J Supercond Nov Magn (2010) 23: 1377–1380
DOI 10.1007/s10948-010-0786-9

ORIGINAL PAPER

The New Superconductors of YBaCuO Materials

P. Udomsamuthirun · T. Kruaehong · T. Nilkamjon · S. Ratreng

Received: 26 November 2009 / Accepted: 19 April 2010 / Published online: 4 May 2010

Abstract The new YBaCuO superconductors are synthesized by using the standard solid-state reaction method as compositions of Y5-6-11, Y7-9-16,Y358, Y5-8-13, Y7-11-18, Y156, Y3-8-11, and Y13-20-23, where the numbers indicate Y, Ba, and Cu atoms respectively; all show the Meissner effect at 77 K. The resistivity measurements used by the four-probe method have shown the highest T_c onset is 94 K. The XRD spectra are shown and they have a similar crystalline structure as Y123 and Y358 materials with some impurities peaks.

Keywords YBaCuO superconductors · Solid state reaction

1 Introduction

In 1986, Bednorz and Muller [1] found the first high-temperature superconductors in La214 compound that showed the transition temperature (T_c) above 30 K. And in 1987 the transition temperature of $YBa_2Cu_3O_7$ (Y123) was increased to around 92 K by Chu and co-workers [2]. The researchers have carried out on the YBaCuO-family compound like Y123, $YBa_2Cu_4O_8$ (Y124), and $Y_2Ba_4Cu_7O_{15}$ (Y247) to find a higher T_c in the YBaCuO-family. They found that Y124 and Y247 became superconductor at 80 K [3] and 40 K [4], respectively. The Y247 exhibits a superconducting transition with T_c ranging from 30 to 95 K, depending on the oxygen content [5, 6].

Recently, Aliabadi, Farshchi and Akhavan [7] and Tavana [8] found the new Y-based high-temperature superconductor in $Y_3Ba_5Cu_8O_{18}$ (Y358) that become superconducting above 100 K. They also proposed that in order to have a stronger superconductor with higher T_c in YBaCuO-family, one should pump more holes from the chains to the oxygen sites of the planes tending to diagonal charge order. The Y123 has two CuO_2 planes and one CuO chain. The Y124 has one CuO double chain. Y247 has one CuO_2 plane and one CuO chain, and one double chain. Y358 has a crystalline structure similar to that of Y123 with five CuO_2 planes and three CuO chains. The increase in the number of CuO_2 planes and CuO chains has an important effect on the T_c of Y358. The YBaCuO-family has shown the difference in their number of CuO_2 planes and CuO chains or double chains that are believed to be the carrier reservoirs. The band structure calculations of Y358 were studied by Tanvana and Akhavan [9]. However, Nakajima et al. [10] had proposed the limited increase in the number of the CuO_2 planes in all high-T_c cuprate superconductors to 3.

We think that there should be the relations between the superconductors in YBaCuO-family. The assumptions about the relation in these materials are made and the new superconductors are synthesized by using our assumptions. Finally, we find 7 new superconductors with the different critical temperature.

2 Experimental Assumptions

We know that the YBaCuO-family consists of Y123, Y124, Y247 and Y358 with the Y358 having the highest T_c in this

P. Udomsamuthirun (✉) · T. Kruaehong · T. Nilkamjon · S. Ratreng
Prasarnmitr Physics Research Unit, Department of Physics, Faculty of Science, Srinakharinwirot University, Sukumvit 23, Bangkok 10110, Thailand
e-mail: udomsamut55@yahoo.com

P. Udomsamuthirun · T. Nilkamjon · S. Ratreng
Thailand Center of Excellence in Physics (ThEP), Si Ayutthaya Road, Bangkok 10400, Thailand

family. Aliabadi, Farshchi and Akhavan [7] proposed that the lattice parameters, *a* and *b*, of Y123 are very close to those of Y358, but the lattice parameter *c* of Y358 is almost 3 times that of Y123. Y123 has two CuO_2 planes and one CuO chain and Y358 has five CuO_2 planes and three CuO chains. We postulate the following compositional relations for the unit cell:

1. The number of CuO_2 planes equals the number of Ba-atoms.
2. The number of CuO chains equals the number of Y-atoms.
3. The number of Ba-atoms plus Y-atoms is equal to the number of Cu-atoms.

The relation between the number of CuO_2 planes and number of Ba-atoms, and the number of CuO chains and the number of Y-atoms, cannot be proved in this paper. However, the number of Ba-atoms plus Y-atoms being equal to the number of Cu-atoms can be proved experimentally. In Y123, there is 1 Y-atom and 2 Ba-atoms, so we get 3 Cu-atoms. In Y358, there are 3 Y-atoms and 5 Ba-atoms, so we get 8 Cu-atoms. So we think that the main idea to synthesize a new superconductor in this family is the number of Ba-atoms plus Y-atoms being equal to the number of Cu-atoms.

To reach the highest T_c, we should pump more holes into the CuO_2 planes. We assume that the number of Y-atoms should be missing to create more holes to get higher the critical temperature. At this point, we can make the following assumptions to synthesize a new superconductor in the YBaCuO-family:

1. The number of Ba-atoms plus Y-atoms is equal to the number of Cu-atoms.
2. The number of Y-atoms can be missing to reach the higher T_c, but the first assumption must be obeyed.

The Y123 and Y358 can be explained by our assumption as in Y123 there is no Y-atoms missing and in Y358 there is 1 Y-atom missing for every 5 Ba-atoms.

According to our assumptions, there are many new superconductors to be found. For example, in case of 1 Y-atom missing, the general formula should be $Y_{x-2}Ba_xCu_{2x-2}O_\delta$. The Y358 is the example of this group which has the percent of Y-atoms missing to the number of Ba-atoms as $\frac{1}{5} \times 100 = 20\%$. For the 2 Y-atoms missing, the general formula should be $Y_{x-3}Ba_xCu_{2x-3}O_\delta$. We can get Y5-8-13 with the percent of Y-atoms missing to the number of Ba-atoms as $\frac{2}{8} \times 100 = 25\%$.

3 Experimental Details

To validate our assumptions, we synthesize a new group of YBaCuO superconductors by using the standard solid-state reaction method. Appropriate stoichiometric ratios of powders Y_2O_3, $BaCO_3$ and CuO are mixed, ground, and react in air at 950 °C for 24 hours, and cooled to 100 °C. Calcinations are repeated twice with intermediate grinding. The powders are reground, pressed into pellets of 30 mm diameter and about 5 mm thickness under 2000 psi pressure. Finally, the samples obtained are sintered at 950 °C for 24 hours and annealed at 500 °C for 24 hours in the air.

The Meissner effect at 77 K is used to test the superconductivity state of our samples and for all materials obtained the Meissner effect is shown in Table 1. This means that all of our samples are superconductors with the critical temperature above 77 K. Because Y5-6-11 and Y7-9-16 do not show the perfect Meissner effect, we do not measure the critical temperature of these samples.

The four-probe resistivity measurements,using a current density of 2.55×10^{-3} A/m^2 are shown in Figs. 1 and 2. All samples show that with increasing the measuring current,

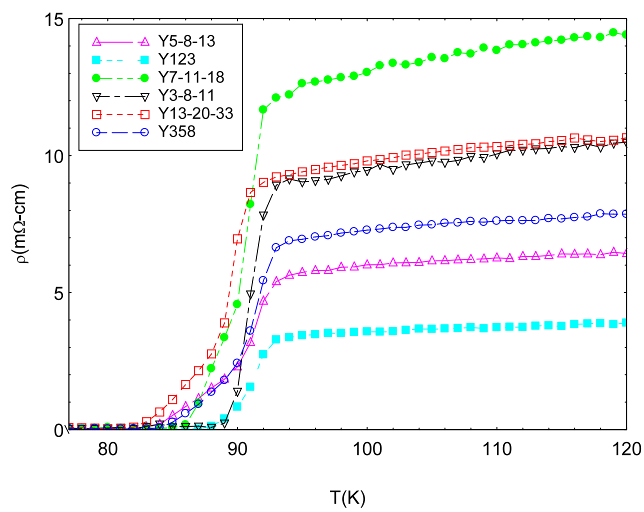

Fig. 1 The resistivity versus temperature of our samples

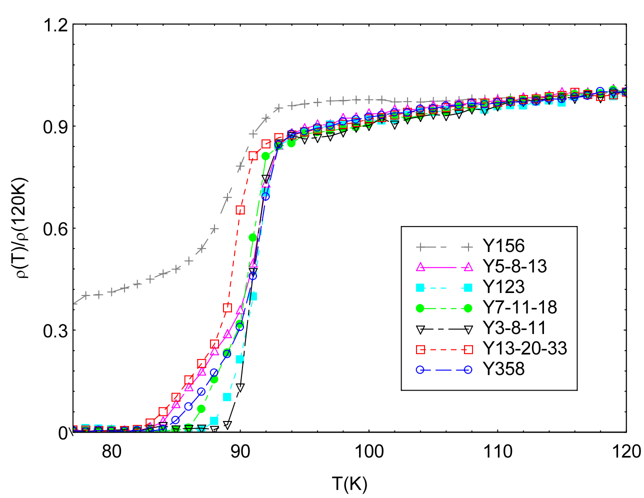

Fig. 2 The normalized resistivity versus temperature

Table 1 The new synthesized YBaCuO-superconductors

Compound	Y-atom missing per Ba-atom	% of missing	Meissner effect shown at 77 K
Y123	0	0	Yes
Y5-6-11	0	0	Yes
Y7-9-16	1:9	12.5%	Yes
Y358	1:5	20%	Yes
Y5-8-13	2:8	25%	Yes
Y7-11-18	3:11	27%	Yes
Y156	3:5	60%	Yes
Y3-8-11	4:8	50%	Yes
Y13-20-33	6:20	30%	Yes

Table 2 The T_c summation of our samples

Compound	T_c offset (K)	T_c middle (K)	T_c onset (K)
Y123	87	91.2	93
Y358	84	91.2	94
Y5-8-13	83	90.8	94
Y7-11-18	86	90.8	93
Y156	77	89	93
Y3-8-11	89	91	94
Y13-20-33	82	89.4	92

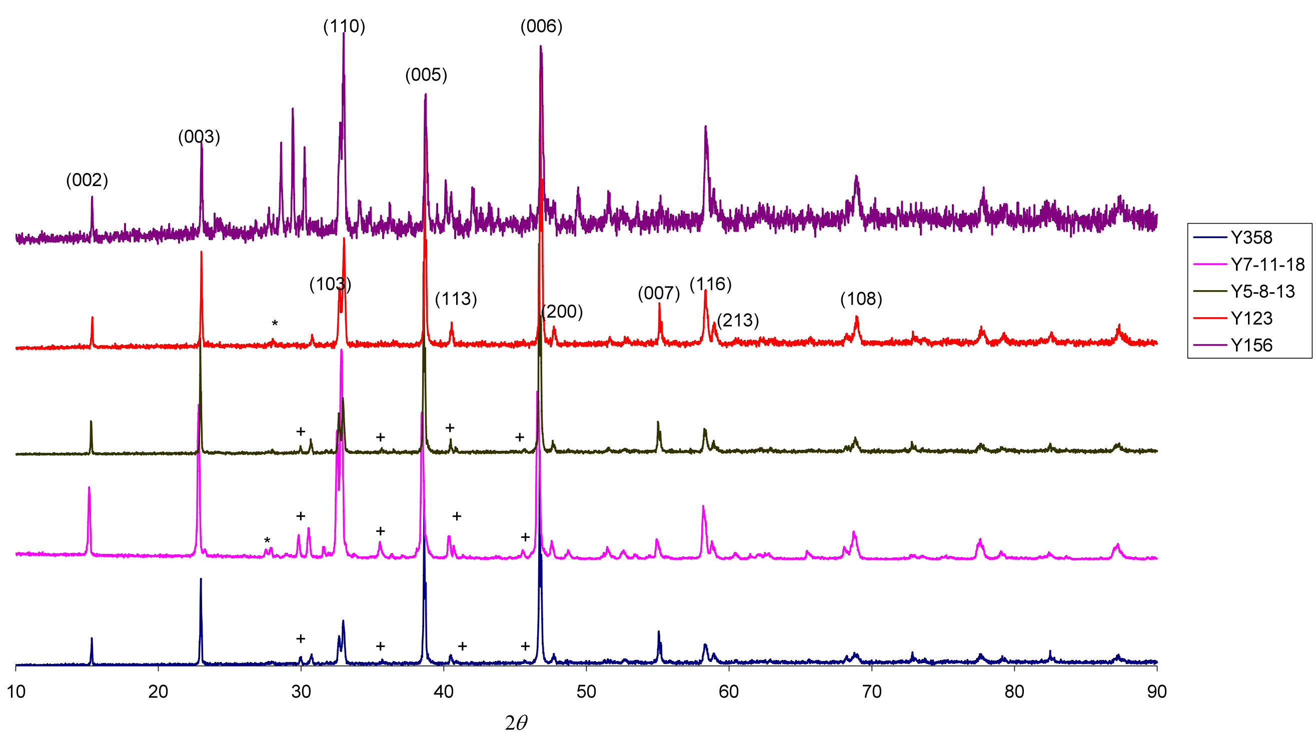

Fig. 3 The XRD patterns of some materials obtained: $*$ is $Ba_2Cu_3O_5$ peak, $+$ are other impurities

the onset of resistivity drop is shifted to lower temperature. The Y156 has the highest resistivity that cannot be shown in the same scale of the other samples in Fig. 1. The normalized resistivity versus temperature curves are shown in Fig. 2. The summation of the T_c offset, T_c middle and T_c onset of our samples read from Figs. 1 and 2 are shown in Table 2. We find that the highest T_c onset is 94 K of Y358, Y5-8-13 and Y3-8-11, and Y13-20-33 has the lowest T_c onset at 92 K. The Y3-8-11 has the highest T_c offset at 89 K. The Y156 has the lowest offset at 77 K. The Y3-8-11 shows the sharp curve at a critical temperature. However, all of our samples show T_c onset in the same order as Y123 but they have the difference in T_c offset.

The diffraction patterns of our samples are shown in Fig. 3. By comparing the new superconductors XRD spectra with Y123 and Y358 spectra, we find that the main peaks are the ones which exist in Y123 and Y358 with some impurities peaks of $Ba_2Cu_3O_5$(* in Fig. 3) at $2\theta \approx 28^\circ$ and of the other impurities (+ in Fig. 3) at $2\theta \approx 30^\circ, 35^\circ, 37^\circ, 41^\circ, 46^\circ$ that occurred by the missing of Y-atom in some planes. These results mean that the lattice parameters of all samples should be of the same order as Y123: $a = 3.82030A$, $b = 3.88548A$ and $c = 11.68349A$ with Pmmm symmetry. However, there is one main peak at about 15° that was not included in the Aliabadi, Farshchi and Akhavan's [7] calculation of Y358. We think that if they included this peak, the lattice parameter should be of the same order as Y123 because this peak has the high intensity and corresponds to (020) plane.

4 Results and Discussion

We make the assumptions to synthesize a new superconductor in YBaCuO-family as the number of Ba-atoms plus Y-atoms is equal to the number of Cu-atoms, and the number of Y-atoms can be missing to reach the higher T_c, but the first assumption must be obeyed. The new formula of YBaCuO superconductors is synthesized by using the standard solid-state reaction method for Y5-6-11, Y7-9-16, Y5-8-13, Y7-11-18, Y156, Y3-8-11, Y13-20-33 materials. The highest T_c onset at 94 K is found in Y358, Y5-8-13, and Y3-8-11 materials. The Y3-8-11 shows the sharp curve at a critical temperature. Our samples have shown a similar crystalline structure as Y123 and Y358 with some impurities peaks occurring by the missing of the Y-atom in some planes, and in some $Ba_2Cu_3O_5$. There are many impurities peaks in Y156 that agree with the T_c measurements, as they do not show the sharp curve at a critical temperature.

The effect of oxygen-doping on superconductors is not considered in this paper. All samples were annealed in the air, which may be the one of the main parameters to increase the critical temperature. We think that the highest T_c superconductor may be found by using our assumptions and the optimal doping. More experimental details will reveal the mechanism of superconductivity occurring in these materials.

5 Conclusions

We made the assumptions to synthesize a new superconductors in YBaCuO-family with the higher T_c. The new formula of YBaCuO superconductors is synthesized by using the standard solid-state reaction method for Y5-6-11, Y7-9-16, Y5-8-13, Y7-11-18, Y156, Y3-8-11, Y13-20-33 materials. The Y358, Y5-8-13, and Y3-8-11 have shown the highest T_c onset as 94 K. The crystalline structures are similar to that of Y123 and Y358 with some impurities peaks.

Acknowledgements The authors would like to thank Professor Dr. Suthat Yoksan for the useful discussions and Professor Dr. C.W. Chu for his useful suggestions to our work. The financial support of the Office of Higher Education Commission, Faculty of Science at Srinakharinwirot University, and ThEP Center are also acknowledged.

References

1. Bednorz, J.G., Muller, K.A.: Z. Phys. B **64**, 189 (1986)
2. Wu, K., Ashburn, J.R., Torng, C.J., Hor, P.H., Meng, R.L., Gao, L., Huang, Z.J., Wang, Y.Q., Chu, C.W.: Phys. Rev. Lett. **58**, 908 (1987)
3. Marsh, P., Fleming, R.M., Mandich, M.L., DeSantolo, A.M., Kwo, J., Hong, M., Martinez-Miranda, L.J.: Nature **334**, 660 (1988)
4. Bordet, P., Chaillout, C., Chenavas, J., Hodeau, J.L., Marezio, M., Karpinski, J., Kaldis, E.: Nature **336**, 596 (1988)
5. Karpinski, J., Rusiecki, S., Bucher, B., Kaldis, E., Jilek, E.: Physica C **161**, 618 (1989)
6. Genoud, J.-Y., Graf, T., Triscone, G., Junod, A., Muller, J.: Physica C **192**, 137 (1992)
7. Aliabadi, A., Farshchi, Y.A., Akhavan, M.: Physica C **469**, 2012–2014 (2009)
8. www.superconductors.org, A. Tavana acknowledges private correspondence with E.J. Eck
9. Tavana, A., Akhavan, M.: Eur. Phys. J. B (2009)
10. Nakajima, S., Kikuchi, M., Syono, Y., Oku, T., Shindo, D., Hiraga, K., Kobayashi, N., Iwasaki, H., Muto, Y.: Physica C **158**, 471 (1987)