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Superparamagnetism and FMR study of Nano Mn-Zn Ferrite

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ABSTRACT

Nanosize particles of mixed ferrite have been prepared by chemical route i.e Sol-gel technique and characterized by FMR and VSM . Resonance linewidth and g_{eff} factor with Zn substitution has been discussed. When size of the particles reduces and convert into single domain nanoparticles, transition of ferrites takes place from ferromagnetic to superparamgentic state which was observed due to decrease in remenant magnetization with crystallite size.

Keywords: Ferrite, FMR, Superparamgnetism, single-domain

INTRODUCTION

The unusual magnetic properties exhibited by nanoparticles and their promising technological applications have attracted much interest in recent years. Magnetic properties of ferrites strongly depend on microstructure, particle size and surface to volume ratio. The saturation magnetization for the nanocrystalline ferrites, in general is found to be lower compared to their bulk value, which is attributed to surface spin effects.The advancement of high frequency ferrites was initiated by work done by Snoek who found that Mn-Zn and Ni-Zn ferrites provide a family of magnetic materials useful for radio and TV sets as well as mobile telephone. Mn-Zn ferrite has been used widely in high frequency devices such as transformer and magnetic heads[1]. Maganese zinc ferrites exhibit some unique properties such as enhanced coercivity, modified saturation magnetization, superparamagnetism, and metastable cation distribution. Mn-Zn ferrites possess a spinal structure in which Mn^{2+}, Zn^{2+} and Fe^{3+} cations are distributed among two interstitial tetrahedral and octahedral sites so Mn-Zn have mixed spinal structure[2].The electromagnetic properties of Mn-Zn ferrite such as magnetization, permeability and electrical resistivity are also closely related to eddy current. Ferrites are manufactured by different technique. The resulting product is hard and brittle. It is also a semiconductor, which means that its electrical resistivity is at least a million times that of a metal. This very large resistivity means in turn that an applied alternating magnetic field will not induce eddy currents in a ferrite. This property makes ferrites almost ideal materials for high – frequency applications. The ferrites are ionic compounds, and their magnetic properties are due to the magnetic ions they contain. Eddy current loss of Mn-Zn ferrite is widely reduced by increasing the electrical resistivity and high permeability. Mn-Zn ferrite is having low anisotropy(high anisotropy is structure sensitive). Required structure of composition of Mn-Zn ferrite is only obtainable with very low anisotropy which also reduces loss of magnetization. High permeabilities of Mn-Zn nanoferrites concentrates flux density inside the coil and enhances the inductance [3,4].

MATERIALS AND METHODS

Nanosize $Mn_{1-x}Zn_xFe_2O_4$ (X= 0 to 1) have been synthesized by chemical route i.e. sol-gel technique .The process has the advantage of inexpensive precursor , simple equipment , low temperature and the resulting homogenous nano sized particles. Analytical grade of precursor salts of $MnCl_2.4H_2O$, $FeCl_3.6H_2O$, $ZnCl_2.4H_2O$ were taken in the stoichiometric amounts and dissolved in 75 ml of distilled water. It was stirred well so that all salts get mix Completely in water[5]. The P^H of the solution was varied between 2-3 as it plays very crucial role for producing sample in nanosize. At lower P^H precipitation of Mn is incomplete and for high P^H there may be a zinc loss from composition therefore, optimum P^H for gel formation of solution was found to lie between 2 to 3.

During heating we add citric acid which removes the insoluble residue with formation of cationic citric acid complex and holds the metal ion together. Ethylene glycol has also been added for homogeneity. Mn is preferred over Zn in nucleation process during the particle growth. This is due to fact that Zn has a very strong chemical preference for A- site.

The purpose of clacination is to start the process of forming the ferrite lattice. It inter-diffuses the substituents chemically and crystallographyically uniform structure. One advantage of clacination is that it reduces shrinkage for final sintering. Also it helps to homogenize the material. The introduction of non-magnetic ion like Zn in $MnFe_2O_4$ results in lowering the total anisotropy[6].

RESULTS AND DISCUSSION

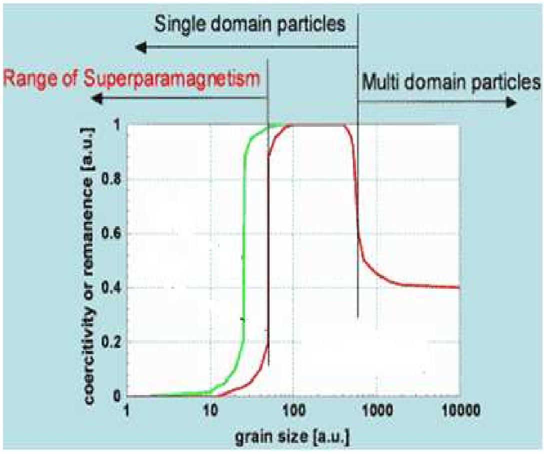
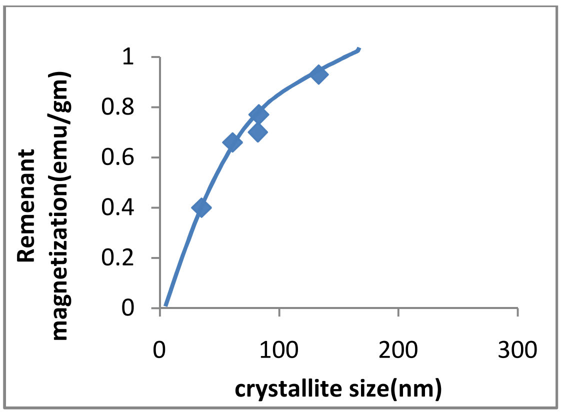


Table 1: Crystallite size & remenantmagnetization

Crstallite size (nm)	remenant magnetization
133	0.93
83	0.77
82	0.7
61	0.66
35	0.4



Graph (1) of Rem. Mag. And Crystalite size

In the cubic system of ferrimagnetic spinels, the magnetic order in mainly due to a super exchange interaction mechanism occurring between the metal ions in A and B sublattices. Hence by varying the degree of Zn substitution the magnetic properties of fine particles can be varied [7]. It has been observed that as Zn substitution degree increases the remenant magnetization (M_r) decereases. The substitution of non magnetic Zn ion which is having a preferential A site occupancy results in reduction of the exchange interaction mechanism occurring between the metal ions in A and B sublattices.

Std graph

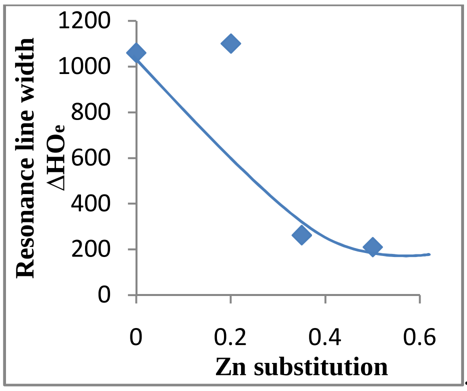
The samples prepared by Sol-gel technique showed superparamagnetic behavior which was documented by the hysteresis loop, measured at room temperature which is in time with the results obtained by other researches. The variation of Hc can be interpreted in terms of thermal activation of spins, according the superparamagentism theory. Hc tends to decrease due to the thermal activation of the particle volume shown in graph 1.

From the ESR, it has been observed that the resonance linewidth is decreasing with temp. & resonance field is increasing with Zn substitiution. The increase of the EPR resonance signal is due to random orientation of ferromagnetic particle in samples[8]. It has also been observed that as Zn substitution increases from 0.2, 0.35, 0.5 , g_{eff} values decreases from 2.57, 2.04, 2.03.

The FMR data tend to yield g value slightly larger than the free electron value. This can be explained by spin spin and spin lattice relaxation models. The spin lattice relaxation process is characterized by a time constant, which is function of static magnetic field and depends on the rate at which microwave energy can be absorbed and dissipated. The relaxation time is correlated with the line width of ESR. The spin spin relaxation time limits the broadening of line width. [9].

Table 2: Zn Substitution verses Resonance Line width

Zn substitution	Resonance line width ΔH O_e
0	1060
0.2	1100
0.35	262
0.5	210



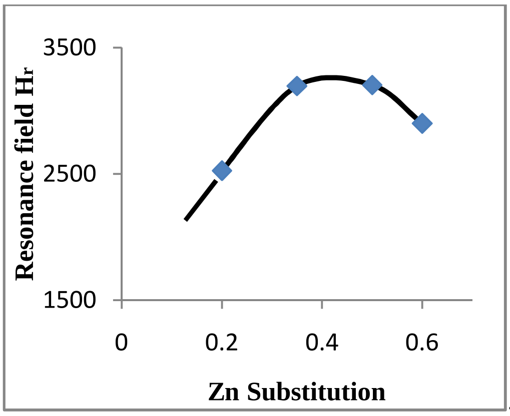
Graph (2) of Resonance line width and Zn substitution

Table 3: Zn Substitution and Resonance field Hr

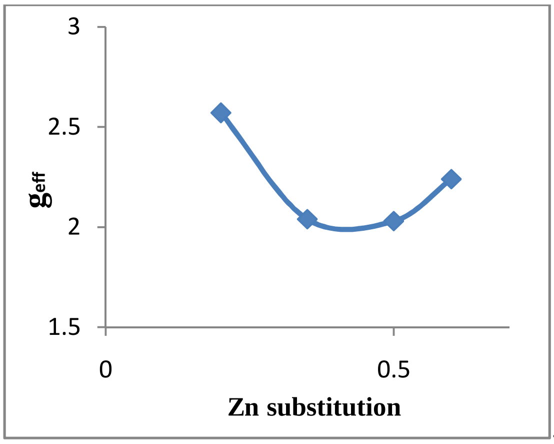
Zn substitution	Resonance Field H_r
0.2	2525
0.35	3197
0.5	3205
0.6	2900

Table 4: Zn substtution and g_{eff}

Zn substitution	g_{eff}
0.2	2.57
0.35	2.04
0.5	2.03
0.6	2.24



Graph (3) of Resonance Field Hr and Zn Substitution



Graph (4) of g_{eff} and Zn substitution

As in case of ESR, it has been observed that as Zn addition increases, resonance line width decreases, which indicates that the sample have low electric loss. As a very important applications, the studied ferrite with Mn content has a lower loss of electric energy than that without Mn which makes it very useful as cores of transformers in the microwave region[10].

CONCLUSION

Ultrafine magnetic particles exhibit the phenomenon of superparamagentism due to the thermal fluctuations of the magnetic moments.

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