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THE EFFECT OF GRAPHENE OXIDE ADDITION ON MAGNETIC PROPERTIES OF IRON OXIDE (FE_2O_3) NANOPOWDER WITH SINTERING AND NON-SINTERING PROCESS

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Abstract

Graphene Oxide is a material that has a thickness of one atom composed of carbon atoms to form a hexagonal lattice and a material that has unique properties, namely mechanical, optical, thermal, and electrical properties. Fe_2O_3 is a material that has magnetic properties and can be used for various applications such as enzyme separation, drug transport, microwave absorption, photocatalysts, biological applications, biomedicine, metal separation, and magnetic resonance imaging (MRI). In this study, the addition of graphene oxide was carried out using the coprecipitation method on Fe_2O_3 nanomaterials that had been treated with sintering and non-sintering. The coprecipitation method is the synthesis of inorganic compounds which is based on the deposition of more than one substance together when it passes the saturation point. The purpose of this study was to determine whether the addition of graphene oxide to the Fe_2O_3 material can increase the magnetic properties of the Fe_2O_3 material or vice versa. The result was Highest Magnetic Saturation (Ms) and Magnetic Retentivity (Mr) belong to the Fe_2O_3 GO sample without heat treatment with values of 6.304 and 1.863 emu/g. While the lowest Ms and Mr values are in samples with heat treatment up to 900ºC, namely 0.156 and 0.033 emu/g.

Keywords: Graphene Oxide, Fe_2O_3, Magnetic Properties, Sintering and Non-sintering

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1. Introduction

Graphene Oxide is a material that has a thickness of one atom composed of carbon atoms to form a hexagonal lattice and a material that has unique properties, namely mechanical, optical, thermal, and electrical properties. Graphene oxide was first made by A. Geim and K. Novoselov in 2004 where both were scientists at the University of Manchester, England[1,2]. At low energy limits, graphene oxide has an energy gap of zero so the electrons in graphene oxide satisfy an equation similar to Dirac's equation for particles of zero mass[3]. Fe_2O_3 is an interesting material to study because it has many applications for catalyst reactions in electronic devices, for example, semiconductors, paint formulations, and rechargeable lithium batteries[4]. Fe_2O_3 is an iron oxide material that has the same crystal structure as magnetite and also includes spinel ferrite and part of ferromagnetic. This material has a gray shade, red and brown[5]. In this research, we will add graphene oxide material to Fe_2O_3 material to determine whether the addition of graphene oxide to Fe_2O_3 material can increase the magnetic properties of Fe_2O_3 or vice versa will decrease the magnetic properties of Fe_2O_3. The method used is coprecipitation where the process uses low temperatures which makes it easier to control the particles and shortens the processing time of the material. Hydroxides, carbonates, sulfates, and

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oxalates are some of the substances commonly used as sediment agents. The results of using this method are expected to produce smaller and homogeneous particle sizes compared to other methods[6].

2. Simulation Method

The process of adding graphene oxide to the Fe_2O_3 material uses the coprecipitation method with various sintering and non-sintering treatments, namely, graphene oxide is added to Fe_2O_3 with a composition of 0.999 gr Fe_2O_3 and 0.001 graphene oxide. Then add 30 ml of ethylene glycol and put it in a biker glass which can then be stirred using a magnetic stirrer. Then mixed with 1 mole of NaOH (25 ml) until the PH of the solution reaches 11.5. Then it is heated at a temperature of 70-80 ºC for 1 hour so that it becomes a gel. After it becomes a gel, it is washed using 750 ml distilled water and left for a while so that the material can settle. Then filtered using filter paper so that the material can be separated from the distilled water. Then the material on the filter paper is sprayed with 60 ml of acetone and then put in an oven at a temperature of 110ºC for 3 hours so that the moisture content is lost and dry. After drying the material is put in a mortar to pound for 1 hour so that the material becomes soft. Then the material is put in the furnace to be heated according to the temperature variations of the study, namely 400 ºC, 500 ºC, 600 ºC, 700 ºC, 800 ºC, 900 ºC for 1 hour. In this study, the researcher wanted to see the effect of adding graphene to Iron Oxide (Fe_2O_3) material with and without sintering treatment. Treatment without sintering could only be carried out on one test sample. While the sintered test samples were carried out with six different temperature variations. This research was carried out in real-time by conducting a Vibrating Sample Magnetometer (VSM) test directly to see its magnetic properties after all materials were treated from synthesis to sintering and without sintering. The novelty of this research is that there has been no previous research that has examined Iron Oxide (Fe_2O_3) mixed with graphene. Researchers are interested in using graphene because of its unique properties.

3. Results and Discussion

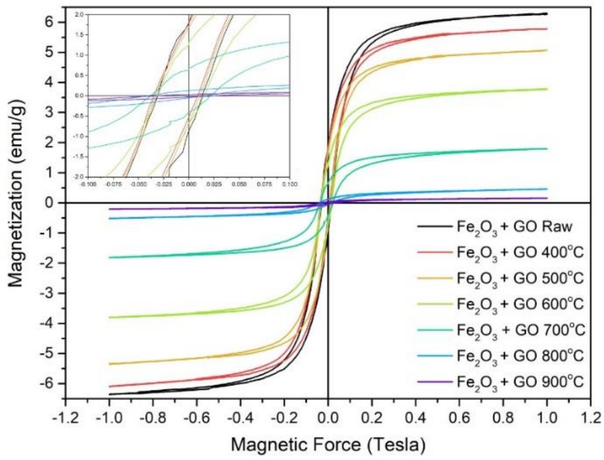

Fig. 1. Magnetic hysteresis curve from all samples of Fe_2O_3 + GO

Table. 1. The value of Fe_2O_3 + GO magnetic properties on the Vibrating Sample Magnetometer test

Sample	Magnetic Saturation (emu/g)	Magnetic Rententivity (emu/g)	Magnetic Coercivity (Tesla)
Fe_2O_3 + GO Raw	6.304	1.862	-0.031
Fe_2O_3 + GO 400ºC	5.786	1.805	-0.034
Fe_2O_3 + GO 500ºC	5.073	1.692	-0.033
Fe_2O_3 + GO 600ºC	3.785	1.358	-0.031
Fe_2O_3 + GO 700ºC	1.821	0.890	-0.038
Fe_2O_3 + GO 800ºC	0.471	0.129	-0.041
Fe_2O_3 + GO 900ºC	0.156	0.033	-0.031

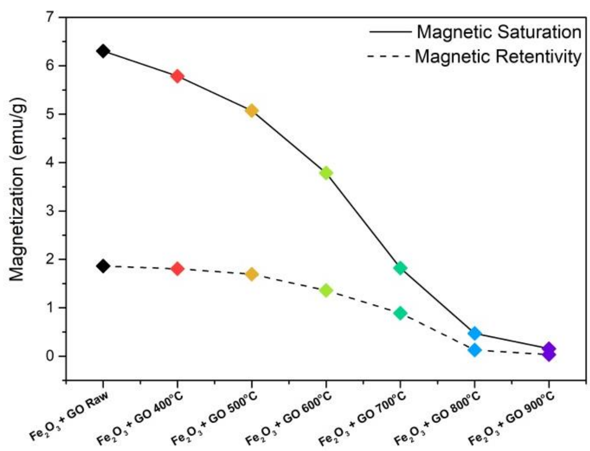

Fig. 2. Comparison graph of magnetic saturation value and magnetic retentivity of Fe_2O_3 + GO samples

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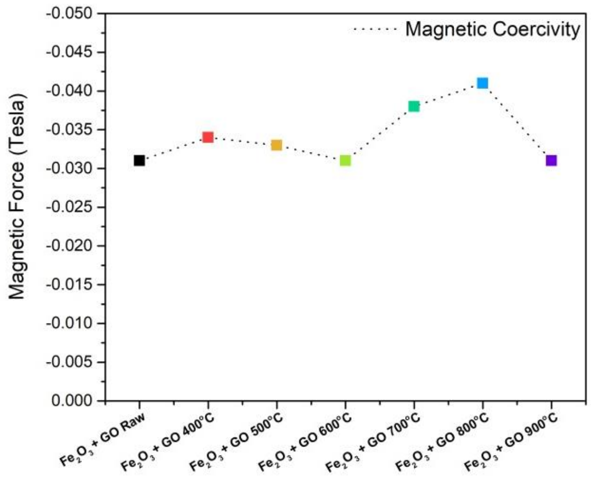

Fig. 3. Graph of magnetic coercivity value Fe_2O_3 + GO samples

Testing through the Vibrating Sample Magnetometer (VSM) aims to determine the magnetization value of the sample in Table 1 which consists of magnetic saturation (Ms), magnetic retentivity (Mr), and magnetic coercivity (Hc)[7–9]. This value could be known through the magnetic hysteresis curve when testing through VSM. S-slim-shaped loop curve indicates that the sample is superparamagnetic [10–13]. The effect of doping the Graphene Oxide (GO) here shows a transformation of magnetic properties because Iron Oxide is Ferromagnetic and after being added by GO it turns to superparamagnetic. This transformation phenomenon is known as super-exchange interaction.

Super-exchange interaction is a phenomenon of changing magnetic properties due to the interaction between strong magnetic materials and weak or non-magnetic magnetic materials[14–21]. This interaction causes the emergence of new properties due to the change in the direction of the electron spin in the material which results in a difference in magnetic moment. Events of magnetic strength, in general, will arise due to a large number of unidirectional electron spins. The more electrons spin in the same direction, the greater the magnetic moment [20,21]. The spin of electrons in magnetic materials could change due to the presence of a magnetic field. Paramagnetic and superparamagnetic will move in the direction of the magnetic field current[22–24]. Ferromagnetic has its constant strength but magnetic field current could affect the original direction of ferromagnetic [25–27]. The magnetic field current would reduce the magnetic moment of the ferromagnetic if it is the opposite. Then for antiferromagnetic materials, all the spins of the magnetic electrons will produce a zero moment both under conditions that are influenced or not influenced by a magnetic field[20,28–32].

In the case of this study, the sample results indicate a super-exchange interaction between Ferrite and Graphene Oxide (GO). Iron is ferromagnetic material influenced by GO which is diamagnetic[33]. The interaction of the two materials causes the magnetic moment of the entire material to decrease in conditions that are not flowed by an external magnetic field. However, it causes the spin electron of ferrite unlocked from its fixed direction as ferromagnetic when it receives an external magnetic field. So that the spin of the ferrite electrons will move in the direction of the external magnetic field. This is what causes Fe_2O_3 + GO material to have superparamagnetic properties.

Sintering on magnetic materials is heating the material below its melting temperature to solidify the material with a certain temperature and pressure [27,34–36]. The sintering heat treatment on Fe_2O_3 + GO would not give a transformation effect on its magnetic properties, but instead gave a change in the magnetization value. The biggest change in magnetization lies in the saturation value. The 6 samples that had been sintered decreased along with the higher temperature by the sintering process. The higher temperature certainly changes the phase structure of the material. The phase structure of the metal also influences its magnetic strength[37–40].

Fig. 1 shows that the highest Magnetic Saturation (Ms) and Magnetic Retentivity (Mr) belong to the Fe_2O_3 GO sample without heat treatment with values of 6.304 and 1.863 emu/g. Although this value is relatively low compared to other superparamagnetic [11, 41] and ferromagnetic nanoparticles [27,42,43], but the graphene oxide phase has a role to influence the change of its magnetic properties. While the lowest Ms and Mr values are in samples with heat treatment up to 900ºC, namely 0.156 and 0.033 emu/g.

Based on the comparison graph of Magnetic Saturation in Fig. 2 it could be concluded that the increasing temperature in the sintering process causes the values of Ms and Mr to decrease. This is caused by increasing the intensity of the GO phase which is diamagnetic[44–46]. The iron phase also changes after the sintering process[40,47]. Thus, the spin electrons of diamagnetic properties that have the opposite direction to the induced external magnetic field cause a resultant reduction of magnetic moment in the Iron Oxide [48,49]. In addition, the ability to maintain the same position of the electron spin influenced by an external magnetic field is getting lower, indicated by a lower Mr value

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than the ferromagnetic Iron Oxide material [50]. So, it can be concluded that Graphene Oxide acts as a reducer on the value of magnetic saturation and magnetic retentivity of Fe_2O_3 GO.

However, a unique thing happened to the magnetic coercivity value of Fe_2O_3+ GO 800ºC in Fig. 3 which increased by 0.041 Tesla. Magnetic coercivity is a magnetization value to measure the ability of a magnet to maintain its magnetic energy when given the opposite direction of an external magnetic field. This relates to the GO phase which is diamagnetic at a temperature of 800ºC which causes the sample to have more ability to retain its magnetic energy [23,51]. So it can be concluded that at a temperature of 800ºC Graphene Oxide acts as a barrier from an external magnetic field in the opposite direction to prevent the electron spins from returning to their original direction before being flowed by a magnetic field.

4. Conclusions

Heat treatment of sintering on Fe_2O_3 GO does not have a transforming effect on its magnetic properties, but rather gives a changing effect on its magnetic value. The increase in temperature during the sintering process caused the Ms and Mr values to decrease. In this study, graphene oxide has a role as a reducer in the magnetic saturation and magnetic retentivity values of Fe_2O_3 GO. Highest Magnetic Saturation (Ms) and Magnetic Retentivity (Mr) belong to the Fe_2O_3 GO sample without heat treatment with values of 6.304 and 1.863 emu/g. While the lowest Ms and Mr values are in samples with heat treatment up to 900ºC, namely 0.156 and 0.033 emu/g.

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