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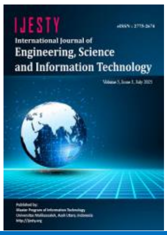

Study on Magnetic Properties Characterization of Aceh Iron Sand as Raw Biomedical Application Materials

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Abstract

The magnetic properties characterization of Aceh iron sand as the preferred material for biomedical applications was studied. Meanwhile, Aceh's iron sand is used as raw cement-making material. It is hoped that in the future, it can be used in many different biological and medical applications, such as diagnostic tests for early disease detection, to serve as tools for non-invasive imaging and drug development. Samples of the natural resource were prepared using a magnetic separator, and the concentrates were mashed by the ball milling method to achieve 112.7µm (MK), 119.3 µm (MT), 112,4 µm (LP), and 115.1 µm (SK) particle size. These features were evaluated from loop hysteresis using a vibration sample magnetometer (VSM), while x-ray diffraction (XRD) was employed to analyze iron oxide. The results estimated the values of saturation magnetization, remanent magnetization, and coercivity from Mon Klayu, Mantak Tari, Lam Panah, and Syiah Kuala at 67.79 emu/g, 10.36 emu/g and 0.02 T; 83.49 emu/g, 13.22 emu/g and 0.02 T; 62.17 emu/g, 9.32 emu/g and 0.02 T; 73.26 emu/g, 10.34 emu/g and 0.02 T, respectively. However, Fe_3O_4 (magnetite) occurred predominantly in the selected locations.

Keywords: *Aceh, Biomedical, Iron Sand, Magnetic, Materials.*

1. Introduction

Naturally occurring particles are of enormous interest in the development of science and technology in recent times. For this significant reason, several tools were produced to examine the benefits and usability. Several scientists portray magnetic materials as one of the most essential substances due to their characteristic nature and wide potential applications in diverse fields, including ferrofluids, catalysts, colour pigments, medical diagnosis, cancer therapy, and radiology.

Iron oxide minerals exist in various crude forms worldwide, e.g. Aceh - Indonesia Province [1] [2]. For instance, magnetite (Fe_3O_4), maghemite (γ-Fe), and hematite (α-Fe2O) are generally referred to as iron oxide [3][2] and are also incredibly significant in industrial and medical applications [4]. Table 1 summarises the sample's selected physical and magnetic properties.

Table 1. Physical and magnetic properties of iron oxide [3]

Properties	Oxide		
	Magnetite	Hematite	Maghemite
Molecular formula	Fe_3O_4	α-Fe_2O_3	γ-Fe_2O_3
Density (*g/cm*^{3})	5.18	5.26	4.87
Melting point (°C)	1583-1597	1350	-
Hardness	5.5	6.5	5
Type of magnesium	ferromagnetic	Weak ferromagnetic	ferromagnetic
Curie temperature (K)	850	956820-986	
Ms at 300K (A-m^2/kg)	92-100	0.3	60-80
Standard free energy of formation ΔGf° (kJ/mol)	-1012.6	-742.7	-711.1

Crystallographic system	Cubic	Rhombohedral, hexagonal	Cubic or tetrahedral
Structural type	Inverse spinel	Corundum	Defect spinel
Space group	Fd3m	R3c (hexagonal)	$P4_332$ (Cubic); $P4_12_12$ (tetragonal)
Lattice parameter (nm)	a =0.8396	a=0.5034, c=1.375 (hexagonal), a_{Rh}=0.5427, α=55.3° (rhombohedral)	a=0.83474 (cubic); a=0.8347, c=2.501 (tetragonal)

Hematite is an outdated form of iron oxide with a wide distribution and is also referred to as iron dioxide, red ocher, specularite, specular iron ore, and kidney ore (martite). In addition, the material exhibits a blood-red colouration in a perfectly shaped structure but tends to be black or grey as a rough crystal. However, the substance appears extremely steady and is frequently the end product of other iron oxide conversion.

Magnetite occurs as a dark ferrous material, iron ore magnetism, loadstone, iron ferrite, or Hercules stone, and is among the toughest magnetic substances [3][5].

Maghemite originates in the soil as a magnetite-eroding product or as other heat-generated iron oxides. In addition, the substance is highly stable compared to hematite, although it forms a continuous solid solution with magnetite [5].

The magnetic properties of iron oxide are applied in a wide range of fields, including seals and inks, recording media, catalysts, ferrofluids, contrast agents for magnetic resonance imaging, and as a therapeutic agent for cancer treatment, with a high preference for fine-sized materials, specific shapes and surface characteristics [6]. Moreover, magnetite and maghemite are increasingly popular in biomedical applications due to inherent biocompatibility and low toxicity in humans [5][7]. However, the primary area of interest appears to be bio-test, where magnetic properties were employed to influence magnetite nanoparticles [5][8]. The development of highly sensitive magnetic micro-array utilizes ferromagnetic sensors to detect the binding of target DNA and proteins [9]. Furthermore, magnetic materials were applied as contrast agents in magnetic resonance imaging (MRI) [5][10]. Superparamagnetic magnetite in these carriers helps to differentiate healthy and diseased tissue and is generally coated with a polysaccharide layer for colloidal stability [11]. Also, MRI cell tracking was successfully carried out by Song *et al.* [12]. Magnetic particles with polymer coatings are utilized in cell separation [13], protein purification [14], environmental and food analysis, organic synthesis and biochemistry, medical, industrial water, and biosciences [5]. So far, Aceh's iron sand is used as a raw material for making industry-cement. This research is conducted to develop further characterization to be used in various biological and medical applications such as diagnostic tests for early disease detection, as a non-invasive imaging tool and drug development. This study examines Aceh iron sand's magnetic properties as a suitable material for biological and medical applications.

2. Methods

2.1. Test Sample Preparation

The iron sand samples were acquired from four beaches, termed Mon Klayu (MK), Mantak Tari (MT), Lam Panah (LP), and Syiah Kuala (SK). Subsequently, the materials were separated based on the individual magnetic properties using a separator, where the magnetic minerals are attracted to the roll while the residues drift towards the tailings. This was closely followed by the milling process to obtain 112.7µm (MK), 119.3 µm (MT), 112,4 µm (LP), and 115.1 µm (SK) particle size. The particle size measurements were carried out using scanning electron microscopy (SEM).

2.2. Vibrating Sample Magnetometer (VSM) Test

The device was employed to analyze the magnetic properties of the samples and is located in BATAN Serpong-Indonesia. Characterization of the magnetic properties of the Fe-C material was carried out using a Vibrating Sample Magnetometer (VSM) with an outer magnetic field range of ± 1 Tesla at room temperature; the increase in speed and reduction in the external magnetic field was set at 0.25 Tesla, per minute. As a radiation source, iron sand samples characterized by VSM were irradiated with 250 kGy Co-60 gamma rays. The samples that have been irradiated are characterized by their magnetic properties using VSM to determine the changes that occur due to irradiation.

3. Results and Discussion

The experiment reported varied results in terms of saturation magnetization (Ms), remanent magnetization (Mr), and sample coercivity (Hc) for each location, including Mon Klayu (Figure 1a), Mantak Tari (Figure 1b), Lam Panah (Figure 1c) and Syiah Kuala beach (Figure 1d). Since the samples were collected from the beaches, there is a high possibility of varying compounds' content, grain size, distribution, etc. However, this research focuses on the magnetic properties of the separated materials. It was reported that the phases of these locations were predominantly Fe_3O_4 (magnetite), while the remains were insignificant [2]. Table 2 and Fig. 1 represent the magnetic properties of iron in the selected sites and the Hysteresis loop curve, respectively.

Table 2. Magnetization properties

Location	Magnetic Properties		
	Saturation Magnetization	Remanent Magnetization	Coercivity
Mon Klayu	67.79 emu/gram	10.36 emu/gram	0.02 T
Mantak Tari	83.49 emu/gram	13.22 emu/gram	0.02 T
Lam Panah	62.17 emu/gram	9.32 emu/gram	0.02 T
Syiah Kuala	73.26 emu/gram	73.26 emu/gram	0.02 T

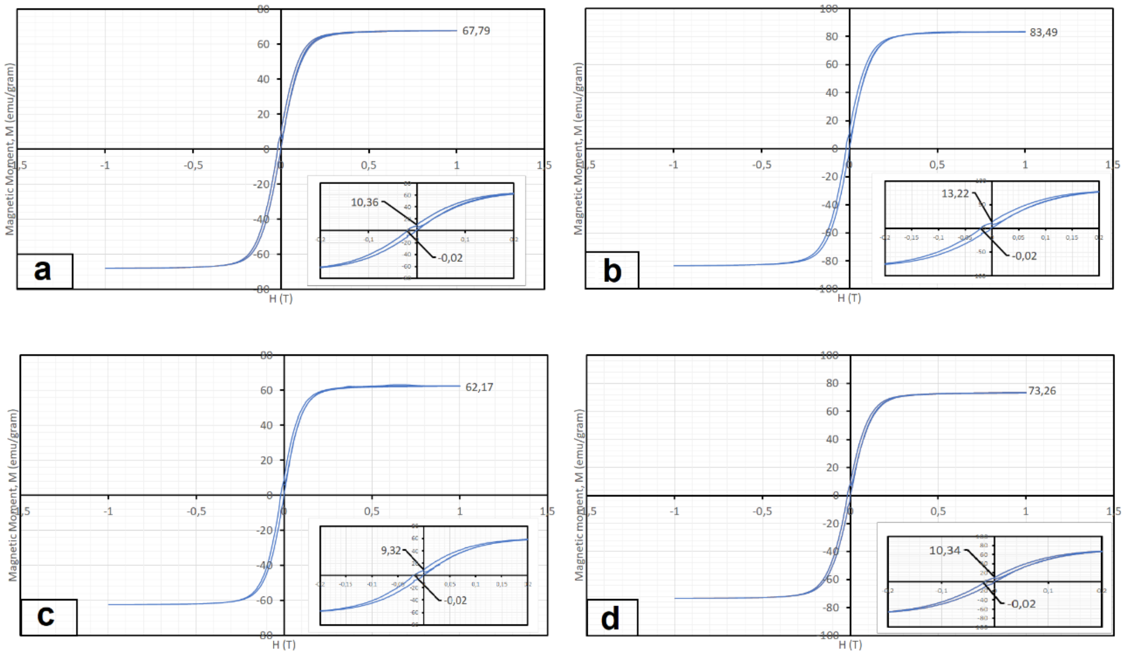

Fig 1. Hysteresis loop curve; a) Mon Klayu, b) Mantak Tari, c) Lam Panah and d) Syiah Kuala

The magnetic test results showed a high saturation magnetization (Ms) value and a low coercivity field (Hc), indicating the superparamagnetic state, although nanomaterials are required. For this reason, the nature of this magnetic matter largely depends on the particle size. Consequently, lesser dimensions yield enhanced flexible properties and magnetic capacity [15]. These nanoparticles are superparamagnetic at room temperature, as the thermal energy can impede the anisotropic energy of a single state.

Furthermore, magnetic particles applied in biomedical industries generally demand superparamagnetic and dispersed properties or form stable colloids in environmentally neutral pH water and physiological salts [16][17], depending on several factors, including size, load, and surface chemistry [18]. However, lesser particle sizes tend to ignore the gravitational influence. Meanwhile, increased charge and surface chemistry allow repulsive forces to stabilize the dispersed particles in water. Similarly, a superparamagnetic state is possibly achieved using lesser particle size, resulting in reduced interactions [19].

Furthermore, saturation occurred at the magnetic field value (H) of 0.2 T compared to the samples tested. This shows the dominant components of the sand were soft magnetic minerals, including magnetite and maghemite, below 0.3T, while the complex substances, e.g. hematite and goethite, remained unsaturated at 1T. Previous observations reported that the soft sand components were of enhanced purity compared to samples from the Southern Yellow Sea, China, L.Wang et al. (2018) [20].

4. Conclusions

Based on results and discussion, the values of saturation magnetization, remanent magnetization and coercivity from samples collected at Mon Klayu, Mantak Tari, Lam Panah and Syiah Kuala were estimated at 67.79 emu / g, 10.36 emu / g and 0.02 T; 83.49 emu / g, 13.22 emu / g and 0.02 T; 62.17 emu / g, 9.32 emu / g and 0.02 T; 73.26 emu / g, 10.34 emu / g and 0.02 T, respectively. In addition, Fe_3O_4 (magnetite) occurred predominantly in the phases from these four locations, while the remaining were insignificant. The magnetic test results showed a high saturation magnetization (Ms) value and a low coercivity field (Hc), indicating a superparamagnetic nature. However, a particle size of 112.7µm (MK), 119.3 µm (MT), 112,4 µm (LP), and 115.1 µm (SK) employed in this study did not contribute to the change. However, lesser dimensions (nano) are required to produce superior superparamagnetic properties with higher Ms value and lower Hc.

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