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Effect of Gamma Radiation on Super paramagnetic Nano-Particles

Nguyen Thi Ai Thu

Abstract— **Background: Nanosized spinel ferrite particles, a kind of soft magnetic materials with structure formula of MFe_2O_4 (M = divalent metal ion, eg. Mn, Mg, Zn, Ni, Co, Cu, etc.), are one of the most attracting class of materials due to their interesting and important properties such as low melting point, high specific heating, large expansion coefficient, low saturation magnetic moment and low magnetic transition temperature, etc [1], [2]. Because of these properties, the spinel ferrites have many technical applications such as in photoelectric device [3], catalysis [4], sensors [5], nano devices [6], microwave devices [7], [8] and magnetic pigments [9].**

In this work, the synthesis of Fe_3O_4, $NiFe_2O_4$, $MgFe_2O_4$ nano-particles by coprecipitation method is reported. The influence of gamma radiation on magnetic properties of these superparamagnetic nano-particles is examined.

Methods: The samples were prepared by coprecipitation route. The X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Vibrating Sample Magnetometer (VSM) were used to characterized the samples. In this study, we used ^{60}Co gamma radiation to emit on superparamagnetic materials.

Results: The result of XRD showed that the products were pure Fe_3O_4, $NiFe_2O_4$, $MgFe_2O_4$ particles. The hysteresis loop obtained from VSM measurements showed Fe_3O_4, $NiFe_2O_4$, $MgFe_2O_4$ superparamagnetic nanoparticles have an inverse spinel structure. From the SEM micrographs, it is proved that the nanoparticles obtained are cube like and rather uniform. The average particle size was changed under affecting of radiating and found to be in the range of 52 ÷ 54 nm that increased up to 48.6 ÷ 112% of 52 ÷ 54 nm that increased up to 48.6 ÷ 112%.

Conclusions: Nanosized ferrite particles were synthesized with coprecipitation route and were irradiated by ^{60}Co gamma radiation source. The result showed that magnetic properties and particles size changed.

Index terms – ***ferrite nanoparticles, magnetic properties, nanostructure.***

I. INTRODUCTION

The study of effecting of gamma radiation on magnetic properties of ferrite materials is one of the most attracting issues. Many researches had proved that magnetic properties of bulk form of the ferrite materials are unchangeable under effecting of radiating [10], [11], [12] but they are changeable on nanosized ferrite particles [13]. The purpose of this work is to investigate magnetic properties and to examine change in the size of nanoparticles Fe_3O_4, $NiFe_2O_4$, $MgFe_2O_4$ under the influence of gamma radiation. Investigations on nanosized particles are carried out by XRD, SEM and VSM techniques.

II. EXPERIMENTAL SIGN

A. Synthesis of Fe_3O_4

A mixture of $FeCl_2.4H_2O$ and $FeCl_3.6H_2O$ [Fe^{2+}: Fe^{3+} = 1:2] were mixed with distilled water to make the orange solution of salt. This solution was mixed with NaOH (4M) and stirred by ultrasonic agitator at 80^0C. The change in color of solution is from orange to brown and finnally products were black. The black precipitate was filtered off, washed with distilled water in magnetic field several times and dried in a vacuum oven at 80^0C for 12 hours. Next, samples were fine crushed and final products obtained were a fine black powder. These samples were analysed structure using XRD technique. The result of XRD showed that the broad feature of XRD lines is an indicative of nanosized Fe_3O_4 ferrite (about 20÷25 ± 2 nm) and the pattern shows the existence of single-phase cubic inverse spinel structure.

The chemical reaction of Fe_3O_4 precipitation is expected below:

$$2FeCl_3.6H_2O + FeCl_2.6H_2O + 8NaOH \rightarrow Fe_3O_4 + 8NaCl + 22H_2O$$

B. Synthesis of $NiFe_2O_4$ and $MgFe_2O_4$

Also we prepared $NiFe_2O_4$ and $MgFe_2O_4$ nanoparticles via co-precipitation process.

A (400 ml) solution of ion chloride ($FeCl_3.6H_2O$) and a (200 ml) solution of nickel chloride ($NiCl_2.6H_2O$) in distilled water were mixed with stirring to manufacture $NiFe_2O_4$ nanoparticles.

A (400 ml) solution of ion chloride ($FeCl_3.6H_2O$) and a (200 ml) solution of magnesium chloride ($MgCl_2.6H_2O$) in distilled water were mixed with stirring to manufacture $MgFe_2O_4$ nanoparticles.

(6M) NaOH was used to adjust the pH at 13. The processes were performed as above (synthesis Fe_3O_4) at 100^0C.

The chemical reaction of $NiFe_2O_4$ and $MgFe_2O_4$ precipitation is expected:

$$2FeCl_3.6H_2O + NiCl_2.6H_2O + 8NaOH \rightarrow NiFe_2O_4 + 8NaCl + 22H_2O$$

$$2FeCl_3.6H_2O + MgCl_2.6H_2O + 8NaOH \rightarrow MgFe_2O_4 + 8NaCl + 22H_2O$$

The result of XRD showed that the sizes of $NiFe_2O_4$ and $MgFe_2O_4$ magnetic nanoparticles are 27÷32 ± 2nm and 35÷39 ± 2nm. The pattern showed that these superparamagnetic nanoparticles are single phase cubic inverse spinel structure.

A ^{60}Co radiation was used as a radiator. The above products were exposed to gamma radiation with dose after from 1000÷2000 kGy.

III. RESULT AND DISCUSSION

A. Magnetic properties

Figures 1, 2, 3 shows the hysteresis loop obtained from VSM measurements for Fe_3O_4, $NiFe_2O_4$ and $MgFe_2O_4$ nano particles. The magnetic properties of them with an inverse spinel structure can be explained in term of cations distribution and magnetization originates from Fe^{3+} ions at both tetrahedral and octahedral sites and Ni^{2+}, Mg^{2+} ions in octahedral sites [4], [5]. Hysteresis loops in fig 1, 2, 3 are typical for soft magnetic materials and the "s" shape of curves together with the coercity = zero indicate the presence of small magnetic particles exhibiting superparamagnetic behaviors [16]. This behavior is an important property for magnetic targeting carriers [17]. The saturation magnetization (M_s) values of products are listed in table 1, the saturation magnetization changes under affecting of radiation.

Table 1: The saturation magnetization (M_s) of Fe_3O_4, $NiFe_2O_4$ and $MgFe_2O_4$ nano particles before and after irradiating:

	M_s (emu/g)		
Before and after irradiating	**Fe_3O_4**	**$NiFe_2O_4$**	**$MgFe_2O_4$**
Before	39.67 ± 0.06	40.50 ± 0.04	± 3,75 ±0,12
1000 kGy	37.19 ± 0.09	41.63 ± 0.1	± 3,92 ±0,09
1500 kGy	39.93 ± 0.12	40.98 ± 0.06	± 3,84 ±0,05
2000 kGy	46.08 ± 0.08	40.87 ± 0.1	± 4,03 ±0,07

B. Morphology microstructure:

To investigate the morphology and particle size of products, the SEM images of samples were obtained and are shown in figures 4, 5, 6. From the SEM micrographs, it is clear that the nanoparticles obtained are cube like and rather uniform. Average grain size obtained from SEM image of sample Fe_3O_4 is approximately 53 nm and of sample $NiFe_2O_4$ is about 54 nm and of the sample $MgFe_2O_4$ is about 52 nm, which is in good agreement with size determination by Scherrer equation from XRD pattern.

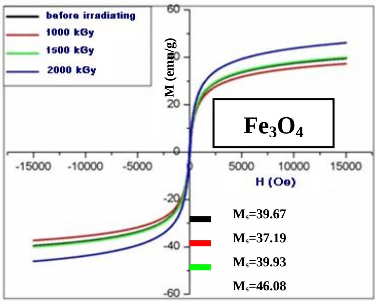

Fig.1: Hysteresis loop of Fe_3O_4

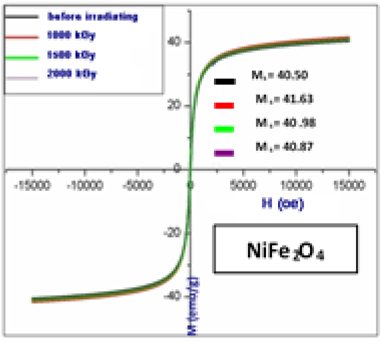

Fig.2: Hysteresis loop of $NiFe_2O_4$

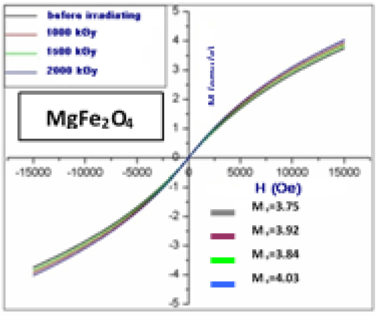

Fig.3: Hysteresis loop of $MgFe_2O_4$

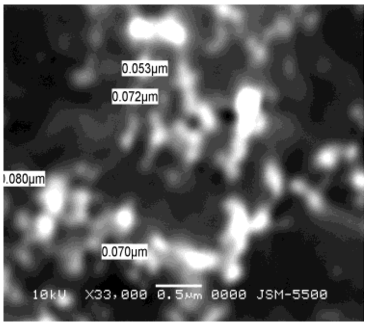

Fig. 4: SEM of 53 nm Fe_3O_4

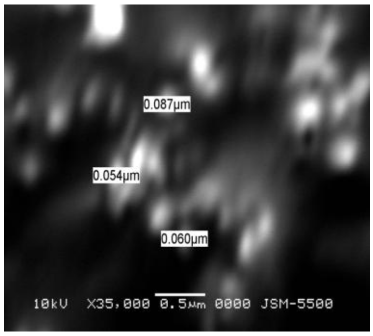

Fig. 5: SEM of 54 nm $NiFe_2O_4$

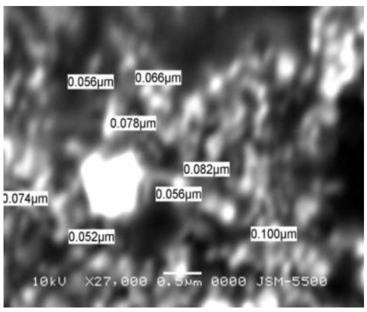

Fig. 6: SEM of 52 nm $MgFe_2O_4$

The saturation magnetization of Fe_3O_4, $NiFe_2O_4$ and $MgFe_2O_4$ superparamagnetic materials changes under effecting of gamma irradiation. It agrees well with the results of [4].
The size of Fe_3O_4, $NiFe_2O_4$ and $MgFe_2O_4$ superparamagnetic nanoparticles before and after irradiating shows the change is significant.

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AUTHORS BIOGRAPHY

Nguyen Thi Ai Thu. In 2011 she received her Ph.D degree from University of Science of Nuclear Physics – Saigon City – South Vietnam and in 2013 she became member of American Nuclear Society (ANS) – USA. Currently, she is studying and working in University of Science and Saigon University – Saigon City – South Viet Nam.