Phase Formation of M-Type $BaFe_{12}O_{19}$/ZnO Magnetic Material

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Abstract: High Energy Milling (HEM) followed by heat treatment was used to prepare M-type $BaFe_{12}O_{19}$/ZnO magnetic material in toluene media. High purity of $BaFe_{12}O_{19}$ and ZnO powder was milled for 12 h followed by drying for 4 h before being calcined at a temperature of 900°C. The powder was then filtered by using T-200. An appropriate amount of BaFe12O19 and ZnO were then mixed in wet-milling for 15 mins and dried at 200°C for 1 h. The magnetic properties were analysed using VSM, whereas the phase formation was derived from XRD-pattern (powder method) using X-ray CuKα 40kV-30mA with λ= 1.5418 Å. The phase occurrence was determined using MATCH-software program. It was obtained that $BaFe_{12}O_{19}$ lattice parameter: a = 5.8930 Å, c = 23.1940 Å. In order to get soft magnetic state, ZnO was added with a composition of: 0/100, 25/100, 50/100, 75/100, respectively. It was found that addition of 75% ZnO to $BaFe_{12}O_{19}$ converted hard magnet to soft magnet.

1 INTRODUCTION

It has been known that the magnetic material development is very vast in practical technical use and industry application. Magnetic materials are used in electronics, sensors, biomaterial as well as transportation. Since 1950s, there were intensive and extensive researches have been done. This kind of material became interesting in the hexagonal ferrites, known as hexaferrites [Pullar, 2012], which is increasing exponentially until nowadays.

Barium hexaferrite ($BaFe_{12}O_{19}$) is a permanent magnet based on ferrite (Ahmed et al, 2013; Yu, 2013). $BaFe_{12}O_{19}$ is a type of M-ferrite hexagonal (Ba-M) has some advantages compare to other materials. The advantages of this material are: high coersivity and high Curie temperature (An, 2014; Burak, 2015), chemical stability, corrosion resistant, high coersivity (Burak Kaynar, 2015). These good characteristics make this M-type of magnet becomes an interesting material to be developed.

Many methods of synthesis have been developed over the laboratory and research centre over the world to obtain a low production cost of powder particles of barium hexaferrite. The scientists have been developing many methods like powder metallurgy method and chemical routes such as sol-gel method as well as co-precipitation method (Setiadi et al, 2015). Setiadi (2018) also reported the application of the powder magnetic material as Pb ion adsorbent. Syahrul Humaidi (2015) has reported the role of Cu^{2+} in $BaFe_{12-x}Cu_xO_{19}$ preparation.

Sintering process is widely used to modify the characteristics of the magnet. It is common that some additives may be used to enhance the characteristic of the magnet such as silica (SiO_2), Al_2O_3, Na_2O, Fe_2O_3. Not only dampen the grain growth, but also those additives have the ability to serve lower the sintering temperatures (Li et al., 2012). Supradedi et al (2017) have investigated the addition of Na_2O to $BaFe_{12}O_{19}$. All of them reported that the composition of additive Na_2O at the sintering temperature 1200°C did not influence the crystal structure. In this work, $BaFe_{12}O_{19}$ magnet was prepared by High Energy Milling (HEM) method and ZnO was used as additive to the phase formation of M-type $BaFe_{12}O_{19}$. The main goal of the work is a change from hard magnetic to soft magnetic.

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2 MATERIALS AND METHODS

The preparation of the magnetic material using solid state reaction method was started from preparation of precursor: $BaFe_{12}O_{19}$ powder and ZnO powder. At first, barium ferrit as a matrix was mixed together with ZnO powder in wet medium (toluene) and experienced High Energy Milling (HEM) for 12 h. The powder was then dried at 200°C for 4 h in oven before sintering at 900°C for 3 h. Rigaku Smartlab X-Ray Diffraction (XRD) Cu Kα (30kV, 40mA, λ = 1.5406 Å) was used to collect the maximum peaks XRD-pattern. Analyse of the pattern was used by MATCH program. Permagraph was used at room temperature and normal atmosphere to get magnetic properties in hysteresis curve form.

3 RESULTS AND DISCUSSION

XRD-pattern of Ba-hexaferrit is shown in Figure 1, whereas the ZnO phase is shown in Figure 2.

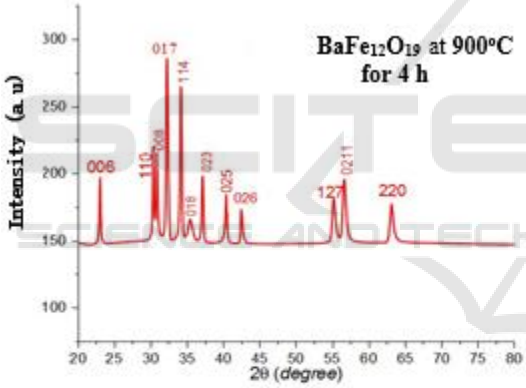


Figure 1: XRD -pattern of $BaFe_{12}O_{19}$ at 900°C/4 h.

It can be seen clearly that four maximum peaks: (110), (008), (017), and (114) occur in 30° < 2θ < 40°. The occurrence of these peaks indicate that the phase occurrence corresponds to $BaFe_{12}O_{19}$ structure as a major phase. This results are in a good agreement with the previous finding (Syahrul Humaidi, 2015). This sample has a hexagonal crystalline structure whose space group (P63/mmc) with lattice parameter: a = 5.8930Å and c=23.1940 Å. Preparation of ZnO precursor with sintering temperature at 500°C as shown in Figure 2 also a confirmation of ZnO as a major phase. It can be seen that three maximum peaks: (100) related to 2θ= 31.80°; (002) at 2θ= 31.8° and (101) at 2θ= 34.42°. According to the results of MATCH program, the crystalline structure of ZnO is hexagonal with the value of a parameter = 3.22Å and b= 5.22Å space group of P63mc (wurtzite). As such, ZnO can be used as a filler to barium-hexaferrit magnet.

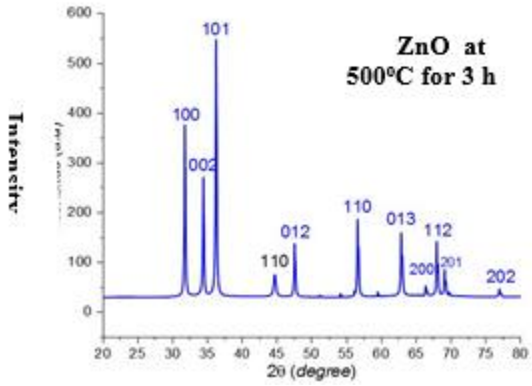
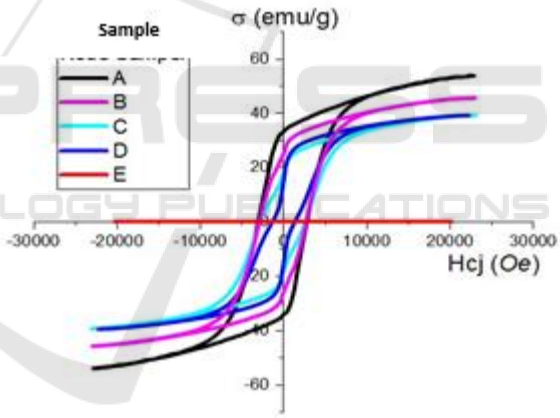


Figure 2: XRD -pattern of ZnO at 500°C/3 h.

Figure 3 tells magnetic characteristics of produced composite magnet. Based on this graph, the value of magnetic remanence (Mr) as well as coersivity (Hcj) can be gained as tabulated in Table 1.



The curve style as presented in Figure 3 starts to deviate in the composition of (50/50) % weight of the precursor. A narrower curve can be observed in the composition of (25/75) % weight of ZnO. Based on the graphs, it can be concluded that the addition of 75%-weight of ZnO has turned the hard magnetic into soft magnetic. The value of soft magnetic properties can be referred on Table 1. As it can be seen, the smallest value of Mr as well as the Hcj have been noted in the sample C. However, further investigation is still needed to confirm this phenomena. Based on this result, this composition (25% $BaFe_{12}O_{19}$ + 75% ZnO) is reasonable to be developed as a starting material composition especially in the application of microwave absorber.

Table 1: Magnetic properties of composite magnet

Sample code	Mr (emu/g)	Hcj (Oe)
A (100/0)	33.06	2943
B (75/25)	24.60	2821
C (50/50)	17.20	2728
D (25/75)	1.27	152.4
E (0/100)	14.69	1365

4 CONCLUSIONS

We have successful prepare a composite magnetic material $BaFe_{12}O_{19}$/ZnO via solid state reaction. The composition of 25/75 can be referred as a starting composition in the next soft magnetic investigation.

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