BARIUM FERRITE MAGNET AS ANTI-RADAR MATERIAL

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Kata Kunci*:*

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INTISARI

Artikel ini bertujuan untuk mendiskusikan tentang magnet barium ferit dan potensi penggunaannya sebagai material anti radar dalam teknologi siluman di Indonesia. Studi ini menggunakan berbagai macam literatur dan hasil penelitian terbaru. Teknologi siluman dikembangkan melalui penciptaan zat anti radar yang mampu menyerap sinyal radar yang dikenal dengan *radar absorbing material*. Berdasarkan hasil studi literatur didapatkan informasi bahwa magnet berbasis barium ferit berpotensi menjadi bahan baku penyerap gelombang radar karena dapat menyerap gelombang mikro, termasuk frekuensi gelombang yang digunakan pada radar. Karakteristik magnet dan kemampuan magnet barium ferit untuk menyerap gelombang radar dipengaruhi oleh berbagai kondisi, termasuk bahan kimia dan komponen organik. Magnet barium ferit telah digunakan sebagai bahan anti radar di militer, di kapal, pesawat, kendaraan darat, dan pakaian. Potensi barium ferit sebagai penggerak teknologi militer modern di Indonesia cukup besar namun masih terbatas dalam penelitian laboratorium. Sebagai usaha dalam penguasaan teknologi siluman, pemerintah Indonesia dapat menerapkan strategi *dual-use technology* dan model inovasi *triple helix*.

Keyword*:*

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ABSTRACT

This article discusses barium ferrite magnets and their potential use as anti-radar materials for stealth technology in Indonesia. This study uses a variety of literature and the latest research results. Stealth technology was developed by creating an anti-radar substance capable of absorbing radar signals known as radar absorbing material. According to the literature review findings, barium ferrite-based magnets have the potential to be raw materials for radar wave absorbers since they absorb microwaves, including the frequency of waves utilized in radar. The magnetic characteristics and ability of barium ferrite magnets to absorb radar waves are affected by various conditions, including chemical and organic components. Barium ferrite magnets have been used as anti-radar materials in the military, in ships, aircraft, land vehicles, and clothing. The potential of barium ferrite as a determinant for modern military technology in Indonesia is considerable, but it is still limited in laboratory research. The Indonesian government can acquire stealth technology by implementing a dual-use technology strategy and a triple helix innovation model.

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1. INTRODUCTION

National defense capabilities are interconnected to technology for dealing with any threats. The use of modern detection systems such as radar is a considerable strategy for avoiding enemy attacks. Defensive technology is evolving with the times, and technology that enables a vehicle to be difficult to detect by radar has already been discovered. It is known as stealth technology. This technology evolved from camouflage methods to make fighter aircraft harder to see directly and hide the aircraft on the battlefield. The camouflage method was straightforward, painting an abstract pattern on the fuselage.

Stealth technology is a barometer of military strength that allows war equipment to be undetected by enemy radar. This technique implements by creating an anti-radar substance capable of absorbing radar radiation, known as radar absorbing material. Indonesia can adopt this technology to increase its military technology and anticipate security disturbances in the border area.

Magnetic materials are used in various applications, demanding continuous research and development of magnetic materials that meet the needed properties. Because ferrite magnets can absorb microwaves, including waves with frequencies used in radar, barium ferrite-based magnets offer possibilities as raw materials for synthesizing radar wave absorption materials.

The magnetic characteristics of barium ferrite, and various research on its ability to absorb electromagnetic waves, will be discussed in this article. It will serve as the basis for future research and development, particularly in Indonesia's efforts to develop anti-radar technology.

2. METHODS

The study is based on a literature review gathered from secondary data sources. A literature review is a procedure for discovering, analyzing, and summarizing research works and ideas created by academics and practitioners that is systematic, explicit, and reliable. Researchers get data and information indirectly from various reliable sources, including literature/bibliographic studies, scientific publications, and previous studies.

3. RESULTS AND DISCUSSION

3.1. Anti-Radar Material

The absorption of radar waves by a substance capable of absorbing radar waves is the basis for stealth technology. The radar wave-absorbing substance is essential for detecting and strengthening military defense systems, and its use may rise during a conflict. These materials apply to various camouflage equipment, especially modern fighter aircraft. There are two techniques to generate stealth technology applications. The first method is to develop military weapons structures that reflect radar radiation in various directions. The second method uses a substance capable of absorbing radar signals, such as radar wave absorption material for coating the ship's surface. Several unique inorganic materials, particularly iron-based compounds, have been created as radar wave absorbers [1], carbon-based materials (graphite and carbon fiber) [2], and ceramic-based (silicon carbide) [3].

Radar is an electronic and electromagnetic system that uses radio waves to detect and locate objects. Radar operates by sending electromagnetic waves and analyzing the reflected signal [4]. Stealth technology refers to preventing radar signals from being seen. The method is based on the reflection and absorption of radar signals by the weapon or military vehicle's body surface when covered with radar absorbing material. Nicolaescu describes the mechanism of undetected material by reducing the Radar Cross Section, which measures the target's ability to reflect the radar signal towards the receiver [5].

According to Won-Jun L, a substance may absorb electromagnetic waves by absorbing magnetic fields with magnetic materials and converting incoming waves with dielectric materials into thermal energy [6]. This substance absorbs radar radiation, reducing the number of waves reflected off the metal structure used in stealthy submarine hulls. Radar wave absorption material is helpful in stealth technology because it helps avoid detection (radar, acoustic, infrared, etc.). Hebeish claimed that a radar-absorbing material must meet numerous criteria, including thin, light, durable, affordable, easy to apply, and broad absorption frequency range [7]. In addition, the material must also be able to interact well with the electric field of the radiation and the electrical components of electromagnetic radiation [8].

3.2. Barium Ferrite Magnet

Barium ferrite ($BaFe_{12}O_{19}$) is a material to make permanent magnets, magnetic absorption mediums, and microwave absorbers. Ferrite magnets have high permeability, permissively, and spontaneous magnetization. The combination of inherent qualities of such ferrite's magnetic and electrical capabilities puts ferrite magnetic material as a buffer for microwaves, including waves of frequencies used in RADAR [9]. Ferrite magnets are widely produced compared to other permanent magnets such as (Al-Ni-Co) and steel magnets. Ferrite magnets have a strong coercivity field, preventing magnetic characteristics from being readily lost. Iron sand is one of the basic materials used to make ferrite magnets, and it is abundant and inexpensive [10].

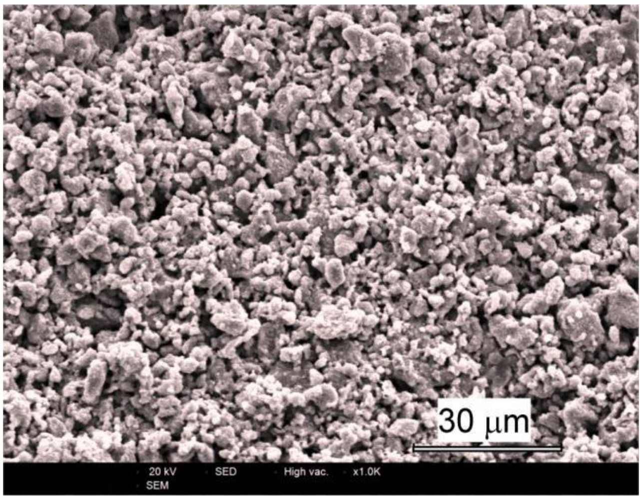

Figure 1. SEM results of the morphological structure of barium ferrite ($BaFe_{12}O_{19}$) [11]

A barium ferrite magnet is a hard magnetic ceramic material with a hexagonal structure (BaFe12O19), sometimes known as a barium hexaferrite. Barium ferrite has high coercivity, high curie temperature, and high saturation magnetization. It is also chemically stable, corrosion-resistant, and produces high rates. There are six types of barium ferrite: M, Z, Y, W, X, and U. Type M, often known as BAM, is one of the most extensively used. Table 2.5 shows the characteristics of BaM, which has the stoichiometric chemical formula BaFe12O19.

Table 1. Properties of barium ferrite [12]

Material properties	Barium ferrite
Melting point (°C)	1500
Curie Temperature (°C)	450
Specific Gravity (g/cc)	5.3 (20°C)
Melting point	± 1500
Coercivity (Oe)	6700
Saturation (emu/g)	72
Colour	Blackish Brown

3.3. Magnetic Properties of Barium Ferrite

Barium ferrite synthesizes in powder form, then combined with other materials to produce composite ceramics that fulfill the requirements and purposes. Magnetic characteristics may be measured using the parameters of remanent induction (Br), coercivity (Hcj), and maximal energy (BHmax). The following are some studies related to various compositions of materials in barium ferrite composites and the magnetic properties produced in Table 1. The effect of additives on the magnetic properties of barium ferrite is in Table 2.

Table 1. Magnetic properties of barium ferrite in various compositions of materials

Magnetic Synthesis	Br (kG)	Hcj (kOe)	BHMax (MGOe)	Reference
Barium ferrite 80% + 20% natural rubber	0.79	1.017	0.02	[13]
80% barium ferrite + 20% cult	0.75	2.880	0.690	[14]
Barium ferrite 90% + 10% Portland cement	0.66	1.707	0.55	[15]

Table 2. Magnetic properties of barium ferrite in various additions of additives

Magnetic Synthesis	Br (kG)	Hcj (kOe)	BHMax (MGOe)	Reference
Barium ferrite + FeMo 5%	1.08	1.03	0.140	[16]
Barium ferrite +MNO_2 1.5%	1.55	2.245	0.46	[17]
Barium ferrite +SiO_2,0.75-1.5% CaO	1.97	2,314	0.64	[18]

Magnetic properties of barium ferrite can vary depending on the treatment given. The research results on adding additives show an effect of additive composition on magnetic properties and crystal structure [19]. Refinement of the particle size of the composite magnetic material also affects the magnetic properties of the barium ferrite composite magnetic material, which causes a decrease in residual or remanent magnetization [20].

3.4. Barium Ferrite as Anti-Radar Material

Barium ferrite's ability as an anti-radar material is due to its ability to absorb microwaves. The ability of barium ferrite to absorb microwaves may be measured using VNA Characterization. Vector Network Analyzer (VNA) calculates the reflection loss (RL) value, namely the amount of material absorption against microwaves. The following research data in Table 3 related to the reflection loss of several barium ferrite magnets synthesized through several methods.

Table 3. Reflection loss of barium ferrite

Magnetic Synthesis	**Method**	***Reflection Loss* (dB)**	**Reference**
Barium ferrite + doping Ni^{2+}	Sol-gel	-27.30 dB (8.30 GHz)	[21]
$BaCO_3$ and Fe_2O_3	Solid-state method	23.07 dB (10.72 GHz)	[11]
Mg–Al Binary Doped Barium Hexaferrite	Co-precipitation method	-53.23 dB (10.83 GHz)	[22]

Barium ferrite ranges from radar electromagnetic wave absorbing materials at a frequency of 8-15 GHz [23]. However, barium hexaferrite type M can absorb microwaves at the S-band frequency [9]**.** Plant-based materials increase the absorption properties of electromagnetic waves [24]. Doping can increase the wave absorption capacities of barium ferrite**.**

3.5 Application of Barium Ferrite as an Anti-Radar Material

Barium ferrite is used as an anti-radar material through its ability to absorb radar waves. The use of barium ferrite can range from a single layer of magnet to numerous layers, depending on the demands and designation of the wave to be absorbed. Military uses include using stealth technology on the outside of the body to employ military aircraft to absorb radar radiation to escape detection by opponents. *Radar Absorbing Material* (RAM) consists of sheets of neoprene containing ferrite particles or carbon black. This substance was employed in early versions of the F-117A Nighthawk. It is similar to iron paint in that it converts radar radiation into heat. Some stealth aircraft have been coated by radar-absorbing coatings made of ferrofluid and nonmagnetic materials. Colloidal mixes of nano-sized (less than 10 nm) ferromagnetic particles suspended in a carrier liquid are known as ferrofluids. Ferrofluids are superparamagnetic, which implies that electromagnetic radiation polarizes them strongly. When a liquid is exposed to a sufficiently robust electromagnetic field, polarization occurs, causing wrinkles to appear on the surface. The electromagnetic energy needed to create these waves weakens or decreases the reflected radar signal's energy. RAM (radar-absorbent material) cannot absorb radar at all frequencies. The material's composition and shape are tuned to absorb radar signals in a specific frequency band [24].

When a radar wave strikes the radar absorption layer, a magnetic field is created in the layer's metal components. The magnetic field has alternating polarity and drains the signal's energy [26]. The active element in the radar absorption substance might be ferrite carbonyl ferrite. As demonstrated in Figure 2, the energy that is not dispersed by each element of the ferrite iron carbonyl is reflected in the other components.

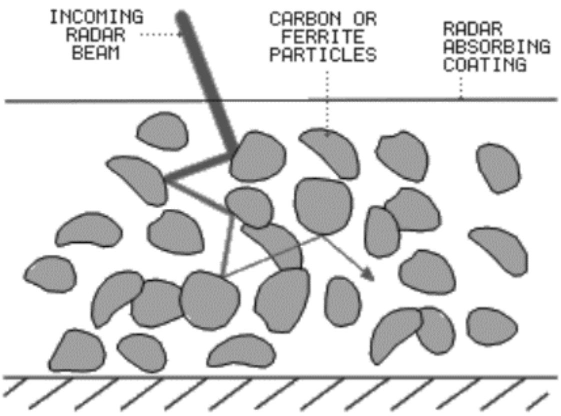

Figure 2. Scattering of electromagnetic waves in the RAM layer

Radar works on the principle where microwaves use to detect aircraft by analyzing the signals reflected from the aircraft. Every metal or thing will have its unique set of reflecting characteristics. As a result, stealth aircraft are constructed with minimal reflectivity or are covered with materials that absorb rather than reflect the signal returning to the source. The radar detection capability of this type of aircraft is quite low. Instead of deflecting incoming radar signals, the radar absorbing surface absorbs them. This absorbent substance employs widely in aircraft and warships, tanks, and ground vehicle systems [25].

Research related to radar-absorbing materials has been widespread, and the characterization of flexible radar-absorbing materials based on ferromagnetic nickel micron fibers enables fabrics that can absorb radar waves [26]. Soldiers, especially infantry, can wear it as material that the enemy cannot identify. Figure 3 shows the structure, features, and characteristic qualities of microwave absorbent fabric that can be applied in the future.

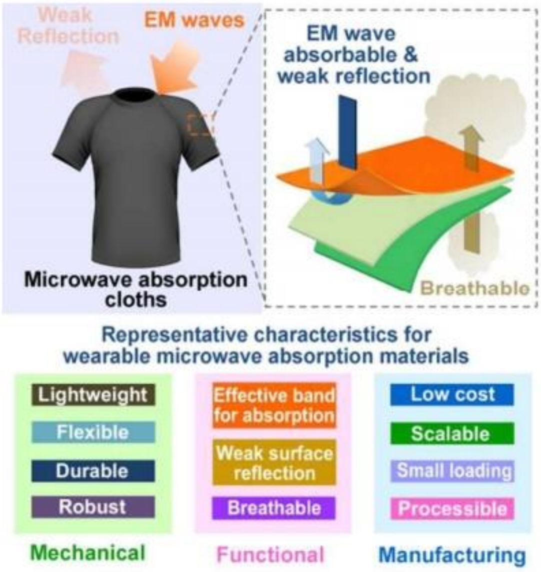

Figure 3. Illustration of structure, properties, and representative characteristics for wearable microwave absorbent fabrics

3.6 Barium Ferrite Magnets Potential in Indonesia

In Indonesia, there has been a lot of research and development of magnetic products using barium ferrite materials. Research on the innovation of making barium ferrite magnets using welding waste [27], composite magnets made from barium ferrite with natural rubber binders [13], Preliminary study of the utilization of ilmenite processing sludge as a magnetic material [28], fabrication of composite magnets made from recycled magnets with cult binders [29]. The use of organic materials such as cassava peel and chitosan is a material that absorbs radar waves and can be combined with barium ferrite magnets [30].

The raw materials are easily accessible, and the manufacturing process is easy. Iron sand, which is used as a raw material in barium ferrite magnets, is commonly accessible, for example, in Cilacap's Binangun area [31] and Sijunjung Regency, West Sumatra [32]. Various methods have also developed the characterization of barium ferrite magnets synthesized from iron sand and barium carbonate [33].

Barium ferrite can be utilized in infrared wave-absorbing composites and absorbing radar signals [34], thus enabling its broader application in the military and the general public. The potential for barium ferrite magnets is also getting wider because it can form at nano-size through nanotechnology [35].

3.7 Discussion

The world's technological competitiveness and military industry have resulted in modern technology that has become a strength for the countries that possess it and a threat to other countries. Defense technology is constantly thought to represent the contemporary since it is always driven by deterrent capacities to respond to ever-changing threats. From a military perspective, stealth technology is one of the latest technologies today's staple products of developed countries' defense industries. This stealth technology has been completely adopted by fifth-generation aircraft [36]. The Indonesian Airforce is currently having problems regarding the availability of stealth and radar technologies to confront these threats. Other counties' military forces have deployed modern technology defense and security equipment with stealth and

Unmanned Aerial Vehicle (UAV) capabilities to invade and breach Indonesia's territorial sovereignty. Since Indonesia has not yet mastered the technology, this poses a challenge to state sovereignty.

Researchers in Indonesia and worldwide have developed stealth technology previously utilized in the military sector. Recent research has shown that barium ferrite, the primary raw material used in producing anti-radar materials, is of high quality. Combining barium ferrite with other materials can improve its anti-radar performance, expanding the electromagnetic wave absorption frequency range and making the material more effective in its application. The potential of barium ferrite as a determinant for military technology in Indonesia is relatively considerable, although it is still limited in laboratory research. The next challenge is to develop an anti-radar material product from barium ferrite on an industrial scale that can be used and implemented advantageously for military technologies in Indonesia. As a result, it is intended to strengthen national defense and cause apprehension.

The Indonesian government can adopt a dual-use technology strategy and a triple helix innovation model to elevate stealth technology. Dual-use technology can be defined as technology that can be used for both commercial (peaceful) civilian purposes and defense (military or security) purposes [37]. The development of barium ferrite as an anti-radar material using this concept will provide massive benefits for the commercial sector in the form of spillover effects and spin-offs of commercial products derived from military products. If technological improvement in other fields has a spillover effect, the sale value of barium ferrite magnets will rise, resulting in higher economic growth.

The triple helix concept will be reminiscent of the development of barium ferrite as an anti-radar material. This strategy addresses the stakeholders of science's three pillars: research institutions/universities, industry, and users [38]. A supportive innovation ecosystem will result in synergies between the government, which acts as a regulator, universities/institutions of science and technology, which produce innovation, and industry, which develops, creates, and manufactures barium ferrite for anti-radar materials. A comprehensive roadmap for developing barium ferrite for defense and security equipment with stealth technology is required to accomplish the triple helix concept.

4. CONCLUSION

Barium ferrite magnets have been widely used as anti-radar materials in the military, from ships, airplanes, and ground vehicles to clothes. The magnetic characteristics and capacity of barium ferrite magnets to absorb waves can be modified by various circumstances, including chemicals and organic components. The potential of barium ferrite as a determinant for modern military technology in Indonesia is considerable. However, it is still limited in laboratory research. The Indonesian government can acquire stealth technology by implementing a dual-use technology strategy and a triple helix innovation model.

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