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Research Paper

Investigation of the Structural Properties of Chromium-Zinc Spinel Ferrite by Sol-Gel Technique

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Abstract—The research on ferrites is fast moving to their exponentially growing applications in magnetic shielding, magnetic biosensors, magnetic recording devices, information storage, mobile communication, electronic devices, gyromagnetic device, medical device, transformers, pollution control, catalysis and pigments. Zinc-chromium ferrites doped aluminium with chemical formula $Cr_{0.7x}Zn_{0.3}Fe_{2\text{-}x}Al_xO_4$ ($x = 0.0 \leq x \leq 0.5$) were successfully prepared by sol-gel technique. The aim of this research was to investigate the effect of Al^{3+} ion substitution on the structural properties of Cr-Zn ferrite. The structural characterizations of the samples were analyzed by using X-Ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). The single phase spinel cubic structure of all the prepared samples were tested by XRD and FTIR. The influence of Al^{3+} substitutions on the structural properties of the prepared nanoferrite were studied. The crystal size found by XRD decreased from 26.57nm to 14.62nm and the lattice parameters "a" also decreased from 8.4196 to 8.3689Å with increasing the Al^{3+} content. Formation of spinel structure is affirmed by using FTIR and the spectra of the samples displayed two strong absorption bands (υ1 and υ2) in the range of 600-400cm^{-1} and are found to shift gradually toward the higher frequency side with substitution of Al^{3+}, which have been attributed to the decrease in the lattice constant. It is expected this research work will provide important contribution to the production of electronic devices and transformers.

Keywords— Sol-gel technique; Nanoparticles; Spinel ferrite; XRD; FTIR; Structural properties.

1. Introduction

Magnetic materials such as garnet ferrites, spinel ferrites and hexaferrites have attracted the attention of scientist due to their excellent magnetic properties which is vital for various magnetic storage applications, high frequency application as well as microwave shielding and absorption [1]. In addition, spinel ferrites have more potential for possible technological application because of their soft magnetic nature, good dielectric properties and low temperature of synthesis [2].

The 32 large oxygen ions form a face centered cubic (FCC) lattice in which two kinds of interstitial sites are present (tetrahedral and octahedral). The chemical formula of spinel ferrites is generally expressed as AB_2O_4, where A represents a divalent metal ion (like, Ni^{2+}, Mn^{2+}, Mg^{2+}, Co^{2+}, Zn^{2+}, $Cu^{2+}etc$) and B represents trivalent metal ions such as aluminum, iron or chromium [3]. In most ferrite materials, the substituent's play an important role in determining the variation of the physical properties, the magnetic and electric transport properties. The substitution can be divided into the following types: direct replacement of Fe^{+3} on tetrahedral (A) or octahedral (B) sub lattice by the substituent ion, with consequential redistribution of Fe^{+3} ions between $A-$ $and\ B-$ sub lattices which lead to change of ferromagnetic spin structure. The extent of iron redistribution depends on the specific nature of the substituting ion [4]. In this study, $Cr_{0.7}Zn_{0.3}Fe_{2-x}.Al_xO_4$ferrite materials will be synthesized by sol-gel method. The structural, optical and dielectric properties will be investigated using different characterization techniques.

2. Related work

Muhammad *et al.,* (2017) synthesized spinel ferrites with the composition $MnPr_yFe_{2\text{-}y}O_4(y = 0.0, 0.025, 0.05, 0.075, 0.10)$ by the sol-gel technique followed by auto-combustion. The dielectric and electrical properties of praseodymium substituted $MnFe_2O_4$ferrite as a function of frequency (1 MHz to 3 GHz) at room temperature have been studied. The dielectric constant, complex dielectric constant and loss tangent of these samples decreased with an increase in the praseodymium concentration, following the Maxwell–Wagner two-layer model. Complex impedance analysis has been used

to separate the role of grains and the grain boundary's resistance in $MnPr_yFe_{2-y}O_4$ ($y = 0.00, 0.025, 0.05, 0.075, 0.10$). The values of the activation energy, calculated from the direct current conductivity, increase with the substitution of praseodymium, which suggests that the conduction mechanism in the present ferrite system is due to polar on hopping [5].

Simi *et al.,* (2019) synthesized Zinc-doped manganese spinel ferrite nanocrystals with chemical formula $Mn_{0.75}Zn_{0.25}Fe_2O_4$ by the chemical co-precipitation method. The structural properties of the synthesized nanoparticles were studied by X-ray diffraction analysis (XRD), whereas morphological analysis was performed high-resolution transmission electron microscopy (HR-TEM) and scanning electron microscopy. The XRD study confirmed the formation of single-phase spinel face-centered cubic nanocrystals with an average size of approximately 19nm. HR-TEM analysis gave an average particle size of approximately 15nm, with the nanocrystals being almost spherical. The selected-area electron diffraction pattern obtained in the HR-TEM study clearly indicated the polycrystalline nature of the nanocrystals. The Fourier transform infrared spectrum confirmed the formation of a pure spinel ferrite structure.

Williamson-Hall plot analysis, using the XRD data, was used to obtain information on the different elastic properties, such as residual strain, stress, and energy density, considering the uniform deformation model, the uniform stress deformation model, and the uniform deformation energy density model. The results were compared with the results obtained by the size-strain plot method.

The XRD data were used to determine the lattice parameter, which was found to be 0.81nm. With use of the calculated lattice parameter, the ionic radii, bond lengths of the tetrahedral and octahedral sites, and hopping lengths of the spinel ferrite nanocrystals were calculated. A magnetic study using a vibrating-sample magnetometer showed that the nanocrystal sample is superparamagnetic [7].

Channa, *et al.,* (2020) studied nickel-substituted manganese spinel ferrite $Ni_xMn_{1-x}Fe_2O_4$ (x= 0.1, 0.2, 0.3, 0.4 and 0.5) nanoparticles prepared by $sol-gel$ auto-combustion method. X-ray diffraction analysis reveals that prepared nanomaterials are spinel ferrite due to existence of secondary phase. The synthesis parameters such as molarity of reactants, magnetic stirring speed, temperature, amount of citric acid and annealing in ambient atmosphere have been optimized to control the crystallite size from 14 to 16 nm. The nickel substitution significantly affects the structural parameters such as lattice strain, micro-train, stacking fault and dislocation density. Dielectric properties were analyzed through impedance analyzer (LCR meter) for frequencies ranging from 1 kHz to 20 MHz and results depicted that synthesized nanoparticles respond to the electromagnetic radiations in terms of variation in tangent loss and dielectric constant as a function of grains and resistive grain boundaries that contribute to the dielectric relaxation in these nanoparticles. The structural, dielectric and impedance analysis suggested that these nickels incorporated manganese spinel ferrite nanoparticles would have Ni^{2+} content. This behavior is related to the microstructural differences among conducting potential applications in high-frequency applications [8].

Abdul Hakeem *et al.,* (2021) analyzed the structural, magnetic, and electrical properties of manganese based spinel ferrites to see the impact of yttrium ions upon manganese spinel ferrite. The samples of $MnY_yFe_{2-y}O_4$ (Y= 0-0.1) were created by wet chemical sol–gel method. The development of cubic spinel configuration was observed in all models with the use of X-ray diffraction analysis. The values of different magnetic parameters like saturation magnetization and remanence declined with the increase of yttrium concentration, while coercivity was enhanced. The real and imaginary parts of permittivity decreased with the increase in Y concentration. The impedance enhanced with the substitution of Y^{3+} ions. The $M-H$ loops of all the samples were experimentally measured from $-2\,K\,Oe\,to\,+2\,KOe$. All these parameters suggested that manganese-based ferrites may be used in microwave absorption [9].

M. Lakshmi1 *et al,* (2015) synthesized Cr_x Zn Fe_{2-x} O_4 (with x = 0.0, 0.1, 0.2, 0.3, 0.4, and 0.5) spinel ferrite nanoparticles via sol–gel method. The precursor compound was calcined at a temperature of 900 ^{0}C for 3 h. The size, shape, and chemical state of the synthesized powders were structurally characterized by powder XRD, SEM, TEM, HRTEM, SAED, energy-dispersive X-ray analysis (EDAX), and Fourier transform infrared spectroscopy (FTIR) spectral techniques. The XRD pattern of Cr–Zn ferrite provides information about single-phase formation of spinel structure with cubic symmetry. Both crystallite size and lattice parameter decrease with increasing Cr content. Formation of spinel structure is affirmed by using XRD and FTIR spectra which shows that the bands are found to shift gradually toward the higher frequency side with substitution of Cr, which have been attributed to the decrease in the lattice constant. SEM and TEM micrographs demonstrated that nanoparticles with narrow size distribution were obtained. The average grain size was found to be in nanometer range and of the order of 43–63 nm obtained using TEM images. Compositional stoichiometry was confirmed by EDAX technique. The magnetic properties of synthesized chromium-substituted Zn ferrite nanoparticles were studied using vibrating sample magnetometer at room temperature under the applied magnetic field of 15 KG. The result indicated that the amount of Cr contents significantly influenced the crystal morphology and structural and magnetic properties of Cr-doped Zn ferrite nanoparticles [10].
Rintu Mary *et al,* (2014) studied zinc chromium ferrites with chemical formula $ZnCr_xFe2_{-x}O_4$ (x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0) prepared by Sol - Gel technique. The structural as well as magnetic properties of the synthesized samples have been studied and reported here. The structural characterizations of the samples were analyzed by using X – Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscope (SEM), and Transmission Electron Microscope (TEM). The single phase spinel cubic structure of all the prepared samples was tested by XRD and

FTIR. The particle size was observed to decrease from 18.636 nm to 6.125 nm by chromium doping and induced a tensile strain in all the zinc chromium mixed ferrites [11].

Talaat M. Hammad *et al,* (2020) synthesized nanoparticles of undoped and cobalt-doped copper ferrite $Cu_{1-x}Co_xFe_2O_4$ (x=0.2, 0.4, 0.6, 0.8, and 1.0) by a co-precipitation method. The influence of Co^{2+} substitutions on the structure, morphological, optical, and magnetic properties of $Cu_{1-x}Co_xFe_2O_4$ nanoferrites was studied. The crystallite size found by XRD increased from ∼10 to∼ 25 nm. The lattice parameter increased from 8.332 to 8.371 Å with increasing the Co^{2+} content. The FTIR spectra of Cu1xCoxFe2O4 display two strong absorption bands in the range of 400–200 cm^{-1}. The band gap energy of nanoferrites is found to decrease from 3.65 to 3.20 eV with an increase in the content of Co^{2+} ions. It has been observed that the luminescence intensity decreases in copper ferrite matrices with an increase in the ratio of Co^{2+}. The results show the magnetic properties of copper ferrite are significantly affected by the doping amount of Co^{2+} ions [12].

Sami ullah Rather and O. M. Lamine (2020) prepared aluminum doped zinc ferrite ($ZnFe_{2-x}Al_xO_4$) nanoparticles with x ranging from 0 to 0.9 via thermal treatment method using PVP as a capping agent. The Al-dopant concentration was controlled by ratio of Al/Fe precursors. Structural, morphological, and magnetic properties were investigated for the effect of non-magnetic Al in ferrite samples. Single phase with normal spinel ferrite structure was revealed by XRD measurement. Furthermore, reduction in nanocrystalline particle size as the Al content increases has been confirmed by XRD analysis. It was discovered that particle size decreases as the Al concentration increases, which attributed to structural effect of Al on grain size [13].

Tahir Abbas *et al,* (1992) studied lattice parameter, oxygen positional parameter and cation distribution in spinel structural ferrites $Mn_xZn_{1-x}Fe_20_4$ (x = 0.00, 0.25 and 0.50) were determined for the best fitting of the curve between In ($I_{obs}{}^{hkt}$/ $I_{cal}{}^{hkl}$) and (sin $\boldsymbol{\theta}^2/\lambda^2$). There is a continuous increase in the lattice par- a meter a with the compositional parameter x, in these mixed spinels. It has been observed that Zn 2+ ions prefer the tetrahedral sites in the spinel structure [14].

Parvatheeswara Rao *et al, (2006)* studied two mixed ferrite systems, namely $Ni_{0.65}Zn_{0.35}Fe_2O_4$ (Ni–Zn) and $Mn_{0.75}Zn_{0.18}Fe_2O_4$ (Mn-Zn) prepared by coprecipitation method, and the resulting ultrafine powders were treated at different temperatures from 200 to 800^0C for improved crystallinity and magnetic properties. The samples were characterized by X-ray diffraction, vibrating sample magnetometry, and ferromagnetic resonance spectrometry. As a result of the heat treatment, the average particle size has been found to increase from 9.9 to 15.7nm for Ni–Zn ferrites and from 2.4 to 10.2nm for Mn–Zn ferrites, and the corresponding magnetization values have increased from 9.1 to 23 emu/g for Ni–Zn ferrites and from 7.9 to 11.7 emu/g for Mn–Zn ferrites, respectively [15].

3. Experimental Design

Reagent

All reagent/chemical used are of analytical reagent need no further purification. The raw materials that were used in this study for sol-gel method are listed below:

1. Aluminium (III) nitrate $Al(NO_3)_3.9H_2O$
2. Chromium (II) nitrate $Cr(NO_3)_2$
3. Zinc (II) nitrate hexahydrat $Zn(NO_3)_3.6H_2O$
4. Iron (III) nitrate nanohydrate $Fe(NO_3)_3.9H_2O$
5. Ammoniua solution NH_3
6. Distilled water
7. Citric acid monohydrate $C_6H_8O_7.H_2O$

Equipment required

The required equipment to perform the experiment are listed below

1. Magnetic stirrer 3pcs
2. Glass stirrer
3. pH meter
4. Weighing balance (electronic scale)
5. Electric source
6. Beaker (6pcs 500cm^3)
7. Measuring cylinder (100ml)
8. Spatula (5pcs; big. medium, and small sizes) Oven (900°C)

The methods: Sol-gel synthesis is the method employed to prepare the materials for this research project.

Procedures of sample preparation

Chromium-Zinc spinel ferrites belong to the chemical composition of $Cr_{0.7x}Zn_{0.3}Fe_{2-x}Al_xO_4$ ($x = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5$) were synthesized by wet chemical sol-gel technique. The sample with varying x-concentration were preferred.

Therefore, to prepare the sample, the stochiometric amount of $Cr(NO_3)_2$(9.3368g), $Al(NO_3).9H_2O$,$Zn(NO_3)_3.6H_2O$(2.9749g), $Fe(NO_3)_3.9H_2$, and$C_6H_8O_7.H_2O$(19.213g) raw material were dissolve in 50ml distilled water in a beaker to get a clear solution. Citric acid solution were then be mixed with metal solution with molar ratio of nitrates to citric acid of 1:3. This solution was mixed homogeneously using a magnetic stirrer and then heated in hot plate at 90^0C for about 15 minutes. Aqueous ammonium solution was added slowly drop wise under constant stirring in order to adjust the pH value to about 7. Finally, to create the final powder materials, the fine powder was calcinated at 900°C for 4 hours to obtain the pure compounds.

Characterization

The phase were examined by XRD pattern using the X-ray diffractometer to affirm the crystalinity of the sample. The analysis was made using Schemalt machine model XRD 6000 authomated with Ni-Filtered Cu Kα radiation operating at 40.0 (kV) and 30.0(mA) with a graphite monochromator (λ=1.5418). The diffraction pattern was scanned between 2 theta values of range 10-70^0.

4. Results and Discussion

X-ray diffraction (XRD) analysis

The phase and purity of the synthesized Cr-Zn spinel ferrites were examined by X-ray diffraction (XRD) patterns and are shown in Fig: 1, The XRD patterns of these ferries were synthesized by sol-gel method at a temperature of 900^0 C for 4 hours in oven. From Fig; 1, the peaks of the XRD pattern are sharp and well defined without impurity, suggest the formation of pure crystalline materials and single-phase spinel structure.

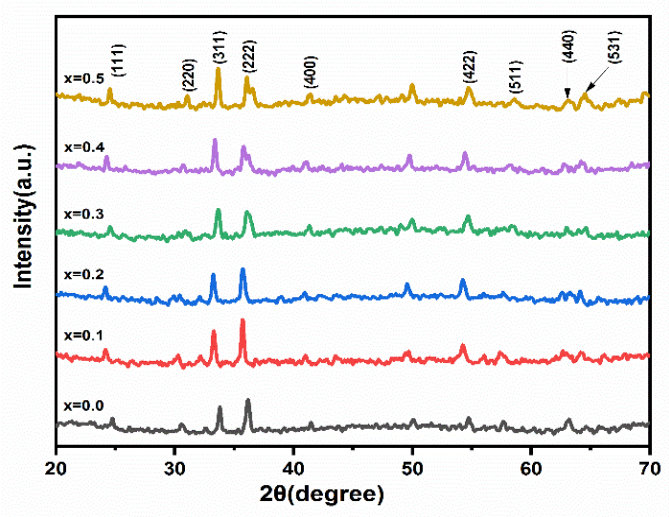


Figure: 1. XRD Pattern of $Cr_{0.7}$-$Zn_{0.3}Fe_{2-x}Al_xO_4$

Equations

The peaks at (111), (220), (311), (222), (400), (422), (511), (440) and (531) planes of a cubic unit cell, all planes are the allowed planes which designated the formation of the pure spinel phase with Fd3m space group. Furthermore, the obtained XRD patterns are in line with the Joint Committee on Powder Diffraction Standard (JCPDS) Card no.030864.

The crystal size was evaluated by measuring the full width at half maxima (FWHM) of the most intense peak (311) from the XRD pattern as it is the strongest peak appeared at the lower diffraction angle and can be analyzed by computer fit (xpowder and origin software) comes from the plane which denote the spinel phase by using the following Dedye-Scherrer equation;

$$D = \frac{0.9\lambda}{\beta Cos\theta} \quad (1)$$

Where;

D is the crystal size, 0.9 is the symmetry constant, λ is the wavelength of incident X-ray, θ is the diffraction angle and β is the full width at half maxima (FWHM). The analysis revealed that the crystal sizes are in the range of 26.57-14.62 nm and exhibit gradual decrease with the increasing of Al^{3+} content.

The interplanar spacing (d) values were calculated for the recorded peaks using Bragg's law;

$$n\lambda = 2d\ sin\theta. \quad (2)$$

The lattice constant (a) of each sample was calculated using the following relationship;

$$a = d_{hkl}\ (\sqrt{h^2 + k^2 + l^2}) \quad (3)$$

Where;

$d_{hkl}$is the interplaner distance for hkl planes; the lattice constant 'a' was calculated for (311) plane and the lattice parameter was found to decrease with the increase of Al^{3+} ions in the Cr-Zn spinel ferrites. The decrement in the lattice parameter is attributed to the replacement of Fe^{3+} (0.67Å) ions by Al^{3+} that is a smaller ion with ionic radius of 0.535Å [16]. Similar behavior of the lattice constant was reported in the literature [17].

The oxygen positional parameter(u) and inversion (δ) parameter was calculated using the following relation [18].

$$u = (r_A + r_o)\frac{1}{a\sqrt{3}} + \frac{1}{4} \quad (4)$$

$$\delta = u - 0.375 \quad (5)$$

Where:

r_A Is the ionic radius of the A-site and is calculated to 0.782Å, r_o is the ionic radius of the oxygen ion which is equal to 1.32Å.

The ideal FCC parameter is u = 3/8 = 0.375, where the packing of ions, within the lattice is taken as perfect. However, slight deviation from the perfect value may occur due to a relatively larger oxygen ions which causes a small distortion of the lattice structure to make space for the cations at the available interstitial sites in the unit.

Table 1: Structural parameters of $Cr_{0.7x}Zn_{0.3}Fe_{2-x}Al_xO_4$ $(x = 0.0 \le x \le 0.5)$

Al^{3+} contents (x)	2θ value for (311) degrees	Crystal size from (311) (nm)	Lattice parameters 'a' (Å)	Cell volume V $(Å)^3$	Oxygen positional parameter 'u'	Inversion parameter 'δ'
x = 0.0	35.328	26.57	8.4196	596.863	0.3940	0.0190
x = 0.1	35.381	22.87	8.4074	594.272	0.3943	0.0193
x = 0.2	35.434	20.08	8.3952	591.169	0.3946	0.0196
x = 0.3	35.487	17.89	8.3831	589.134	0.3948	0.0198
x = 0.4	35.540	16.14	8.3711	586.607	0.3949	0.0199
x = 0.5	35.596	14.62	8.3689	586.145	0.3950	0.0200

Using the value of lattice constant 'a' the distance between magnetic ions (ion jump lengths) available in tetrahedral A-site and octahedral B-site, i.e. 'L_A'and 'L_B', respectively, was calculated using the following relations [19];

$$L_A = \left(\frac{\sqrt{3}}{4}\right)a \quad (6)$$

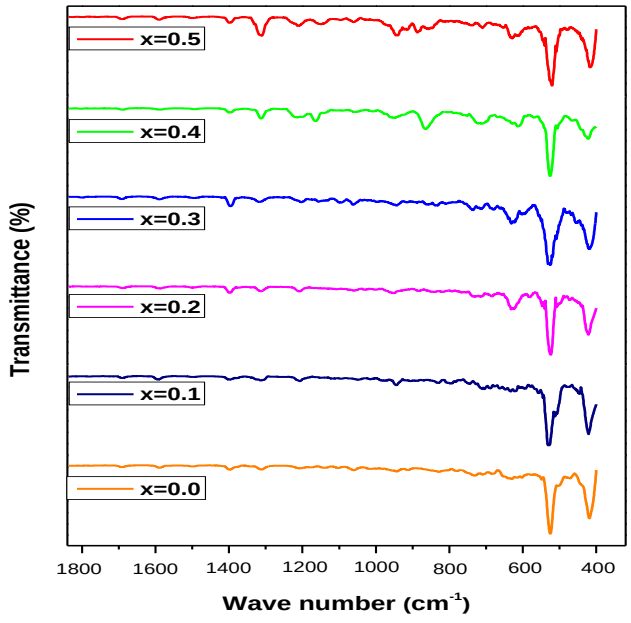
$$L_B = \left(\frac{\sqrt{2}}{4}\right)a \quad (7)$$

The calculated values of ion jump length ($L_A$and L_B) are given in Table 2 the obtained values shows that the ion jump length decreased with the in Al concentration (x), ion jump lengths ($L_A$and L_B) are directly proportional to lattice constant aluminium concentration. Since the lattice constant (a) is decreasing with the increase value.
Hence, ion jump lengths decreased with the increases in Al concentration increased in.

Table 2 Variation of hopping lengths (L_A andL_B) with Al^{3+} content (x)

Composition	Al^{3+} content (x)	L_A (Å)	L_B (Å)
$Cr_{0.7}$-$Zn_{0.3}Fe_2O_4$	x = 0.0	3.640	2.968
$Cr_{0.7}$-$Zn_{0.3}Fe_{1.9}Al_{0.1}O_4$	x = 0.1	3.641	2.972
$Cr_{0.7}$-$Zn_{0.3}Fe_{1.8}Al_{0.2}O_4$	x = 0.2	3.635	2.968
$Cr_{0.7}$-$Zn_{0.3}Fe_{1.7}Al_{0.3}O_4$	x = 0.3	3.630	2.964
$Cr_{0.7}$-$Zn_{0.3}Fe_{1.6}Al_{0.4}O_4$	x = 0.4	3.625	2.960
$Cr_{0.7}$-$Zn_{0.3}Fe_{1.5}Al_{0.5}O_4$	x = 0.5	3.624	2.959

Fourier transformed infrared spectroscopy (FTIR)
FTIR technique allows to detect structural changes in the molecular binding between micro-organisms and metal atoms that can provide detail on the existence of their interactions [20]. Figure 2 displays the FTIR spectra of $Cr_{0.7}$-$Zn_{0.3}Fe_{2-x}Al_xO_4$ $(0.0 \leq x \leq 0.5)$ ferrites system within the range of 400-4000cm^{-1}. Infrared vibration in the octahedral (B-site) [22]. Infrared spectroscopic study supported the formation of Cr-Zn spinel ferrite in the nanocrystalline form with enlightening two bands at around 650 and 400cm^{-1} which are common features of all spinel ferrites [21]; the typical of spinel structure are attributed to the stretching vibrations of the unit cell of the spinel in the tetrahedral (A-site) and the metal oxygen.



Fig; 2: FTIR pattern of $Cr_{0.7}$-$Zn_{0.3}Fe_{2-x}Al_xO_4$ $(0.0 \leq x \leq 0.5)$

Table 3 Data on the position of FTIR absorption band $Cr_{0.7x}Zn_{0.3}Fe_{2-x}Al_xO_4$ $(x = 0.0 \leq x \leq 0.5)$

Al^{3+} content (x)	Compositions	υ1 (cm^{-1})	υ2 (cm^{-1})
x=0.0	$Cr_{0.7}$-$Zn_{0.3}Fe_2O_4$	537	415
x=0.1	$Cr_{0.7}$-$Zn_{0.3}Fe_{1.9}Al_{0.1}O_4$	518	425
x=0.2	$Cr_{0.7}$-$Zn_{0.3}Fe_{1.8}Al_{0.2}O_4$	517	417
x=0.3	$Cr_{0.7}$-$Zn_{0.3}Fe_{1.7}Al_{0.3}O_4$	534	431
x=0.4	$Cr_{0.7}$-$Zn_{0.3}Fe_{1.6}Al_{0.4}O_4$	537	414
x=0.5	$Cr_{0.7}$-$Zn_{0.3}Fe_{1.5}Al_{0.5}O_4$	540	434

5. Conclusion and future scope

Al^{3+} substituted Cr-Zn ferrites with chemical formula $Cr_{0.7}$-$Zn_{0.3}$ $Fe_{2-x}Al_xO_4$ $(0.0 \leq x \leq 0.5)$ were successfully synthesized by Sol gel method. The structural characterization of the powders using XRD, and FTIR confirmed the formation of nano size particles with single-phase spinel structure.

The crystallite size, lattice constant, and the ion jump lengths were reduced with the increase of aluminium content due to the less ionic radii of Al^{3+}. The result of calculation of oxygen positional parameter for $Cr_{0.7}$-$Zn_{0.3}Fe_{2-x}Al_xO_4$ $(0.0 \leq x \leq 0.5)$ is presented in table 1.

Ferrites has u parameter slightly above 0.375. The value of oxygen positional parameter u" for the studied samples increases from 0.3940 to 0.3950 in going from x = 0.0 to 0.5. The increase in u parameter may be due to the shift of the origin at the tetrahedral sites with the decreasing number of the Fe^{3+} ion at the octahedral sites, that is, the distortion of the lattice, and the deviation from FCC ideal case, increases with Al^{3+} content.

This study's focus was on the element, amount, and synthesis process of substituted elements in chromium-zinc ferrite materials. However, in addition to the issues described above, there are many problems related to chromium-zinc ferrite materials that are related to the synthesized technique, the element, and the amount of substituted elements. However, study of magnetic, electrical and optical properties of the prepared sample were not addressed in this study. Therefore, researchers should deeply investigate the type and amount of substitutes that are not covered in this study.

Conflict of Interest
This one-of-a-kind copy has not been distributed and is no not planned for distribution anywhere else. Therefore, there is no conflict of the captivated for us to discover.

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There was no external funding for this study.

Authors' Contributions
This study about work received equally valuable contributions from all authors. They all looked at the first replica and confirmed its drastic correction.

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References

[1] Fu, Wuyou *et al.*,. "Hollow Glass Microspheres Coated with $CoFe_2O_4$ and Its Microwave Absorption Property." *Journal of Magnetism and Magnetic Materials,* **316**: pp **54–58, 2007**

[2] Tsutaoka, Takanori, "Frequency Dispersion of Complex Permeability in Mn-Zn and Ni-Zn Spinel Ferrites and Their Composite Materials." *Journal of Applied Physics* **93: 2789–96**, **2003.**

[3] Yan, Jing, Ying Huang, Xuefang Chen, and Chao Wei. "Conducting Polymers-$NiFe_2O_4$ Coated on Reduced Graphene Oxide Sheets as Electromagnetic (EM) Wave Absorption Materials." *Synthetic Metals* **221: 291–98**, 2016,

[4] Levy D., Pavese A., Sani A., Pischeda V. "Structure and compressibility of synthetic $ZnAl_2O_4$ under high pressure conditions, from synchrotron X-ray powder diffraction. *Physics and chemistry. Minerals*, **28,612-618, 2001**.

[5] Sridhar R., Ravinder D., Kumar K. V. *Advances in Materials Physics and Chemistry*, **2, 192-199, 2012.**

[6] B. P. Jacob, S. Thankachan, S.Xavier and E M Mohammed, *J. Phys. Sci*. **84,** 045702, pp **1- 6**, **2011.**

[6] Simi Debnath, Krishna Deb, Biswajit Saha and Ratan Das (2019). X-ray diffraction analysis for the determination of elastic properties of zinc doped manganese spinel ferrite nanocrystals ($Mn0_{0.75}Zn_{0.25}Fe_2O_4$), along with the determination of ionic radii, bond lenths, and hopping lengths. *Journal of physics and chemistry of solids*. Vol **134**, pp **105-114**, **2019**.

[7] N. Channa,, M. Khalid, A. D. Chandio, "Nickel-substituted manganese spinel ferrite nanoparticles for high-frequency applications", *J Mater Sci: Mater Electron* **31, 1661–1671**, **2020**.

[8] Abdul-Hakeem., T. Alshahrani, H.M.T. Farid, "Manganese-based spinel ferrites for microwave absorption", *J Mater Sci: Mater Electron* **32, 2557–2563**, **2021,**.

[9] M. Lakshmi, K. Vijaya Kumar, and K. Thyagarajan. An investigation of structural and magnetic properties of Cr–Zn ferrite nanoparticles prepared by a sol–gel process. *J Nanostruct Chem*. Vol. **5**, pp.**365–373** DOI 10.1007/s40097-015-0168-8

[10] Rintu Mary Sebastian, Smitha Thankachan, Sheena Xavier, Shaji Joseph, and E. M. Mohammed, "Structural and magnetic properties of chromium doped zinc ferrite" **1576, 91 2014**; doi: 10.1063/1.4861990.

[11] M. Talaat, Hammad & S. Kuhn & Ayman Abu Amsha & R. Hempelmann "Investigation of structural, optical, and magnetic properties of Co^{2+} ions substituted $CuFe_2O_4$ spinel ferrite nanoparticles prepared via precipitation approach" *Journal of the Australian Ceramic Society* **2021.**

[12] Sami ullah Rather and O. M. Lamine, "Effect of Al doping in zinc ferrites nanoparticles and their structural and magnetic properties", *Journal of Alloys and Compounds*. Vol. **812**, issue **152058, 2020**. [13] Tahir Abbas, Y. Khan, Mushtaq Ahmad and Shahid Anwar, "X-RAY DIFFRACTION STUDY OF THE CATION DISTRIBUTION IN THE Mn-Zn-FERRITES", *Solid state communications*, Vol **82**, Issue **9**, pp **701-703, 1992.**

[13] B. Parvatheeswara Rao, Chong-Oh Kim, CheolGi Kim, I. Dumitru, L. Spinu, and O. F. Caltun, "Structural and Magnetic Characterizations of Coprecipitated Ni–Zn and Mn–Zn Ferrite Nanoparticles" *IEEE TRANSACTIONS ON MAGNETICS*, VOL**. 42**, NO. 10, OCTOBER 2006.

[14] R. Waldron, "Infrared spectra of ferrites" Phys. Rev. 99, 1727, 1955.

[15] Haralkar, S., Kadam, R.,More, S., Shirsath,S.E., Mane, M., Patil, S., Mane,D, "Substitutional effect of Cr^{3+} ions on the properties of Mg-Zn ferrite nanoparticles" Phy. B **407**: pp **4338-4346, 2012**

[16] A**.** Kumar, Yadav, K, "Magnetic, magneto capacitance and dielectric properties of Cr doped bismuth ferrite nanoparticles" *Mater. Sci. Eng. B* **17(6): 227-230, 2011.**

[17] H. M. Zaki, S. H. Al-Heniti, and Elmosalami T. A., "Structural. Magnetic and dielectric studies of copper substituted nano-crystallinespinel magnesium zinc ferrite", *J. Alloys and compounds*, Vol. **633**, pp.**104-114, 2015.**

[18] G. Mustafa, M. Islam, Zhang, W., Jamil, Y., Anwar, A.w., Hussain, M., Ahmad, M., "Investigation of structural and magnetic properties of Ce^{3+}substituted nanosized Co-Cr ferrites for a variety of applications", *J. Alloys Comp*. **618,** pp **428-436**, **2015.**

[19] Pan, W., Gu,F., Qi, K,. Liu., Q., Wang, J, "Effect of Zn substitution on morphology and magnetic properties of $CuFe_2O_4$ nanofibers" *J. Mater. Chem. Phys*. **134: 1097**, **2012.**

[20] M. Hashim, S. E. Shirsath, S. Kumar, Kumar, R., Roy, A.S., Shah, J., Kotnala, R. (2013): Preparation and characterization chemistry of nano-crystalline Ni-Cu-ZN ferrite. *J. Alloys Compd*. **549**: pp **348-357, 2013.**

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