Magnetic Ceramic Materials from Iron Sand of the South Coast Bantul Yogyakarta

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Intisari: Kebutuhan bahan magnet di Indonesia semakin meningkat, seiring dengan meningkatnya perkembangan di industri elektronika. Sebagian besar kebutuhan magnet di Indonesia masih diimpor, sementara Indonesia mempunyai potensi bahan pasir besi dalam jumlah besar. Bahan baku magnet keramik berasal dari oksida besi, yang umumnya dihasilkan dari sisa *hot rolling* slab baja. Dalam penelitian ini bahan dasar magnet menggunakan oksida besi dari pasir besi pantai Selatan, Bantul, Yogyakarta. Bahan baku pasir besi dihancurkan kemudian dipisahkan dengan menggunakan magnet dalam kondisi basah, dalam alkohol. Hasil pengujian *X-Ray Diffraction* (XRD) menunjukkan komposisi mineral *magnetite* (Fe_3O_4) dan *maghemite* (γ-Fe_2O_3), yang besifat magnetik. Bahan baku yang telah dipisahkan dicampur dengan barium karbonat dengan perbandingan fraksi berat 6:1. Bahan campuran dikalsinasi pada suhu 1000 ºC selama 1 jam, agar terbentuk *barium-hexaferrite* yang merupakan bahan baku magnet permanen. Pembentukan *green compact* menggunakan mesin pres dengan tekanan 30 MPa. *Green compact* disinter dengan variasi suhu 1000, 1100, 1200, 1300, dan 1400 ºC selama 1 jam. Karakterisasi kemagnetan dengan menggunakan *Vibrating Sample Magnetometer* (VSM) untuk mendapatkan kurva *hysteresis loop*. Hasil pengujian karakterisasi magnet, menunjukkan *saturation magnetization* (Ms) dan *remanent magnetization* (Mr) tertinggi 20,92 emu/g dan 7,20 emu/g pada suhu sinter 1200 ºC, nilai *coercive field* (Hc) menurun dengan meningkatnya suhu sinter yaitu 975 Oersted pada sinter 1000 ºC dan 173 Oersted pada suhu sinter 1400 ºC. Nilai BH max terbesar diperoleh sebesar 0,0605 MGOe pada suhu sinter 1100 ºC. Pasir besi memiliki potensi untuk dijadikan bahan dasar magnet keramik.

Kata kunci: Magnet, Magnetite, Karakterisasi Magnet, Pasir Besi

Abstract: The magnetic material needs in Indonesia increased, with increasing developments in electronics industries. Most of the needs of magnetic materials in Indonesia are imported, while Indonesia has huge amount of iron sand as raw material of magnet. Raw magnetic ceramics material is ferro oxide, which is usually produced from the scale of hot rolling steel. In this research, the iron oxide as raw magnetic materials is developed from iron sand coastal of Southern Bantul Yogyakarta. The raw material was crushed by ball mill and separated by permanent magnet. The characterization of the material using x-ray Diffraction (XRD) showed the compositions of the mineral were magnetite (Fe_3O_4) and maghemite (γ-Fe_2O_3). The raw materials are then mixed with barium carbonate with a ratio of 6:1 weight fraction. The mixture was calcined at a temperature of 1000 °C for 1 hour in order to form barium hexaferrite powder as the raw materials of permanent magnet. The powder was uniaxial pressed with a pressure of 30 MPa. The green compact was sintered at various temperatures of 1000, 1100, 1200, 1300, and 1400 ºC for an hour. Characterization of magnetism was performance by using Vibrating Sample Magnetometer (VSM) to get hysteresis loop curves. The results of magnetism characterization showed saturation magnetization (Ms) and magnetization remanent (Mr) with a highest value of 20.92 emu/g and 7.20 emu/g respectively at sintering temperature of 1200 ºC. The value of coercive field (Hc) decreased with increasing sintering temperatures, which are 975 Oersted of the material sintered at 1000 ºC and 173 Oersted at sintering temperature of 1400 ºC. The highest value of BH max was 0,0605 MGOe which was obtained at sintering temperature of 1100 ºC. it is conducted that iron sand from South Coast of Bantul Yogyakarta has good prospect to be developed as raw material for magnetic ceramics.

Key words: *Magnet, Magnetite, Magnetic Characterization, Iron Sand*

1. INTRODUCTION

Hard magnet is now widely use in electronic devices, and ferrite magnet is one of the importance type magnets. Permanent magnets have been used in electrical machinery for over 100 years, but because of recent dramatic improvements in their properties and availability, their application in electro-mechanical and electronic devices are now rapidly growing [1]. Magnetic ferrite is made of iron oxide of magnetite and hematite. Barium ferrites are well known hard magnetic materials, which are based on iron oxide. They are also called as ferrite magnets and could not be easily replaced by any other magnets [2]. Hexagonal barium ferrite having the chemical formula of $BaFe_{12}O_{19}$ are widely used such as in magnetic recording media, microwave devices and electromagnetic shielding fields [3]. Ferrite magnets are generally made from scale of hot roll steel milling, which contains magnetite and hematite. Iron oxide as a result of hot strip mill waste can be processed into alpha-hematite with additive elements of CaO and SiO_2 powder metallurgy forming techniques. [4].

Iron sand is a mineral mining, which usually contains both magnetite and hematite. Indonesia has enormous amount of raw magnetic materials, which is deposited in iron sand. It expected that the iron sand can be developed to produce magnetic materials, and to supply the needs of local industries. Iron sands contain magnetite and maghemite minerals that have properties of high magnetic susceptibility [5]. Iron sands from Southern Coast of Bantul Yogyakarta contain magnetic minerals that can be detected by using a magnet [6]. XRD analysis of the iron sands from Southern Coast in Bantul Yogyakarta indicate that the iron sand were dominated by magnetite and maghemite minerals, showing a potential candidate of magnetic materials [7]. Iron sand has a high specific gravity about 4.2 to 5.2, generally iron sand consists of an opaque mineral grains mixed with non-metals such as quartz, calcite, feldspar, amphibole, pyroxene, biotite and tourmaline. The minerals consist of magnetic materials such as titaniferrous, magnetite, illmenite, limonite, maghemite. The ferrous content was found in the main iron sand deposits as mineral tetanomagnetic, while its composition 60% Fe, 3.3% Al_2O_3, 0.26% SiO_2, 0.55% P_2O_5, 9.2% TiO_2, and 0.6% MgO. Iron ores in the form of iron sand deposits with Fe content is about 38 to 59%. The aggregate particles were widely available in the beach district Congot Kulonprogo Yogyakarta [8].

2. EXPERIMENTAL METHOD

Raw material was taken from iron sand in Southern Coastal Bantul Yogyakarta. Iron sand was separated by using magnet. A 100 grams of iron sand was separated using a magnet in order to know the rough weight fraction of magnetic content in the sand. The iron sand was separated using a magnetic bar into two parts i.e. magnetic raw materials and non-magnetic raw materials. The magnetic raw materials were ball milled to reduce particle size into fine powder (with particle size ≤ 105 µm). The fine powders were further separated using a permanent magnet to remove non-magnetic material that embedded in the magnetic raw materials. XRD was used to analyze the composition of the fine powders. The magnetic fine powders were mixed with additive of barium carbonate with a ratio of 6:1 weight fraction and the mixture was then calcinated / heating up to a temperature of 1000 ºC for 1 hour. The calcinated powders were uniaxially pressed with a pressure of 30 MPa to produce green bodies. The green bodies were pressureless sintered at various temperatures of 1000, 1100, 1200, 1300 and 1400 ºC in air atmosphere for 1 h. The maximum magnetization at 10 KOe field magnetic, Ms and the coercivity Hc were measured to characterize the samples. The magnetic characterizations were examined using Vibration Sample Magnetometer (VSM) with standard ASTM A977/A977M-07 Standard Test Method for Magnetic Properties of High-Coercivity Permanent Magnet Materials Using Hysteresis graphs.

3. RESULTS AND DISCUSSION

Figure 1 shows the mechanism to separate the iron sand raw materials, into magnetic raw materials and non-magnetic raw materials. It was found that the weight fraction of magnetic raw materials is 66.32 %. The magnetic raw materials has susceptibility magnetic (χ_m) of 1.45×10^{-4} m^3/kg and saturation magnetization of 13,18 emu/g. The magnetic raw materials were milled and further separated in alcohol, susceptibility magnetic increased to 4.3×10^{-4} (m^3/kg) and saturation magnetization to 36,49 emu/g. The increase of susceptibility magnetic and saturation magnetization are caused by removal of material non-magnetic that associated with the magnetic materials [7].

Figure 1. Iron sands from south coast Bantul Yogyakarta attached to permanent magnet.

An XRD pattern of raw magnetic material fine particle is shown in Figure 2. Peaks of the XRD pattern in Figure 2 are well corresponded with magnetite (Fe_3O_4) JCPDS card no 019-0629, with maghemite (γ-Fe_2O_3) JCPDS card no. 39-1346.

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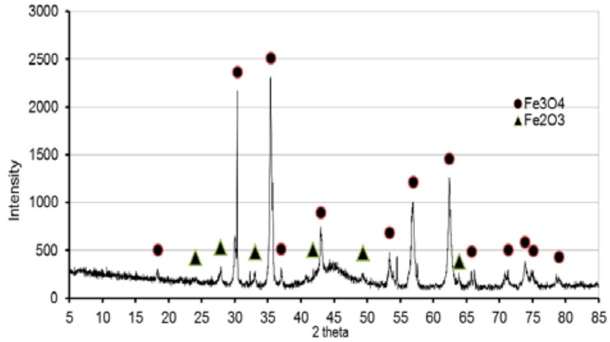

Figure 2. Powder X-ray Diffraction patterns for raw materials fine particles as magnet samples.

The fine powder magnetic raw materials were mixed with barium carbonate with a ratio of 6:1 weight fraction. The mixture was calcinated / heated up to 1000 ºC for 1 hour in air atmosphere. Green body was produced from the mixture using uniaxial pressing. The dimension of the green body was 16 diameter and 8 thickness. The green bodies were sintered at various temperatures of 1000, 1100, 1200, 1300 and 1400 ºC in air atmosphere. Figure 3 shows the examples of the sintered bodies.

Figure 3. Sintered product magnet from iron sand

Figure 4 shows hysteresis graphs of the samples characterization using VSM. The samples with sintering temperatures of 1000 and 1100 ºC shows wider hysteresis loop curves than that of sintering temperatures of 1200, 1300 and 1400 ºC. It is shown that the magnetic characterization of the samples depend on many factors, such as chemical composition [9], and that barium ferrite was easy decomposed at high sintering temperature.

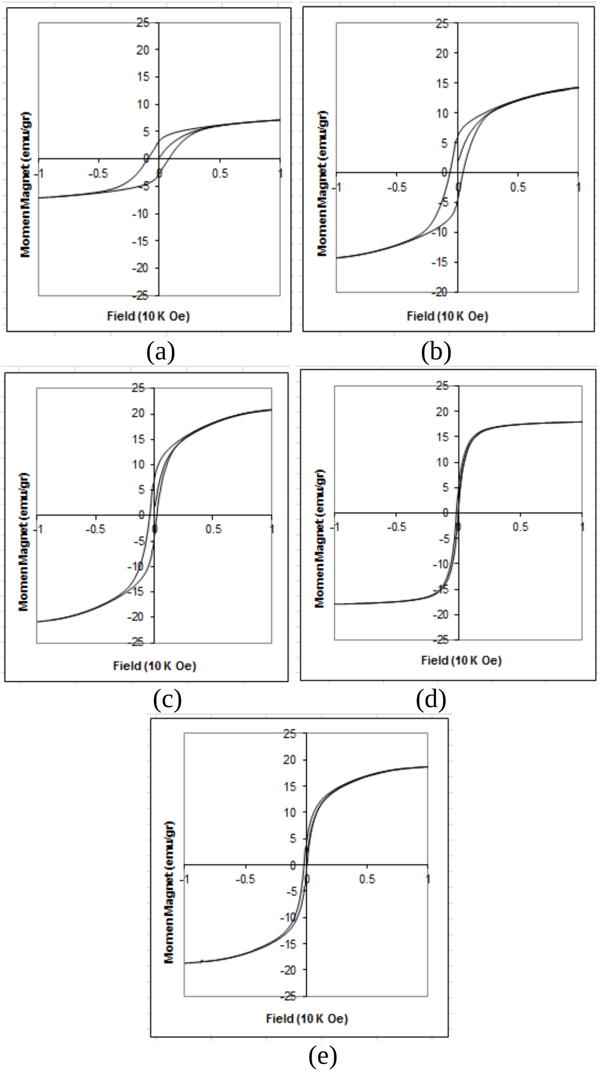

Figure 4. Hysteresigraphs of magnet from iron sand with various sintering temperatures (a) 1000 ºC, (b) 1100 ºC, (c) 1200 ºC, (d) 1300 ºC and (e) 1400 ºC

Saturation magnetization was the state reached when an increase in applied external magnetizing field H. Saturation magnetization cannot increase with increasing external magnetic field of the material further. Remanent magnetization was the magnetization left behind in a ferromagnetic material after an external magnetic field removed.

Figure 5 shows that the maximum saturation magnetization was reached of 20.92 emu/g at magnetic field 10 KOe and maximum remanent magnetization of 7.20 emu/g at sintering temperature of 1200 ºC.

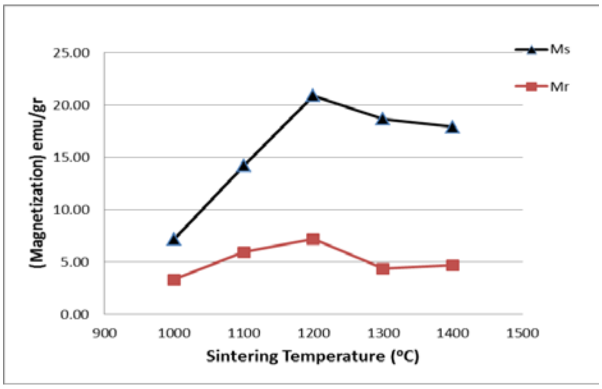

Figure 5. Saturation Magnetization (Ms) dan Remanent magnetization (Mr) of sampels magnet from iron sand with various sintering temperatures

Coercivity, also called as coercive field or coercive force of a ferromagnetic material is the intensity of the applied magnetic field required to reduce the magnetization of that material to zero after the magnetization of the sample has driven to saturation. Thus, the coercivity measures the resistance of a ferromagnetic material to become demagnetized. Enhancement of the coercivity of ferrite magnets is intended to make them as true hard magnets. To get a coercive field higher than the residual magnetization is still a very important issue [10].

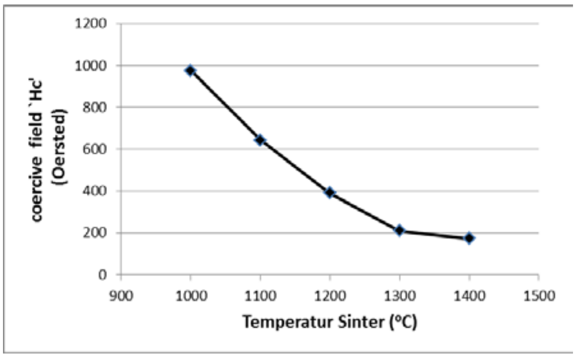

Figure 6. Coercivity (Hc) of the samples from iron sand with various sintering temperatures

Figure 6 shows the coercive value of 975 Oersted of the samples sintered at 1000 ^{o}C decreased to 173 Oersted of the samples sintered at 1400 ^{o}C. The decrease of coercivity of the samples may be caused by decomposition of barium ferrite at high temperature as mentioned by Huang (2011) [11]. In addition, the decrease of coercivity of the samples may also be caused by the grain growth of microstructure as mentioned by Uestuener (2006) [12].

BH max corresponds to the area of the largest B-H rectangle, that can be constructed within the second quadrant of the hysteresis curve. B_s is the saturation flux density and the corresponding magnetization is the saturation magnetization M_s, where $B \approx \mu_o M$. Energy of magnetic product is multiplication of B with H in hysteresis curve. The value of energy product is representative of the energy required to demagnetize of a permanent magnet [13]. The maximum of BH max (energy product) of the samples reached 0,0605 MGOe at sintering temperature of 1100 ^{o}C. The value of magnetization (B) of the samples increased until sintering temperature of 1200 ^{o}C and decreased at sintering temperature of 1400 °C, while magnetic field (H) of the samples decreased with increasing sintering temperatures. The BH value can be obtained from multiplication between B and H values as shown in Figure 7. It can be seen in Figure 7 that the BH max is found in the samples sintered at temperature of 1100 ^{o}C.

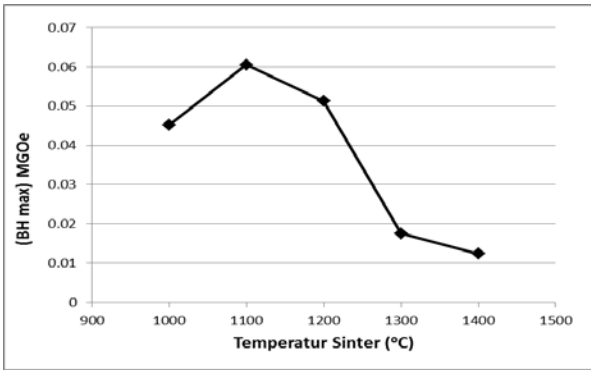

Figure7. Energy products (BH max) of magnetic samples from iron sand with various sintering temperatures

4. CONCLUSIONS

Iron sand from South Coast of Bantul Yogyakarta has good prospect to be developed as raw material for magnetic ceramics. The maximum saturation magnetization is 20.92 emu/g and the maximum remanent magnetization is 7.20 emu/g which are obtained in the samples sintered at 1200 ^{o}C. The value of coercive field (Hc) decreased with increasing sintering temperatures, which are 975 Oersted of the material sintered at 1000 °C and 173 Oersted at sintering temperature of 1400 °C. The maximum energy product (BH max) is 0,0605 MGOe which is found in the samples sintered at 1100 ^{o}C.

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