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Effect of Synthesis Condition on the Structural and Magnetic Parameters of Ni Ferrite

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Abstratct – Nanosized nickel ferrite powders (NiFe2O4) have been prepared by solid-state reaction method at different temperature 900°C(T1) and 1100°C (T2) for 4h. The resulting powders were characterized by Xray diffraction (XRD) and vibrating sample magnetometry (VSM). The powder samples T1 and T2 showed extensive XRD line broadening and the crystallite size calculated from the XRD line broadening was found to be 52.21 nm and 59.60 nm respectively. The saturation magnetization was obtained 43.82emu/g and 63.34emu/g for samples T1 and T2 respectively.

Keywords: Nickel Ferrite Powders, Magnetic Properties, XRD Analysis.

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1. INTRODUCTION

Ferrites usually have the combination of iron (Fe) oxides with oxides. Ferrites have a wide range of technological applications depending upon their properties like curie-temperature, microstructure, density, grain size, saturation magnetization. To get good potential applications from ferrite material depend upon starting materials, stoichiometry, sintering temperature, chemical homogeneity. Among much synthesis process, the solid-state reaction is the best suited method for the synthesis of large scale spinal compound. AB_2O_4 type of compound with spinal structure also possesses interesting structural and magnetic properties, which vary with the synthesis process, the nature of the ions, their charge and sites distribution between tetrahedral and octahedral sites. Various cations can be placed in A site and B site to tune its magnetic properties. Depending on A site and B site cations it can exhibit ferromagnetic, anti- ferromagnetic, spin and paramagnetic behavior Ni ferrites are one of the most prominent magnetic materials which have many useful technological applications such as power transformers, antennas, digital tapes, sensor applications. Nanostructured materials exhibit unusual physical and chemical properties, significantly different from those of conventional bulk materials, due to their extremely small size or large specific surface area (Hayashi, 1987) (Gleiter, 1989) (Fendler, 1987). Nanosized spinel nickel ferrite particles are center of attraction due to theirs technical importance into microwave industries and high-speed digital disk or tape recording devices, repulsive suspension levitated railway track systems, catalysis, and magnetic refrigerant systems. Repulsive suspension to use in levitated railway systems, ferrofluids, catalysis and magnetic refrigeration system (Pannaparayil, et. al., 1988) (Goldman, 1988) (Dormann & Fiorani, 1992). Nickel ferrite ($NiFe_2O_4$) is a well-known magnetic material having spinel structure. In classical solid state reactions technique high calcination temperature required to induces the sintering and hence aggregation of particles take places (Economos, 1959). To produce nanosized ferrite particles, some techniques such as chemical coprecipitation (Tsuji, et. al., 1996), hydrothermal synthesis (Yitai, et. al., 1995) (Komarneni, et. al., 1988), hydrolysis of metal carboxylate in organic solvent (Konishi, et. al., 1996), sol-gel (Chen & He, 2001), freeze drying (Yitai, et. al., 1995), spray drying (Marcilly, et. al., 1970), citrate precursor (Prasad & Gajbhiye, 1998) and aerosolization (Elmasry, et. al., 1997) have been developed. In the present study, ni ferrite nanoparticles were synthesized solid state reaction method. Since in this method there is no need to add any other chemicals or catalyst to the main solution which makes it simple, reduce its cost and risk by product effect on final characterization and environmentally friendly operation. The structural and magnetic characteristics of the prepared nickel ferrite nanoparticles were studied.

2. EXPERIMENTAL

Ni ferrite particles are mainly depending upon the synthesis process. NiFe2O4 were prepared by solid-state reaction method. All analog grade nickel oxide (NiO), zinc oxide (ZnO), ferric oxide (Fe2O3)[Himedia Chem.] were weighed according to stoichiometric proportion. To form a homogenous mixture, it was carried out by using

agate mortar in acetone medium. The slurry was placed in a crucible and calcined at and 900^{o}C and 1100^{o}C for 4 hours. The calcined powders again grounded. It results in better homogenization of the sample.

The samples send to x-ray diffraction (Pan Analytical, X-Pert pro, Netherland) to know the structure and particle size of the sample and the sample were scanned in the range 10-80^{o}. At this stage, the sample was mixed with 5% PVA used as a binder and pressed into pellets by applying pressure of 5 ton/cm^{2}. The pellets were finally sintered in air at 1100^{o}C for 4 hours to complete the process. Scanning electron micrographs of sintered coated pellets were obtained using JSM-6610LV, JEOL Asia PTE Ltd, Japan. VSM of samples were taken by VSM set up.

Hysteresis loops were obtained at low temperature (6.5 K) as well as at room temperature using a Model 7410 Lake Shore Cryotronics Vibrating Sample Magnetometer (VSM). Hence obtained results are normalized and displayed as saturation magnetization (emu/g) versus field (Oe) curve.

3. RESULTS AND DISCUSSION

3.1 X-Ray Analysis

Crystallite size calculation The Scherer formula relates the thickness of the crystallite to the width of its diffraction peaks and is widely used to determine particle size in ceramics, clays, and polymers.

The Scherrer formula is given by D = (kλ)/(βcosθB). (1) Where D is the crystallite thickness, β is the broadening of diffraction line measured at half its maximum intensity, k is the shape factor and λ is the wavelength of the x-ray beam.

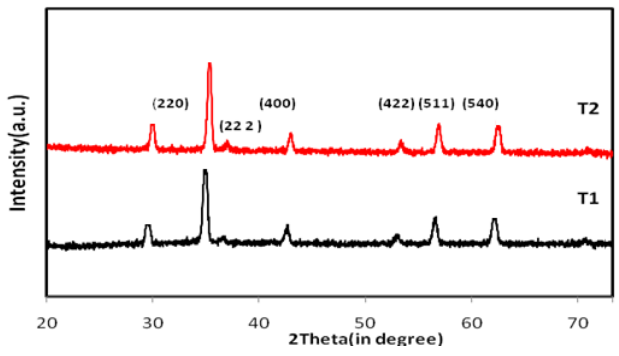

Fig. 1 XRD pattern of samples T1 and T2

Table 1: Structural parameters of nickel ferrites

Sample	Crystallite Size D (nm)	Inter planar Spacing (Å)
T1	52.21	2.6106
T2	59.10	2.6032

The XRD patterns of the composition T1 and T2 are shown in Figure 1. The analysis of x-ray powder diffraction patterns revealed that the single–phase cubic structure. The reflections in the figure are well matched with the spinel structure. The observed reflections are (220) (311), (222), (400) (422) (511) and (440) 311 peak is more intensive when compared to other peaks (Standley, 1962) (Nabiyouni, et. al., 2010) (Lazarević, et. al., 2012). These are well matched with reported values. The average particle size was found 52.21 nm and 59.60 nm respectively for sample T1 and T2. Structural paramteres of samples T1 and T2 shown in Table. 1. Crystallite size was found to be increase with increase in temperature.

3.2 Magnetic Properties

Hysteresis loops samples T1 and T2 are shown in Figures 2. The figure shows that the hysteresis loops for all synthesis samples are closed ones, showing almost some value of the coercivity, which is considered to be a typical superparamagnetic behavior. The values of the saturation magnetization increase magnetization increases as the temperature increases. This behavior could be referred to as the decreasing of particle size with the temperature leading to an increase in the area to volume ratio (Nejati and Zabihi, 2012), (Moradmard and Shayesteh, 2015).

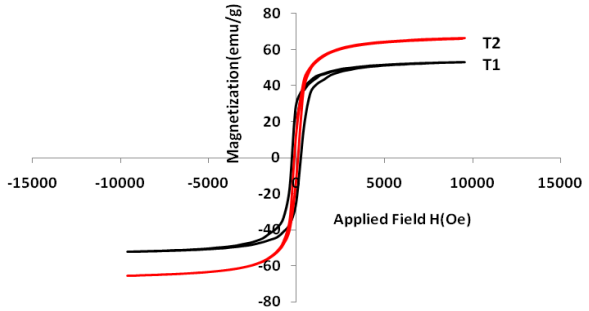

Fig. 2 VSM of samples T1 and T2

Table 2: Magnetic Parameters of Nickel ferrites

Sample name	Saturation Magnetization (M_s) e.m.u./gm	Coercivity (H_c)
T1	43.82	375
T2	63.34	270.1

Variations of the values of saturation magnetization (emu/g) which are measured for samples T1 and T2 are represented in Figure 3. It is clear that at 1100°C the values of magnetization are higher than those at 900°C. These activities can be explained mainly on the basis of thermal disorder of magnetic moments. The values of saturation magnetization were obtained 43.82emu/g and 63.34emu/g respectively.

CONCLUSION

NiFe2O4 have been synthesized by solid-state reaction technique. X-Ray powder diffraction patterns revealed that the single–phase cubic structure. The observations reflections are (220) (311), (222), (400) (422) (511) and (440) for both the samples. The average particle size was found 52.21 nm and 59.60 nm respectively for sample T1 and T2. Magnetization Ni ferrites lead to an increase in the values with increase in temperature. The values of saturation magnetization were obtained 43.82emu/g and 63.34emu/g respectively.

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