International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Structural, Optical and Dielectric Properties of ($Co_xCu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) Ferrite Synthesized by Auto Combustion Method

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Abstract: ***The structural, optical and dielectric properties were studied of cobalt ferrite ($Co_xCu_{0.15}Zn_{0.85-x}$ Fe_2O_4) where x =0.15, 0.3, 0.45 and 0.6 synthesized by sol-gel/auto combustion method. All samples were investigated by X-ray diffraction (XRD), UV–Visible, LCR meter and scanning electron microscopy (SEM). The results appeared the average grain size was found in the range of (24 nm –37 nm) and found that, the lattice parameter decreased from 8.412Å to 8.377Å with increasing Co^{+2} ions content. The dielectric measurements as dielectric constant and dielectric loss for the prepared samples are studied as a function of frequency and cobalt content. The optical measurements are carried out in the wave length range between (200nm – 1000nm), the results showed the transmittance and absorbency spectrum depend on the Co content for all samples.***

Keywords: Sol- Gel, Auto Combustion, Structural, Optical, Dielectric, Cobalt ferrite

1. Introduction

Ferrites are ferromagnetic materials take different chemical structuresand crystalline structures that can be taken spinel structure, hexagonal structures, garnet structure and ilmenite structure. Most of the ferrites materials is crystallized with a cubic structure similar to a metal structure Spinal ($MgAl_2O_4$) is called the spinal ferrimagnetism, a complex of oxides composed of two types of positive ions than negative ions. The chemical formula (MFe_2O_4) and M are a two-valence positive metal ion [1].Preparation ferrite in the form of powder then pressed and sintering to take the form. It is a don'texpensive material, easy to manufacture and form unlike other metals [2]. Preparation method of nanoparticles is the auto-combustion method, which is a characteristic method, because of the easy of preparation, the short time, and the need for high temperatures [3]. Hard spinel ferrites, $CoFe_2O_4$ is a useful magnetic material because of its excellent chemical stability, high coercivity, mechanical hardness as well as moderate saturation magnetization. The characteristics of ferrite nano-particles are influenced by the microstructure and composition which are more sensitive to the composing methodology applied in their prepared. There are several methods to prepare the ferrites and each one of them has its own characteristics using the method of sol - Gel with automatic combustion [4].

In this research, we study the effect of Co substitutions instead of Zn on the structural, optical and dielectric properties of the ferrite synthesized by sol-gel auto combustion technique.

2. Experimental

Nanoparticle cobalt ferrite were synthesized by auto-combustion method, using the analytical grade iron nitrate [$Fe(NO_3)_2$. $9H_2O$], copper nitrate [$Cu(NO_3)_2.3H_2O$] and zinc nitrate [$Zn(NO_3)_2$. $6H_2O$] and citric acid [$C_6H_8O_7.H_2O$] were used to synthesize (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) with x =0.15, 0.3, 0.45 and 0.6. Citric acid [$C_6H_8O_7.H_2O$]is used as a fuel. In a specific amount of deionized water. Metal nitrates were dissolved and then mixing of nitrates to citric acid at molar ratio 1:1.BY using ammonium solution the pHof prepared solution was obtained resulted 7. Then the mixed solution washeated at 90ºC.The water of solution was slowly evaporated until a high viscosity gel formed to convert into gel. As the temperature increased to 200^{o}Cwhich led water evaporated to convert dry gel finally started to self-ignition forming the final product was then calcined at 700^{o}Cfor 2 h to get the Co-doped $CuZnFe_2O_4$ nanoparticles.

3. Results and Discussion

3.1 X-Ray Diffraction

Cobalt ferrites (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) with x =0.15, 0.3, 0.45 and 0.6 were synthesized by sol-gel auto-combustion method. XRD patterns are shown in Fig 1. which indexed by using standard (JCPDS card No. 19-0629). The result shows that all samples have single phase structure at 700 °C.The grain size of O1, O2, O3, and O4 were found to be 28, 33, 37 and 24 nm respectively. It is observed from Fig. 1that the increase in cobaltion, increases the grain size may be due by increasing the molecular concentration at the grain surface, results in enhancing the grain growth. The grain size of the sample O4 was found to decrease with the increase in cobalt iondue to the requirement of high energy for ions to entering to the lattice [5].

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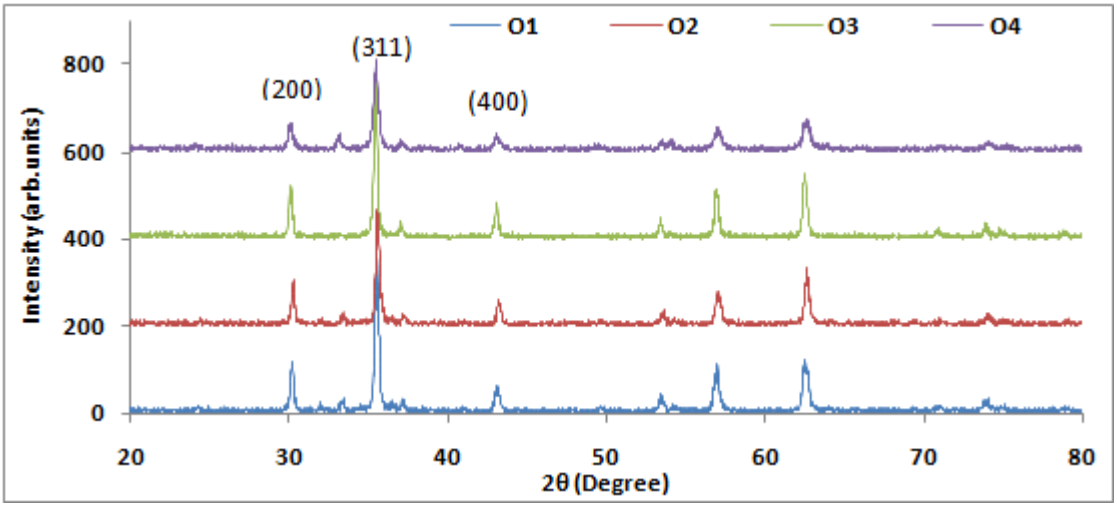


Figure 1: X-ray diffraction pattern of Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4(x = 0.15, 0.3, 0.45and 0.6) samples calcined at 700°C for 2hrs

Table 1: Grain size and Lattice parameter ofCo_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4(x = 0.15, 0.3, 0.45and 0.6) system

sample	x	D_{ave} (nm)	Lattice parameter (a)(Å)
O1	0.15	28	8.412
O2	0.3	33	8.397
O3	0.45	37	8.384
O4	0.6	24	8.377

The average grain size of the cobalt ferrites was gave from the measured width of their diffraction pattern by using Debye Scherer's formula[6]:

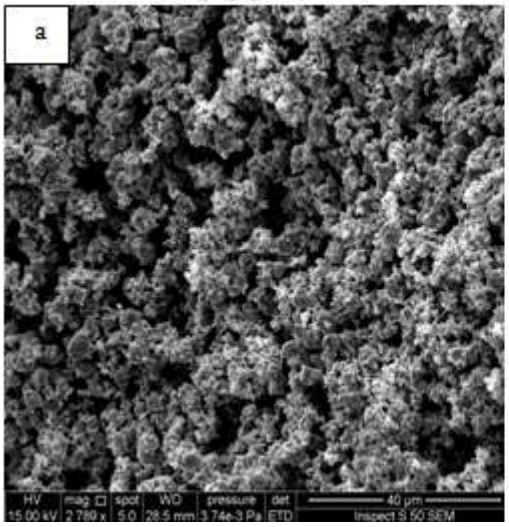
$D = 0.9\lambda/\beta \cos \theta$

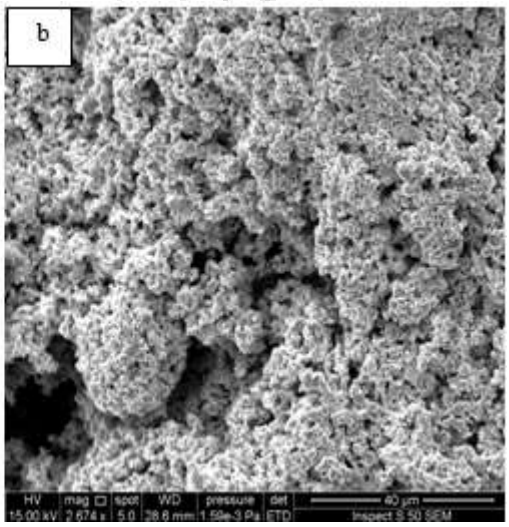
Where () and (FWHM) are the wavelength of X-ray diffraction and the full width half maximum in radians, respectively.

The value of the obtained lattice parameter(a) of cobalt ferrite after Co-doping is reduced from 8.412to 8.377Å, Table (1) shows decrease lattice constant with increase the of cobalt content (Co) can explained by ionic radius reduction due to the fact that the doping action Co^{+2} (0.79 Å) has a smaller ionic radius compared with the Zn^{+2} (0.88 Å) [1].

3.2 Morphological analysis

The microstructure of the ferritesidentify by SEM andfigure 7 shows the two-dimensional surface morphological images of Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) (x = 0.15, and 0.6) NPs. Fig. 2a and 2b reveal the SEM images of these ferrites NPs, which show the highly agglomerated semi spherical shaped particles. The agglomeration of the ferrites NPs perhaps emerge from magnetic interactions between ferrite particles [7].We found from the statistical calculations that there is a great approximation between the results of x-rays and SEM.





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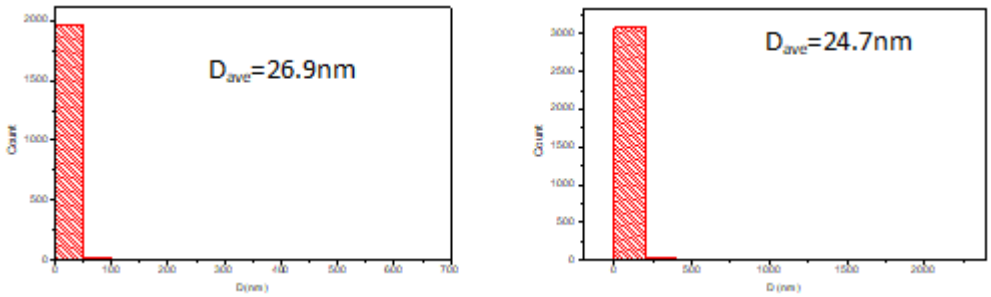

Figure 2: SEM micrograph of $Co_xCu_{0.15}Zn_{0.85-x}Fe_2O_4$ ferrites (a-x=0.15, b-x=0.60)

3.3 Dielectric Properties

Figure3 shows the dielectric constant of the ($Co_xCu_{0.15}Zn_{0.85-x}Fe_2O_4$) decreases with increasing frequency range (50Hz - 1MHz) for all the composite samples due to the presence of whole of polarizations types [8]. The dielectric constant remains constant at higher frequencies, due to electronic polarization. In electronic polarization, electric dipoles are incapable to follow the fast different of the applied alternating electric field which giving low dielectric constant [9].The decrease in dielectric constant with increasing Co ion for all samplesperhaps due to the migration of Fe^{3+} ions from octahedral site to tetrahedral site which decreases the mobility[10].

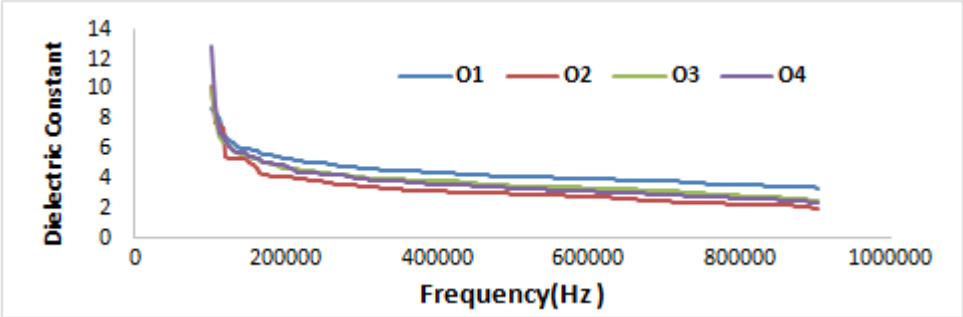

Figure 3: Dielectric constant against frequency of (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) (x = 0.15, 0.3, 0.45 and 0.6) system

Figure 4 shows the dielectric loss dependency of the frequency in (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) ferrites with different Co (x) content. The dielectric loss decreases with increasing frequency range (50 Hz - 1MHz) for all the composite samples due to the low value of dielectric loss pointed low diversion to heat energy from electrical energy and reduced power loss for the network the loss factor, also another electrical parameters, depended on the frequency, humidity and sample purity [11].For the sample O3 the decreasing ofdielectric loss with Co content due to cobalt substitution to the octahedral site which strengthens the dipole-dipole interaction that restricts the rotation of the dipoles[10, 12].

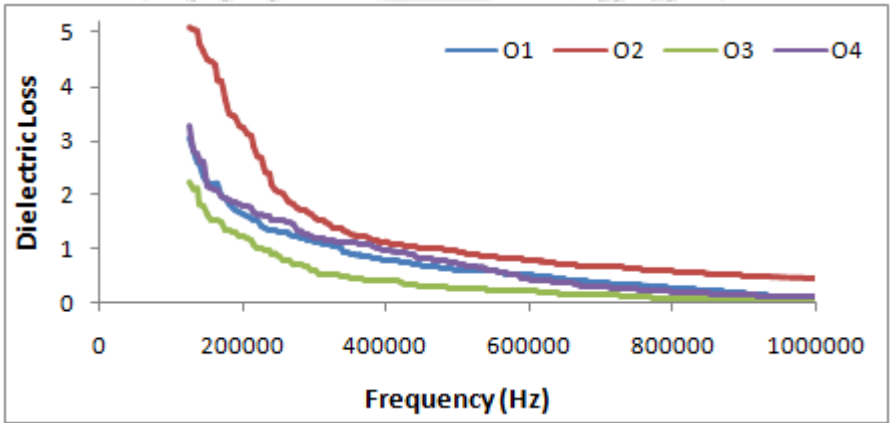

Figure 4: Variation of dielectric loss with frequency of (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) (x = 0.15, 0.3, 0.45 and 0.6) system

3.4 Optical Properties

The absorbance spectrum behaves in a behavior that is opposite to the permeability spectrum in general. It is observed from the figure (5) that decrease absorption with increasing wave length, and that absorption is greatest at short wavelengths. It is also showed that absorption increases as the Co^{+2} concentration increases. The crystal structure of the prepared samples by forming localized levels within the energy gap led to the absorption of low-energy photons [13].

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The spectra of (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) ferrite samples are shown in figure (6) the transmittance dependency of the wavelength with different Co (x) content. The Transmission decreases with increasing wave number for all the composite samples due to vibration mode of octahedral sub lattice in the spinel structure [14].

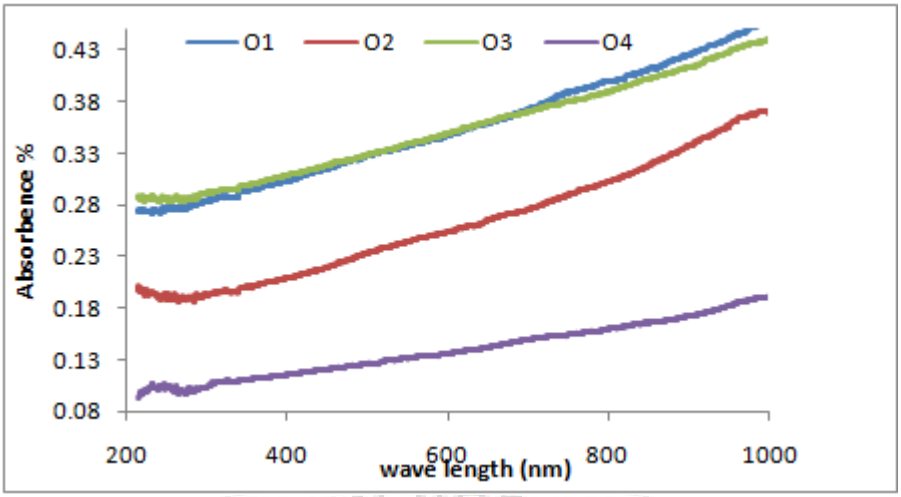

Figure 5: Shows the variation of absorbance of (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) (x = 0.15, 0.3, 0.45 and 0.6) as a function of wavelength

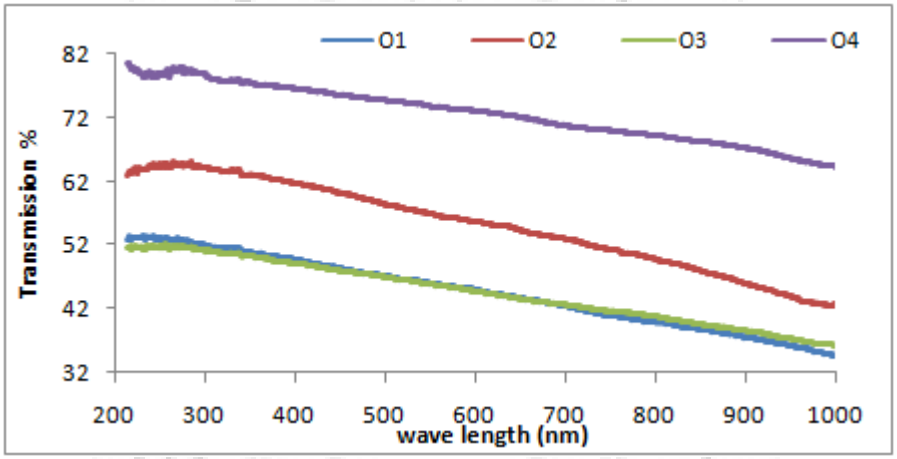

Figure 6: Shows the variation of transmittance of (Co_x $Cu_{0.15}$ $Zn_{0.85-x}$ Fe_2O_4) (x = 0.15, 0.3, 0.45 and 0.6) as a function of wavelength

4. Conclusions

Nano-structure O1, O2, O3 and O4, have been succeeding synthesized via a adjusted sol-gel auto combustion method.(XRD) analysis patterns emphasizedthe spinel structure phase presence of the synthesized samples.Thelattice parameterdecreasesand the grain size increases with increasing Co amount, which may be due to by increasing the molecular concentration at the grain surface, results in enhancing the grain growth. The grain size of the sample O4 was found to decrease with the increase in cobalt ion attributed to the demands of high energy for ions to entering to the lattice.The dielectric constant of composite show decreases with increasing frequency for all the composite samples attributed to the existence whole of polarizations types. Show the dielectric loss dependency of the frequency where decreases with increasing frequency.The optical measurements showed that absorbance of the($CoxCu_{0.15}Zn_{0.85}$-xFe_2O_4) ferrite increased with doping percentageincreases and transmittance decrease with doping proportion increases and, this is attributed to the forming of new centralized levels which are able of electrons receive. This studydetailed the influence of doping proportion on the OpticalandDielectric Properties has offered that all properties like Conductivity, dielectric loss, dielectric constant, transmittance and absorption have been influenced by the doping proportion increasing.

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