RESEARCH ARTICLE   OPEN ACCESS

Barium-Cobalt-Zirconium Hexagonal Ferrites Permeability Studies.

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ABSTRACT
Barium M-type hexagonal ferrites doped with Co^{2+} and Zr^{4+} having the compositional formula $BaCo_xZr_xFe_{12-2x}O_{19}$ where x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 were prepared by double sintering ceramic method. The crystallographic properties, grain size and initial permeability of these ferrites have been investigated by XRD, SEM, and FTIR and found to initially increases up to x=0.6 and decrease after that. A similar variation of grain sizes has been found concerning Co-Zr composition. Consequently, the interactions of the magnetic vector with the electromagnetic signal and the change in the magnetic vector's direction due to substitution will determine the magnetic characteristics. When the frequency was increased to a particular amount, it was shown that the real (μ') part of the permeability remained virtually constant before starting to decline at higher frequencies. The imaginary (μ'') part of the permeability steadily grew with frequency and reached its peak at a particular frequency, where μ' rapidly declines. Natural resonance is the term for this quality. 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 gains becomes larger the domains and their wall motion would increase, causing the permeability to increase.

I. INTRODUCTION

  The $BaFe_{12}O_{19}$ (BaM) hexagonal ferrites have been considered as promising materials for applications in high-density magnetic recording and microwave devices [1,2]. The magnetic properties of these materials are determined by chemical compositions, microstructure and process mechanism [3]. Different cationic replacements for Fe^{3+} ions are investigated in order to better enhance the inherent magnetic characteristics of BaM. When other pairings, such as Zn -Ti, Co-Sn, Mn-Sn, Co-Ti, etc., are used to replace Fe^{3+} in M-type barium ferrite, it was discovered that the initial permeability initially increases and then decreases. In the current study, the initial permeability of Ba hexagonal ferrites with Co-Zr substitutions is examined as a function of composition and frequency. In this publication, the findings of such a study are given.

II. EXPERIMENTAL DETAILS
2.1 SAMPLE PREPARATION
  BaM hexagonal ferrites codoped with Co^{2+} and Zr^{4+} (Ba-Co-Zr) having the compositional formula $BaCo_xZr_xFe_{12-2x}O_{19.}$ By using the conventional double sintering method, (where x = 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0) were prepared. The samples were pre-sintered for 10 hours at 1000 ºC, and the final sintering was performed for 15 hours at 1250 ºC in an environment of air. The specifics of sample preparation were provided elsewhere [4].
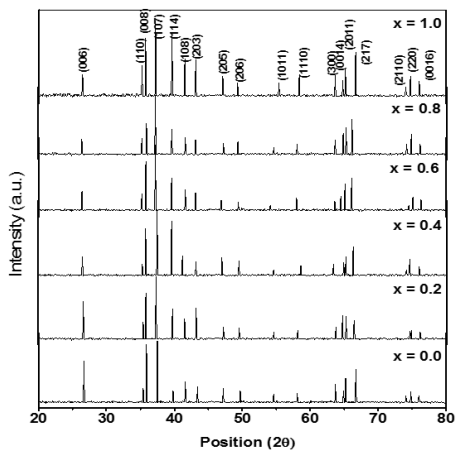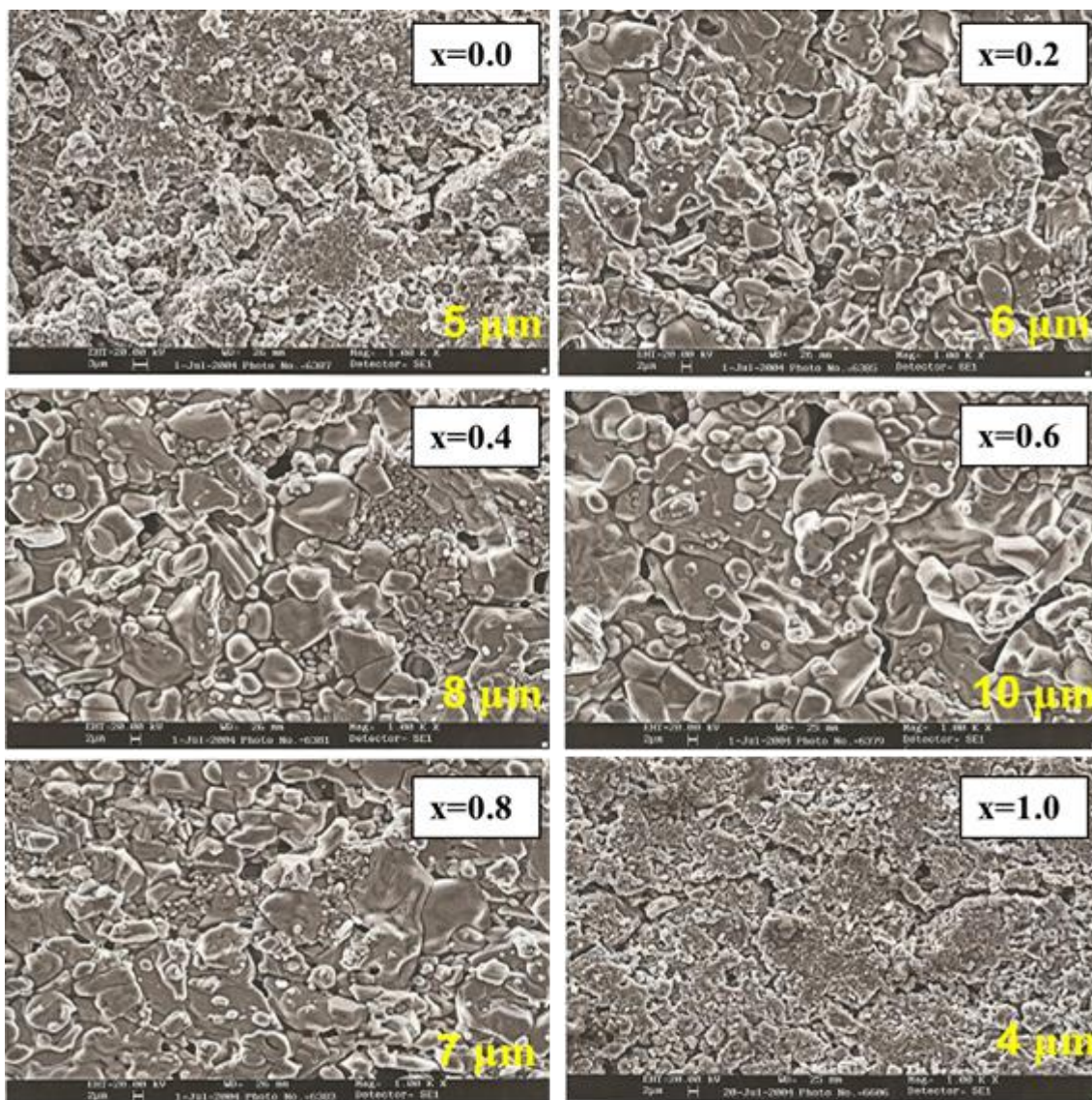
Fig. 1: X-ray diffraction patterns of BaCo$_x$Zr$_x$Fe$_{12-2x}$O$_{19}$ hexaferrite samples (with x = 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0).

Figs. 2.: SEM micrographs of BaCo$_x$Zr$_x$Fe$_{12-2x}$O$_{19}$ hexagonal ferrite samples

2.2. STRUCTURAL STUDIES

Utilizing Co K radiation with = 1.7902 A0, X-ray diffraction patterns for all of the Ba-Co-Zr hexagonal ferrites under investigation have been produced. The X-ray diffraction pattern for hexagonal Ba-Co-Zr ferrites is shown in Fig. 1. The M-type hexa ferrite phase structure is present in a single phase, according to the diffraction patterns. The mixed ferrites' lattice properties, which were determined via d-spacing, are shown in Table 1. As observed in the table, the values of the lattice parameters, a and c, rise steadily as Co and Zr concentrations rise. This is to be expected given that the Co^{2+} ions' ionic radius is 0.82 A° and the Zr^{4+} ions' is 0.84 A°, both of which are greater than the latter's value of 0.64 A° for the Fe^{3+} ions. Fig.3 shows that FTIR studies of BaM hexa ferrites are formed at 435-578cm^{-1}
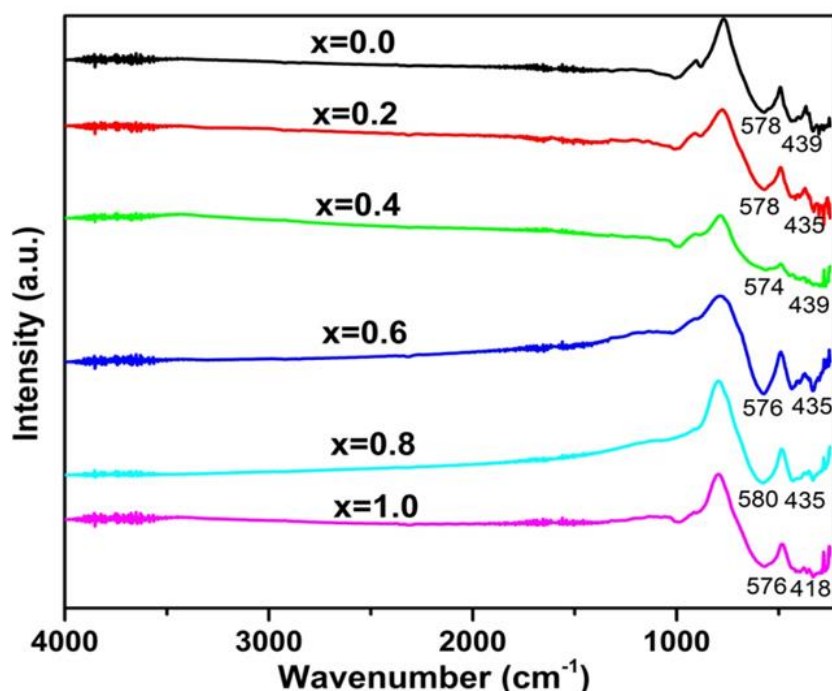

Figs3.FTIR studies of BaM hexagonal ferrites

Table 1: Lattice parameters, X-ray density and grain size of Ba-Co-Zr hexagonal ferrites

Sl. No.	Ferrite composition	a(A^0)	c (A^0)	Volume (Å^3)	X-ray density (g/cm^3)	Grain size (μm)
1.	$BaFe_{12}O_{19}$	5.890	23.208	697.266	5.271	5
2.	$BaCo_{0.2}Zr_{0.2}Fe_{11.6}O_{19}$	5.891	23.213	697.654	5.285	6
3.	$BaCo_{0.4}Zr_{0.4}Fe_{11.2}O_{19}$	5.893	23.224	698.458	5.322	8
4.	$BaCo_{0.6}Zr_{0.6}Fe_{10.8}O_{19}$	5.897	23.243	699.979	5.336	10
5.	$BaCo_{0.8}Zr_{0.8}Fe_{10.4}O_{19}$	5.903	23.267	702.128	5.348	7
6.	$BaCo_{1.0}Zr_{1.0}Fe_{10}O_{19}$	5.905	23.271	702.725	5.426	4

The SEM images of Ba-Co-Zr hexa ferrites are shown in Fig. 2. The micrographs show that the shape of the particles is identical and that they are primarily agglomerated. The samples' average grain size, determined using the line intercept method from SEM micrographs, ranges from 4 to 10 m. The average grain size for all samples increases with an increase in Co-Zr doping up to x=0.6, then grain size decreases with an increase in x.

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www.ijera.com
ISSN: 2248-9622, Vol. 13, Issue 7, July 2023, pp 76-81

Table **2**: Data of magnetic properties of Co-Zr doped $BaFe_{12}O_{19}$ hexagonal ferrites.

S.No	Composition (x%)	μ'	μ''	Resonance frequency (f_r)
1	0.0	12.5	2	1.3
2	0.2	14.8	2.4	1.31
3	0.4	17.2	2.8	1.32
4	0.6	18.5	3.3	1.35
5	0.8	15.5	3.1	1.36
6	1.0	13.4	2.9	1.4

III. Results and Discussions

Frequency dependence of real (μ') and imaginary (μ'') part of permeability in the range of 1 MHz - 1.8 GHz

Figures 4 and 5 depict the real (μ') and imaginary (μ'') parts of permeability in the 1 MHz– 1.8 GHz frequency range. The magnetic characteristics will depend on how the magnetic vector interacts with the electromagnetic signal and how substitution changes the magnetic vector's direction. The figures showed that the real (μ!) portion of permeability stayed nearly constant until the frequency was increased.
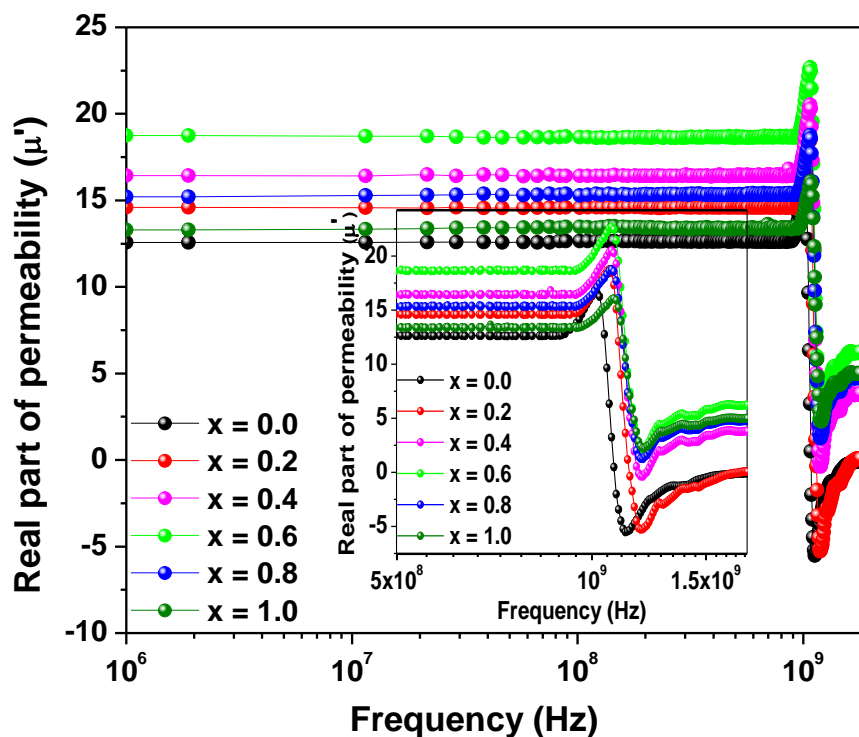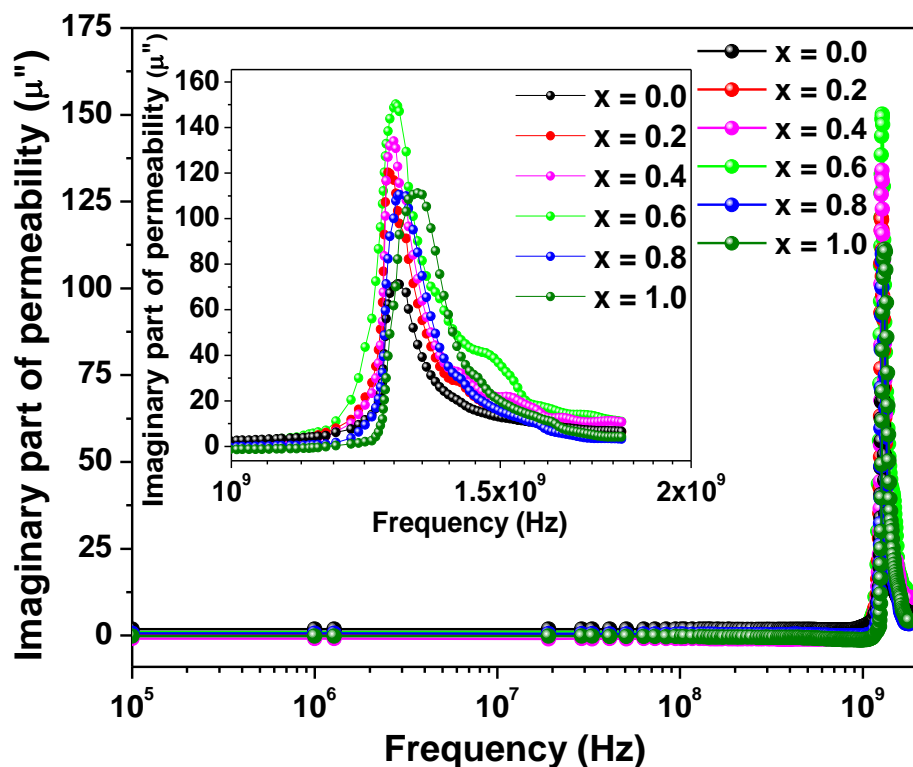

Fig 4.Frequency dependence of real (μ') part of permeability for Co-Zr doped $BaFe_{12}O_{19}$.

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www.ijera.com
ISSN: 2248-9622, Vol. 13, Issue 7, July 2023, pp 76-81

Figs 5 Frequency dependence of imaginary (μ") part of permeability for Co-Zr doped BaFe$_{12}$O$_{19}$.

to a certain value and then began to decrease at higher frequency. The imaginary (μ'') part of permeability gradually increased with the frequency and took a maximum at a certain frequency, where the μ' rapidly decreases. This feature is well known as natural resonance. The real (μ') and imaginary (μ') components of permeability at 1MHz are represented by the numbers in Table 2. The figure shows that the relaxation frequency is more than 1 GHz for all samples and is due to domain wall motion. It is well known that the permeability of polycrystalline ferrites may be modelled as a superposition of two separate magnetising mechanisms, namely spin rotation and domain wall motion [5]. According to Globus's hypothesis [6], the domain wall motion was influenced by grain size and might be improved with a larger grain size. It becomes clear from comparing the magnetic characteristics with the microstructures (Fig. 5) that the increase in initial permeability is directly connected to the densification and grain size of sintered ferrites. When ferrites are made up of tiny. The relative higher volume percentage of grain boundary and defects in ferrites, where domain wall pinning may happen, would reduce the impact of domain wall motion. Additionally, due to the presence of a spin canting layer [7], small grains would cause a drop in magnetization, which might

increase the effective magnetic anisotropy field. In addition to reducing the demagnetizing field due to holes, greater ferrites density also increases the spin rotational contribution, which increases permeability [8]. Additionally, as the grain size was increased by x up to 0.6, multidomain grains started to emerge. The domain wall motion in these grains may cause higher permeability values [9]. Given that they are both proportional to one another, grain size and permeability declined when x was further increased. From Fig. 5, it is evident that frequency dependent exhibits a similar behavior. The maximum of μ" for a domain wall relaxation is related to $\dfrac{M_s D}{\sqrt{K}}$, where D is the average grain size and K is the anisotropy coefficient, according to the Globus model created for polycrystalline materials [6]. Therefore, there is good consistency between the rise of μ" with the replacing ratio x at this resonance frequency and the fall of the uniaxial magneto crystalline anisotropy. For compositions with x = 0.6 and higher resonance frequencies, the largest magnetic losses are seen at x = 1.0.

IV. CONCLUSIONS

The relationship between the real (μ') and imaginary (μ'') parts of permeability measured between 1 MHz and 1.8 GHz. At 60% Co-Zr concentration, the permeability at room temperature reaches its maximum. The Globus relation, which states that there is a linear relationship between grain size and permeability, was used to explain this behavior. Initial permeability varied as a function of frequency, remaining constant up to 1 GHz before drastically changing at 1.5 GHz. On the basis of domain wall moments at various frequencies, this behavior is explicated.

ACKNOWLEDGMENTS

REFERENCES

[1]. Z.Simsa, S. Lego, R. Gerber, E. Pollert, J. Magn. Magn. Mater. 140-144(1995)2103.

[2]. G.Mendoza-Suarez, J.C. Corral Hiracuz, M.E. Contreras-Garica, H.Jucarez-Medina, J. . Magn. Magn. Mater. 234(2001)73.

[3]. Smit.J, Wijn. H.P.J, Ferrites,Wiley, New York,1965.

[4]. Ch.Venkateshwarlu, P.Vijaya Bhasker Reddy, Ch.Gopal Reddy.J. Eng. Research and Application

[5]. J.P. Bouchaud, P.G. Zerah, J.Appl.Phys., 67 (1990) 5512.

[6]. A.Globus, J.Phys., France 38 (1977) C1.

[7]. X. Batlle, X. Obradors, M. Medarde, J. Rodriuez Carvajal, M. Pernet, M. Vallet-Regi, J.Magn.Magn.Mater., 124 (1993) 228.

[8]. J.J. Shrotri, S.D. Kulkarni, C.E. Deshpande, S.K.Date, Mater. Chem. Phys., 59 (1999) 1.

[9]. T. Nakamura, J.Magn.Magn. Mater., 168 (1997) 265.