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Development of rare-earth doped nano-ferrites for Industry applications.

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ABSTRACT:
Synthesis of Magnesium-Zinc Erbium nano-ferrites having the chemical formula $Mg_{0.8}Zn_{0.2}Er_xFe_{2-x}O_4$ (Where x = 000, 0.005, 0.010, 0.015, 0.020, and 0.025) have been prepared by citrate-gel auto-combustion technique. Characterization of prepared powders was done by using X-Ray Diffraction (XRD). XRD pattern of Mg-Zn-Er nano particles confirm single phase cubic spinal structure. The structural variables such are lattice constant (a), and crystallite size (D) were computed from XRD patterns. The observed results can be explained on the basis of composition. Based on the small values of crystal size of nano-ferrites can be used in electronic industry for microwave devices such are isolators, Phase shifters and gyrators.

Key Words: Nano-ferrites:; Nano-Particles: Nano-Magnetic Materials ; XRD; Crystal Size

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I. INTRODUCTION:

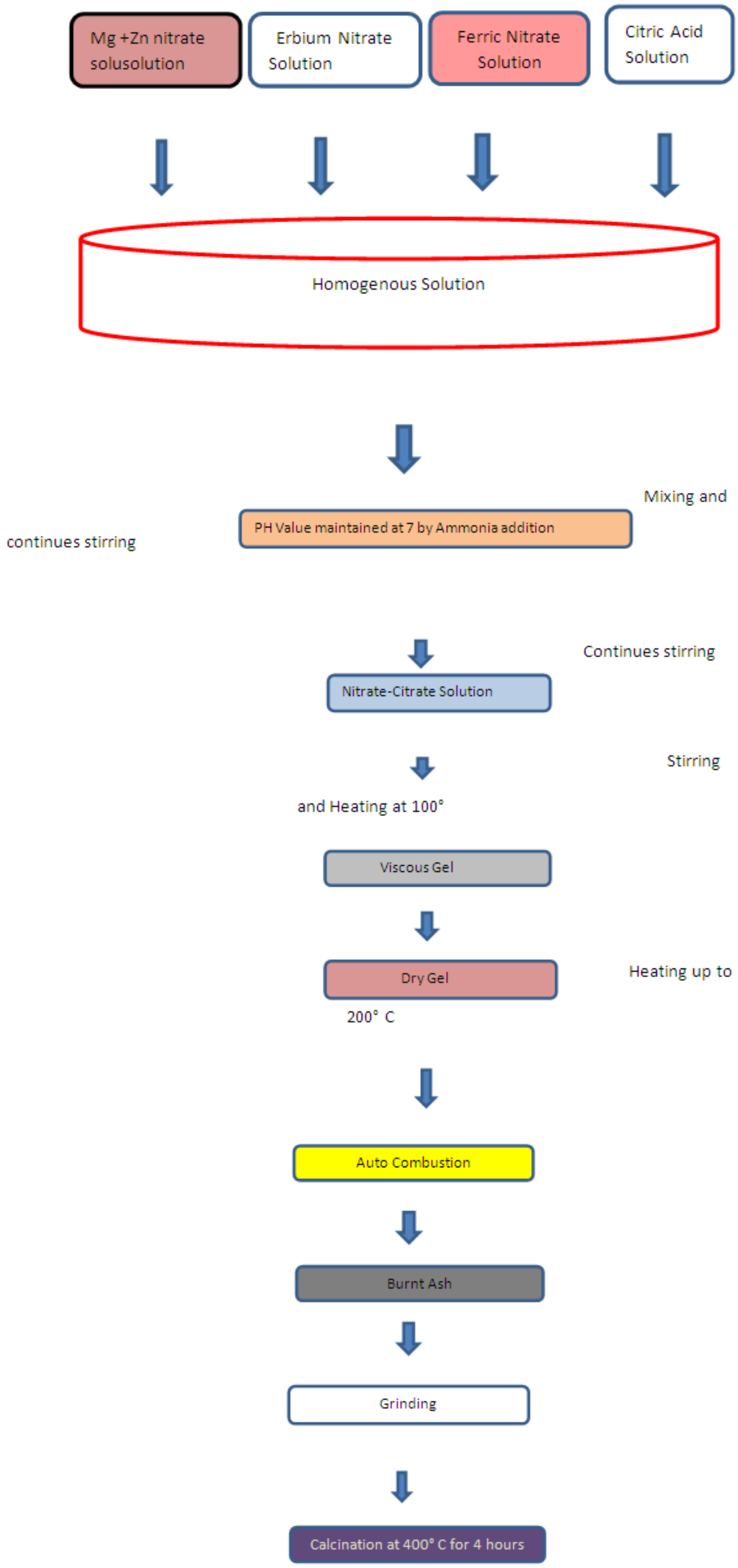
Vigorous research has been accomplished on the fundamental, technological and potential applications of nano-ferrites. Nanomaterials of spinel ferrite have several applications in technology that include in potential applications and high density magnetic information storage devices[1], ferrofluid technology[2], magneto caloric refrigeration[3], magnetic diagnostics and drug delivery[4], magnetic recording media, magnetostriction[5], magnetic sensors, microwave devices and electrical generators etc. Ferrites are also used for catalyst and electronic devices. Ferrites are insulators exhibiting various magnetic and electric properties such as low electrical conductivity, dielectric loss, magnetic loss, relative loss factor, moderate dielectric constant, high initial permeability and saturation magnetization. Doping and thermal changes during synthesis and processing of cobalt-ferrites alter the distribution of metal ions influencing their structure and magnetic properties [6]. As per the literature net magnetic moment of lanthanide series elements/ions depend on f-orbital electron number in which Er^{+3} is of small size (89 pm) with large magnetic moment (7 μB) [7]. Low eddy current and high resistivity makes ferrites better choice than metals [8]. The present work reports the preparation and characterization of erbium doped magnesium Zinc nano- ferrites were prepared by Citrate-gel auto combustion.

II. EXPERIMENTAL PROCEDURE:

2.1. Materials and Methods

Synthesis of Magnesium-Zinc -Erbium nano-ferrites with citrate-gel auto combustion technique have been given as flow Chart in Fig.1.

Fig.1.Flow chart of Magnesium-Zinc-Cobalt-Erbium nano-Ferrite



The starting materials Magnesium Nitrate (Mg (NO3)2·6H2O), Zinc nitrate (Zn Mg (NO3)2·6H2O ,Ferric nitrate (Fe (NO3)3·9H2O), Erbium Nitrate (Er (NO3).6H2O), Citric Acid (C6H8O7·H2O) and Ammonia solution (NH3) of 99.9% purity after weighing as per stoichiometric ratio. Later liquification of metal nitrates in distilled water was done and the mixture was stirred at 300 rpm for one hour to obtain a clear homogeneous solution. Next citric acid in aqueous form and metal nitrate was maintained in 1:3 ratio for all samples. Now, ammonia solution was added drop by drop to maintain Ph=7. This solution on stirring was heated at 100 °C temperature for ten to twelve hours to form a viscous gel. The water contained in the mixture gets evaporated slowly to form dry gel generating internal combustion to form a black colored desired sample. This sample was manually grinded and subjected to calcinations at 500°C in furnace for 4 hours. Later these samples in pellet or powder form undergo characterizations with XRD (Bruker, Cu Kα, λ=0.15406nm).

3.1. Analysis of XRD:

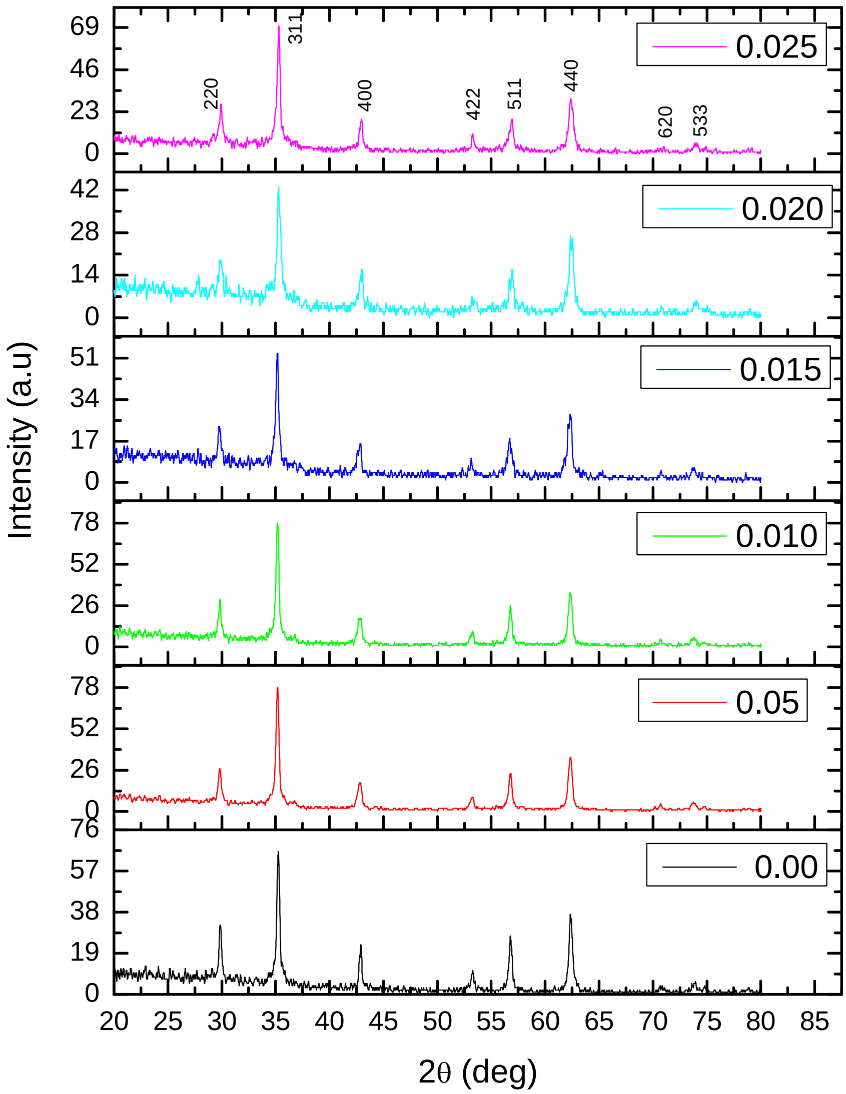


Fig.2.XRD Patterns of Mg-Zn-Er nano-ferrites.

Figure.2 depicts the XRD pattern for Mg-Zn--Er nano-ferrites. From XRD pattern, nano-ferrites depicts the single-phase cubic spinel structure without any impurity peak. The values of 'a' were calculated from the equation

$a= d *(h^2+k^2+l^2)^{1/2}$

where cell constant is given by 'a', inter planer spacing calculated from Bragg's equation ($2\,d\sin\theta = n\lambda$) is denoted by 'd' and miller indices are done by '*h,k,l'*.

Scherrer formula was used to calculate the crystallite size given by

$$L=\frac{0.9*\lambda}{\beta cos\theta} \quad (2)$$

where 'λ' = wavelength of Xray,'β' = peak width at half maximum height and constant 'K' = 0.9. The data related to intense peak (311) was used in estimating size (L). The results indicated reduction in size of crystallite from 20.84nm to 14.40nm (for x=0.0 to 0.030).

Table1: Lattice constant and Crystal Size for Mg-Zn-Er Nano-ferrites

Composition	Lattice Constant Å	Crystal Size (nm)
$\mathbf{MgFe_2O_4}$	**8.449**	**17.84**
$Mg_{0.8}\,Zn_{0.2}\mathbf{Er_{0.005}\,Fe_{1.995}\,O_4}$	**8.465**	**17.84**
$Mg_{0.8}\,Zn_{0.2}\mathbf{Er_{0.010}\,Fe_{1.990}\,O_4}$	**8.465**	**17.84**
$Mg_{0.8}\,Zn_{0.2}\mathbf{Er_{0.015}\,Fe_{1.985}\,O_4}$	**8.468**	**26.74**
$Mg_{0.8}\,Zn_{0.2}\mathbf{Er_{0.020}\,Fe_{1.980}\,O_4}$	**8.432**	**26.77**
$Mg_{0.8}\,Zn_{0.2}\mathbf{Er_{0.025}\,Fe_{1.975}\,O_4}$	**8.435**	**26.76**

The computed values of lattice parameter and crystal size have been in given Table.1.

It can be seen from the table that the values of lattice parameter varies from 8.435A to 8.465 A increases with the increase of erbitum content in Mg-Zn nano-ferrites. The small values of nano-ferrites can be used in electronic industry for microwave devices such are isolators, Phase shifters and gyrators.The increase in lattice parameter is due to replacement of 8 small $Mg\text{-}Zn^{2+}$ and Fe^{3+} ions with big Er^{3+} ions. Huge difference in radii of these three ions induce strain during formation of lattice and diffusion processes. Requirement of more energy in absorbing RE^{3+} ions with more radii while replacing Fe^{3+} to form RE-O bond decreases crystallization energy and leads to particles of small size. Earlier literature reported similar results on RE-ion substituted cobalt ferrite [9-14]. Therefore, XRD results are liable for expansion of unit cell due to larger Er^{3+} ion doping in Mg-Zn nano-ferrites. Similar behavior of nano-ferrites with rare earth ions have been observed in various nano-ferrite systems [15-19].

III. CONCLUSIONS:

Synthesis and characterization of Mg-Zn-Er nano- ferrites have been successful prepared by citrate-gel auto combustion method. Significant induced effect of Erbium was observed on crystal structure and morphology, The values of crystal size varies from

17,84 nm to 26.76 nm and indicates the nano-nature of ferrites. Based on the small values of crystal size of nano-ferrites can be used in electronic industry for microwave devices such are isolators, Phase shifters and gyrators.

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