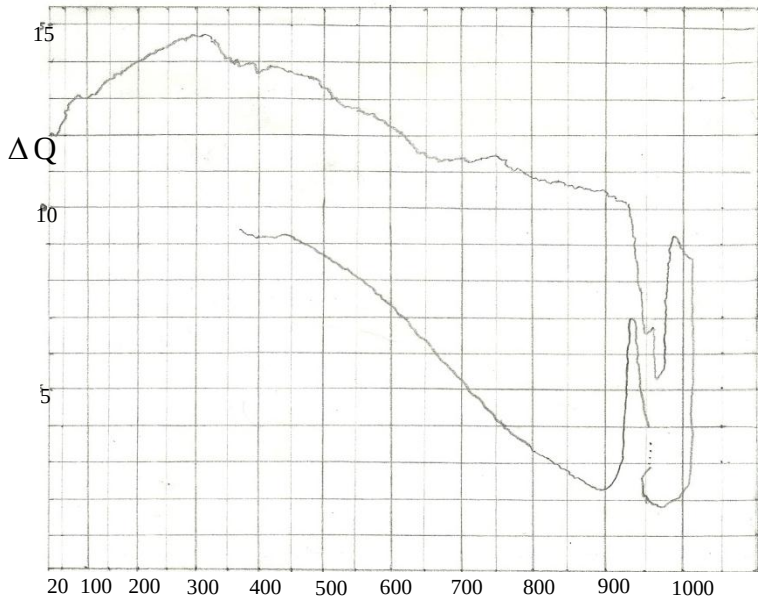

Fig.(1) The DTA spectrum of the superconductor $Y_{0.85}$ $Ho_{0.15}$ Ba_2 Cu_3 O_7.

Taking the log of this last equation gives;

$\log\ln(1/(1-x)) = n \log t + \log k$.....(2)

Thus if we plot log [ln(1/(1-x))] against log t, the liner relation between them will outputs the value of the slope of the plot as the value of n and the plot intersection represents the log of the rate of the growth (log k).

Thus the slope of the plot gives the value of n and its intersection gives the rate of the growth. Fig.(2) shows the Avrami plots, and the data exerted from this figure are listed in Table (1). According to the formal theory of transformation and growth [9] when the values of n in the range 2-3, there is a partial redistribution of the atoms in two dimension which leads to a partial deviation in the lattice constants. This indicate the orthorhombic to tetragonal phase transformation by evolving O(1) atoms until b- parameter become equal to a-parameter and the structure become tetragonal.

The Arrhenuis equation:

$k = k_0 \exp - (E_a/K_B T)$ .....(3)

where k is the rate constant (in Avrami equation), k_0 is a constant, E_a is the activation energy, K_B is Boltzman constant, and T is the temperature in Kelvin.

The result of the application of this equation to our data is shown in Fig.(3).

Notice the negative values of lnk, this is due to the fact that the values of 1/ T are always fractions less than one in the present work.

The activation energy E_a is found to be equal to (0.72 eV). We think that this value of activation energy is the reason for the nucleation growth in two or three dimensions.

Table (1)
The results of the Avrami equation.

T (K)	*n*	*k*
748	2.02	0.025
938	2.30	0.012
1233	3.25	0.03
1208	3.02	0.05

Conclusion

The application of Avrani equation to the data extracted from the DTA spectrum of our superconducting compound $Y_{0.85}$ $Ho_{0.15}$ Ba_2 Cu_3 O_7 , (see Fig.(1)), shows that the kinetic of transformation n has values of 2.2 and 2.4 for peak temperatures of 748 and 938 Kelvin respectively. This implies that there is a partial redistribution for the atoms in two dimensions, which in turn imply that there is a partial deviation in the lattice constants.

The activation energy of our superconductor $Y_{0.85}$ $Ho_{0.15}$ Ba_2 Cu_3 O_7 is found to be equal to 0.72 eV. It is believed that this value is the main reason for the nucleation growth in the sample.

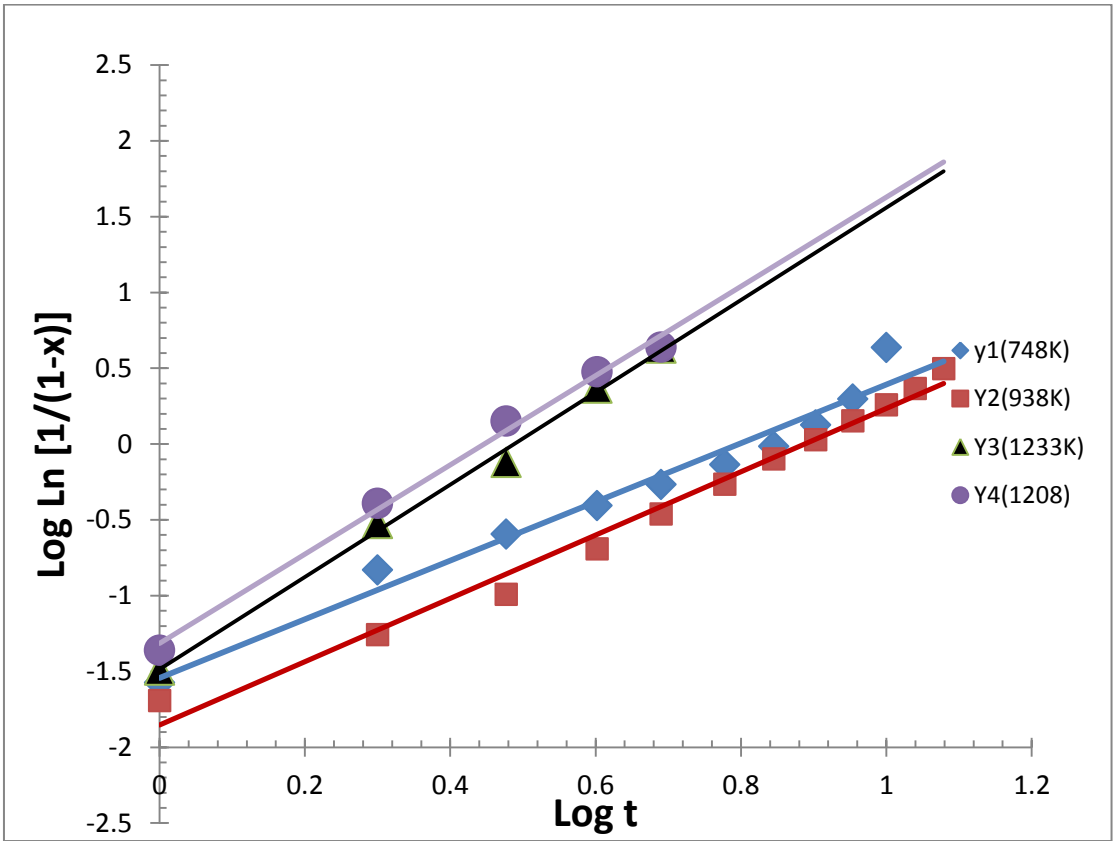

Fig.(2) The applications of Avrami equation due to DTA-spectrum.

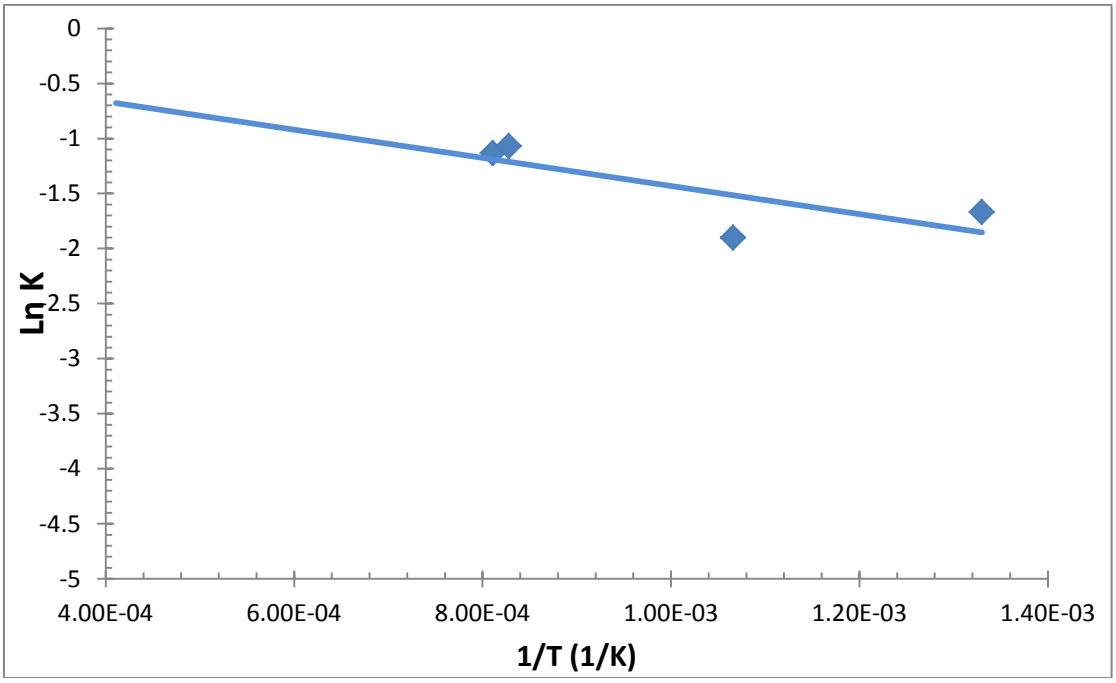

Fig.(3) The application of Arrhenuis equation.

(k) وميكانيكية التحول الطوري (n) وطاقة التنشيط (Ea). فقد أظهرت النتائج أن طاقة التنشيط (Ea=7.2eV) والتي تمثل طاقة تواجد ذرات الأوكسجين في المركب وعلاقتها مع التحول الطوري للمركب.

References

[1] Chu C.W. "Superconductivity at 93 K in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure", Phys. Rev. Lett., Vol. 58, pp. 908, 1987.

[2] Antipov E.V. et al. "Structural features, oxygen and florine doping in Cu-based superconductors", Physica C 61-64, pp. 282-287, 1997.

[3 Goodwin T.J. "Synthesis Composition and Structure of Superconducting (Y,Ca) (Sr,Ba)2Cu2GaO7" J. Supercond., Vol. 8, pp.21, 1995.

[4] Shakarchi E.Kh. "The effect of Partial Substitution on the Thermoanalytical Behavior of the Compound $Y_{0.95}$ $Eu_{0.05}$ $Ba_{1.9}$ $Sr_{0.1}Cu_3$ O_7 ", J. Al-Nahrain Univ.-Sci. Vol. 4, No. 2, 2000.

[5] Shakir Sk.J."Thermoanalytical Study of Superconducting $Y_{0.95}$ $Eu_{0.05}$ $Ba_{1.9}$ $Sr_{0.1}Cu_3$ $O_{6.798}$ ", J. Al-Nahrain Univ.-Sci, Vol. 3, No.1, 1999.

[6] Sugai T. and Imai S. "Thermoanalytical Studies on Preparation Conditions of Superconducting YBa Cu_3 O_{7-y} ", Jap. J. Appl. Phys., Vol. 28, No.3, p.341, 1989.

[7] Shakarchi E.Kh. and Al-Bythany M.T. "Thermoanalytical Study and its Effect on the Nucleation Growth of $Y_{0.7}$ $Eu_{0.3}$ Ba_2 Cu_3 $O_{7-\sigma}$ Crystaline Superconductor", Eng Technology, Vol. 20, Suppl. of No. 4, 2001.

[8] Christain J. W. "The Theory of Transformation in Metals and Alloys", 2nd ed., Part 1, Pergamon Press, 1975.

[9] Shi D. "Phase Transformation in Y Ba_2 Cu_3 $O_{7.5}$", Phys. Rev. B, Vol. 39, p.4299, 1989.

الخلاصة

يتضمن البحث دراسة الخواص الحرارية للمركب فائق التوصيل (Y0.85Ho0.15 Ba2 Cu3 O7)

والذي تم تحضيره بإستخدام طريقة الحالة الصلبة. أجريت الدراسة بإستخدام جهاز التحليل الحراري DTA ضمن المدى الحراري ٢٠ – ١٠٠٠ درجة مئوية. ومن خلال دراسة القمم الظاهرة في طيف التحليل التفاضلي وتطبيق معادلتي فرامي وأرهينيوس على النتائج المستخرجة من الطيف تم إيجاد المعادلات التي تربط العلاقة بين التفاعلات الحرارية للمركب وعوامل التحول الطوري الممثلة بمعدل النمو