Role Of Graphene Oxide Nanoparticles Addition On Microstructural Properties Of $YBa_2Cu_3O_{7-\delta}$ Superconductor

N.A. Zulkarnain[2], S. Z. Ismail[3], N. H. A. Kadir[1], M. M. Awang Kechik[4] and Aima Ramli[1,2*]

[1]Advanced Nano Materials (ANoMA) Research Group, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, Terengganu, 21030 Kuala Nerus, Malaysia.

[2]Department of Nanophysics, Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, Terengganu, 21030 Kuala Nerus, Malaysia.

[3]Instrumentation and Control Laboratory Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, Terengganu, 21030 Kuala Nerus, Malaysia.

[4]Department of Physics, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

**Corresponding Autor's Email: aima.ramli@umt.edu.my*

Abstract: Superconductor is known as its ability that can conduct electricity with zero resistance and zero energy loss. Yttrium Barium Copper Oxide ($YBa_2Cu_3O_{7-\delta}$) is a group of crystalline chemical compound and famous for displaying high temperature superconductivity (HTSC's). However, $YBa_2Cu_3O_{7-\delta}$ superconductor suffers from low grain conductivity and weak links of the grains, thus resulting in disruption of superconducting performance. Thus, in this research, the high temperature superconductor $YBa_2Cu_3O_{7-\delta}$ was added with graphene oxide nanoparticles (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt.%) and synthesized via solid state method. All samples then being characterized using thermogravimetric analysis (TGA), X-ray diffraction (XRD) and scanning electron microscope (SEM). As a conclusion, it was shown that the addition of the graphene oxide nanoparticle in $YBa_2Cu_3O_{7-\delta}$ increase the grain growth of $YBa_2Cu_3O_{7-\delta}$.

Keywords: $YBa_2Cu_3O_{7-\delta}$, Superconductor, Graphene, Solid State Method, Nanoparticles.

INTRODUCTION

In a superconducting state, a superconducting material shows the zero electrical resistivity. The resistance of the superconductor material will reduce to zero when these superconductor materials is cooled below its critical temperature [1] and related to the magnetic flux penetrating in superconductor. Superconductor cannot carry current with zero electrical resistance if the flux lines always moved. Hence, by the addition of impurities or other kinds of impendent, flux lines can be pinned. As nanoparticles were added into the sample, the behaviour of the superconductor critical current density in the applied magnetic field was found to increase, which can be due to the presence of flux pinning centres [2]. By pinning the flux line effectively, vortex movement can be prevented. $YBa_2Cu_3O_{7-\delta}$ (YBCO) is the most desirable superconductor among the different types of high temperature superconductors because of its good physical properties, such as the higher value of superconducting transition temperature, good response to the higher value of the magnetic field applied, and mechanical stability at room temperature [3]. Based on the previous research many additions had been conducted towards the $YBa_2Cu_3O_{7-\delta}$ superconductor.

Many additions of impurities had been conducted to improve the superconducting properties by other researchers. In this research the addition of x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt % graphene oxide (GO) nanoparticles were experimented upon the $YBa_2Cu_3O_{7-\delta}$ superconductor. Graphene oxide (GO) is a unique material that can be viewed as a single monomolecular layer of graphite with various oxygen-containing functionalities [4]. The oxygen in the functional groups of GO is parted and GO reduced into reduced graphene oxide (RGO) when undergoes the sintering process with temperature more than 650 °C. Hence, the removed oxygen enters the CuO chains of YBCO and leads to the reduction of oxygen vacancies and increases the superconducting parameters [5].

MATERIALS AND METHODS

All the samples of $YBa_2Cu_3O_{7-\delta}$ were prepared via solid state method by mixing with the suitable amount of Y_2O_3, (Alfa Aesar, 99.9%), $BaCo_3$, (Alfa Aesar, 99.8 %), and CuO, (Alfa Aesar, 99.7 %) referring to the stoichiometry formula of 1:2:3 for $YBa_2Cu_3O_{7-\delta}$. The mixture of powders was ground approximately for 1 hours in agate mortar until the powders were well blended. The blended powder was then calcined at 900 ^{0}C for 36 hours and 45 minutes. The calcination process was repeated twice with the intermediate grindings. The calcined powders then were reground with the addition of x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt % of graphene oxide powder. Then the mixed powders were pelletized into pellets of 13 mm and 10 mm diameter using Specac automatic operated hydraulic press and sintered at 900 ^{0}C for 15 hours before allowed to cool down at 1 ^{0}C/min to room temperature in the furnace.

All samples then being characterized using thermogravimetric analysis (TGA), X-ray diffraction (XRD) and scanning electron microscope (SEM). The thermal properties of the precursor powder were analyzed by Mettler Toledo TGA/DSC 1 from 30 ºC to 900 ºC at a heating rate of 10 ºC/min. The samples of 2g were approximately placed in aluminum pans under a dynamic flow of nitrogen 50mL/min. The Rigaku Mini Flex II Desktop X-ray diffractometer as shown in Figure 3.9 with Cu-Kα was used to perform the phase formation of the ground sintered samples. The mixture of finely ground and homogenized YBa2Cu3O7 added with graphene oxide (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt.%) were analyzed with XRD. The powder was placed on a glass holder and placed at the sample stage. The scanning was carried out from 20° to 80° at a step width of 0.02°. SEM measurement was performed by using JEOL JSM-6360LA. The pellets were carefully fractured into small pieces using a pestle and mortar. To get better imaging for the surface and cross section, the fractured pellets were then coated with ultra-thin coating of gold before analyzing the samples to increase the thermal conduction and improve the secondary electron that detected by SEM. The result that SEM investigate were the surface morphology, homogeneity, grain sizes and orientation of the samples.

RESULTS AND DISCUSSION

Thermogravimetry Analysis (TGA)

Figure 1 shows the decomposition of moisture and water from the lattice of copper oxide occurring at temperature below 200 °C. Then, the complete decomposition of barium carbonate, $BaCO_3$ to barium oxide, BaO occurred at 760 °C and fully decomposed at 855 °C. From the graph it showed that there was small mass loss appeared above 900 °C which might be resulted from $YBa_2Cu_3O_{7-\delta}$ phase formation.

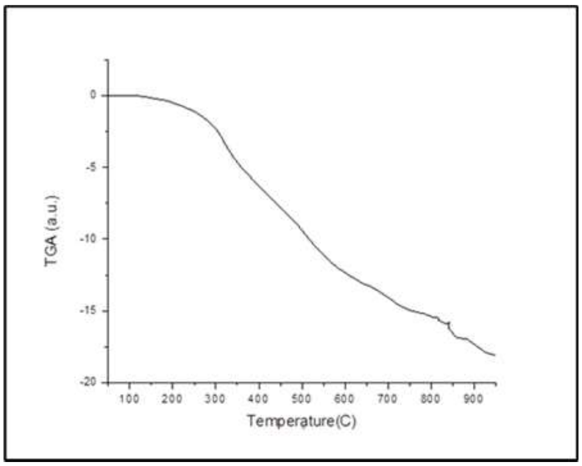

Fig. 1. Thermogravimetric analysis (TGA) of $YBa_2Cu_3O_{7-\delta}$ powder.

X-ray Diffraction (XRD)

All the XRD results as shown in Figure 2 were being analysed using the Crystallographica Search-Match software. It was found that all samples showed orthorhombic structure with pre-dominant Y-123 phase with space group symmetry for orthorhombic crystal system, Pmmm and impurities of the unreacted graphene appeared with addition of the x = (0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt.%) graphene oxide. The peak at plane of (013) and main peak of 2θ = 32.45⁰ were all maintained which indicates the orthorhombic structure.

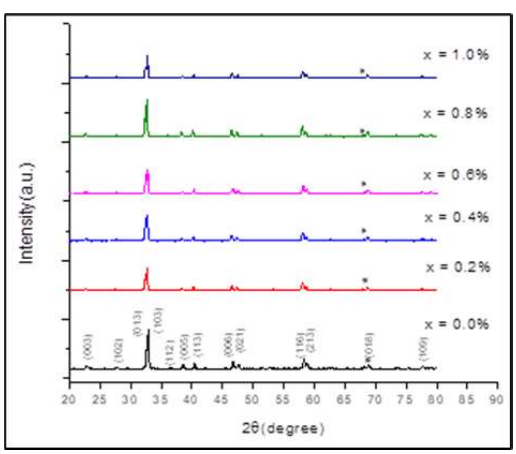

Fig. 2. X-ray diffraction pattern of YBCO with various addition of graphene oxide

Scanning Electron Microscope (SEM)

Based on Figure 3 all the samples became porous and their grain sizes increased as the addition of graphene oxide increased. It shown that the addition of the graphene oxide nanoparticle in $YBa_2Cu_3O_{7-\delta}$ increase the grain growth of $YBa_2Cu_3O_{7-\delta}$ [3]. It proved that as the concentration of graphene oxide increased, the average grain size of the samples also increased. This may be attributed to enhancement in superconducting volume fraction in sample, as graphene oxide nanoparticles resides near the grain boundary region to increase the weak link between superconducting grains which displays the granular structure with the enhancement of particle size after the addition of graphene oxide. The inter-linking among the superconducting grains is increased and due to the inclusion of graphene oxide [5].

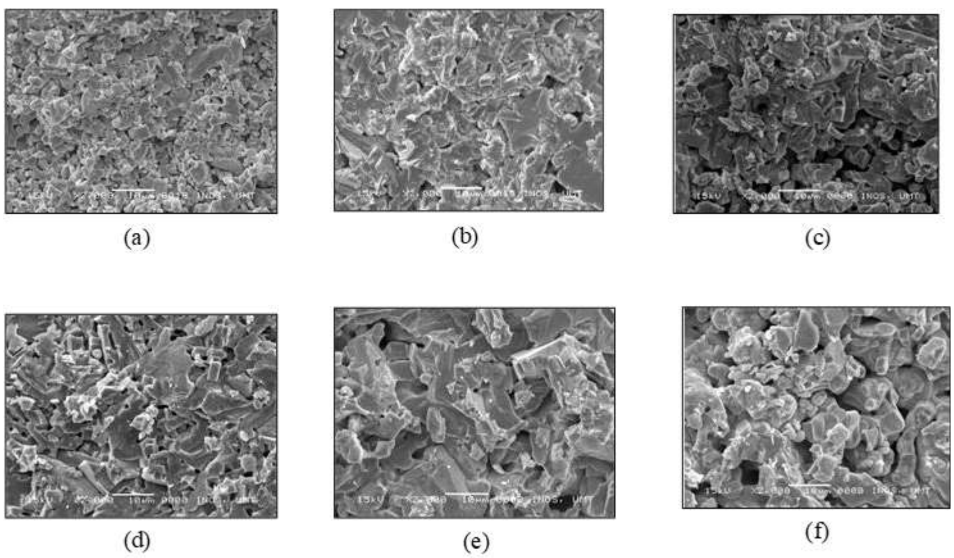

Fig. 3. SEM micrographs of the cross-section of the $YBa_2Cu_3O_{7-\delta}$ when added with (a) 0.0 wt%, (b) 0.2 wt%, (c) 0.4 wt%, (d) 0.6 wt%, (e) 0.8 wt%, and (f) 1.0 wt% of graphene oxide.

CONCLUSIONS

The preparation of $YBa_2Cu_3O_{7-\delta}$ when added with graphene oxide (x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 wt.%) was successfully done via solid state method. All the samples had been characterized by the thermogravimetric analysis (TGA), X-ray diffraction (XRD) and scanning electron microscope (SEM). The result obtained from the TGA shows that the thermal decomposition behaviour of $YBa_2Cu_3O_{7-\delta}$ during the TG measurement is analysed. From the XRD result proved that all the samples which demonstrated that the samples have an orthorhombic structure with Y-123 phase. While SEM show that there is presence of graphene oxide through the increasing of the grain size and porosity as the amount of graphene oxide increase. Particularly, this improvement may be attributed to good interlinked between the superconducting grains, as the irregularities and voids are filled by the graphene oxide.

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