Abstract Samples of the nominal composition, \( Y_{x}Ag_{y}Ba_{2}Cu_{3}O_{7-\delta} \) where \( x = (0.10, 0.30, 0.50, 0.70, 0.90) \) and \( y = (0.12, 0.36, 0.60, 0.84, 1.09) \) were prepared using the conventional solid state reaction. XRD patterns show that silver was incorporated into the Y123 orthorhombic structure up to 1.09 molar ratios and released the excess Ag\(_2\)O. Silver was present within the grains of Y123 composite as confirmed by field emission scanning electron microscopy (FESEM) images and energy dispersive spectroscopy (EDS) analysis. Silver atoms were agglomerated among the Y123 intercrystalline grain growth as shown by FESEM images and filling the voids within the grain boundaries. As a result, the microhardness properties were improved.

Keywords Solid state reaction • Y123 • Silver • Microhardness • Grain boundaries

1 Introduction

The discovery of the high-\( T_c \) superconducting materials Yttrium Barium Copper Oxide (Y123) in 1986 set into motion an extraordinary worldwide outburst of superconductivity research [1, 2]. However, it shows relatively poor mechanical
properties such as brittleness and others superconducting properties. With respect to that addition of other doping material such as silver (Ag) may provide a large number of beneficial effects to the Y123 composite.

Ag can be incorporated into the Y123 matrix by different methods: mixing with metallic Ag [3–5] or Ag2O [6, 7] and electrochemical ways [8–10]. The former produced a random non-uniform distribution of Ag in the composite while the later produced a non-random distribution of Ag on the grain surface of the composite.

Ag was combined with Y123 oxide in many solid states sintering process, which shows signs of superior superconducting and mechanical properties [10–19]. It has been used either as an isolated phase filling voids within the solid-state sintered Y123 bulk [10–14], as the substrate material in the Y123/Ag composite wire or tape [16–18]. The hardness properties of Y123 bulk at room temperature were mostly obtained by conventional Vickers measurements in the range of 5–8 GPa [19, 20].

In this chapter, we synthesize Ag doped Y123 superconductor by using conventional solid state reaction technique. We show that the addition of Ag into the Y123 matrix has improved the microstructure and hardness properties of the composites.

2 Experimental Method

The current investigation involved a series of sample preparation by conventional solid-state reaction. High-purity powders of Y2O3, BaCO3, CuO and Ag2O were mixed in the stoichiometric proportions. The mixtures were then calcined at 930°C for 24 h and subsequently pressed into pellet form under 5 tonne of pressure. It follows a sintering process at 950°C under oxygen flow for 20 h. The samples were then cooled and oxygenation to 500°C with a cooling rate of 1°C/min. It continues until reaching 300°C with a higher cooling rate of 10°C/min. The structural properties of the samples were tested by Philips X’Pert MPD PW3040 XRD with CuKα radiation at 1.5406 Å. The surface morphology and elemental analysis were carried out using Zeiss AURIGA and EDAX TSL, respectively. The microhardness measurements were performed by Mitutoyo MVK-H2.

3 Results and Discussion

XRD patterns shown in Fig. 1 indicate that the addition of Ag2O does not change the superconducting structures nor form an undesirable second phase. The peak appearing at 2θ value of 44.2° be indexed as (200) reflection of Ag and appears as a separate phase at the grain boundaries of Y123. The (111) plane of Ag2O which has the highest intensity, overlapped with the (013) plane of Y123 orthorhombic structure at 2θ = 32.9°. The (111) plane of Ag2O is clearly seen in the diffraction
pattern indicating that excess of Ag$_2$O remains in a separate phase and has not been decomposed to Ag and O.

Figure 2 shows the FESEM micrograph of pure Y123 and several composites materials. The granular and porosity of the sample are clearly seen. The pure Y123 exhibits a non-uniform structure and relatively with large number of pores. The surface of the Ag$_2$O diffused sample is much denser than that of the pure material. These results indicate that the surface morphology of the Y123 sample is improved by Ag diffusion doping. The grain growth enhanced with Ag concentration up to $y = 0.12$. Beyond this concentration, the grain growth is inhibited, as illustrated in Fig. 2d. The prominent change of grain growth can be seen at $y = 0.36$ as shown in Fig. 2c. Ag atoms were agglomerated among Y123 composites and formed a bulk sample up to 0.47 μm size. The EDAX result shows that Ag existed in the bulk sample of Y123 as shown in Fig. 3.

In Fig. 4, the microhardness of samples increases with the increase Ag$_2$O content with the exception of $y = 1.09$. This indicates that effect of Ag in the Y123 superconducting phase on strengthening the composites. It could be inferred that this could be due to the reduction of pores in the samples as shown in Fig. 2b–f.

Fig. 1 XRD patterns of Y$_x$Ag$_y$Ba$_2$Cu$_3$O$_{7-\delta}$
Furthermore, the existence of Ag produces a compressive stress field in the Y123 matrix. However, the standard deviation was 42.14 HV with Ag addition does not show any clear tendency and the strength depend on the amount of Ag and yttrium in the composites.

Fig. 2 FESEM micrographs of a Y123, b Y_{0.90}Ag_{0.13}Ba_2Cu_3O_{7-δ}, c Y_{0.70}Ag_{0.30}Ba_2Cu_3O_{7-δ}, d Y_{0.50}Ag_{0.60}Ba_2Cu_3O_{7-δ}, e Y_{0.30}Ag_{0.84}Ba_2Cu_3O_{7-δ} and f Y_{0.10}Ag_{1.09}Ba_2Cu_3O_{7-δ}
4 Conclusion

In summary, we have demonstrated that the addition of Ag$_2$O to Y123 matrix does not only increase the microhardness, but also affects their microstructures. It was found that Y123 sites are substituted by Ag ions at 1.09 molar ratios, as well as Ag$_2$O also fills the pores in the grain boundaries. In addition, Ag has promoted good grain growth among the multiphase composition.

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References