Synthesis and Effect of \( \text{Al}_2\text{O}_3 \) Added in Yttrium Barium Copper Oxide \( \text{YBa}_2\text{Cu}_3\text{O}_6 \) by Solid State Reaction Method

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Abstract

The aim of this research was to synthesize \( \text{YBa}_2\text{Cu}_3\text{O}_6 \) (YBCO) and to study the effect of \( \text{Al}_2\text{O}_3 \) additions at \( x = 0.00, 0.10, 0.20, 0.50, 1.50 \) and 3.50 wt.%. The samples were investigated through Thermogravimetric Analyzer (TGA) and X-Ray Diffraction (XRD). All samples prepared by solid state reaction method with calcination process at 900°C and sintering process at 950°C. The TGA analysis indicated weight loss was complete at 910°C. XRD patterns showed the orthorhombic structure with lattice parameters \( a=3.821 \) Å, \( b=3.880 \) Å and \( c=11.663 \) Å, respectively. The \( \text{Al}_2\text{O}_3 \) added samples did not show any new peak however the sharpness and broadening peaks was changed. The crystallite sizes of the samples were calculated from the width of the selected peak and half maximum. The size is slowly increased by increasing the \( \text{Al}_2\text{O}_3 \) addition. These result indicated that addition does not affect on the structure but the crystallite sizes increase affect the morphology images.

1. Introduction

The high temperature superconductor YBCO has generated enormous amount of activities in the field of ceramic superconductor (Paulose et al. 1992). The production of high temperature superconductor has generally been through conventional methods such as solid state, sol gel, spray drying and co-precipitation reaction (Bolzan et al., 1996). The fine powder has assumed a large importance, minimization of processing time and temperature during heating, homogenization and to avoid the constituent oxide are importance criteria to synthesis YBCO (Pathak et al. 2005).

In this paper, we report the synthesis YBCO ceramic and effect of addition \( \text{Al}_2\text{O}_3 \) produced by the solid state method. The research also shown the weight loss and the phase formation temperature of the sample also describe the structure of the ceramics.

2. Materials and Methods

\( \text{YBa}_2\text{Cu}_3\text{O}_6 \) samples were prepared by solid state reaction method. Yttrium oxide \( \text{Y}_2\text{O}_3 \), barium carbonate \( \text{BaCO}_3 \) and copper oxide \( \text{CuO} \) powder is taken in a stoichiometric ratio (1:2:3). The powders are ball-milling for 24 hours. The mixture will be first calcination at 900°C for 12 hours with intermediate grinding in order to ensure the homogeneity. Lastly, the powders were pressed into pellet and sintered at 950°C for 12 hours. The thermal analysis (TGA) recorded the changes for exothermic and endothermic reaction. The phase identification will be carried out by using X-ray Diffraction (XRD) technique performed by using a Brukers D2Phaser with Cu-K\( \alpha \) radiation source.

3. Results and Discussion

Thermogravimetric analyzer (TGA) used to detect the mass loss as a function of increasing temperature and it has been applied to the study the oxygen diffusion in YBCO powder and polycrystalline. Figure 1 show the TGA curve for the pure samples with increasing temperature up to 1000°C. Base on the research by Khoshnevisan (2002), there was a no weight changes until 400°C and after that different reaction carried out. Meanwhile, from 420°C to 995.62°C, the weight change was at 13.14% for 10.158 mg. From the temperature of 900°C to 950°C, the sample show a stabilize end product which is comparable to past research from (Suan & Johan, 2013). The sample of YBCO with the addition of \( \text{Al}_2\text{O}_3 \) show in the Figure 2, where the TGA curve shows the formation of YBCO at the range temperature of 900°C to 950°C. The \( \text{Y}_2\text{O}_3 \), \( \text{BaCO}_3 \) and \( \text{CuO} \) powder after this
massive weight loss were stable up to 900°C. Beyond 900°C, the raw materials became non-stable and believed to be reactive in forming YBCO pure powder. On the other hand, the Al₂O₃ nanoparticles stayed as it was and did not involve in any reaction because it is very stable in that temperature range as a ceramic material (Singh et al., 2007).

The XRD patterns of pure YBCO along with Al₂O₃ addition have been shown in Figure 3. It is clear to see that the intensity for YBCO increases at elevated addition of Al₂O₃. The same additional phase that exist in the sample after calcination does not shows any changes in term of intensity with increases addition of Al₂O₃ nanoparticles (Widad et al., 2012). The lattice constant parameters for prepared specimens are nearly same with average values of a = 3.821 Å, b = 3.880 Å and c =11.663 Å which are comparable with the literature for Y-123 (Benzia et al, 2004). The Al₂O₃ addition samples did not show any changes in terms of structural properties and is quite similar as observed in the XRD patterns of pure YBCO. This is attributed to the fact that in these compositions Al₂O₃ nanoparticles were existed as another phase and uniformly distributed in YBCO matrix (Suan et al., 2013). Thus, the Table 1 shows the unit cell parameter and the unit cell volume for YBa₂Cu₃O₇ₓ with Al₂O₃ addition.

It is expected that the a and c lattice parameter increase slightly in that amounts of Al₂O₃ addition whereas b parameter almost remains constant. The a and c lattice parameters are noticed to increase as the Al₂O₃ nanoparticles content was increased in samples from the Figure 4, respectively. The increments are believed because O²⁻ ions try to fill in its deficiencies site and incorporation of Al³⁺ ions at the Y site as shown by the YBa₂Cu₃O₇ molecular structure (Suan & Johan, 2014).
These alterations illustrate that the Al$^{3+}$ ions occupy in both Y and Cu sites. The addition of Al$_2$O$_3$ slightly decreases the difference between a and b parameters and thus reduces the orthorhombic.

**Table 1:** The lattice parameter and the volume of the unit cell for YBa$_2$Cu$_3$O$_7$ with Al$_2$O$_3$ additions

<table>
<thead>
<tr>
<th>Al$_2$O$_3$ addition (wt%)</th>
<th>a (Å)</th>
<th>b (Å)</th>
<th>c (Å)</th>
<th>V(Å$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>3.8410</td>
<td>3.8830</td>
<td>11.6710</td>
<td>174.0683</td>
</tr>
<tr>
<td>0.10</td>
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<tr>
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<tr>
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<td>3.8864</td>
<td>11.6945</td>
<td>173.8443</td>
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<tr>
<td>3.50</td>
<td>3.8184</td>
<td>3.8857</td>
<td>11.7010</td>
<td>173.6096</td>
</tr>
</tbody>
</table>

**Figure 3:** XRD pattern of YBa$_2$Cu$_3$O$_7$ added with Al$_2$O$_3$ at different x =0.00, 0.10, 0.20, 0.50, 1.50, 3.50

**Figure 4:** Evolution of lattice parameters versus Al$_2$O$_3$ addition

4. Conclusion

The YBCO pure powder was successfully synthesized and confirmed its phase and quality of the samples. On top of that, Al$_2$O$_3$ nanoparticles addition were successfully introduced and well distributed into YBCO superconductor through solid state reaction. In this paper a systematic study on the addition of Al$_2$O$_3$ nanoparticles with different weight percentage to YBa$_2$Cu$_3$O$_7$ was the orthorhombic structure and the is no structure change in the superconducting YBCO compound due to Al addition, a few additional peaks located at 2θ = 29.82° and 30.50°, compared to pure YBCO.

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References


