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Research Article

Magnetic Behavior of Natural Fe_2O_3 from Lhoong Iron Ore Mining Area, Aceh Province, Indonesia

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The mineral composition and magnetic behavior of nano-Fe_2O_3 of iron ore from Lhoong mining area, Aceh province, were studied. The iron ore was prepared by mechanical milling method. The mineral and chemical compositions of samples were investigated by XRD and XRF analysis tests. The XRF test showed that the Lhoong iron ore contains Fe_2O_3 (93.88%) in association with other isomorphous impurities, such as SiO_2, MnO, and Al_2O_3, in varying proportions. Compared to XRD results, it was consistent with XRF; the phase compositions of iron ore were mainly hematite (Fe_2O_3). The XRD revealed that hematite was the major mineral component in the Lhoong iron ores. SEM observation showed fine crystalline structure of Lhoong iron ore after the milling process. The main mineral morphology was microcrystalline in agglomerate forms. The magnetic properties of the samples after milling showed the increasing in the remanent (B_r) and coercivity (H_c). This increasing can be explained that nano-Fe_2O_3 phase after milling for 20 hours plays an important role in the magnetic behavior of Lhoong iron ore. It is understood that the longer milling time is sufficient to complete the transformation of hematite (Fe_2O_3) to magnetite (Fe_3O_4).

1. Introduction

Nowadays, iron oxide plays a crucial role in various applications and is intensively investigated, especially for its application in magnetic materials [1]. This type of materials has diverse applications, from data storage to biocatalysis applications [2–6]. For advanced material applications, one of today's challenges is the production of nanostructured metal oxide materials.

Interestingly, iron oxide can be obtained from natural iron ore (e.g., from mineral rock, beach sand, etc.). Indonesia, which is rich in iron ore, should strive for self-sufficiency in meeting the needs of the industry, such as iron-steel industry. One of the areas known as the largest deposits of iron ore is the Aceh province.

In this paper we provide a qualitative data that includes the identification phase, the percentage of mineral, morphology, and the magnetic properties of the iron ore in Lhoong, Aceh Besar. Iron ore reserves in Aceh are spread in several areas such as Aceh Besar, Pidie, Aceh Barat Daya, Aceh Selatan, Subulussalam, Gayo Lues, and Aceh Timur with total deposits exceeding 92.3 million tonnes [7]. Lhoong area, as already mined, has a deposit of 4.2 million tonnes. Mostly, the Lhoong iron ore is exported abroad.

2. Materials and Methods

The iron ore samples were collected from the strip mine in Lhoong area, Aceh Besar district, Aceh Province, Indonesia. The iron ores are irregularly scattered in the ore body layer, making them show an even chemical distribution; therefore, this research randomly collected samples in each ferralitic soil profile. The iron ore rock was firstly crushed by a disc-mill in 30 minutes to produce powders. Then, for advanced milling, the powders were filled into a hardened steel vial and sealed together with 10 balls (5.6 mm in diameter). The mixture powders were milled in a home-made planetary ball mill (PBM) at a rotational speed of 300 rpm (ball to powder ratio 10 : 1) for 20 hours. Structural changes during milling were characterised by XRD (Philips PW 7310, Co-Kα radiation), and a high resolution scanning electron microscope (SEM

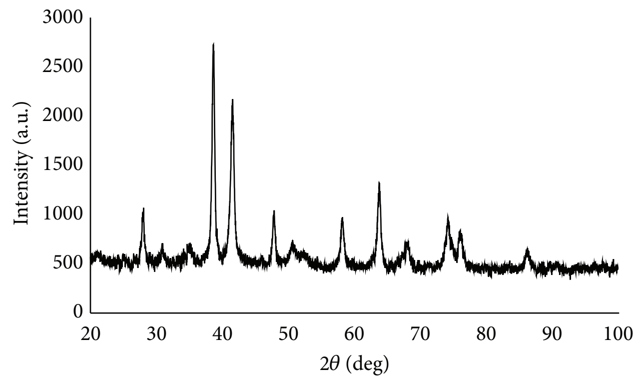
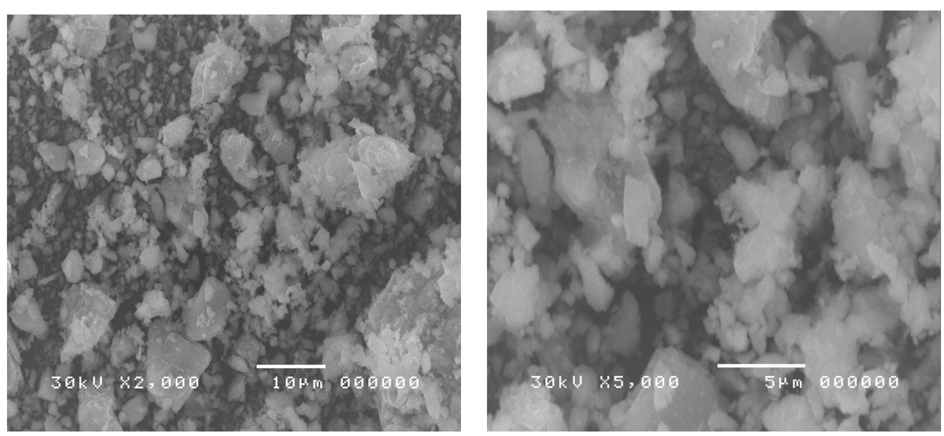


Figure 1: XRD profile of Lhoong iron ore after 20 hours milling.



(a) (b)

Figure 2: SEM image of Lhoong iron ore before (a) and after 20 hours milling (b).

JEOL JSM-5310LV) was used to observe the morphological changes during milling. The chemical composition was analyzed by X-ray fluorescence (XRF, Brucker S2 Stranger). Furthermore, the magnetic behavior of Lhoong iron ore was investigated by Permagraph (Magnet-Physik, 2T).

3. Results and Discussion

Figure 1 shows the evolution of the X-ray diffraction pattern of Lhoong iron ore after milling process for 20 hours. It was identified that the main phase is Fe_2O_3 (hematite) on the position of the diffraction angles $2\theta = 27.92^\circ$, 38.58°, 41.42°, 47.66°, 57.98°, 63.66°, 67.54°, 73.92°, and 76.93°, while the minor phase was not detected because the element is very small in percentage.

As a result, by using a planetary ball mill (PBM) for 20 hours, effectively managed to form a fine powder sample which is believed to have a crystal size on the nanometer scale. Based on XRD observations, there has been peak broadening phenomenon. Using Scherrer formula [8], the crystallite size is nearing 114 nm. The qualitative analysis showed no changes in phase, namely, the emerging majority Fe_2O_3 phase.

Furthermore, the observation of microstructure using SEM as shown in Figure 2, before milling (a) and after 20 hours of milling (b), clearly showed that the particles before milling process are bigger and after the milling process for 20 hours has produced fine powders. However, the powders are agglomerated to each other.

As shown, particle size of less than 5 mm indicates that the particle is polycrystalline fine particle (fine polycrystal). It can be mentioned that, the milling process of 20 hours obtain by high energy ball mill affects the grain size reduction of natural Fe_2O_3 powder. This result also shows that mechanical alloying (MA) method is very attractive and promising in the preparation of nanoscale materials from iron ore.

Then, the X-ray fluorescence (XRF) test and the results for elements percentage are summarized in Table 1.

As shown, the XRF results are consistent with the XRD data, where the main element is iron oxide of hematite Fe_2O_3 (93.88 wt%). Besides hematite, some other elements were detected but with a small percentage, for example, silica SiO_2 at 3.43 wt%, MnO (0.55 wt%), Al_2O_3 (0.43 wt%), and several others.

The process of further milling the sample using a planetary ball mill for 20 hours has shown that the size of the crystals on the nanometer scale affects magnetic properties. As shown in Figure 3, the magnetism test was for samples before milling and Figure 4 for the sample after milling

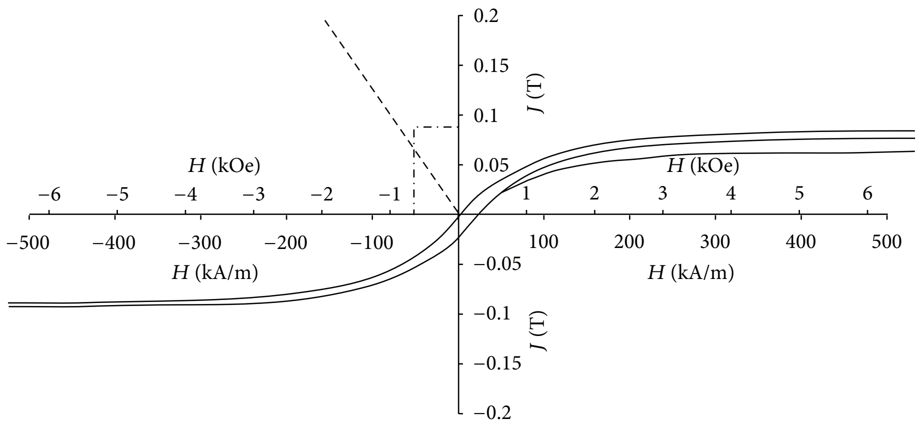


FIGURE 3: Hysteresis loop of Lhoong sample before milling.

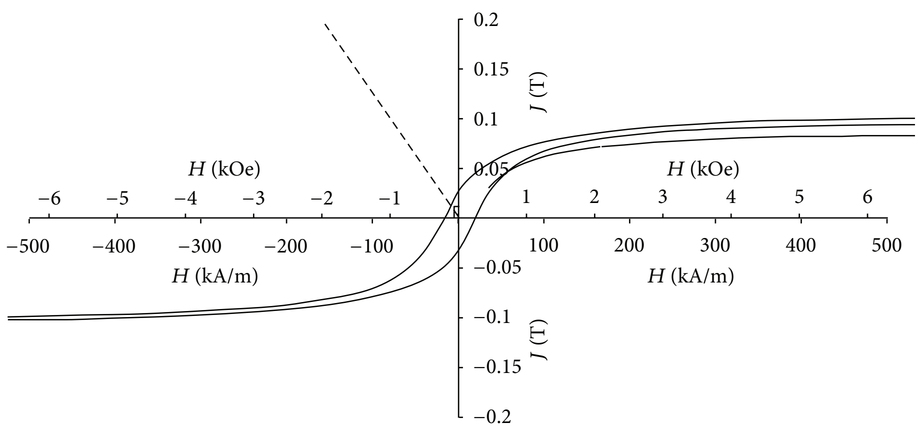


FIGURE 4: Hysteresis loop of Lhoong sample after 20 h milling.

TABLE 1: Chemical composition of Lhoong iron ore.

No.	Formula	Concentration (%)
1	Fe_2O_3	93.88
2	SiO_2	3.43
3	MnO	0.55
4	Al_2O_3	0.43
5	K_2O	0.38
6	P_2O_5	0.33
7	SO_3	0.29
8	Nd_2O_3	0.27
	Total	99.56

for 20 hours. Hysteresis loop curve as a representative of the nature of the magnetization is shown in Figure 3. As a result, for the sample before milling process, the saturation magnetization (M_s) was found as 0.1 tesla (T), and then the remaining magnetization (B_r) value is 0.026 and coercivity (H_c) 15.7 kA/m. It seems that the longer milling time is sufficient to complete the transformation of hematite (Fe_2O_3) to magnetite (Fe_3O_4).

From the magnetic properties test, the samples after milling show that there has been an increase in the value of remanent magnetization properties (B_r) and coercivity (H_c). The increase can be explained that nano-Fe_2O_3 phase after the milling process plays an important role. It can be noted that the milling process using mechanical alloying (MA) method, which forms of nano-Fe_2O_3 phase, is an attractive method in magnetic properties observations. Therefore, the particle size reduction has significantly affected the magnetic properties of natural Fe_2O_3 based iron ore. The coercivity of as-milled powders increased with milling time; this was attributed to the introduction of defects, oxide, and other contamination during the milling [9, 10]. Obviously, the enhanced magnetic properties can be explained as the presence of a surface layer with high concentration of defects induced by the milling process [11].

4. Conclusions

From the initial identification of Lhoong iron ore using both techniques of X-ray diffraction (XRD) and X-ray fluorescence (XRF), showed that the Fe_2O_3 appeared as the major phase and has a chemical composition of 93.88 wt%. The surface microstructure which was investigated with scanning electron microscope (SEM) informed that the elements of the iron oxide hematite Fe_2O_3 are very dominant. Accordingly, the process of milling iron ore grains also showed that the material can be modified into nanostructured materials, as shown by the peak broadening in XRD patterns and correlated well with the observation of the surface morphology by electron microscopy. The magnetic properties of the samples after milling showed that there has been an increase in the remanent (B_r) and coercivity (H_c). This increase can be explained that nano-Fe_2O_3 phase after the milling process plays an important role in the magnetic behavior of Lhoong iron ore.

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