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Real and Complex Permeability of Ni- Zn-Ti Ferrite

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Abstract

Titanium substituted nickel zinc ferrite was prepared by standard ceramic technique. The prepared ferrites were presintered at750^{0}C and powdering of the formed product was final sintering at 1200^{0}C. Powder x-ray diffraction study shows the formation of single phase spinel structure. The frequency variation of real part of initial permeability (μ') and complex part of initial permeability (μ") were studied by using Hioki LCR-Q meter. The frequency variation of initial permeability clearly indicates the low frequency dispersion which may be attributed to domain wall movements. The compositional variation of permeability of titanium substituted nickel zinc ferrite decreases with increase of titanium substitution.

Keywords: Real permeability, ceramic method, x-ray diffraction

1. INTRODUCTION

Ni-Zn ferrite are useful for making antenna rod, high frequency inductors, transformers, cores and read write heads for high speed digital tape or disc recording. Despite the fact that Ni – Zn ferrites are very good microwave absorbers. The magnetic properties of ferrites depend upon chemical compositions, porosity, grain size, and microstructure. Parvatheeswara et al [1] synthesized Ni-Zn-In-Ti ferrite nanoparticles using classical ceramic method. Also they have studied complex permeability and power loss measurements of Ni-Zn-In-Ti ferrites. They have showed that complex permeability exhibit a stable frequency response up to 5MHz beyond which the real permeability drops and imaginary permeability increases to display a peak around 10 MHz [2].

Maskar et al [3] studied wall permeability of titanium doped Ni-Zn ferrite. With increase of titanium in Ni- Zn ferrite, the permeability decreases which is related to the impedance to the domain wall motion. Khan [4] studied structural and magnetic properties of Ti substituted Ni- Zn ferrite. Odah [5] reported magnetic properties of nickel zinc ferrites. They have showed that the initial permeability has been increased with the increase of zinc content and attributed to the grain growth. The aim of present work is to prepare $Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$ (x = 0.00 to 0.015) ferrites by standard ceramic technique and study their frequency variation of real part of initial permeability (μ') and complex part of initial permeability (μ'') by using Hioki LCR-Q meter.

2. EXPERIMENTAL DETAILS:

The ferrites with the general formula $Ni_{0.55}Zn_{0.45}Ti_x Fe_{2-x}O_4$ (x = 0.00 to 0.015) were prepared by standard ceramic method using AR grade metal oxides of NiO,ZnO,TiO_2 and Fe_2O_3. These oxides were weighed in the required mole proportions and mixed thoroughly in the agate morter in acetone for about two hrs. The mixture of each composition was presintered in platinum crucible at 750^0C to achieve homogenization of end products. The presintered samples were then ground by agate morter in acetone medium and fine powder was collected.The fine powder was used for the preparation of pellet and torroids using hydraulic press machine by applying pressure of 6tones/sq. inch. The pellets and torroids were sintered at 1200^0C in air atmosphere.

X- ray diffraction analysis of prepared powder was carried out by using X-ray powder diffractometer with Cu-Kα radiation in the range 20^0 to 80^0. The grain size of all the ferrite samples were determined from scanning electron microscope. For measurements of magnetic properties the torroids were obtained by wounding a 100 turns of copper wire. The real (μ') and imaginary (μ'') part of initial permeability were measured at various frequencies in the range 42 Hz to 1MHz by using Hioki (3532-50) LCR-Q meter.

3. RESULT AND DISCUSSION:

X-ray powder diffraction method is most economic widely used and well established technique to confirm single phase conformation and extract structural information. The powder method is widely used experimental technique for determination of crystal structure. The typical X-ray diffraction patterns of the $Ni_{0.55}Zn_{0.45}Ti_{0.005}Fe_{1.995}O_4$ are shown in fig. 1.

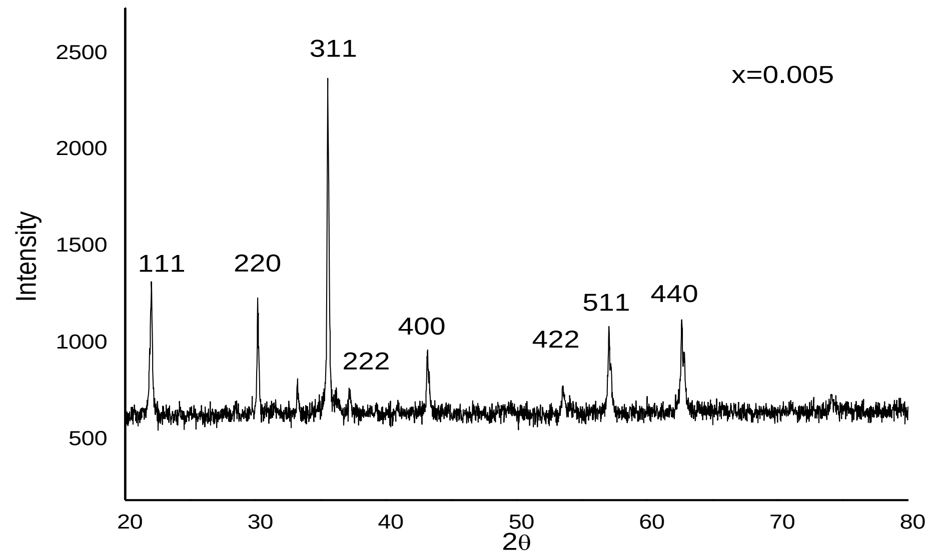

Fig. 1 Typical XRD pattern of $Ni_{0.55}Zn_{0.45}Ti_{0.005}Fe_{1.995}O_4$

The diffraction maxima have been indexed and indices tallied with those expected for spinel structure. The reflections observed are (111), (220), (311), (222), (400), (422), (511), (440); these correspond to allowed value of reflection for cubic spinel structure. The absence of extra peaks in the XRD pattern confirms the single phase formation of samples.

The understanding and control of microstructure in polycrystalline material is important technologically. Since some properties such as mechanical strength, electrical conductivity, magnetic susceptibility, optical transmission etc. are strong functions of the average grain size, porosity and range of grain size. Thus microstructure is in turn a direct consequence of the grain growth mechanisms. For polycrystalline ferrites the microstructure means the porosity, grain structure and phase detectable by micro-graphic analysis. We have computed the grain size and determined spatial features of samples. For finding the average grain size, SEM-micrographs of all samples were taken using a well-polished pellet surface. Typical SEM photographs of $Ni_{0.55}\,Zn_{0.45}\,Ti_{0.005}Fe_{1.995}O_4$ is as shown in fig. 2.

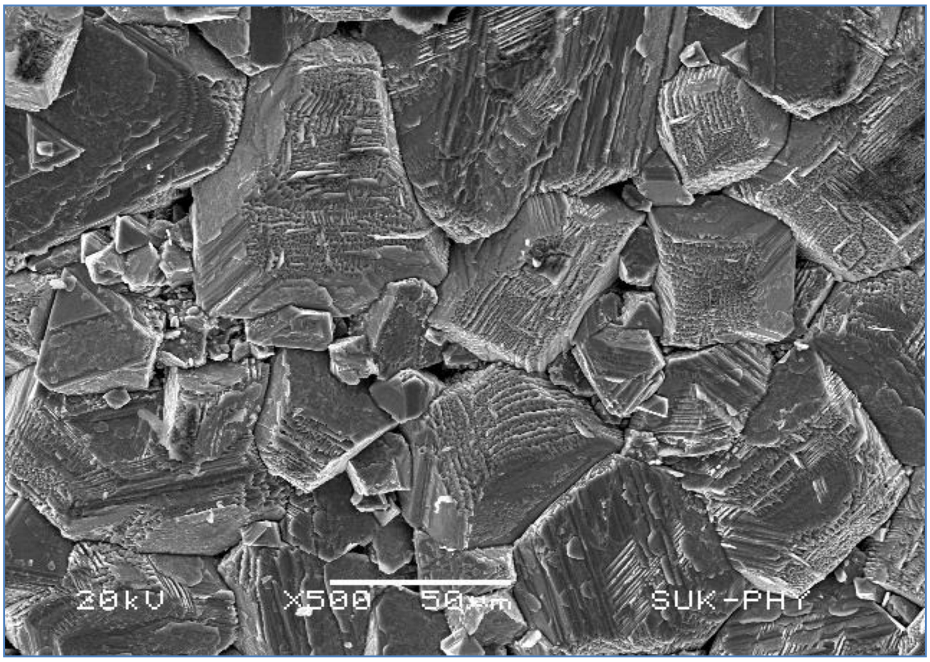

Fig. 2 Typical microstructure pattern of $Ni_{0.55}Zn_{0.45}Ti_{0.005}Fe_{1.995}O_4$

From SEM photographs the grain size is calculated from line intercept method [6] is as follows i) Drawing a diagonal on the photograph, ii) Measuring the maximum unidirectional grain size in the vertical direction against diagonal, iii)Averaging the maximum unidirectional grain size.. It is seen that the grains are closely packed with very small intergranular porosity. The average grain size (d) of all samples is reported in table 1.

Table 1. The data on real part of initial permeability (µ'), complex part of initial permeability (µ'') and L.F for $Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$(x= 0.00 to 0.015)

x	d µm	µ'		µ''		LF*10^{-3}	
		10kHz	1MHz	10kHz	1MHz	10kHz	1MHz
0.0	42	72.13	68.98	10.61	0.65	2.02	0.14
0.005	39	63.14	62.88	10.47	0.81	2.59	0.21
0.010	38	39.50	39.84	7.90	0.42	4.23	0.19
0.015	52	34.07	34.18	6.70	0.29	5.99	0.33

Initial permeability is an extrinsic magnetic property is defined as the derivative of the induction B with respect to the internal field H in the demagnetized state. Brito etal [7] have studied complex magnetic permeability of Ni-Zn ferrite in frequency range 100 kHz – 100 MHz using an impedance analyzer. Initial permeability is dependent on the conditions of preparation through grain size and porosity. Increasing the temperature of the sintering the porosity decreases i.e. the density of the sample and hence the initial permeability increases. It has also found that the permeability increases in proportion to the grain size if the grains are pore free and the crystallites have a homogeneous shape. As the grain size is increased it is expected that domain walls can move easily and that the initial permeability will be large.

Initial permeability (μ_i) depends on method of preparation, porosity within the material and grain size. Rado [8] and others [9 - 10] observed high frequency dispersion and absorption in initial permeability and attributed it to rotational resonance in the combined anisotropy and demagnetizing fields. They have considered the lower frequency dispersion region to be due to domain wall displacements. Srivastava etal [11] studied Mossbauer and magnetic properties of Ti^{4+} substituted Ni-Zn ferrites. They have observed nonlinear behavior of magnetization with the increase of Ti^{4+} ions is explained by the presence of canted spin structure. Pippin etal [12] measured initial permeability of a series of Ni-Co ferrites containing a small amount of Mn as a function of sample density. A rapid increase of initial permeability was observed at high densities. They have suggested that wall motion as well as domain rotations contribute to initial permeability. Initial permeability is one of the properties which can be very dependent upon the method of manufacture. Its magnitude often varies markedly with firing temperature. The occurrence of dispersion absorption at frequencies in the region of 1 MHz was first established experimentally by Snoek [13] who attributed the phenomena to spin resonance in the internal anisotropy field.

The permeability as a function of frequency at room temperature was measured over the frequency range from 100 Hz to 1 MHz for the $Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$(x=0.0 to 0.015). The initial permeability was calculated from the low field inductance measurements with torroidal core by using the formula $L = 0.0046\mu_i N^2 h \log (d_2/d_1)$ where, μ_i is the initial permeability of the core, L is the inductance, d_2 is the outer diameter, d_1 is the inner diameter, and h is the height of the core in inches. The variation of real (μ') and imaginary part (μ'') of initial permeability with frequency for the composition $Ni_{0.55}\ Zn_{0.45}Ti_x\ Fe_{2-x}O_4$(x=0.0 to 0.015) are shown in figure 3 and 4. From Fig. 3 and 4, it is seen that real part of initial permeability (μ') remains almost constant as frequency increases whereas imaginary part of initial permeability (μ'') gradually decreases up to 100KHz and above these frequencies it is almost remained constant. Similar frequency variation of real (μ') and imaginary (μ'') part of permeability was reported by Chaudhari etal [14] for Ni-Zn ferrites. From fig.4, it is concluded that the low frequency dispersion which may be attributed to the domain wall movement. In all the samples it is seen that with increase of titanium the permeability decreases is as shown in table 1.The major contribution to initial permeability in titanium substituted nickel zinc ferrite is due to wall permeability.

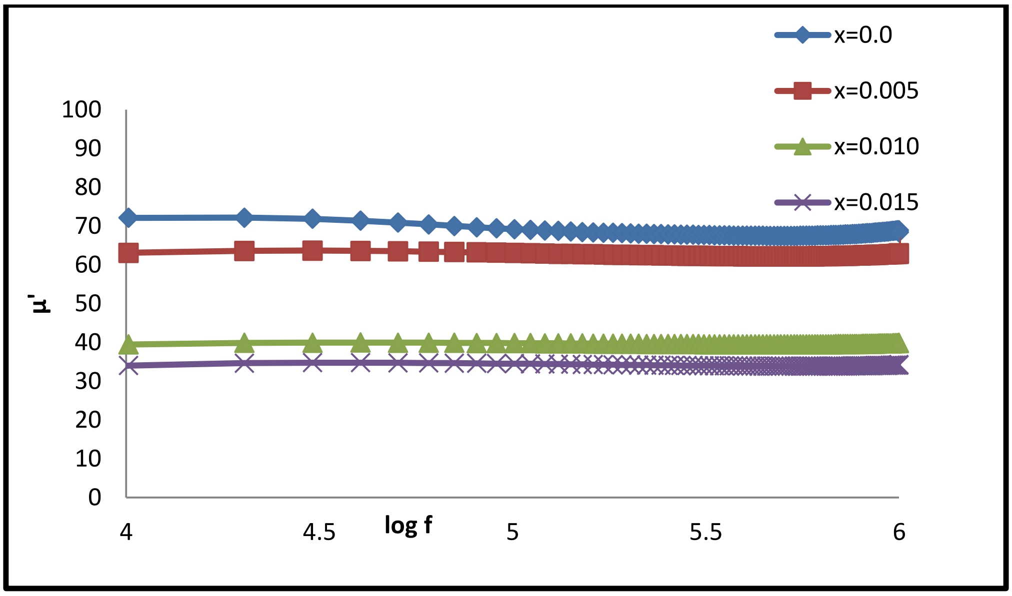

Fig. 3 Frequency variation ofμ' of $Ni_{0.55}$ $Zn_{0.45}$ Ti_x $Fe_{2-x}O_4$(x= 0.00 to 0.015)

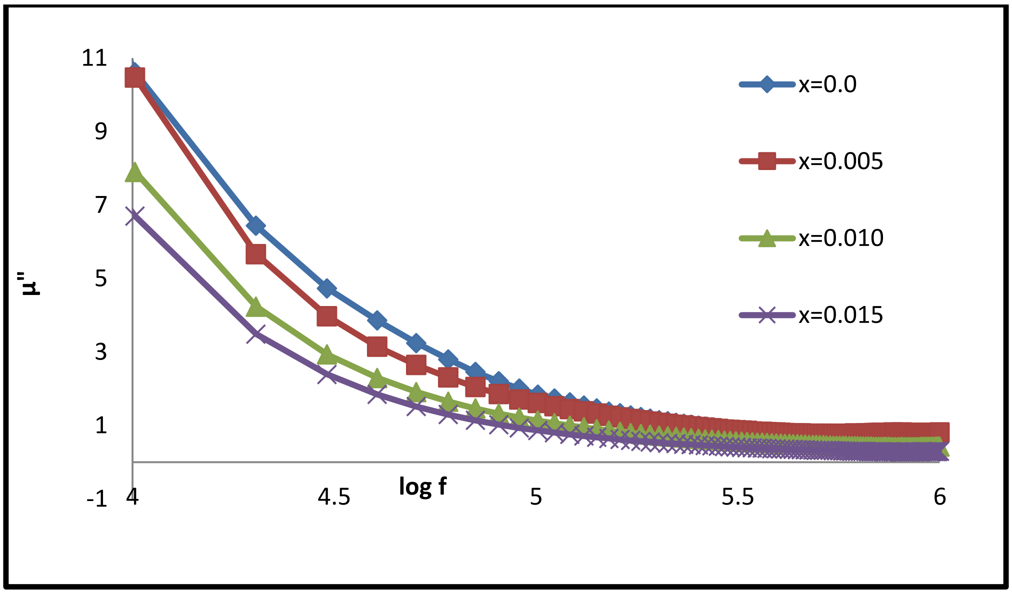

Fig. 4 Frequency variation ofμ" of $Ni_{0.55}$ $Zn_{0.45}$ Ti_x Fe_{2-x} O_4(x= 0.00 to 0.015)

Loss tangent is ratio of real part of permeability to imaginary part of the permeability. For a good ferrite this loss factor parameter (LF) should be as low as possible. In table1 data on LF for compositions $Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$(x=0.00 to 0.015) are given. It is seen that the loss factor goes on increasing with the addition of titanium in Ni – Zn ferrite. Fig. 5 shows dispersions of Loss Factor for the compositions $Ni_{0.55}$ $Zn_{0.45}Ti_x$ $Fe_{2-x}O_4$(x=0.00 to 0.015). It is seen that the Loss factor initially suddenly decreases up to the frequency 100 KHz and above these frequencies the loss factor almost remains constant.

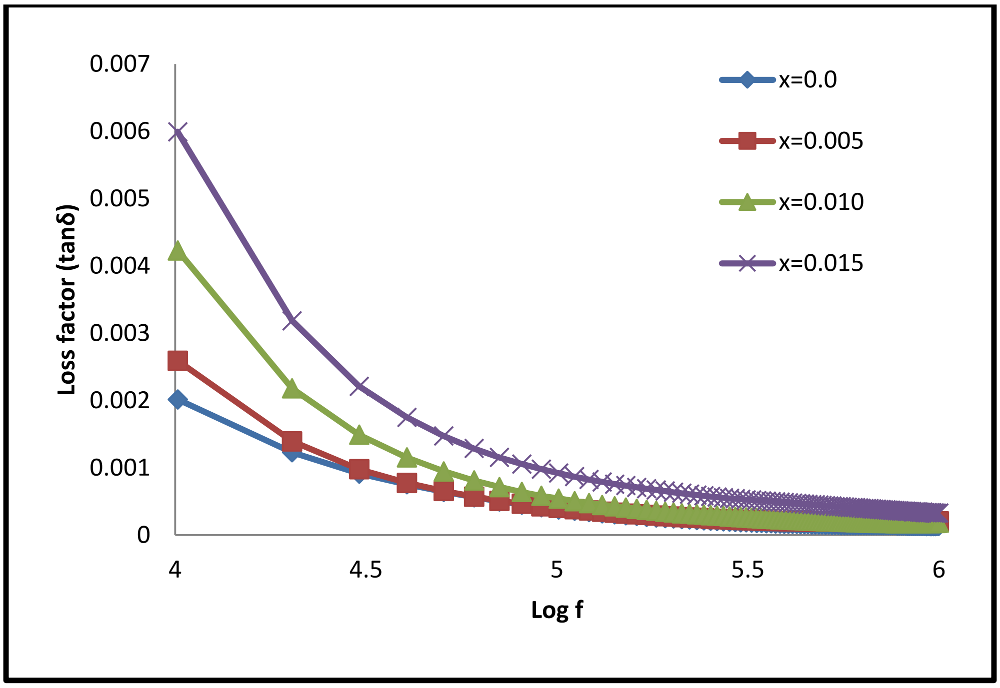

Fig.5 Frequency variation of loss factor of $Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$(x= 0.00 to 0.015)

4. CONCLUSIONS

$Ni_{0.55}Zn_{0.45}Ti_xFe_{2-x}O_4$(x= 0.00 to 0.015) ferrites successfully prepared by standard ceramic technique. The prepared powder was presintered in air at 750^0C for 8hr and powdering of the formed product was final sintering at 1200^0C. XRD study shows the formation of single phase cubic spinel structure. The compositional variation of initial permeability of titanium substituted Nickel Zinc ferrite decreases with increase of titanium substitution. The decrease of initial permeability is due to the domain wall motion. The frequency variation of initial permeability clearly indicates the low frequency dispersion which may be attributed to domain wall movements. Loss factor initially suddenly decreases up to the frequency 100 KHz and above these frequencies it is almost remains constant.

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