Engineering, 2011, 3, 1095-1097
doi:10.4236/eng.2011.311136 Published Online November 2011 (http://www.SciRP.org/journal/eng)

The Effect of the Pressure for the Formation of $YBa_2Cu_3O_{7-d}$ Bulk Ceramics with Domestic Microwave Oven

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Received September 6, 2011; *revised September* 30, 2011; *accepted October* 12, 2011

Abstract

We fabricated $YBa_2Cu_3O_{7-d}$ bulk ceramics with a domestic microwave oven and investigated the effect of pressure at the press procedure. If the pressure was not high enough, the ratio of $BaCuO_2$ phase became large, estimated from x-ray diffraction (XRD) measurements. We found that the pressure should be 700 kgf/cm^2 at least in order to suppress the $BaCuO_2$ phase.

Keywords: Microwave Oven, Bulk Ceramics, $YBa_2Cu_3O_{7-d}$ Superconductor

1. Introduction

High Tc superconductors are well known nowadays. Technical developments of this kind of superconductors are so attractive to be applied to practical use. Among various materials, $YBa_2Cu_3O_{7-d}$ (YBCO) has been significantly well studied in the wide range of the field on superconducting in a bulk [1] or porous [2] ceramics as well as in a thin-film form. This material is surely supposed to be the most reliable high Tc superconductor. Nowadays, sophisticated study has been performed: the YBCO/metal interface and its application [3,4], YBCO composites with Ag [5] or polymer [6]. Comprehensive survey of current knowledge on this material is described in a book [7].

The bulk ceramic superconductor of YBCO is usually produced by means of sintering process. Since this process is based on a solid chemical reaction, it requires long time and high temperature maintained with a large amount of energy. Baghurst *et al.* reported microwave syntheses for the formation of YBCO ceramics [8] for the merit of low cost of energy.

Kato *et al.* reported [9] that a domestic microwave oven was capable to grow YBCO ceramics. This report symbolized that the weak microwave could be applied to form YBCO ceramics effectively. The advantage of this method is surely low energy cost for the processing. One different thing is that BaO was required as a starting material instead of $BaCO_3$.

The interesting method was applied to a continuous growth process by Marinel *et al.* [10] in such a way that a starting material was passed through a microwave cavity. This is similar to floating zone method for the growth of single crystal of silicon. We expect that the microwave processing will be widely used as a rapid and low-cost method for superconductors.

For the production of YBCO bulk ceramics, a press procedure to form a pellet is known to be one of key points. It is because YBCO is formed by solid phase reactions. We investigated the effect of the pressure on the obtained YBCO characteristics in the microwave procedure.

2. Experimental Details

Commercially available Y_2O_3, BaO_2 and CuO powder at the atomic ratio of Y:Ba:Cu = 1:2:3 (totally 12 g) were mixed and milled in a mortar for 20 min. A fraction of the mixed powder (3 g) was pressed mechanically to be a pellet with the dimensions of 20 mm in diameter and 3 mm in thickness. The pressure was varied between 80 and 2000 kgf/cm^2. We did not use any binder materials through the experiment.

The coin-formed pellet was surrounded by an additional mixed powder of 5.5 g and wrapped by a quartz glass wool (2.18 g) and put in a crucible. These surroundings were important to suppress heat dissipation during heating and to absorb enough oxygen into the pellet. The pellet was heated for 25 min. at the microwave power of 200 W and then cooled down naturally. The domestic microwave oven we used was a EM-B1(W) type manufactured by Sanyo Co. Ltd. This oven was useful because the output power of microwave was continuously varied between 50 and 500 W. The frequency was 2.45 GHz.

The samples were investigated by an XRD measurement with RAD-IIA diffractometer (Rigaku, Japan). The x-ray from Cu target whose wavelength was 0.15405 nm was used. The pellet was put on the diffractometer without any process. In the measurements, the θ-2θ method was employed.

3. Results and Discussion

Figure 1 shows XRD pattern when the pellet was pressed at 160 kgf/cm^2. The Miller indices are assigned to those of YBCO. The other non-labeled structures may derived from the existence of impurities such as starting materials that did not react enough or other phase. A relatively strong impurity structure situated around 30 degrees corresponds to three reflections by (5 3 0), (6 0 0) and (6 1 1) planes in $BaCuO_2$, assigned with JPCDS card of x-ray diffraction data.

Figure 2 shows in contrast the XRD pattern from the sample that was pressed at 2000 kgf/cm^2. In this pattern, the impurity structures are much less than that shown in **Figure 1**. This means the fraction of YBCO increased with the pressure at the pellet making process. The peak at 32.6 degree was noticeably strong where the structure of three peaks belonging to $BaCuO_2$ was quite weak in **Figure 2**.

In order to clarify the amount of impurity phase and its dependence on the pressure, the intensity ratio of $BaCuO_2$ (6 0 0) and YBCO a superimposed structure of (1 1 0), (1 0 3) and (0 1 3) was calculated as shown in **Figure 3**. In general, the ratio became small with the pressure. When the pressure was over 700 kgf/cm^2, the $BaCuO_2$ fraction reached a minimum value with the exception of two data. Based on the fact, at least the pressure of 700 kgf/cm^2 is needed to suppress the impurity phase to the minimum. The obtained data were dispersed to a large extent. This dispersion was partly caused by the uncertain in size and shape of the pressed powder. Poor reproducibility is fatal to ceramics. Under this difficulty, the result shown in **Figure 3** seems to be the comparatively systematic.

4. Conclusions

YBCO ceramics were grown by means of microwave heating with a domestic microwave oven. The advantage of this method is low energy cost for the production. The milled powder of the three kinds of starting materials was pressed to form coin-shaped pellets. Investigated was the dependence of the pressure on the impurity phase fraction to YBCO phase on the basis of an XRD

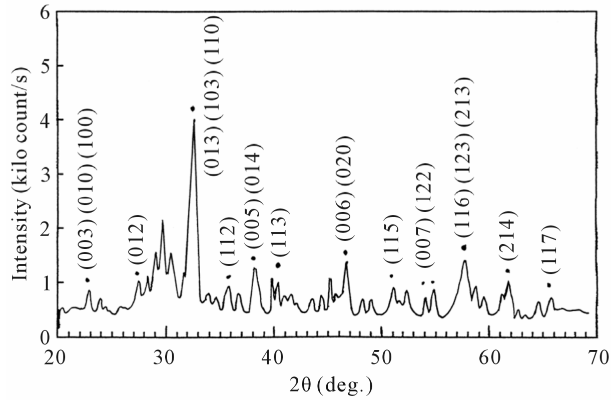

Figure 1. The XRD pattern from YBCO (pressed at 160 kgf/cm^2). The Millar indices correspond to that of YBCO. The three-peaked structure around 29 degree derived from the impurity phase of $BaCuO_2$.

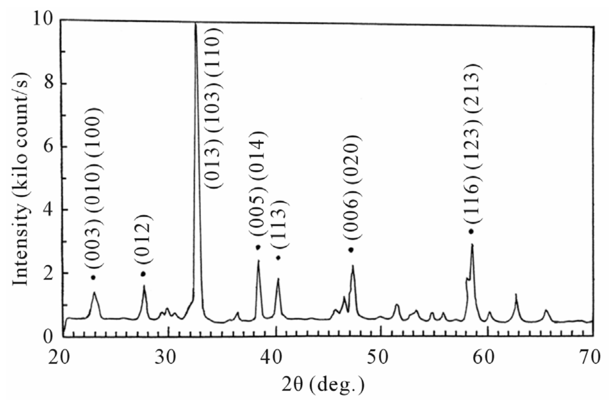

Figure 2. The XRD pattern from YBCO (pressed at 2000 kgf/cm^2). It was found that any impurity phase decreased to the extent that the sample was almost a single phase.

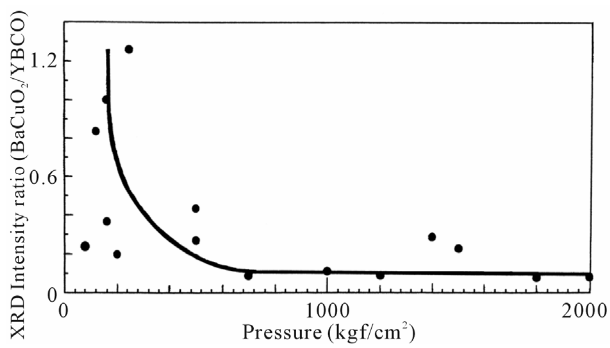

Figure 3. The dependence of the pressure on the intensity ratio of $BaCuO_2$ to YBCO. Over 700 kgf/cm^2, The ratio of $BaCuO_2$ was decreased to the minimum.

measurement. It was found that at least 700 kgf/cm^2 was needed during the press procedure in order to suppress the amount of the $BaCuO_2$ impurity phase to the minimum. The next interesting point is the investigation of the optimization of the design in the microwave heating method.

5. References

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