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Structural and FT-IR Spectroscopic Studies of Mg-Cu-Zn Ferrite Nanoparticles Useful For Multilayer Chip Inductor

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ABSTRACT

Nanoparticles of $Mg_xCu_{0.1}Zn_{0.9-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7) ferrite have been preparaed by co-precipitation method at annealing temperature 600 ^oC. The results obtained from XRD and IR analysis are reported. XRD patterns confirm the formation of cubic spinel phase of ferrite samples along with secondary phase of α-Fe_2O_3 with low concentration. The observed crystallite sizes are in the range of 20-24nm and the lattice parameter decreased with increase in Mg^{2+} ion concentration. FTIR spectra of three compositions gives only higher vibrational frequencies and no peaks of lower vibrational frequencies. This is due to presence of fine particles in the samples. The variation in ν_1 shows that Cu is going to the octahedral site in Mg-Zn matrix. This paper reports the structural results obtained from XRD and FTIR studies and successed to densified ferrite powder at low sintering temperature useful for Multilayer Chip Inductros.

Keywords : XRD, FTIR, Ferrites, Nanoparticles.

I. INTRODUCTION

Mg-Zn spinel ferrite is promising candidate because of easy of synthesis employing different synthesis routes[1]. Recently many researchers focused to synthesize versatile magnetic materilas capable for multilayer chip inductor (MLCI) and surface mount devices (SMD). These MLCIs are produced by coating ferrite powder on silver (Ag) electrode layers and followed by cofiring [2]. MgCuZn is one of the useful ferrite for MCLI because of its desification at low sintering temperatures. The aim of the work to achieve higher saturation magnetization by densifying MgCuZn nanoferrite at low sintering temparetures keeping 0.1 mole percent of Cu. In the present paper the results of structural studies obtained from X-ray diffraction and FTIR measurements are presented.

II. EXPERIMENTAL

$Mg_xCu_{0.1}Zn_{0.9-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7) were synthesized by co-precipitation method which was described in our earlier studies [3]. An INELXRG 3000 powder diffractometer was employed to obtain the X-ray diffraction patterns of the samples using Co K_α (1.78901Å) radiation. A Carl Zesis EVOMA15 scanning electron microscope was employed to check the morphology of the samples. IR spectra were recorded in the 400cm^{-1} to 4000cm^{-1} using Perkin Elmer spectrometer.

III. RESULTS AND DISCUSSION

The X-ray diffractograms of $Mg_xCu_{0.1}Zn_{0.9-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7) annealed at 600 ^oC are shown in Fig. 1. The XRD patterns of all the samples reveal

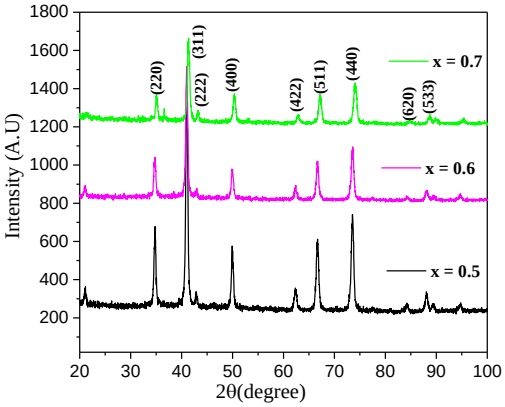

Figure 1. XRD patterns of $Mg_xCu_{0.1}Zn_{0.9-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7) annealed at 600 °C.

characteristic peaks of cubic spinel structure along with the traces of secondary phase of α-Fe_2O_3 with low concentration. The observed secondary phase slightly increased with in increase Mg^{2+} ion concentration. The observed peaks (220), (311), (400), (422), (511), (440), (620), (533) are well with JCPDS card no. 08-0234[4].The sharpness of diffraction peaks decreased with increase in Mg^{2+} ion concentration attributes to decrease in crystallite size. But close examination at the base of the diffraction peaks shows the broadening of the peaks. This broadening resembles the distribution of ferrite nanoparticles of different sizes present in the samples. The values of lattice parameter are calculated using [5]

$$a = d\sqrt{h^2 + k^2 + l^2}.$$

The crystallite sizes and lattice strain are calculated using Williamson and Hall equation [5] as given below

$$\beta \cos\theta = \frac{K\lambda}{D} + 4\eta \sin\theta$$

Where β is full width at half maximum (FWHM), θ is angles of diffraction, K is shape factor (0.89), λ is wavelength of X-rays (Co K_α = 0.178901nm), D is crystallite size and η is lattice strain. The plots between β.cosθ and 4η.sinθ are drawn similar to the graph drawn for x = 0.7 as shown in Fig.2. The crystallite sizes and lattice strain are estimated from the calculated values of y-intercepts and slopes of the graphs. The calculated values of crystallite size, lattice strain and lattice parameter are given table1. The variation in crystallite size (D), lattice parameter (*a*) and lattice strain (η) with Ni concentration is shown in Figure 3. It was observed that both crystallite size and lattice parameter decreases with increase in Ni^{2+} ion concentration. The increase in lattice strain is in accordance with the variation in crystallite size. The decrease in lattice parameter is attributed to smaller

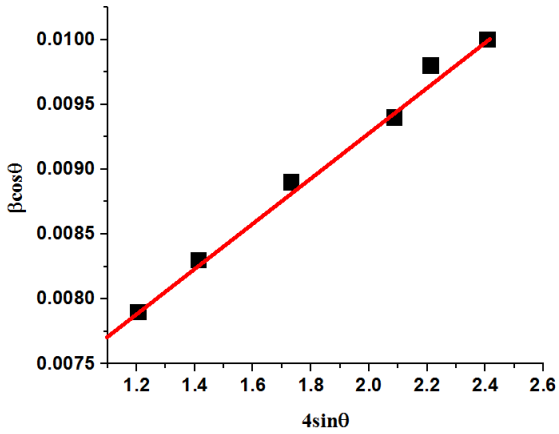

Figure2. Williamson and Hall plot for $Mg_{0.7}Cu_{0.1}Zn_{0.2}Fe_2O_4$ annealed at 600 °C.

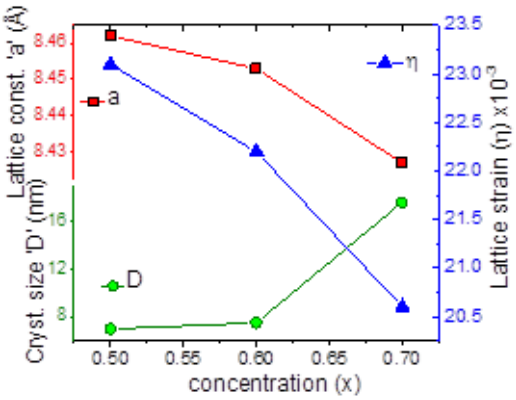

Figure 3. The variation in crystallite size (D), lattice parameter (*a*) and lattice strain (η) with Mg^{2+} ion concentration.

ion radius of Mg^{2+} (0.66Å) compared to ionic radius of Zn^{2+} (0.74Å) and Cu (0.72Å). Similar reports have been reported in different ferrites [6].

The SEM micrograph of the sample $Mg_{0.5}Cu_{0.1}Zn_{0.4}Fe_2O_4$ annealed at 600 °C is shown in Fig. 4. The nature of SEM micrograph presents the small sizes of ferrite nanoparticles. These small

particles are agglomerated into large clusters as observed from SEM micrographs. Anwar et al [7] reported the similar results for Cu substituted Mn-Zn nanoferrites.

Fourier Transform Infrared spectroscopy has been employed to observe the structural variations and formation of spinel ferrite phase. The cubic spinel ferrite structure is assigned with two vibrational bands, one is higher vibrational frequency (ν_1) is in the range of 600-500cm^{-1} corresponds to Fe^{3+}-O^{2-} stretching vibrations tetrahedral site and the another one lower vibrational frequency (ν_2) is in the range 450-350cm^{-1} corresponds to Fe^{3+}-O^{2-} stretching vibrations at

Table 1. Lattice parameter (a), crystallite size (D), lattice strain (η), vibrational frequency (ν_1).

composition	*a* (Å)	D (nm)	η x10^{-3}	ν_1 (cm^{-1})
x = 0.5	8.462	21.1	5.94	589.67
x = 0.6	8.453	20.2	6.46	589.71
x = 0.7	8.427	18.6	14.63	593.27

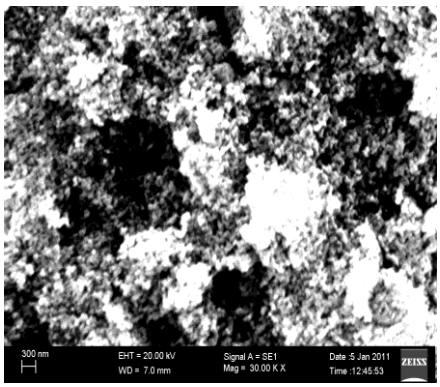

Figure4. SEM Micrograph Of $Mg_{0.5}Cu_{0.1}Zn_{0.4}Fe_2O_4$ Annealed At 600 ^oc.

Octahedral site [8].The FTIR spectra of $Mg_{0.6}Cu_{0.1}Zn_{0.3}Fe_2O_4$ annealed at 600 ^oC is shown in Figure 5.

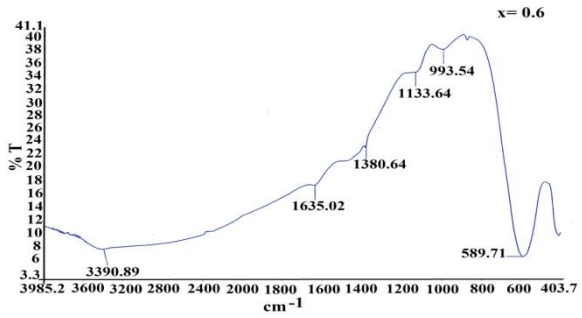

Figure 5. FTIR spectra of $Mg_{0.6}Cu_{0.1}Zn_{0.3}Fe_2O_4$ annealed at 600 ^oC.

Form the spectra higher vibrational frequencies are only observed, but lower frequency bands are not detectable. This may be due to the broadening of the peaks attributed to presence of fine particles in the ferrite sample[9]. This observation is in consistent with the observation drawn from XRD and SEM studies. It was observed that ν_1 is shifted to higher frequency values with increase in Mg^{2+} ion concentration. This is due to the contraction of Fe^{3+}-O^{2-} bond length at tetrahedral sites, reveals that Cu is going into octahedral site in Mg-Zn matrix. There is a noticeable peak in between ν_1 and ν_2 whose intensity slightly increased with increase in Ni^{2+} ion concentration. This is assigned to secondary phase of α-Fe_2O_3 which is also observed from XRD patterns. Raghavender et al [10] reported the similar observation in FTIR spectra of Ni-Zn ferrite system and confirmed this observation comparing to IR spectra of pure Fe_2O_3. The bands near the 3400cm^{-1} and 1800cm^{-1} attributes to presence of hydroxyl groups present in the samples.

IV. CONCLUSION

$Mg_xCu_{0.1}Zn_{0.9-x}Fe_2O_4$ (x = 0.5, 0.6, 0.7) ferrite nanoparticles succefully prepared using co-precipitation technique. XRD patterns confirm the formation of spinel phase of ferrite samples along with secondary phase with low concentration Both crystallite sizes and the lattice parameter decreased with increase in Mg^{2+} ion concentration.The variation

in ν_1 shows that Cu is going to the octahedral site in Mg-Zn matrix. A densified ferrite powder at low sintering temperature useful for Multilayer Chip Inductros.

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