Influence of Ti-Doping on Y257 Superconductor

Narin Sukgree, Apichart Phatthanawiriyapisal, Thitipong Kruaehong *

Department of Physics, Faculty of Science and Technology, Suratthani Rajabhat University, Surat Thani, 84100 Thailand

Received 23 November 2017; Revised 21 April 2018; Accepted 25 April 2018

Abstract

The bulk of Y257 doped with Ti was synthesized by solid state reaction. The formula of the Y257 are $Y_2Ba_5Cu_7TixO_{15}$–x, which x = 0, 0.05, 0.10, 0.15, 0.20, 0.25 mol. Critical temperatures were measured by using a standard four-probes technique. The surface and element analysis employed used the EDX mapping method. Thermal analysis was characterized by Differential Thermal Analysis (DTA). The maximum critical temperature value increased at a Ti concentration of 0.20 mol. The surface of the samples has a Ti composite. The surfaces were smooth, denser and homogenous. The peritectic temperature of the Ti-doped samples was lower than the pure samples.

KEYWORDS: Y257 Superconductor; Solid state reaction; Titanium–doped

* Corresponding authors; e-mail: kruaehong@hotmail.com

Introduction

Since the discovery of the high-temperature superconductors in ceramic superconducting material, researchers have attempted to improve this material for commercialism [1]. The main properties that have been improved are critical temperature (T_c) [2]. Critical current density (J_c) [3] Critical magnetic field (H_c) [4]. However, the weak link problem in this material makes the commercial application difficult. Several years after the discovery of the Y123 [5] superconductors, many groups of Yttrium compound superconductors were found [6 – 9]. Their critical temperature increase depended on the oxygen content concentrations in the crystal structure [10]. Recently, new Y358 superconductors witha critical temperature of 102 K, the highest critical temperature was found [11]. In 2010, a new Y-based superconductor was reported by Udomsamutirun et al [12]. The new superconductor was synthesized under the assumption that, the numbers of Y atoms plus Ba atoms equals to Cu atoms. The offset critical temperature ($T_{c\ offset}$) range from 88 K to 94 K and onset critical temperature range from 90 K to 92 K were reported. Their critical temperature remains in critical temperature of Y123. After that, in 2013, Kruaehong [13] synthesized Y-based superconductors having two atoms of Yttruim, Y257($Y_2Ba_5Cu_7O_{15-x}$). The temperature of calcinations and sintering was at 950 °C. The critical temperature (T_c) was measured by the four-probes method and showed a critical temperature over 90 K. The higher sintering temperature remains porosity on surface of the samples. So, the method solved the inhomogeneous and porosity in the samples. In 2014, Sahoo and Behera [14] studied the influence of Ti doping on structural and superconducting properties of $YBa_2Cu_3O_{7-y}$ with concentration of 0%, 0.01%, 0.02%, 0.04%, 0.05% and 0.07%, respectively. The samples were prepared by the solid state reaction method. The calcined and sintered were at 927 °C with annealed temperature at 450 °C. The Ti-doping did not improve the weak-link surface, the superconducting grains and the critical temperature. The *a* and *b* lattice parameter did not change, but *c* lattice parameter increased following Ti-doping concentration. The grain sized of pure samples more doped samples. For 0.05% Ti-doping, the grain size decrease was important.

In this paper, we reported the properties of Y257 doped Ti with various concentrations. Improvement of physical properties of Y257 superconductors was expected. The samples were synthesized by solid state reaction and investigated the transition critical temperature, morphology surface, elemental analysis and peritectic temperature.

Materials and Methods

Samples of Y257($Y_2Ba_5Cu_7Ti_xO_{15-x}$) were added with various concentrations of titanium were x= 0, 0.05, 0.10, 0.15, 0.20, 0.25 mol of titanium. Starting materials were Y_2O_3, $BaCO_3$, CuO and TiO_2 with the ratio appropriate amount of high-purity powder and prepared by solid state reaction method. The mixed powder was calcined twice in a box furnace at 950 °C for 24 hrs. The resulting powder was reground. The fine powder was pressed into pellets with a diameter of 30 mm and 3 mm in thickness and sintered at 950 °C for 24 hrs. Temperature was decreased in the furnace for annealing at 500 °C for 12 hrs. in air environment. Transition critical temperature was measured by using the standard four-probes technique. Simultaneous results of the surface morphology and elementary distribution were investigated by using Energy Dispersive X-ray spectroscopy (EDX, Quanta 400) with the mapping technique. The peritectic temperature was investigated, showing temperatures between 940 °C – 1,200 °C with increment temperature of 2 °C min^{-1} by DTA measurement (DTA7 Perkin Elmer).

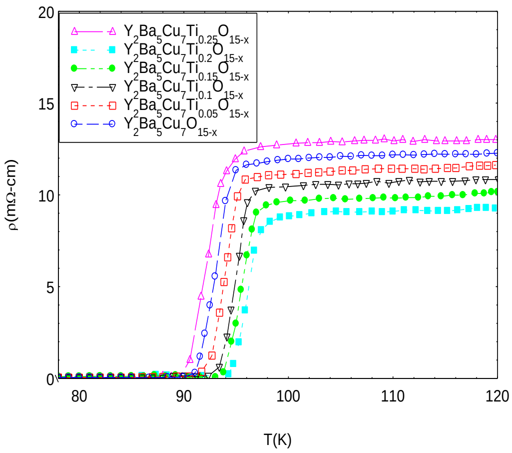

Fig. 1 Shown the resistivity versus temperature of Y257 and Y257 + Ti superconductors.

Table 1 The critical temperature of our samples.

Sample	$T_{c\ offset}$(K)	$T_{c\ onset}$(K)
Y257	89.92	94.99
Y257 + 0.05Ti	90.55	95.87
Y257 + 0.10Ti	92.37	96.81
Y257 + 0.15Ti	93.03	96.95
Y257 + 0.20Ti	94.99	97.37
Y257 + 0.25Ti	89.64	94.08

Results and Discussion

The bulk samples of Y257 and Ti composite were investigated for transition critical temperature using the conventional four-probe method. The temperature measurement interval was between 77 K – 120 K and simultaneous inject the current density of 2.55 × 10^{-3} Am^{-2}. $T_{c\ onset}$ (K) and $T_{c\ offset}$ (K) can be read from the curve between resistivity and temperature as shown in Fig.1. The $T_{c\ onset}$ (K) is defined as it intersects with the tangent of the part where resistance dropped abruptly, and $T_{c\ offset}$ (K) is defined as the temperature at which the electrical resistance reached zero. The obvious effect of the Ti-doped on Y257 superconductor was found. The $T_{c\ offset}$ and $T_{c\ onset}$, increased with increasing titanium content. The maximum of both T_c (K) occurred in Y257 + 0.20Ti as 94.99 K and 97.37 K, respectively. At Ti concentration of 0.25 mol, both T_c values were the lowest critical temperature of all samples. Thus, The Ti-doping was limited. The Ti-doping concentration about 0.20 mol can improve the critical temperature.

The EDX (Energy Dispersive X-ray Spectroscopy) mapping was used as a technique to measure the simultaneous of surface and elementary analysis and attached SEM (Scanning Electron Microscope). The micrographs of EDX are shown in the Fig. 2. The mapping method was considered area of point of the surface. The mapping results showed the simultaneous of the surface and elementary apparent at the considered area. Moreover, indicated the characteristic X-ray of each element and final self of electron transition. The results revealed that, the surface of pure Y257 was inhomogeneous and porous. The Ti-doped samples had higher density and lower porosity than the pure sample. The best sample with smooth surfaces and density occurred in Y257 + 0.20Ti. The pure and Ti doped sample consist of Y, Ba, Cu and O elements and Ti, respectively. The final transition of the characteristic X-ray can be classified in two groups. The $L_{\alpha 1}$ belong to Y and Ba and $K_{\alpha 1}$ belong to Cu, O and Ti. The elementary distribution is shown in different colors. The maximum distribution of element were Y and O elements as shown in pink color and green color without impurity.

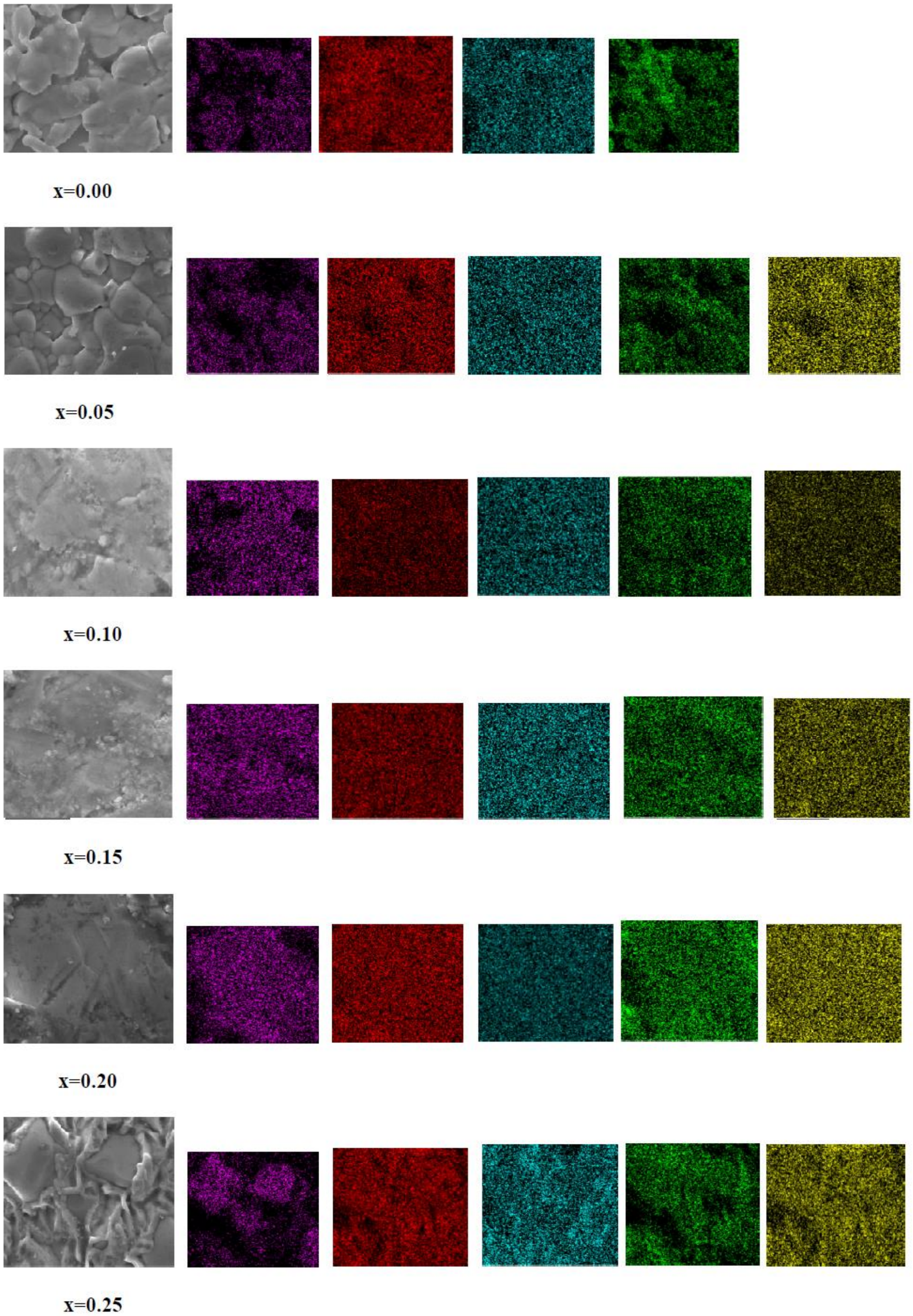

Fig. 2 The surface morphology Y257 and Y257 doped Ti superconductor.

The thermal properties of samples were measured by Differential Thermal Analysis (DTA) interval temperature of 941 °C – 1,200 °C with increasing heating rate of 2 °C min^{-1}. The heat reaction showed the endothermic reaction. The determined peritectic temperature value was about that for the temperature of the sintering temperature. The synthesized sample above peritectic temperature can be the sample transform to from solid to liquid phase. The superconducting compound changed to a more non-superconducting compound. The peritectic temperature of Y257 and Ti doped are shown in the Table 2. The peritectic temperature was decreased with increasing the content of Ti additives. The pure sample showed the highest the peritectic temperature. The maximum Ti-doped showed the lowest peritectic temperature. The peritectic temperature of Y257 + 0.25Ti were close to the sintering temperature process. The more Ti-doped peritectic, the lower the temperature of all the samples. This benefit of the lower peritectic temperature can be applied for synthesizing thin film superconducting material.

Table 2 The peritectic temperature of Y257 and Y257 + Ti samples.

Sample	Peritectic Temperature (°C)
Y257	976.73
Y257 + 0.05Ti	973.73
Y257 + 0.10Ti	970.12
Y257 + 0.15Ti	960.03
Y257 + 0.20Ti	957.12
Y257 + 0.25Ti	955.37

There are many approaches that can improve the physical properties of Y-based superconductors with Ti doping. One of the methods used to synthesize is the melt textured process. In 2002, Yanmaz et al [15]. Synthesize Y123 by the melt process with Ti doped in the range of 0 – 10 wt.%. The samples were calcined at 938 °C for 24 hrs. and melt at 1025 °C for 1 hrs. The Ti doped interval 1% to 5% decreased the critical temperature, and 7 – 10 wt.% increased the critical temperature. Thus, in order to improve physical properties of Ti-doped samples, many concentrations of Ti are required.

Conclusion

The bulk of Y257 and Ti composite were synthesized by solid state reaction. The formula of doped Ti as are $Y_2Ba_5Cu_7TixO_{15-x}$ which x=0, 0.05, 0.10, 0.15, 0.20, 0.25 mol. The physical properties of the samples was investigated. The critical temperatures were measured using the standard four-probe technique. The surface and element analysis were employed by using the EDX mapping method. The thermal analysis was characterized form Differential Thermal Analysis (DTA). The critical temperature value increased with Ti concentration. However, the Ti-doped improvement was limited. The maximum critical temperature value occurred at 0.20 mol. At Ti concentration at 0.25 mol, the critical temperature was lower than pure sample. The Ti-doped on Y257 can improve the surface which are smooth and denser. Mostly the samples of Ti-doped provided homogenous surface. Finally, the peritectic temperature of Ti-doped was lower than pure samples and close to the sintering temperature.

References

[1] H. Fang, K. Chandar, Fabrication of Y123 Disk by the Seeded Infiltration and Growth Method, Physica C. 340 (2000) 261 – 268.

[2] S.B. Guner, O. Gorur, S. Celik, M. Dogruer, G. Yildirim, A. Varilci, C. Terzioglu, Effect of Zirconium Diffusion on the Microstructural and Superconducting Properties of $YBa_2Cu_3O_{7-\delta}$ Superconductors, J. Alloy. Compd. 540 (2012) 260 – 266.

[3] T. Goto, Critical Current Density of Filamentary Y123 Superconductor, Physica C. 263 (1996) 450 – 452.

[4] H. Cao, N. Moutalbi, C. Harnois, R. Hua, J. Li, L. Zhou, J.G. Noudem, Novel Configuration of Processing Bulk Textured $YB_2Cu_3O_{7-x}$ Superconductor by Seeded Infiltration Growth Method, Physica C. 470 (2010) 68 – 74.

[5] C.W. Chu, P.H. Hor, R.L. Meng, L. Gao, Z.J. Huang, Y.Q. Wang, Evidence for Superconductivity above 40 K in the La-Ba-Cu-O compound system, Phys. Rev. Lett. 58 (1987) 405 – 407.

[6] P. Marsh, R.M. Fleming, M.L. Mandich, A.M. Desantolo, J. Kwo, M. Hong, L.J. Miranda, Crystal Structure of the 80 K Superconductor $YBa_2Cu_4O_8$, Nature. 334 (1988) 141 – 143.

[7] J. Karpinski, S. Rusiecki, B. Bucher, E. Kaldis, E. Jilek, The Non-stoichiometry of high-T_c Superconductor $Y_2Ba_4Cu_7O_{15\pm x}$(14 «T_c«68 K), Physica C. 161 (1989) 618 – 625.

[8] P. Romano, R. Dileo, A.M. Cucola, A. Nigro, B. Dabrowski, P.G. Radaelli, Tunnel Junction on1:2:4 Y-Ba-Cu-O Single Crystal, Physica C. 235 – 240 (1994) 1913 – 1914.

[9] P. Chainok, S. Sujinnapram, T. Nilkamjon, S. Ratreng, K. Somsri, N. Phomphuang, P. Mychareon, P. Udomsamuthirun, The synthesis of $YBa_3Cu_4O_x$ superconductor and comparison with $YBa_2Cu_3O_x$, Adv. Mat. Res. 979 (2014) 220 – 223.

[10] J.Y. Genoud, T. Graf, G. Triscone, A. Junod, J. Muller, Variation of the Superconducting and Structural Properties of $Y_2Ba_4Cu_7O_z$ with Oxygen Content(14.1«z«15.3,30 K«Tc«95), Physica C. 192 (1992) 137 – 146.

[11] A. Aliabadi, A. Farshchi, M. Akhavan, A New Y-based HTSC with T_c above 100 K, Physica C. 469 (2009) 2012 – 2014.

[12] P. Udomsamuthirun, T. Kruaehong, T. Nilkamjon, S. Ratreng, The new superconductors of YBaCuO materials, J. Supercond. Nov. Magn. 23 (2010) 1377 – 1380.

[13] T. Kruaehong, Preparation and Characterization of the new Y257 superconductors, Adv. Mat. Res. 770 (2013) 22 – 25.

[14] M. Sahoo, D. Behera, Effect of Ti Doping on Structural and Superconducting Property of$YBa_2Cu_3O_{7-y}$ High T_c Superconductor, J. Supercond. Nov. Magn. 27 (2014) 83 – 93.

[15] E. Yanmaz, S. Balci, T. Kucukomeroglu, Magnetic Properties of Melt Textured $YBa_2Cu_3O_{7-\delta}$with TiO_2 dopant, Mat. Lett. 54 (2002) 191 – 199.