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Characterization of Barium Hexaferrite and Iron Sand as Microwave Absorbing Materials

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Abstract
This research aims to analyze the characteristics of Barium Hexaferite and iron sand as microwave absorbing materials, their influence on microwave absorption properties, and the frequency range of waves produced by these materials. The research method used is the Co-Precipitation method. Dissolve barium hexapherite and iron sand in distilled water with the appropriate mass ratio. The results of this study show that the synthesis of iron sand and barium hexapherite material produces a single phase material. The single phase material is shown through X-ray diffraction pattern data, namely iron sand and barium hexapherite, namely hematite and barium hexapherite. Iron sand and barium hexapherite materials are characterized using EDS which shows a composition that is close to stoichiometry. Observations using VNA show that iron sand and barium hexapherite materials are able to absorb electromagnetic waves at a radar wave frequency of 11.1 GHz, which is -25.64 dB.

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INTRODUCTION

Efforts are required to create absorbers to address electromagnetic wave interference triggered by high-frequency microwave technology for wireless electronic devices. High-frequency electronic equipment, such as amplifiers, often faces challenges related to high-frequency noise emissions. Previously, electromagnetic wave absorbers have been developed using ferrite-based materials (Adi W.A., 2012). The development of electromagnetic wave technology has significantly advanced in recent years, especially in the telecommunications sector. The density of electromagnetic wave traffic in the Earth's atmosphere has become increasingly congested with the growing number of telecommunications service providers (An, Y.J. et al., 2008). Consequently, this includes damage to critical security systems and electronic devices. Additionally, exposure to microwaves emitted by cell phone signals is known to increase the risk of cancer in body cells (Yunasfi et al., 2018). The use of microwave-absorbing materials has been considered an effective solution to reduce the impact of such radiation (Singh et al., 1999). Indonesia's natural potential as a maritime country with coastal areas includes iron sand. In Indonesia, the utilization of iron sand as an iron source has not been optimal, unlike countries such as New Zealand and China that have utilized iron sand as a raw material in steel production (Wida and Josephine, 2015).

The minerals contained in iron sand include magnetite, which consists of iron and oxygen. Magnetite, known chemically as Fe3O4, is often used as a radar-absorbing material. A study by Dessy Putri E and colleagues in 2013 also demonstrated that magnetite nanoparticles from iron sand in East Java could be synthesized. These nanoparticles are then transformed into a magnetic material known as barium M-hexaferrite, which is effective in absorbing microwaves (Efhana et al., 2017). Barium hexaferrite and iron sand are two materials of interest in this research due to their promising properties as microwave-absorbing materials. Barium hexaferrite has high magnetic permeability and large magnetostriction, while iron sand has high electrical conductivity. The combination of these properties is expected to produce an effective, low-cost, and environmentally friendly microwave-absorbing material (Rosyidah, 2013).

Barium hexaferrite and iron sand are used in an effort to engineer the magnetic and electrical properties of the material. The use of limestone as a calcium source and iron sand as a ferrite source allows for the combination of their magnetic and electrical properties, with ferrite magnetic material acting as a microwave absorber at appropriate frequencies. This study utilizes natural raw materials, namely iron sand and barium hexaferrite, which will be combined. The sample variations in this study involve the mass ratio of the materials; these sample variations are expected to produce magnetic materials with effective microwave absorption capabilities.

METHOD

The research method employed is the Co-Precipitation method. Dissolve barium hexaferrite and iron sand in distilled water (aquadest) with an appropriate mass ratio. This research is conducted in the Physics Laboratory of Universitas Sumatera Utara (USU) from January 2024 to March 2024. The materials used in the study include iron sand and barium hexaferrite, synthesized using the Co-Precipitation method. These materials are dissolved in distilled water, NaOH is added, and the mixture is left to stand for 24 hours. The sediment is then washed and dried at 100°C for 2 hours before being calcined at 1000°C for 2 hours. The samples are subsequently characterized using X-Ray Diffraction (XRD), Scanning Electron Microscope-Energy Dispersive Spectroscopy (SEM-EDS), and Vector Network Analyzer (VNA). This study aims to understand the properties of these materials and their potential applications in various fields. The design of this research process is presented in Figure 1.

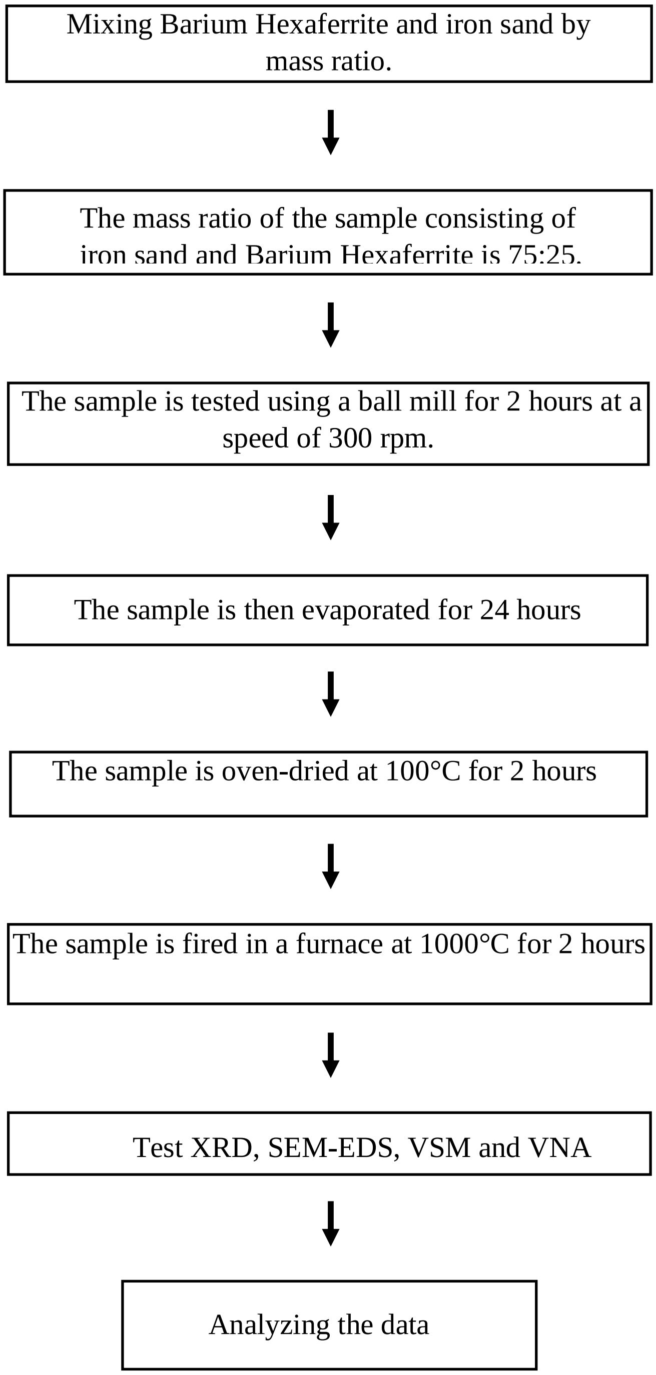
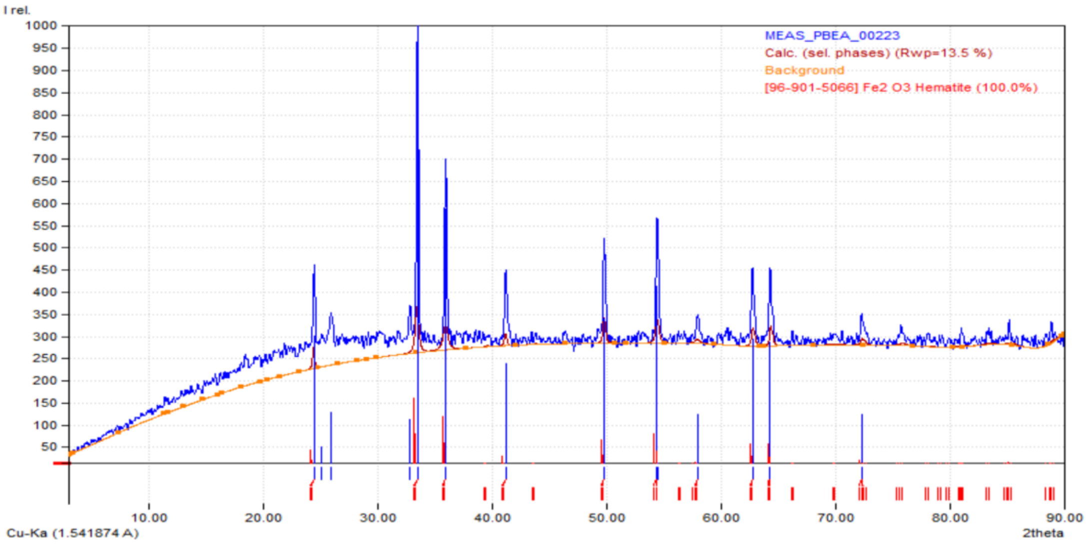


Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Analysis of the sample using XRD

The X-ray diffraction patterns of iron sand and Barium Hexaferrite materials are shown in the following figure. The above diffraction patterns indicate the presence of various phases in the iron sand and barium hexaferrite materials. To determine the phases present in the materials, phase identification referring to the Crystallography of Database (COD) is required within the Match!4 software, as shown in Figure 2.



2θ (°)

Figure 2. Matching XRD results with Match!4 results on iron sand and barium hexaferrite materials with a sample composition of (4:1).

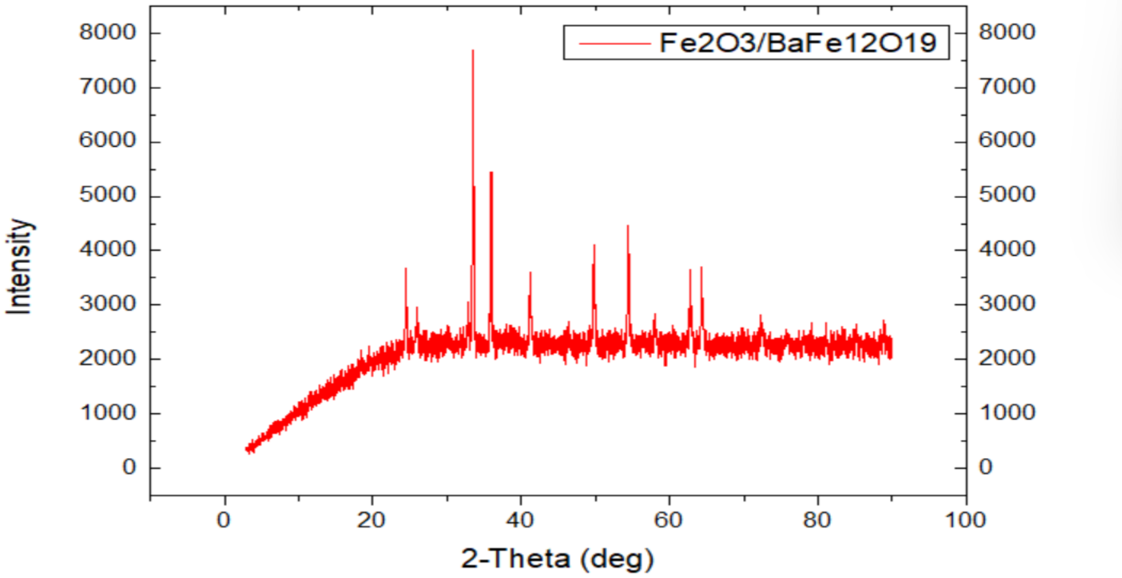


Table 1. Crystal Parameters of Iron Sand and Barium Hexaferrite for Sample Composition (4:1)

Sample	2θ (deg)	FWHM (deg)	a (Å)	c (Å)	c/a	ρcalc (g/cm3)
Iron sand: Barium Hexaferrite (4:1)	24.50	0.1763	5.0249 Å	c= 13.7163 Å	3.72	5.305 g/cm³

In the Match!4 software, phase matching of the material was performed. In the iron sand and barium hexaferrite sample (4:1), a single phase is present, as shown in Figure 4. It can be observed that the sample consists of a single phase of barium hexaferrite. From Figure 4, peak shifting occurs towards smaller 2θ (o) angles after combined with iron sand. The peak shifting difference affects lattice parameters as seen in Table 1. Mixing these two materials results in increased intensity, while the Full Width at Half Maximum (FWHM) value decreases. This indicates that the combination of these materials significantly influences the growth of crystal grains from the iron sand and barium hexaferrite sample blend.

The crystal system (lattice parameters) formed is trigonal (hexagonal axes). The trigonal crystal structure (hexagonal axes) has characteristics that affect the radar-absorbing properties of the material. Trigonal crystal structures generally exhibit magnetic anisotropy, where the magnet prefers to rotate more easily in one direction than in others. This anisotropy enhances the radar absorption ability at certain frequencies. The combination of these materials makes it have better radar absorption capability, supporting its magnetic resonance mode

Result SEM-EDS Analysis

The composition ratio of the sample between iron sand and barium hexaferrite is (4:1). The composition of each element in the iron sand and barium hexaferrite sample (4:1) is shown in Table 2.

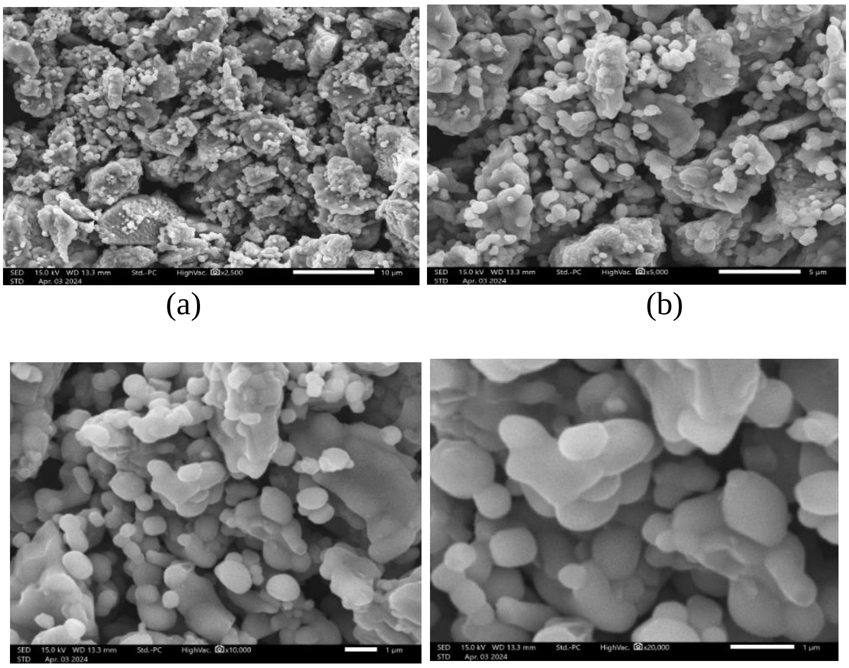
Table 2. Composition of the experimental results in mass percent and atomic percent of iron sand and barium hexaferrite samples (4:1) with EDS..

Sampel Pasir besi dan barium heksaferit (4:1)				
Elemen	EDS-1		EDS-2	
	% mass	% atom	% mass	% atom
Fe (Iron)	72,76	46,76	72,21	49,69
O (Oxigen)	22,44	50,33	18,77	45,08
Ba (Barium)	4,20	1,10	8,10	2,27
C (Carbon)	0,60	1,82	0,93	2,97

The composition of each element in the iron sand and barium hexaferrite sample (4:1) is as shown in Table 1. The EDS testing results revealed the presence of elements C, O, Fe, and Ba in the sample testing. This indicates the formation of the iron sand and barium hexaferrite samples. Elements C, O, and Fe are formed in the iron sand, while elements C, O, and Ba are formed in barium hexaferrite. Based on observations, the distribution of elements from Fe ions indicates successful substitution into Fe. This is supported by the atomic percentage data of the barium hexaferrite and iron sand powder samples in the table above. The mass percent and atomic percent composition of iron sand and barium hexaferrite materials (4:1) as shown in Table 2 are more accurate because they approach the actual composition as shown in Appendix 1, page 20. This is because the material contains other phases. Based on the XRD and EDS characterizations above, it is concluded that the formed sample produces a single phase and an element composition close to the stoichiometric reaction.

Analysis of SEM results of iron sand and barium hexaferrite samples (4:1)

The SEM analysis results of iron sand and barium hexaferrite samples (4:1) are shown in Figure 3.



(a) (b) (c) (d)

Figure 3. SEM images of iron sand and barium hexaferrite (4:1) at magnifications (a) 2,500x, (b) 5,000x, (c) 10,000x, and (d) 20,000x**.**

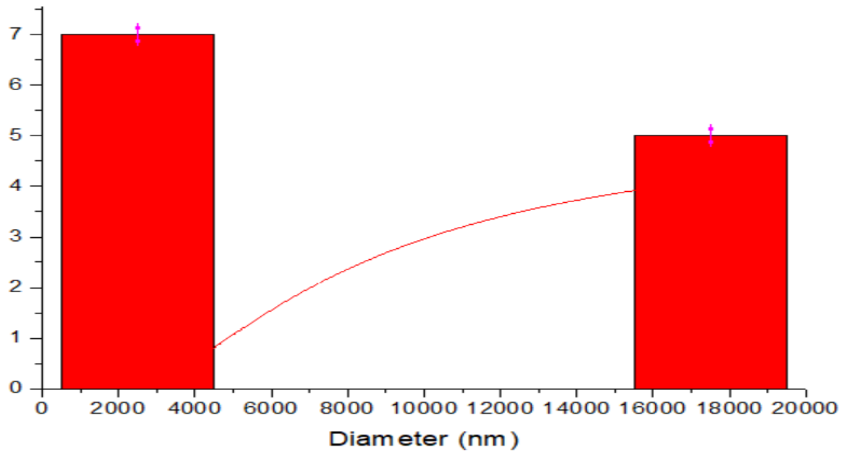


Figure 4. Particle size distribution of iron sand and barium hexaferrite samples

Based on the analysis from ImageJ, the estimated average diameter size of the iron sand/barium hexaferrite sample (4:1) is ± 8659.703 nm. SEM testing was conducted on iron sand and barium hexaferrite samples with a mass ratio of (4:1). Based on the morphological observations above from the SEM-EDX test results, it can be seen that the structure of the sample is hexagonal, indicating the formation of a perfectly blended sample.

Analysis of VNA sample

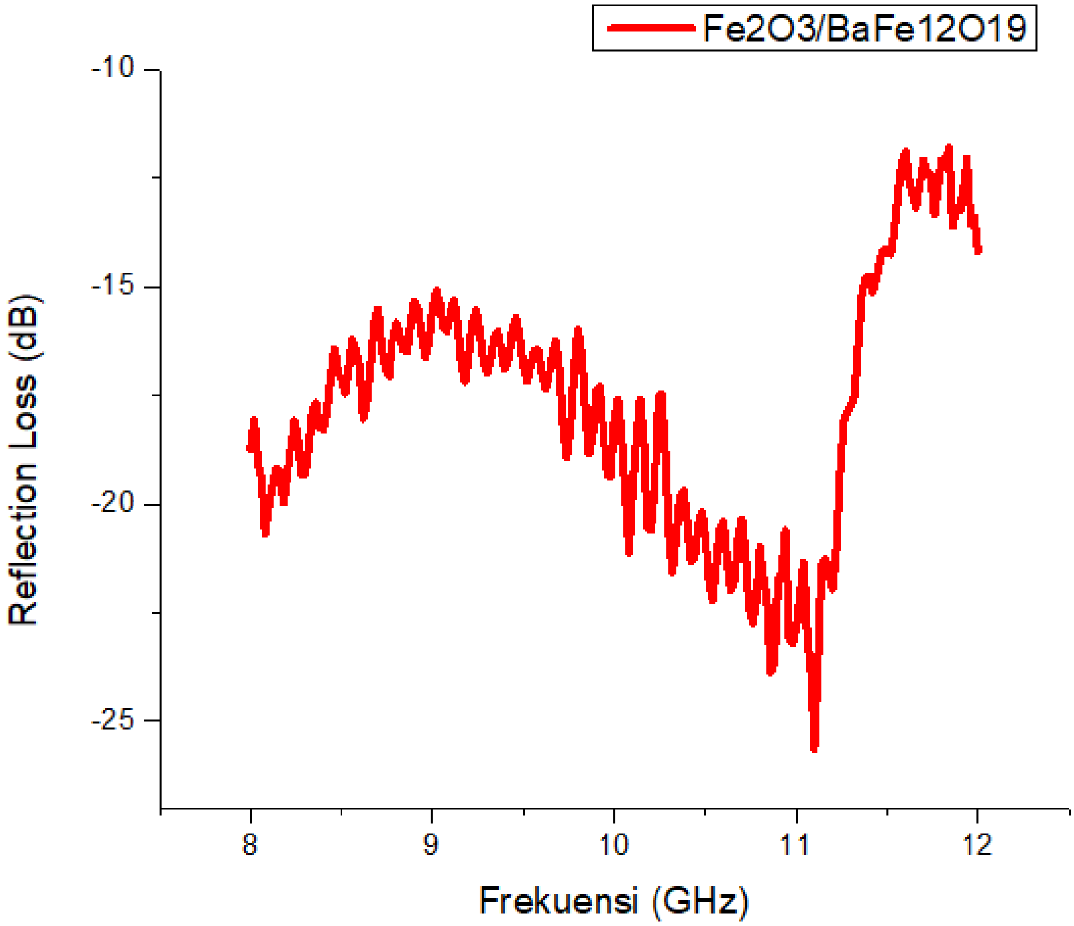


Figure 5. Analysis of VNA Sample

The reflection loss curve of the barium hexaferrite and iron sand samples, as shown in Figure 3, indicates signals from the sample appearing in the frequency range of 8 GHz to 12 GHz, which is the microwave absorption frequency range. The maximum reflection loss of the barium hexaferrite and iron sand samples occurs at a frequency of 11.1 GHz, which is -7.94 dB. This indicates that the material is capable of absorbing microwaves. The process of microwave absorption correlates with the quantity of particles composing the microwave-absorbing material towards its absorption capability. The absorption parameters in good sample variations are not only seen from the reflection loss value but can also be assessed from the effectiveness of the sample in its application as a microwave absorber.

Conclusion

This study demonstrates the synthesis of iron sand and barium hexaferrite using the solid-state reaction method, resulting in a single-phase material. X-ray diffraction data show hematite and barium hexaferrite with compositions approaching stoichiometry. The material is capable of absorbing electromagnetic waves at a radar wave frequency of 11.1 GHz, with a reflection loss of -25.64 dB. The study suggests material modification, such as replacing Co, Zn, or rare earth metals, to enhance frequency range and better reflection loss. Further research is needed to understand the effect of particle size on wave absorption properties.

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