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Effect of Sintering Temperature and Value of Ratio on Density and Composition of $Zn_xFe_{3-x}O_4$

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ABSTRACT

This article describes the result of an experiment that has been done on zinc ferrite ($Zn_xFe_{3-x}O_4$ where x = 0.0, 0.2, 0.4, 0.6 and 0.8) to determine the properties of the material. Although ferrite materials have been utilized as magnetic materials, not much is known about the properties of these compounds. The density and composition is use to develop new devices that have good properties and efficiencies. In order to get the characteristic of $Zn_{(x)}Fe_{(3-x)}O_4$, two objectives has been setup so that the collected data easy to analyze. The two objectives are; to measure the effects of different values of ratio (x = 0.0, 0.2, 0.4, 0.6, 0.8) on properties of $Zn_{(x)}Fe_{(3-x)}O_4$, and to measure the effect of different sintering temperature on properties of $Zn_xFe_{3-x}O_4$. The $Zn_{(x)}Fe_{(3-x)}O_4$ samples were prepared using a conventional solid state approach. Appropriate amounts of ZnO and Fe3O4 powder were mixed together and shaped into pellets. These pellets were then sintered at 1000˚C, 1100˚C and 1200˚C in order to determine the effects of different sintering temperatures on their properties. The samples were then characterized using a gas pycnometer to measure the density and X-ray diffraction to analyze the present phases. The results show an increase in the density when sintering temperature was increased. The samples tested show the presence of the $Zn_{(x)}Fe_{(3-x)}O_4$ phase. From the experiment and analysis have been done, optimum result has been taken as the best result

Keywords: ZnFe2O4, phase formation, sintering temperature.

INTRODUCTION

Zinc ferrites are one of the compound that said to be a thermoelectric material and it is widely used in electrical and magnetism application. As known, zinc (Zn) has more versatility in their properties. Some research did just to analyze and evaluate the mechanical and general properties on this material compound. However, lack of research on their ability and properties on their thermoelectric efficiencies because of the high cost in developing the system for using this material. System using thermoelectric materials such as bismuth telluride are simpler than conventional power generating systems but are not widely used because of high cost concerns. More industries used thermoelectric in their product only used existing material or concept that already known their ability. Thus, this research aim is to study the properties of zinc ferrite [2].

Zinc oxide (ZnO) is an organic compound in white powder form and it's not soluble in water. ZnO has high thermal conductivity, high electron mobility, large exciton binding energy and wide band gap [1]. Ferrite oxide is an organic compound having three main of iron which FeO, Fe3O4 and Fe2O3 [4] while iron oxide are chemical compound which contain iron and oxygen. Fe3O4 contain both Fe^{3+} and Fe^{2+} ion and it exhibit permanent magnetism and ferromagnetic. Fe2O3 is an electrical conductor with conductivity is high [4].

Ferrites also known as alpha ferrites because term for iron as main constituent with a body-cantered crystal structure. Spinel ferrite, MFe2O4 (M=Zn, Mn, Co, Ni, Mg) are material that have application in many field [10]. Zinc ferrites are inorganic compound with general formula ZnxFe3-xO4. The material can be prepared by reacting of iron oxide and zinc oxide at high temperature. In addition, zinc ferrite has low water solubility and can say that is relatively chemically stable. In addition, this particular material ability as magnetic material at high frequency.

Sintering is a heated process also called heat treatment process by giving some heat at required temperature to zinc ferrite in order to increase the properties of the material especially the mechanical property [11]. This treatment process did below the melting point of the compound [11]. Sintering process will remove some residual stress inside the material and make bonding between each particle so that the material become stronger and increasing the properties [11].

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Experimentation:

Materials:

This research used materials namely; ZnO and Iron (III) oxide, Fe3O4. 81.40g/mol is molecular weight of ZnO and density value is 5.61g/cm3. 159.69g/mol is the molecular weight for Fe2O4 and 5.24g/cm^3 of density. Melting point for both zinc oxide and iron oxide is 1975˚C and 1566˚C. AR grade chemical reagents were used.

Sample Preparation:

Mixing of zinc ferrite, ZnFe2O4 are using different ratio of ZnO and Fe2O4. The ratio used are, X = 0, 0.2, 0.4, 0.6, and 0.8. ZnFe2O4 was compounded until it well mixed by using mortar. The products produced are in red colour and green compact form and it is final products before sintering process are done. ZnO with white powder colour will slowly disappear in Fe2O3 during mixing process due to the small ratio. Table 1 shows the weight of ZnFe2O4 based on ratio used.

Table 1: Weight of ZnFe2O4 based on ratio.

Material Ratio	ZnO (g)	Fe2O3 (g)
0	0	23.9535
0.2	1.628	22.36
0.4	3.256	20.7597
0.6	4.874	19.1628
0.8	6.512	17.5659

The mixed powders are then formed into pellet. Each sample was weighted for 2g to form a pellet shape. The pellet should be not too thick to avoid cracking. The pellets were sintered for 6 hours at 1000˚C, 1100˚C and 1200˚C.

Testing:

After the samples are well sintered, some testing are did on the samples namely, density by using A gas pycnometer with helium analysis gas and 10cm³ of chamber size and XRD (Shimadzu-6000 3.6) are used to determine the density and crystalline structure and characteristic of the ZnFe2O4. The density was obtained as the average value of five samples for each of the different testing conditions.

Result and Discussion

The results of the experiment are as follow;

Density:

Figure 1 (a) show the box-plot of zinc ferrite (ZnFe3O4) sintered in 1000˚C with 5 samples with different ration of x. From the box-plot can be seen that sample with x = 0.0 gives 5.4 g/cm³ of density. The pattern of the box plot is slightly decreased when the x value is increase. The sample with x = 0.8 shows more dense rather than other 4 samples with density value of 4.856 g/cm³. Previous research shows the same pattern of box-plot where the increasing in ration will increase the density [9].

Figure 1 (b) shows the box plot with the same material but was sintered in 1100˚C of temperature. From then box-plot noticed that it shows the reverse pattern from Figure 1 (a) [13, 14]. The samples sintered in 1100˚C with x = 0.0 gives 4.8 g/cm³ of density and slightly decrease the density with x = 0.8 and gives the density value 5.197 g/cm³ [12, 13, 14]. Figure 1 (c) shows the ZnFe2O4 sintered in temperature 1200˚C. The dramatic pattern can be seen in this box-plot and different with two pattern before because the x = 0.2, x = 0.4, x = 0.6 and x = 0.8 are near each others. The values of density of these 4 samples are around 4.6 – 4.7 g/cm³. X = 0.0 is less dense compare to the other 4 samples with density value is 4.53 g/cm³ [9]. The unstable value is because it happen some internal microstructure and composition changes [13, 14].

Figure 2 shows the result from XRD test on ZnFe2O4 with three different temperatures; 1000˚C, 1100˚C and 1200˚C. The XRD pattern indicates a mixture of the ZnFe2O4 and Fe2O3 phases were formed in the samples. From the graph, can see that the highest peak refer to ZnFe2O4 and the short peak refers to Fe2O4 [3,8]. The patterns form graph on Figure 4 is same with standard (Reference Code: 00-001-1108) and previous research [3,8]. Even though the samples were sintered in different temperature, the dispersion of the materials is same. Each temperature shows the existing of ZnFe2O4 and Fe2O4 almost at the same place.

Conclusion:

The XRD test verified the ZnFe2O4 pattern [3]. ZnFe2O4 and Fe2O4 still can be seen in every temperature; 1000˚C, 1100˚C and 1200 ˚C. Increasing in sintering temperature will decrease the density of the samples. The highest density shown in x = 0.0 at 1200˚C. Sample dense determine the porosity. The density will decrease when sintering temperature increase [13, 14]. In other way all the values are not directly proportional each other.

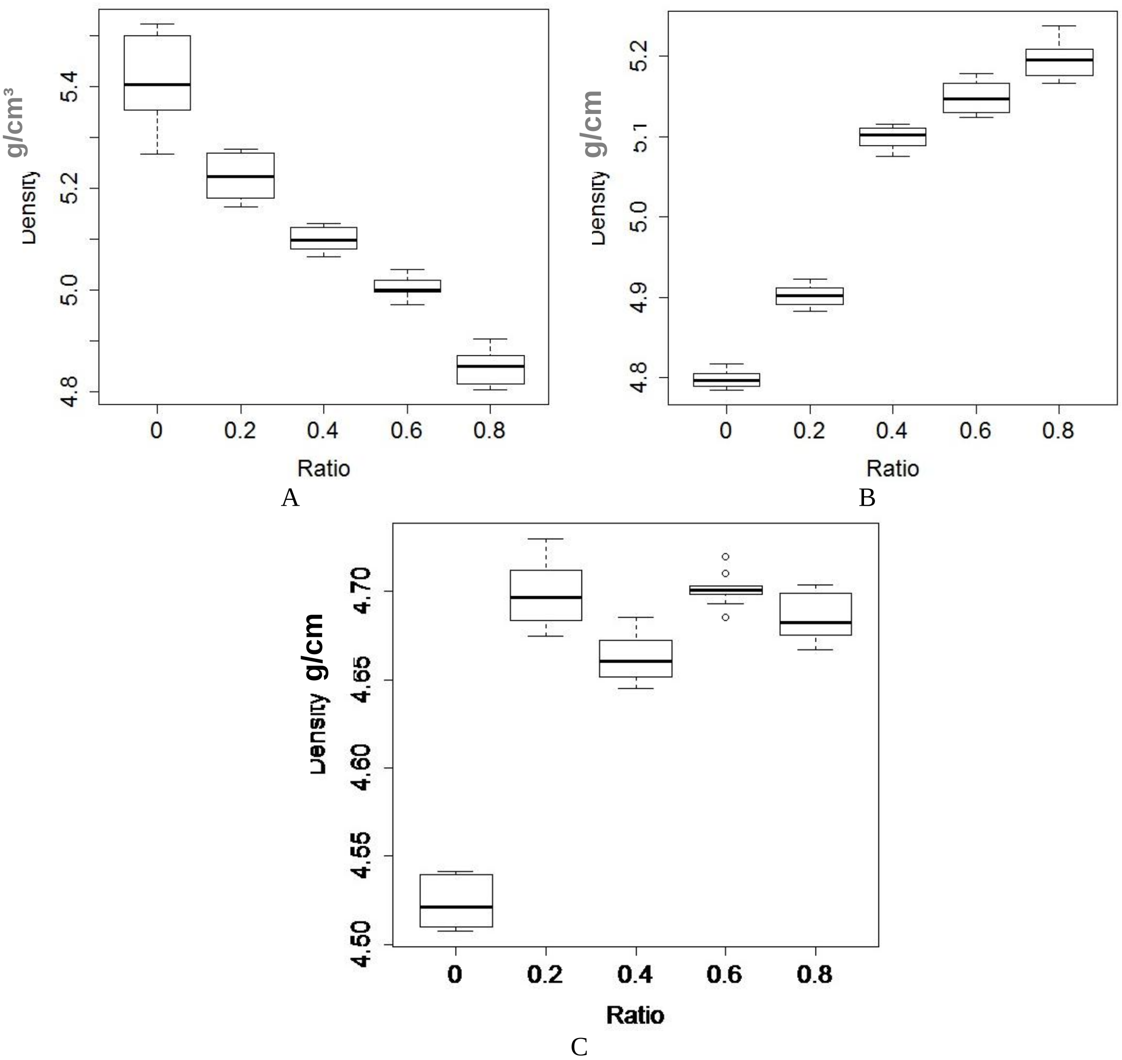
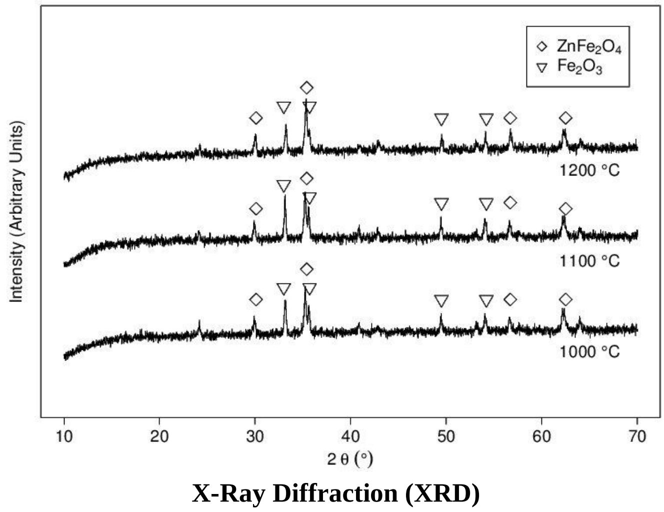


Fig. 1: Box-plot of sample of ZnFe2O4 sintered in different temperature: (a) 1000˚C, (b) 1100˚C and (c) 1200˚C.



X-Ray Diffraction (XRD)

Fig. 2: XRD result of Zn Fe2O4 with three different sintering temperature.

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