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Effect of PEG-2000 on saturation magnetization Fe_3O_4 particles synthesized with coprecipitation method

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Abstract. Synthesis of Fe_3O_4 particles was performed using coprecipitation method. Iron sand base material obtained by processing the iron rocks by means of destruction and extraction. Iron rocks were taken from the village Surian, South Solok of West Sumatera. Iron sand that has been extracted reacted with HCL and NH_4OH. Furthermore, the PEG-2000 were added to see its effect on the resulting magnetization saturation. Variations in the composition ratio of iron sand and PEG-2000 are 1:0, 1:1, 1:2 and 1:4. The crystal structure of the sample was confirm using x-ray diffraction method. Characterization of magnetic properties carried out using vibrating Sample Magnetometer (VSM). The results of magnetic properties show that the saturation magnetization decreases with increasing of PEG-2000 content in the range of 99.50emu/g - 0,84 emu/g.

Keywords: Fe_3O_4; iron sand; PEG-2000; saturation magnetization

1. Introduction

The magnetic material in the nanometer sized has been considerable attention in the recent decades because of both their interesting physical properties and the wide range of their potential applications. Nanoparticles of magnetic material is very useful in terms of both basic materials and applications. Important characteristic of nanoparticle materials is a measure of the effects of nanoparticles on magnetic properties such as saturation magnetization and coercive force and also in terms of nanoparticle morphology and microstructure of the material itself (Wang dkk. 2004; Chen & Chen 2001). Magnetic nanoparticles is the result of advanced research on the properties of magnetic materials and magnetic materials modification of the micron-sized to a size of nanometers.

In recent years, researchers synthesize Fe_3O_4 nanoparticles with different methods. Some of the methods used to synthesize Fe_3O_4 nanoparticles are sol gel method (Xu dkk., 2007), controlled hydrolysis method (Iida dkk., 2007) and coprecipitation method (Hong dkk., 2007). Among various synthesis method, coprecipitation method is the simplest because the procedure is more easier and requires a fairly low reaction temperatures (< 100 ^oC).

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In this study, magnetite Fe_3O_4 nanoparticles prepared by the coprecipitation method in a solution of HCl and using NH_4OH as a precipitation agent. PEG-2000 was added as a template to homogenize and inhibit the growth of particles. Variations in the composition ratio of iron sand and PEG-2000 added is 1: 0, 1: 1, 1: 2 and 1: 4 to see the effect of the resulting changes in the magnetic properties of magnetite nanoparticles.

2. Experimental

The iron rocks were crushed into small parts to make easier in the grinding process. The grinding process carried out using the grinding machine (Los Angeles-LA) and then rotated as much as 300 times. The iron rocks that has become powder and then separated by permanent magnet because magnetic powder attracted to magnet. The magnetite powder was then sieved using a 270 mesh sieve size to obtain magnetite (Fe_3O_4) particles of about 53 µm.

Synthesis of Fe_3O_4 Nanoparticles. The procedure of synthesizing magnetite Fe_3O_4 nanoparticles described as follows: 10 grams of powder Fe_3O_4 dissolved in 20 ml HCl (12M) with vigorous stirring for 60 minutes at a temperature 90 ˚C. The reaction of solution magnetite is complete as follow:

$$3Fe_3O_4(s) + 8HCl(l) \rightarrow 2FeCl_3(l) + FeCl_2(l) + 3Fe_2O_3(s) + 3H_2O(l) + H_2(g) \quad (1)$$

The results of solution was added 25 ml NH_4OH to precipitate the filtrate and aged 30 minutes to obtain a precipitate. The precipitate formed Fe_3O_4 black color is separated from the solution are then rinsed with distilled water 3 times. Precipitation of magnetite is completed as follow:

$$2FeCl_3\ (l) + FeCl_2\ (l) + H_2O\ (l) + 8NH_4OH\ (l) \rightarrow Fe_3O_4\ (s) + 8NH_4Cl\ (l) + 5H_2O\ (l) \quad (2)$$

PEG-2000 in the form of solids are heated and melted at a temperature of 100 ° C. PEG-2000 which has been melted and then added to precipitate Fe_3O_4 that has been cleaned with distilled water. Variations in the composition ratio of iron sand and PEG-2000 are 1:0, 1:1, 1:2 and 1:4. The magnetic properties of the magnetite (Fe_3O_4) nanoparticles were measured using a vibrating sample magnetometer (VSM model OXFORD VSM 1.2H) at room temperature (25℃). The measurement was carried out in maximum field of 1 T.

3. Results and Discussion

Magnetite nanoparticles are successfully synthesized via coprecipitation method with the addition of polyethylene glycol (PEG) as templete. PEG used is PEG-2000 with magnetite and the PEG ratio is 1: 1, 1: 2 and 1: 4. The resulting magnetic nanoparticles were characterized using X-Ray Difractometer (XRD) to determine the crystal structure. Characterization Vibrating Sample Magnetometer (VSM) is performed to determine the magnetic properties of the samples.

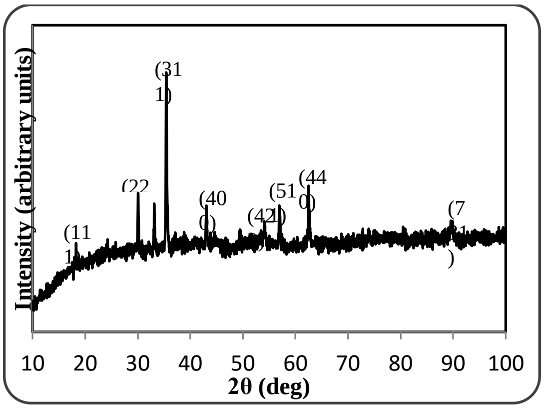

Figure 1. X-Ray diffraction pattern of magnetite, Fe_3O_4

Figure 1 exhibits the x-ray diffraction pattern of magnetite bulk material. The diffraction peaks at 2θ = 18.2750˚; 30.0607˚; 35.4051˚; 43.0527˚; 54.1259; 56.9710˚; 62.5030˚; and 89.6667˚ can be assigned to (111), (220), (311), (400), (422), (511), (440) and (731) planes of Fe_3O_4 (ICDD 01-071-4918), respectively. This result confirmed the presence of the characteristic planes assigned to cubic spinel of the Fe_3O_4 structure.

Measurement of magnetic properties of materials carried out at room temperature (25 ° C) with a maximum field of 1 Tesla using Vibrating Sample Magnetometer (VSM). Hysteresis curve for Fe_3O_4 nanoparticle without PEG-2000 is shown in Figure 2. From the hysteresis curve image can be seen an increase in the magnetization of materials with improved magnetic field. This indicates that the alignment magnetic moment increases with increasing magnetic field for the magnetite nanoparticles without PEG-2000. The change of magnitude of magnetization generally derived from the rotation or displacement of the domain wall. The magnetic moments in the material will align in parallel with the direction of the magnetic field. Figure 2 show that at the low magnetic field the magnetization increases rapidly before reaching a saturation value within the range of the applied magnetic field. Saturation is achieved and become single domain when this domain, by means of rotation, becomes oriented with magnetic field (Callister, 2001).

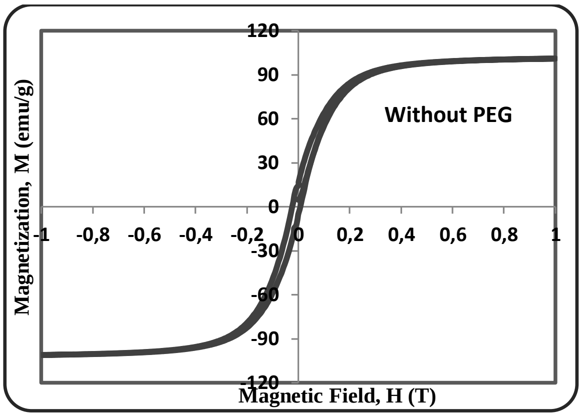

Figure 2. Hysteresis curve for the magnetite Fe_3O_4 without PEG-2000

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From the figure 2 can also be noted that the hysteresis curve generated narrow shape which indicates that the magnetite is a soft magnetic material. The values of magnetic properties generated from figure 2 is the saturation magnetization (M_S) is 99.50 emu / g, remanent magnetization (M_R) is 9.75 emu / g and a coercive force (H_C) is 160 Oe.

The initial magnetization curves for magnetite (Fe_3O_4) with different variation concentration of PEG-2000 are shown in Figure 3. It can be seen that when magnetic field is first applied, the magnetization initially increases slowly, then more rapidly as the domains begin to grow through domain wall motion. Later, the magnetization is slowly increasing as the domains eventually rotate to reach saturation where the dipoles are optimally oriented (Askeland, 1994) Saturation magnetization (M_S) decreased with increasing concentration of PEG from 6.83 emu/g to 0.84 emu/g.

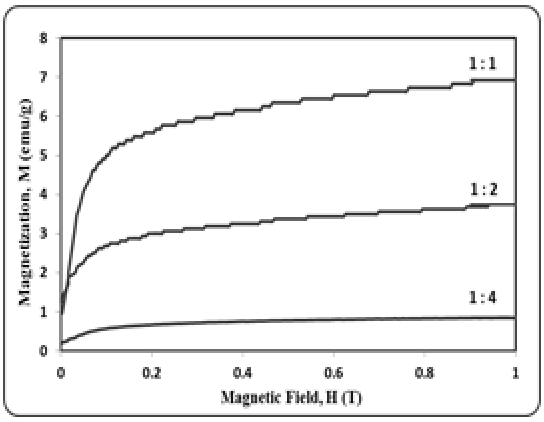

Figure 3. Initial magnetization curve with the variation concentration of PEG-2000

Figure 4 shows that the hyteresis curves for magnetite (Fe_3O_4) with variation concentration composition ratio of magnetite and PEG-2000 are 1:0, 1:1, 1:2 and 1:4. The results show that the narrow-shaped of hysteresis curve indicated low energy losses because the area within a loop represent magnetic energi losses. The narrow hysteresis loop indicated that the samples are soft magnetic materials (Callister, 2001).

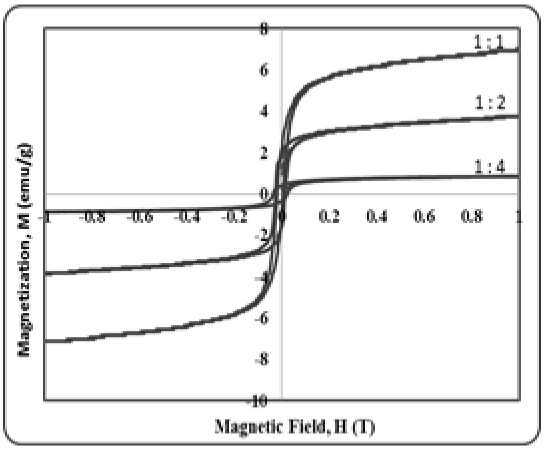

Figure 4. The hysteresis curve with the variation concentration of PEG-2000

The saturation magnetization (M_S), coercive force (H_C) and remanent magnetization (M_R) for all the samples were determined from magnetic hysteresis curves, shown in

Figure 4. The corresponding results from VSM for all samples are listed in Table 1. The value of saturation magnetization demonstrates the ability of nano particles to maintain the alignment of the magnetic domains when the external magnetic field applied. The Coercivity force is the magnitude of the magnetic field required to make the magnetization value become zero. The greater the value of the coercivity field the stronger the magnetic properties. The remanent magnetization shows the magnitude of the magnetic field is left in the material after the external field is removed (Nuzully, 2013).

The values of the magnetic properties resulting from the magnetic hysteresis curves are shown in Table 1. From the table it can be seen that the saturation magnetization MS of the samples decreased with the increased concentration of PEG-2000 were added. This is consistent with that generated by Nuzully (2013) who studied the magnetic properties of magnetite with PEG-4000. Decreases in the value of saturation magnetization is influenced by the addition of PEG which is a material that is paramagnetic.

The Table 1. shows the value of remanent magnetization is decreased with increasing concentrations of PEG-2000. It is due to the addition of a nonmagnetic material into a magnetic material will affecting the magnetic properties of the materials.

Table 1. The values of magnetic properties for magnetite (Fe_3O_4) with variation concentration composition ratio of magnetite and PEG-2000 are 1:0, 1:1, 1:2 and 1:4.

Variation (Fe_3O_4 : PEG)	M_S (emu/g)	M_R (emu/g)	H_C (Oe)
1 : 0	99.50	9.75	160
1 : 1	6.83	1.45	125
1 : 2	3.62	0.63	70
1 : 4	0.4	0.10	70

4. Conclusions

1) The saturation magnetization (M_S) of the samples decreases with increasing concentration of PEG-2000 from 99.50 emu/g to 0.84 emu/g..
2) The values of remanent magnetization of the samples in the range of 0.10 emu/g to 9.75 emu/g.
3) The coercive force values in the range of 70 Oe to 160 Oe.
4) Decreases in magnetic properties of the samples due to the addition of PEG which is nonmagnetic material leads to decreasing of magnetic parameters values.

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