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Physical and Magnetic Properties of Manganese Ferrite Nanoparticles

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ABSTRACT
In this paper, manganese ferrite ($MnFe_2O_4$) nanoparticles were synthesized using chemical bath deposition (CBD) method and characterized by XRD and TEM to determine different properties of nanoparticles. The results obtained showed the formation of manganese ferrite nanoparticles with an average particle size are in good agreement with previous reported experimental results and displayed good magnetic properties. Magnetic properties was determined using Vibrating Sample Magnetometer(VSM). Due to simplicity and low cost of this process, it could be used for synthesis of ferrites nanoparticles. These materials may be used in drug delivery systems, electronic devices and water remediation.
Keywords **–** CBD, Manganese ferrite, Nanoparticles, TEM, XRD,

I. INTRODUCTION

Manganese Ferrite ($MnFe_2O_4$) crystallize in the spinel structure (AB_2O_4) with two divalent cation sites: 8 tetrahedral A sites and 16 octahedral B sites. Manganese ferrite is a kind of magnetic materials which have been extensively used in various technological applications. The properties of manganese ferrite highly depend on the composition, morphology and size, which are strongly connected with the preparation conditions. Among the ferrite materials, manganese ferrite that has been many applications in various fields of industry including magnetic materials, gas sensor and absorbent material for hot-gas. Ferrite based nano-materials show novel properties that are often significantly different from the bulk due to fundamental changes in structural and concomitant electronic rearrangements (induced by the reduced dimensionality) and to significant dominance of the surface atoms. [1–3]. Due to their excellent electrical and magnetic properties spinel ferrites are technologically important ceramic materials. These classes of materials have been widely used for three decades. Recently, progress in synthesis techniques has initiated a new surge of interest in ferrites in order to improve their physical properties and expand their applications [4].

II. METHOD

Manganese ferrite nanoparticles has been synthesized by Chemical Co-precipitation Method because it has such characteristics like low temperature, wet chemical synthesis, fast precipitation often takes place. It is widely used to synthesize ferrite nanoparticles. Co-precipitation reaction involves the simultaneous occurrence of nucleation, growth, coarsening and agglomeration process. When precipitation begins, numerous small crystallites initially from nucleation, but they quickly aggregate together to form larger, more thermodynamically stables particles. The basic ingredients required for the synthesis of ferrites are: $MnCl_2$, Ferric chloride, Oleic acid and Sodium hydro-oxide.

To prepare nanoparticles, the required amount of Manganese and Ferric chloride were taken in molar ratio of 1: 2 and dissolved in suitable volume of distil water. Thereafter, sodium hydroxide added to this solution until the solution to maintain pH value, because it plays an important role in controlling the precipitation and size of the precipitate particles. The solution then heated up to 80-90 °C, and then specified amount of oleic acid added to the solution. The Oleic acid act as the surfactant and coating material which control the size of the growing particles. The solution must be kept on stirring continuously and allowed to cool down up to room temperature slowly.

The precipitate so obtained, taken out and washed with hot distilled water, so as to remove traces of sodium chloride. Finally water was removed by washing it with acetone. The acetone wet-slurry then dispersed in suitable volume of kerosene oil and further heated this at 70^oC for 5 minutes. The resulting fluid, than centrifuged at 1200 rpm for about 10 minutes. After centrifuged the precipitate settled down at bottom. The portion of the fluid was then taken out. For getting dried particles, the precipitate were repeatedly washed with acetone and filtered number of times. Acquired substance then dried at room temperature for 48 hours. The co-precipitated ferrite agglomerates were then grounded using a pestle to have very fine particles. These particles, subsequently heat treated in a box furnace at different temperature.

III. INDENTATIONS AND EQUATIONS

Structural Analysis

After synthesis of nano particles, samples have been subjected to various structural characterizations. We will characterize the material using X-ray diffraction for determination of size and phase of the particles. The sample is irradiated with monochromatic X-rays and the reflected radiation is recorded by the counters. In these techniques various forms of the samples could be used and very less amount about 1 gm is required for the phase determination. The X-ray diffraction patterns are shown in figure 1.

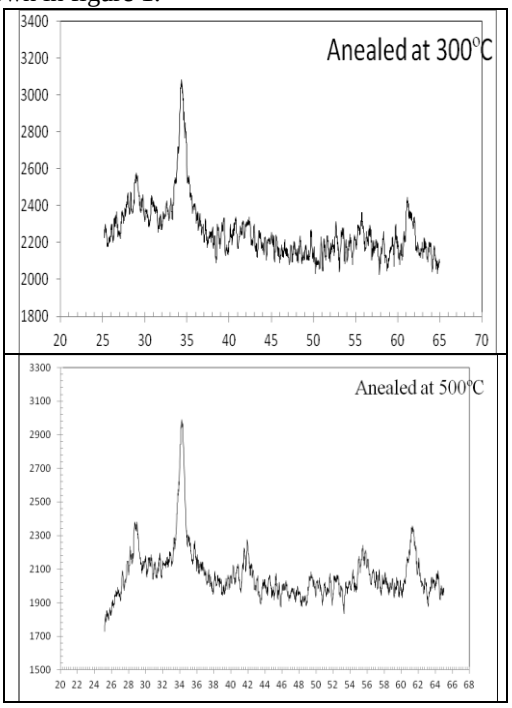
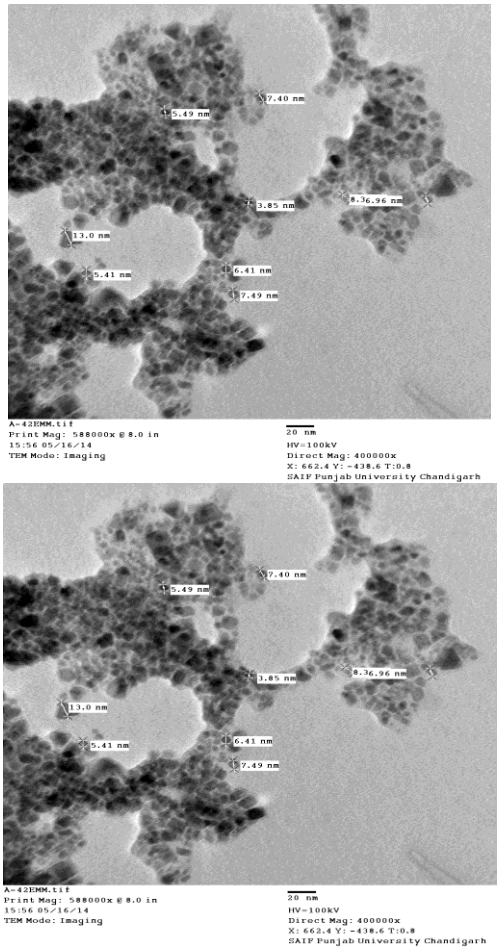


Figure1 shows that as the prepared sample consisted entirely of nano crystalline $MnFe_2O_4$ particles.

XRD pattern coincides with the standard data of the cubic spinel structure with Fd3m space group. The size of particles was estimated using Scherer's equation $D = \frac{k\lambda}{\beta \cos\theta}$ put Scherer's constant k=0.9 and λ = 1.5418 Å. The inter planar spacing (d_{311}) values of samples were calculated using Bragg's law and then lattice constant was calculated by using the formula $a = d_{311}(h2 + k2 + l2)^{1/2}$. The results are shown in the table and compared with the previous reported experimental values[5,8,9].



Sample	Particle size D (nm) Present work	Other Reported results	Lattice Constant (Å) Present work	Other Reported results
$MnFe_2O_4$ without annealing	5.21	10.9[5]	8.40	8.402[5] 8.3413[8] 8.511[9]
$MnFe_2O_4$ annealed at 300ºC	11.03		8.61	
$MnFe_2O_4$ annealed at 500ºC	8.31	14.10[10]	8.71	8.577[10]

Magnetic Properties

Magnetic properties of $MnFe_2O_4$ nanoparticles were performed using the Vibrating Sample Magnetometer and the results of hysteresis curves of the sample are shown in Figure 2(a-c) at different temperatures. Hysteresis loops were measured to determine magnetic parameters such as Saturation magnetization(M_s), Coercivity (H_c), Remanent magnetization(M_r) and corresponding remnant ratio (M_r/M_s) are given in table 2.

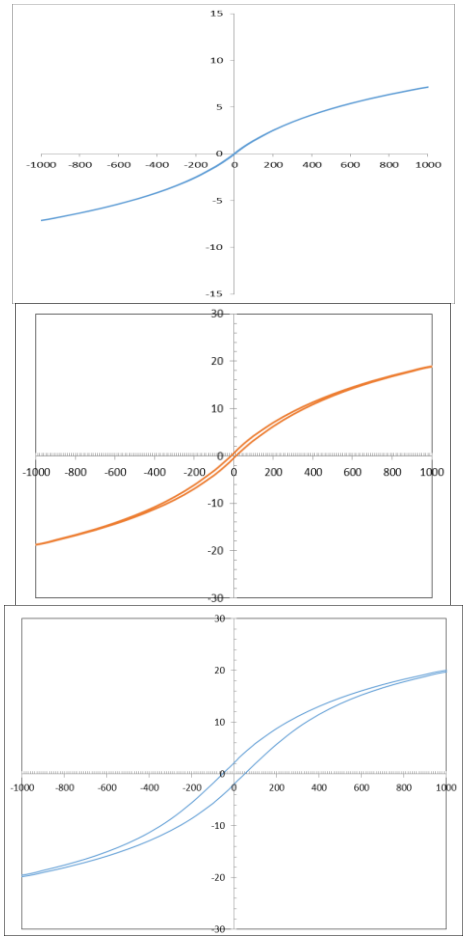


Fig.2: The hysteresis loops of $MnFe_2O_4$ annealed at 0^0C, 300^0C and 500^0C.

As a result, superparamagnetic behaviour was observed without annealing in fig 2(a). That behaviour of nanoparticles may be due to the non-equilibrium distribution of iron ions in tetra and octahedral sites of spinel structure.

Sample	H_c (G) PW	Others	Ms (emu/gm) PW	Others	Mr(emu/gm)	Mr/Ms
$MnFe_2O_4$ without annealing	-	-	-	-	-	-
$MnFe_2O_4$ annealed at 300ºC	13.92	-	38.60	-	0.5048	0.0131
$MnFe_2O_4$ annealed at 500ºC	50	Negligible	35.25	6.31[10]	2.696	0.0764

Table 2: Magnetic parameters of $MnFe_2O_4$ nanoparticles.

The nanoparticles was annealed at 300ºC, the coercivity (H_c) of $MnFe_2O_4$ 13.92 Gauss and saturation magnetization 38.6074 emu/gm and at 500ºC, coercivity is 50 Gauss and saturation magnetization is 35.2556 emu/gm was observed. The results of our experiment verified Brown's relation in which, coercivity is inversely proportional to the saturation magnetization. The values of saturation magnetization of our sample are lower than those reported for the bulk $MnFe_2O_4$(80 emu/g)[6]. Such behaviour is ascribed to the surface effects in nanoparticles. The surface effect may be developed due to the existence of an inactive magnetic layer or a disordered layer on the surface of nanoparticles and/or the heating rate of calcinations. It is clear that, as annealing temperature increases, occupation ratio of iron ions at octahedral sites decreases therefore, magnetic moment of ferrite nanoparticle is enhanced.

The remnant ratio (M_r/M_s) is an indication of the ease with which the direction of magnetization reorients to the nearest easy axis magnetization direction after the magnetic field is removed. The values of the remnant ratio of the prepared samples are low which is an indication of the isotropic nature of the material[7]. These materials can be used in biomedicine and absorbing materials.

IV. CONCLUSIONS

Manganese ferrite nanoparticles were synthesized by Chemical Co-precipitation Method which resulted in cubic spinel structure homogeneously distributed nanoparticles and nano size scale. Also the result indicated that this method might provide a promising option for synthesis of ferrite nanoparticles. The Chemical Co-precipitation Method has such characteristics like low temperature, wet chemical synthesis, fast precipitation, therefore, it results in large particles. Without annealing $MnFe_2O_4$ nanoparticles shown supermagnetic behaviours. The magnetic properties of $MnFe_2O_4$ may be enhanced after annealing. The behaviour of these nanoparticles change from super paramagnetic to ferromagnetic, therefore, these particles become promising materials in drug delivery system and electronic devices to absorbs the microwaves and in sensing devices

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REFERENCES

[1] M. Tsuji, Y. Wada, T. Yamamoto, T. Sano, Y. Tamaura, *J. Mater. Sci. Lett*. *15* 1996 156-165.
[2] J.W. Choung, Z. Xu, J.A. Finch, *Ind. Eng. Chem. Res*. *38* 1999, 4689-4697.
[3] A.J. Rondinone, A.C.S. Samia, Z.J. Zhang, *J. Phys. Chem*. B 2000, 7919-7928.
[4] J. Wang, P. F. Chong, S. C. Ng and L. M. Gan, Mater. Lett. *30*, 1997, 217-225.
[5] Jin-Gyu Kim, Jung-wook Seo, Jinwoo Cheon and Youn-Joong Kim *Bull. Korean Chem. Soc.*, *30(*1) 2009, 183-187.
[6] P. J. Van der Zaag, A. Noordermeer, M. T. Johnson and P. E. Bongers, Phys. Rev. Lett., *68* , 1992, 3112.
[7] Toksha B.G., Sagar E. Shirsath, S.M. Patange, K.M.Jadhav, *Solid State Commun. 147*, 2008 479–483.
[8] Sugimoto, M. J. Am. Ceram. Soc. *82*, 1999, 269.
[9] Jung, J. S.; Malkinski, L.; Lim, J. H.; Yu, M.; O'Connor, C. J.; Lee, H. O.; Kim, E. M. Bull. Korean Chem. Soc. *29*, 2008, 758.
[10] Susan Sam and A. Samson Nesraj, International journal of applied Sciences and Engineering 2011, 9, 4 223-239