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INITIAL PERMEABILITY BEHAVIOUR OF ZINC SUBSTITUTED LITHIUM FERRITE PREPARED BY SOL-GEL METHOD

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ABSTRACT

Nanocrystalline ferrite samples of $Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$, where x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 were prepared by Sol-gel method and sintered at 500^{o}C. The initial permeability (μ_i) as a function of frequency has been studied and found to initially increase for Zn composition of upto x = 0.2 and then decrease. A similar variation of grain sizes have been found with respect to Zn composition. These results were interpreted in terms of the contribution of grain boundaries and pores inside the grains to the domain wall pinning. As the size of the grains becomes larger, the domains and their wall motion would increase; causing the permeability to increase.

INTRODUCTION

Nanocrystalline ferrites have attracted substantial attention in the last few years due to their several applications [1, 2]. Diamagnetically substituted lithium ferrites have been considerable interest because of their potential microwave applications and they combine useful ferromagnetic properties with high saturation magnetization [3] and low microwave dielectric loss [4] besides this low cost material. They form a complex system composed of crystallites, grain boundaries and pores. The magnetic properties of these materials are determined by chemical compositions, microstructure and process mechanism [5]. Among this chemical route has been attracted much attention owing to its certain inherent advantages likes low processing temperature, homogeneous distribution and ability to produce nanosized particles. The aim of the present work is prepare nano-sized zinc doped lithium ferrite (ZLF) using chemical route and to study the effect of particle size on certain magnetic properties, like initial permeability (μ_i) and Quality factor (Q).

EXPERIMENTAL

Li-Zn ferrites having the chemical formula $Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$(x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) were prepared through chemical route using AR grade Li_2CO_3, Zn $(CH_3COO)_2$ $4H_2O$, $Fe(NO_3)_3$ $9H_2O$, HNO_3 and citric acid as raw materials. The details of chemical route synthesis of the ferrite samples in the present investigation are given elsewhere [6]. The ferrite powder so prepared was mixed with an appropriate amount of 2 wt% poly vinyl alcohol as a binder, the granulated powder was uniaxially pressed at a pressure of 4000 kg cm^{-2} to form green pellet and toroidal specimens. The final sintering of the samples is done at temperature 500^{o}C to have different particle sizes in the system. X-ray diffraction (XRD), scanning electron microscope (SEM), Initial permeability (μ_i) of all the samples as a function of frequency were carried out by measuring the inductance using HIOKI 3531 Z Hi-TESTER japan make LCR meter. The initial permeability was calculated using the relation, $\mu_i = L/L_o$ where $L_o = 4.6N^2d \log (OD/ID) x10^{-9}H$, L_o is the air-core inductance in Henry, N is the number of turns of copper wire on toroid, OD is the outer diameter of toroid in mm, ID is the inner diameter of toroid in mm and d` is the thickness of the toroid in mm [7]. All the measurements were carried out only at room temperature.

The LCR meter frequency range from 50 Hz to 5 MHz has been used to study the structural and magnetic properties of the prepared ferrites.

RESULTS AND DISCUSSION

Figure 1 shows the XRD patterns of Li-Zn ferrite samples sintered at 500°C temperature. These were obtained using Panalytical X-pert pro system with Cu-K_α radiation. All patterns show diffraction lines corresponding to single phase cubic spinel structure (JCPDS card number 49-0266). The average particle sizes were determined from the XRD peak broadening of the highest (311) peak using Debye-Scherrer formula [8]; $D = 0.9\lambda/(\beta\cos\theta)$, where D is the particle size, λ is the wavelength of Cu-K_α radiation (1.5418A°), β is the full width at half maximum(FWHM) of the diffraction peaks and θ is the Bragg`s angle. The obtained average particle sizes of the ferrite samples sintered at 500°C temperature are given in Table 1. It can be seen that initially the particle size increases with increasing Zn composition (x) upto x=0.2 and then decreases with increase composition (x).

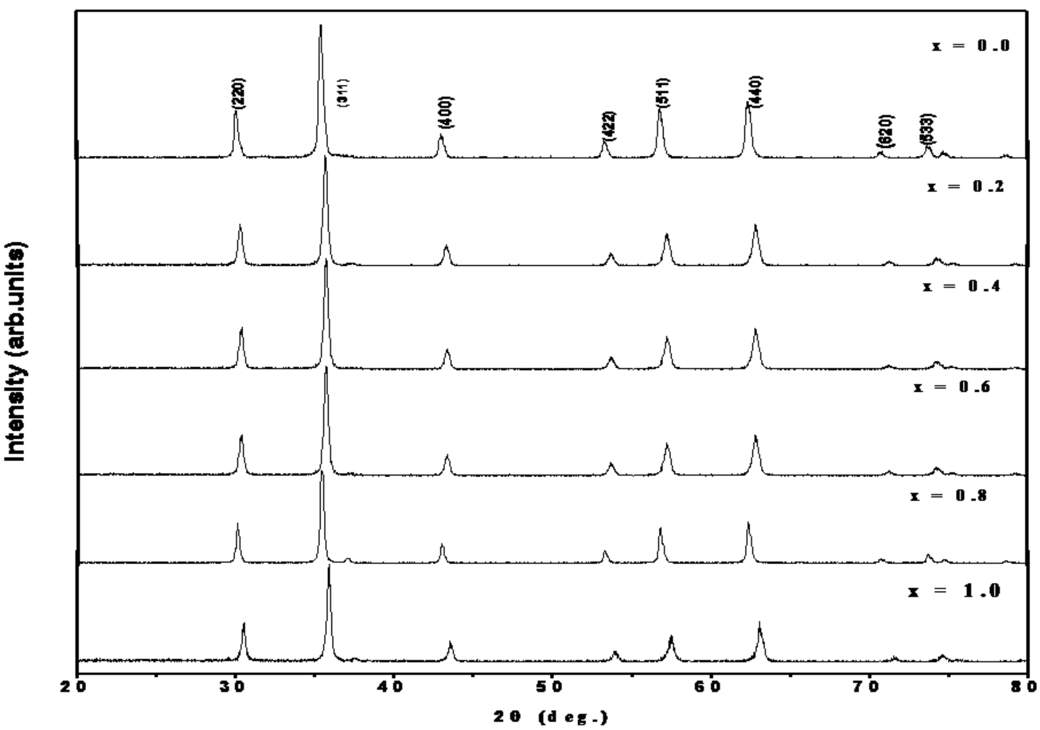

Fig. 1 Room temperature XRD pattern of Li-Zn Ferrites sintered at 500°C.

Table 1 Initial Permeability of $Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$ ferrites sintered at 500°C (measured at 1 MHz).

Zn Content (x)	0.0	0.2	0.4	0.6	0.8	1.0
Initial permeability	20.07	26.94	23.22	16.72	11.88	7.87
Grain size(µm)	1.85	2.11	1.74	1.31	0.85	0.54

Fig.2 shows that the frequency variation of initial permeability (μ_i) of dispersion at low frequency and becomes nearly constant, maintaining a low value at higher frequencies. At low frequency, changes of magnetization direction occur by the motion of domain walls, so that a domain oriented in the direction of the applied field grows at the expense of its neighbours which are oriented in different direction. At higher frequency the domain wall is unable to move sufficiently rapidly to follow the alternating field [9]. The overall magnetization vector does not follow the applied field hence accounting for the low value of permeability. The onset of resonance at still higher frequency as has been reported by other workers [10] has not been observed in the frequency range studied. The present study is 5MHz. The resonance frequency gives the frequency limit up to which a material can be used in a device. Soibam et al.[11] have shown that the resonance frequency is higher for lower μ_i values. The samples prepared by sol-gel method have smaller grain sizes than those prepared by the conventional method and hence lower permeability. This may have pushed the resonance frequency to higher values.

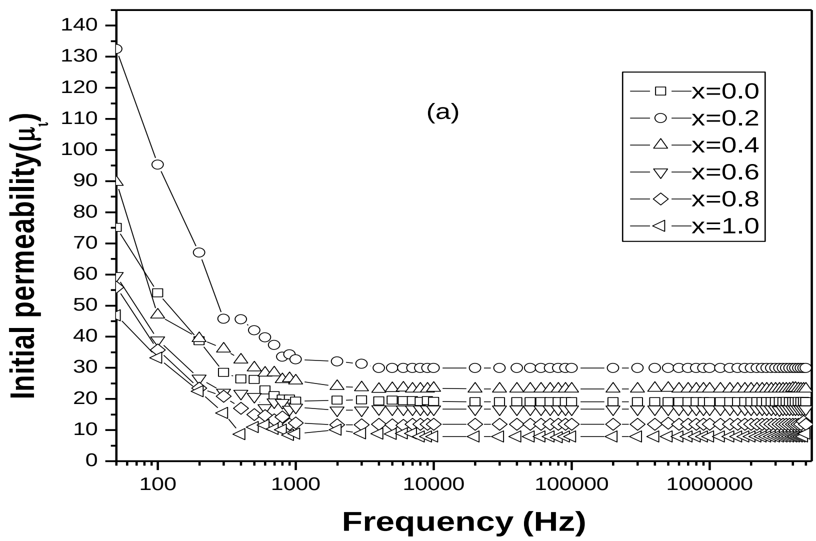

Fig.2. Frequency dependence of initial permeability (μ_i) for Zn substituted $Li_{0.5x/2}Zn_xFe_{2.5-x/2}O_4$ sintered at 500°C.

Initial permeability μ_i is reported to be dependent on the method of preparation, porosity with the material and grain size [12,13]. Rado and Terris [14] have observed low frequency dispersion in ferrites which they have attributed to domain wall displacement. The absence of low frequency resonance indicates that there is no domain wall moment. Thus low frequency dispersion in our case is due to domain wall displacement.

Globus et.al.[15] have given an approximate relation for initial permeability (μ_i) as follows $\mu_i = M_s^2D/K_1^{1/2}$ where D is the average grain size, M_s is saturation magnetization and K_1 is the magnetocrystalline anisotropy constant [16,17]. As per this relation, there exists a linear relationship between the average grain size and permeability. It is also found to be proportional to M_s^2. The diameter of a Bloch wall is related to the grain size as the wall is taken to be fixed to the grain boundary along its circumference. As the size of the grains becomes larger, the domains and their wall motion would increase; causing the permeability to increase. The substitution of zinc in lithium ferrite also enhances densification and reduces the internal stress leading to decreasing magnetic anisotropy. This leads to a decrease in the hindrance given to the movement of domain walls resulting in increased value of μ_i [18,19,20]. Further, the enhanced densification also results in grater grain-to-grain continuity in magnetic flux leading to higher permeability. Hence the observed increase in initial permeability can be understood.

The quality factor (Q) verses frequency plots of all the samples are shown in Fig.3. it can be seen from the figure that the value of Q increases with increasing frequency and attain a maximum value for each sample around 5 to 9 MHz .It may have at higher frequency range. It has been realized that the main loss mechanism at high frequency is mainly due to the eddy current loss [21].

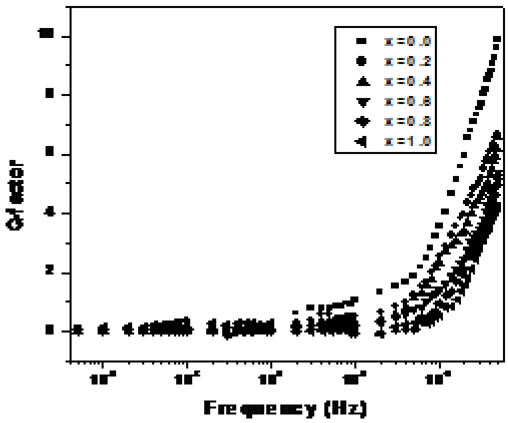

Fig.3: Frequency dependence of Q-factor of $Li_{0.5-x/2}Zn_xFe_{2.5-x/2}O_4$ system sintered at 500°C measured at room temperature

CONCLUSION

The initial permeability (μ_i) at room temperature attains maximum at 20% Zn concentration. This behavior was explained using Globus relation as per which there exists a linear relationship between the grain size and permeability. The variation of initial permeability as a function of frequency showed dispersion at low frequency and becomes nearly constant maintaining a low value at higher frequencies. This behavior is explained on the basis of domain wall movements at different frequencies

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