Characteristics of Barium M-Hexaferrite with Doping Mn and Ni in X-Band Frequency for Microwave Absorption

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Characteristics of Barium M-Hexaferrite with Doping Mn and Ni in X-Band Frequency for Microwave Absorption

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Abstract. Synthesis of Barium M-Hexaferrite samples based on natural iron sand at Ketapang beach, Pringgabaya District, East Lombok with Mn-Ni doping ($BaFe_{12-x}Mn_xNi_xO_{19}$) has been successfully carried out using the coprecipitation method. The synthesis aims to determine the characteristics of the electrical properties of the Reflection Loss sample of $BaFe_{12-x}Mn_xNi_xO_{19}$ doped with Mn-Ni metal. The basic materials used in this study were natural iron sand and Barium Carbonate ($BaCO_3$) powder, while the doping materials used were Nickel (II) Chloride Hexahydrate ($NiCl_2.6H_2O$) and Manganese(II) chloride **(**$MnCl_2$) powder with a variety of mole fraction (X = 0, 2; 0 ,4; 0,6 and 0.8). The solvent uses distilled water, 37% hydrochloric acid (HCl), and 25% NH_4OH solution. The samples were then calcined at 25 ^{0}C, 400 ^{0}C, and 600 ^{0}C. The obtained samples show that the higher the Mn-Ni doping ion content and the calcination temperature, the smaller the resulting Reflection Loss value and the greater the absorption rate of microwaves.

Introduction

The development of technology and information in the industrial era 4.0 is growing rapidly. These developments have both positive and negative impacts. The negative impact of the development of technology and information is the use of electromagnetic waves that exceed the limit, resulting in increased microwave radiation resulting in electromagnetic wave pollution that can damage the environment [1]. The technology of absorption of microwave radiation has been developed by scientists to respond to this problem. This technology can be developed with certain materials. The material that can be used as a micro-wave absorbent material is Barium M-Hexaferrite [2].

Barium M-Hexaferrite (BaM)($BaFe_{12}O_{19}$) has a high coercivity field (6700 Oe), a hexagonal molecular structure, and high saturation magnetization (78 emu/g). Barium m-hexaferrite is a material with a hexagonal molecular structure that is used as a radar wave absorber because of its high anisotropic magneto-crystalline properties and high corrosion resistance [3]. Besides that, Barium m-hexaferrite also has unique magnetic properties, which is that initially hard magnetic can be converted into soft magnetic through ion substitution or ion doping [4,5]. The modification of the Barium M-Hexaferrite material by ion doping allows it to obtain unique properties which can be applied as a microwave-absorbing material [6,7].

This study focuses on the formation of Mn-Ni doped $BaFe_{12}O_{19}$ with variations in doping and calcination temperature to produce $BaFe_{12-x}Mn_xNi_xO_{19}$ which can be used as a microwave absorber. This study aims to determine the characteristics of the Mn-Ni metal dopant application and the temperature of barium M-hexaferrite $BaFe_{12-x}Mn_xNi_xO_{19}$ to phase formation.

Several methods that can be used in the manufacture of barium M-hexaferrite include the mechanical method of milling [8], sol-gel [9], and coprecipitation [10]. Among the three methods, the coprecipitation method is a method that has a high level of purity [11,12], so that in this study the synthesis was carried out using the coprecipitation method.

Experiments

The M-hexaferrite material doped with Mn and Ni ($BaFe_{12-x}Mn_xNi_xO_{19}$) was synthesized using the coprecipitation method. This study uses the basic ingredients of natural iron sand (Ketapang Beach, East Lombok), and Barium Carbonate ($BaCO_3$) powder. The doping material used is Nickel (II) Chloride Hexahydrate ($NiCl_2.6H_2O$) and $MnCl_2$ powder. The solvent uses distilled water, 37% hydrochloric acid (HCl) and 25% NH_4OH solution. The stages in this research include: the first stage, namely iron sand separation, which aims to separate the magnetic material from natural iron sand. The second stage is the synthesis of $BaFe_{12-x}Mn_xNi_xO_{19}$ with different Mn-Ni doping mole fractions (x = 0.2; 0.4; 0.6; and 0.8). The third stage is the process of calcination of samples with temperature variations (T = 25 ^{0}C, 400 ^{0}C and 600 ^{0}C). The fourth stage is the finished characterization process using VNA (Vector Network Analyze) at a voltage of 220 V and a current of 1 A to determine the electrical properties and absorption of the resulting microwaves. to find out the electrical properties of the sample.

Result and Discussion

Identification of electrical properties is carried out through characterization to obtain value reflection loss (RL). This measurement aims to determine the microwave absorption ability of each sample doped with Mn-Ni material. To determine the relationship between refractive loss (RL) and microwave absorption, equations 1 and 2 can be used [13].

$$\mathrm{RL\ (dB)} = 20 \log \frac{|Z_{in} - Z_0|}{Z_{in} - Z_0} \quad (1)$$

$$\mathrm{Absorb}(\%) = (1 - Z)\mathrm{x}\ 100\% \quad (2)$$

Where Z_{in} = material impedance, Z_0 = impedance under vacuum. The results of the microwave absorption test by the sample are shown in Figure 1, 2, 3, and 4 which shows the curve between the reflection loss (dB) and the frequency (GHz).

The reflection loss (RL) value shows the amount of absorption of a material or material against microwaves. The negative value of the reflection loss indicates that the material is able to absorb microwaves, where the greater the negative value of reflection loss, the greater the absorption of the material against microwaves [14]. Measurement of the value of reflection loss (RL) uses a frequency in the range 8-12 GHz. This is because between these ranges the absorption intensity or RL value is quite good.

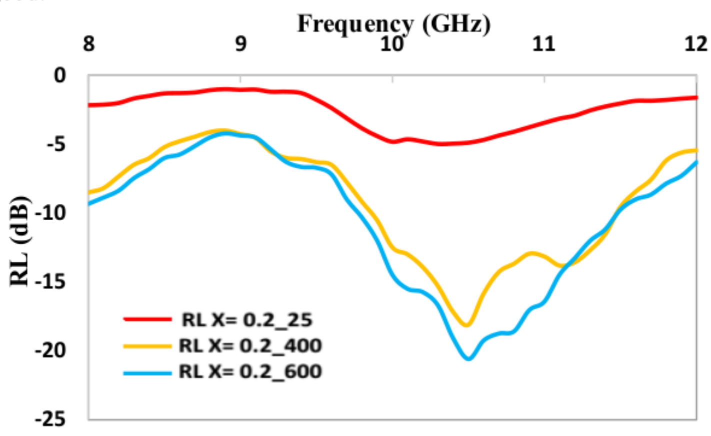

Figure 1. Graph of the relationship between Reflection Loss and the frequency at $BaFe_{12-x}Mn_xNi_xO_{19}$ (x = 0.2)

Figure 1 shows a graph of the relationship between reflection loss (RL) and the $BaFe_{12-x}Mn_xNi_xO_{19}$ frequency with x = 0.2 and temperature variations, namely 25 ^{0}C, 400 ^{0}C and 600 ^{0}C. The value of reflection loss and absorption rate at a frequency of 10.52 GHz at 25 ^{0}C, 400 ^{0}C, and 600 ^{0}C, respectively, are -4.79 dB, -18.27 dB, and -21.01 dB. Meanwhile, the absorption values for each of these temperatures were 66.83%, 98.51%, and 99.21%. This values show that the higher the calcination temperature value, the greater the negative reflection loss value. The higher the calcination temperature value, the higher the absorption rate.

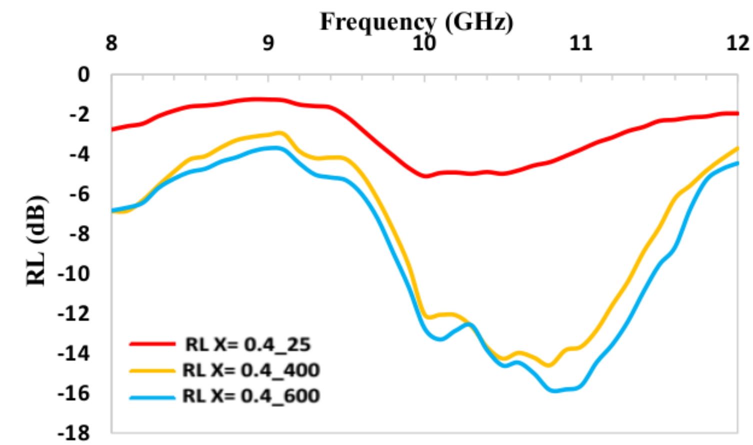

Figure 2. Graph of the relationship between Reflection Loss and the frequency at $BaFe_{12-x}Mn_xNi_xO_{19}$ (x = 0.4)

Figure 2 shows a graph of the relationship between the reflection loss (RL) and the $BaFe_{12-x}Mn_xNi_xO_{19}$ frequency with x = 0.4 and temperature variations, namely room temperature, 400 ^{0}C, and 600 ^{0}C. The value of reflection loss and absorption rate at a frequency of 10.52 GHz at room temperature, 400 ^{0}C, and 600 ^{0}C, respectively, are -3.86 dB, -14.45 dB, and -16.12 dB. Meanwhile, the amount of absorption value for each of these temperatures was 58.88%, 96.41%, and 97.55%. This values show that the higher the calcination temperature value, the greater the negative reflection loss value. The higher the calcination temperature value, the higher the absorption rate.

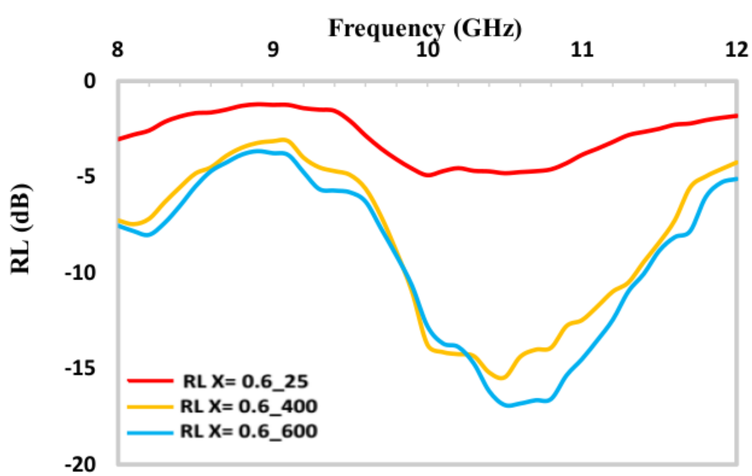

Figure 3. Graph of the relationship between Reflection Loss and the frequency at $BaFe_{12-x}Mn_xNi_xO_{19}$ (x = 0.6)

Figure 3 shows a graph of the relationship between the reflection loss (RL) and the $BaFe_{12-x}Mn_xNi_xO_{19}$ frequency with x = 0.6 and temperature variations, namely room temperature, 400 ^{0}C, and 600 ^{0}C. The value of reflection loss and absorption rate at a frequency of 10.52 GHz at room temperature, 400 ^{0}C, and 600 ^{0}C, respectively, are -4.77 dB, -15.64 dB, and -17.36 dB. While the amount of absorption value for each of these temperatures is 66.69%, 97.27%, and 98.16%. This values show that the higher the calcination temperature value, the greater the negative reflection loss value. The higher the calcination temperature value, the higher the absorption rate.

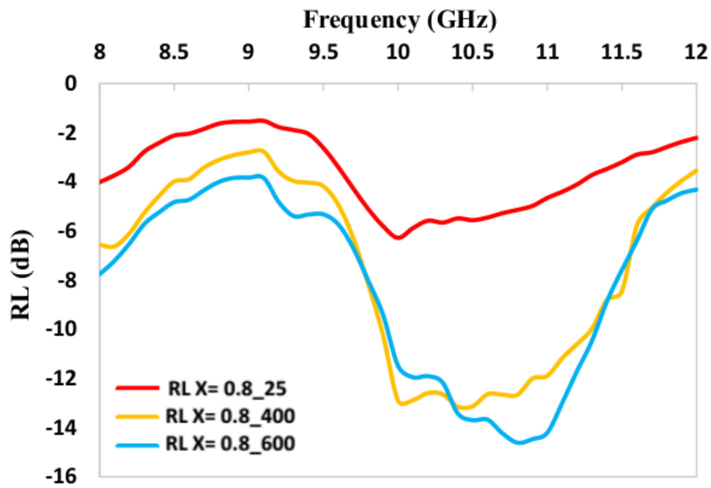

Figure 4. Graph of the relationship between Reflection Loss and the frequency at $BaFe_{12-x}Mn_xNi_xO_{19}$ (x = 0.8)

Figure 4 shows a graph of the relationship between the reflection loss (RL) and the $BaFe_{12-x}Mn_xNi_xO_{19}$ frequency with x = 0.8 and temperature variations, namely room temperature, 400 ^{0}C, and 600 ^{0}C. The value of reflection loss and absorption rate at a frequency of 10.52 GHz at room temperature, 400 ^{0}C, and 600 ^{0}C, respectively, are -5.10 dB, -12.56 dB, and -14.64 dB. Meanwhile, the absorption values for each of these temperatures were 69.12%, 94.46%, and 96.56%. This values show that the higher the calcination temperature value, the greater the negative reflection loss value. The higher the calcination temperature value, the higher the absorption rate.

The value of RL and absorption coefficient indicate the ability to absorb microwaves. The greater the negative value of RL, the greater the absorption of the material against microwaves. Overall, from Figures 1, 2, 3, and 4, it can be seen that the higher the amount of Mn-Ni content included in the sample, the greater the negative RL value. Increasing the negative value indicates that the RL value is getting smaller. The smaller the value of RL, the greater the absorption rate of microwaves. In addition, the absorption rate of microwaves is getting bigger with the increase in the amount of Mn-Ni content added to the sample. These results are consistent with previous research, namely the increasing amount of Zn-Mn doping and calcination temperature, causing greater absorption of microwaves [15]. In addition, the higher the frequency range for measuring the sample, the more likely it is for researchers to obtain higher RL values and absorption coefficients so that a waveguide adapter with a frequency greater than 15 GHz is needed [16].

Summary

The synthesis of Barium M-Hexaferrite samples based on natural iron sand with Co-Ni doping ($BaFe_{12-2x}Co_xNi_xO_{19}$) has been successfully carried out using the coprecipitation method. The results of the measurement of the electrical properties of the samples characterized using a VNA tool in the form of RL value for x = 0.2 and temperature variations of 25 ^{0}C, 400 ^{0}C and 600 ^{0}C were obtained at a frequency of 10.52 GHz, each of which was -4.79 dB, -18.27 dB and - 21.01 dB, while the absorption values for each of these temperatures are 66.83%, 98.51% and 99.21%. The RL value for x = 0.4 and temperature variations of 25 ^{0}C, 400 ^{0}C and 600 ^{0}C were obtained at a frequency of 10.52 GHz, each of which was -3.86 dB, -14.45 dB and -16.12 dB, while the magnitude of the absorption value for those temperatures were 58.88%, 96.41% and 97.55% respectively. The RL value for x = 0.6 and temperature variations of 25 ^{0}C, 400 ^{0}C and 600 ^{0}C were obtained at a frequency of 10.52 GHz respectively, namely -4.77 dB, -15.64 dB and -17.36 dB, while the magnitude of the absorption value for each those temperatures were 66.69%, 97.27% and 98.16% respectively. The RL value for x = 0.8 and temperature variations of 25 ^{0}C, 400 ^{0}C and 600 ^{0}C were obtained at a frequency of 10.52 GHz, each of which was -5.10 dB, -12.56 dB and -14.64 dB. Meanwhile, the absorption values for each of these temperatures were 69.12%, 94.46% and 96.56%. Overall, these results indicate that the $BaFe_{12-x}Mn_xNi_xO_{19}$ sample has a negative RL value which increases with the increase in the doping content of Mn-Ni metal. The smaller the value of RL, the greater the absorption rate of microwaves. In addition, the higher the calcination temperature, the greater the negative RL value.

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