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Preparation and Study of the Properties of CoZnFe2O4 Using Co- Precipitation Method

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Abstract

In this study the magnetic nanoparticles of $Co_{1-X}Zn_XFe_2O_4$ were prepared with different X values (X = 0, 0.1, 0.3, 0.5, 0.7 and 0.9 respectively), using co-precipitation method. The ferrites with a Nano scale was ranging from (10 to28 nm), and the structural properties were tasted prepared samples using X-ray diffraction (XRD), and field emission scanning electron microscopy (FESEM). The structural results showed that the particles have a cubic spindle phase and that the particles have a Nano scale, with a clear agglomeration between the particles sites Finally, the magnetic properties tests showed that the particles have high magnetic saturation.

Keywords: Magnetite Nanoparticles, XRD, Co-precipitation method, FESEM, ferrites, VSM.

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تحضير ودراسة خواص CoZnFe2O4 باستخدام طريقة الترسيب المشترك

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الخلاصة

في هذه الدراسة، تم تحضير الجسيمات النانوية المغناطيسية $Co_{1-X}Zn_XFe_2O_4$ بقيم X مختلفة (0، 0.1، 0.3، 0.5، 0.7، 0.9) على التوالي، باستخدام طريقة الترسيب المشترك. تراوحت الفرآيتات النانوية من (10- 28 nm)، وتم أخذ عينات من الخصائص التركيبية للعينات المحضرة باستخدام حيود الأشعة السينية (XRD) والمجهر الإلكتروني الماسح للانبعاثات الميدانية (FESEM). أظهرت النتائج التركيبية أن للجسيمات طور مكعبي وأن الجسيمات لها مقياس نانوي مع تكتل واضح بين مواقع الجسيمات، وأخيرًا أظهرت اختبارات الخصائص المغناطيسية أن للجسيمات تشبع مغناطيسي عالي.

الكلمات المفتاحية: جسيمات نانوية مغناطيسية، حيود الاشعة السينية، طريقة الترسيب الكيميائي المشترك، FESEM، الفرايت، VSM.

Introduction

Ferrites are iron oxides consist ferric oxide and metal oxides that depend on the crystal structure. They are, classified into three categories, hexagonal ferrite, agate ferrite and spindle ferrite. The magnetic properties arise from the interactions between the metal ions that occupy specific locations with respect to the oxygen ions in the oxide crystal structure, the spindle ferrite is an important class of magnetic materials, as it has a combination of electrical and magnetic properties that make ferrite useful in many technological applications [1, 2].

The general formula of spinel ferrites is MFe_2O_4, where M is one of the bivalent transition elements or is made of a mixture between them, these materials are Mg^{+2}, Co^{+2}, Cu^{+2}, Ni^{+2}, Fe^{+2}, Mn^{+2} and Cd^{+2} ferrites have a high electrical resistivity that reach to ($10^9 \Omega$.cm) and a high magnetic permeability as well as a dielectric constant, ranging between 10 to 15. These quantities can be changed according to the magnetic the electric fields and the ferrites consider from the ferromagnetic material [3]. The high resistance of the ferrites enables electromagnetic waves with high frequencies to travel through ferrites circles with little loss, where the interaction occurs between the magnetic spin component of the material with the component of applied magnetic field. The Interaction of the behavior of magnetic transmittance with the magnetic field strength is applied at the microwave frequency, clear resonance absorption occurs through the ferrite material at a frequency proportional with the intensity of the applied magnetic field [4].

Ferrites have crystalline structures of various shapes of soft ferrites and hard ferrites. The brittle ferrites are the basis of magnetic materials that are used in electrical devises and have many benefits, such as a wide frequency range, high electrical resistance thermal stability and low cost and losses compared to its high magnetic permeability and low density [5]. According to the magnetic properties of ferrites the soft ferrite has a narrow hysteresis loop which is easy to magnetize. As well as easy to demagnetize after its demise the effect and they are used to make electromagnets. The hard form of ferrites, have a large hysteresis loop and it is difficult to demagnetize these materials, the magnetization usually occurs at the M, H regions [6]. The properties of the prepared nano ferrite are controlled by controlling of metals ions redistribution and these are mainly responsible for the behavior of the prepared magnetic ferrites. It is also possible to obtain a type of magnetic Nano ferrites by means of precision and control by pH. The Furthermore, the components concentration of the prepared material and the temperature are used in the preparation and the methods of the preservation of the concentration's measurement of the chemical elements of ferrite due to the distinctive properties of the ferrites [7]. It has been used in sheets of transformers cores magnates, technological and biological uses [8]. Cobalt Ferrite has a cubic structure with oxygen ions and forms a face centered lattice and the cations occupy is one eighth of tetragonal lattice and 50% of Octahedral lattice. The structure consists 32 oxygen ions and 24 cations, making the total number of 56 atoms. The Curie temperature of cobalt ferrite is about 500 ^{o}C, lowest of a degree it has ferromagnetic properties as well as has a magnetic saturation and high dielectric constant [9].

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Experimental part

The compound of cobalt zinc ferrite $Co_{1-X}Zn_XFe_2O_4$ was prepared with co-precipitation method by dissolving the iron chlorides $FeCl_3$ in 100 ml of distilled water, and dissolved zinc dichloride $ZnCl_2$ in 50 ml of distilled water and dissolving cobalt dichloride in 50 ml of distilled water. Sodium hydroxide (5 g) was dissolved and dropped slowly distilled using a glass burette on the homogeneous mixture with continue stirring until we get a mixture at a value of pH = 12. In continuing to add the hydroxide, one can notice that the mixture turns into a jelly-like mixture, after the mixture reaches a value of get a mixture with pH = 12. We heat it up. The mixture gets constant temperature (90-100 °C) for one hour until we get a precipitate, the precipitate is cooled at room temperature and according to the weight ratios of the materials. It is shown in table 1.

Table 1: Shows the weights ratios of the materials used in the preparation of cobalt zinc ferrite

X	Iron chloride III $FeCl_3$g	Zink chloride II $ZnCl_2$g	Cobalt chloride II $CoCl_2$g	Sodium hydroxide NaOHg
0	32.442	0	12.984	5
1	32.442	1.3628	11.6856	5
2	32.442	4.0885	9.0888	5
3	32.442	6.8143	6.492	5
4	32.442	9.5400	3.3452	5
5	32.442	12.2657	1.2984	5

Results and discussion

The structural properties have been studied using X-ray diffraction (XRD) test According to the chemical formula $Co_{1-X}Zn_XFe2O4$ with the ratios of X values 0, 0.1, 0.3, 0.5, 0.7 and 0.9 Respectively. The prepared samples of cobalt zinc ferrite were tested using the co-precipitation method at the temperature of 300^{o}C. The results presented clear peaks appeared within the range Ѳ2=10-80 and proved that the peaks belong to the crystalline levels (111,220,311,400,422,511,440 and 533) figure 1 indicates that the structure is crystalline structure of the ferrite powder, which is the face centered cubic structure, these results are corresponding with standard card (ICSD 00-022-1086). Also, the results confirmed the structure of the single-phase cubic spinel (group Fd-3m.), the lattice constant was calculated from equation 1 [10], for the prepared samples with values that ranged between (8.373-8.430). The result comes with an agreement with the researcher [11], so the crystallite size was calculated using the Scherer equation 2 [12] as shown in table 2.

$$\mathbf{a} = \frac{\mathbf{n\lambda}\sqrt{\mathbf{h^2+k^2+l^2}}}{\mathbf{2sin\theta}} \qquad \mathbf{(1)}$$

where D is the average crystal size, K is the Scherrer coefficient (0. 9), λ is the x-ray wavelength, θ is Bragg's angle (2θ) and β the full width at half-maximum (FWHM) in radians.

$$\boldsymbol{D} = \frac{\boldsymbol{k\lambda}}{\boldsymbol{\beta_{hkl}\cos\theta}} \qquad \mathbf{(2)}$$

Where a the lattice parameter, d is the interplanar distance of each plane and (hkl) are Miller indices, θ is Bragg's angle, λ is the x-ray wavelength, n = 1, 2, 3…..

Table 2: the values of the lattice constant and the grain size of Cobalt Zinc Ferrite at a temperature of 300 °C

Sample	Molar ratio	Composition	2 Θ	a Å	D (nm)
A1	0	$CoFe_2O_4$	35.5279	8.373	20.2
A2	0.1	$Co_{0.9}Zn_{0.1}Fe_2O_4$	35.9820	8.370	14.8
A3	0.3	$Co_{0.7}Zn_{0.3}Fe_2O_4$	35.726	8.328	12.6
A4	0.5	$Co_{0.5}Zn_{0.5}Fe_2O_4$	35.404	8.401	10.8
A5	0.7	$Co_{0.3}Zn_{0.7}Fe_2O_4$	35.4175	8.397	9.07
A6	0.9	$Co_{0.1}Zn_{0.9}Fe_2O_4$	35.267	8.430	8.5

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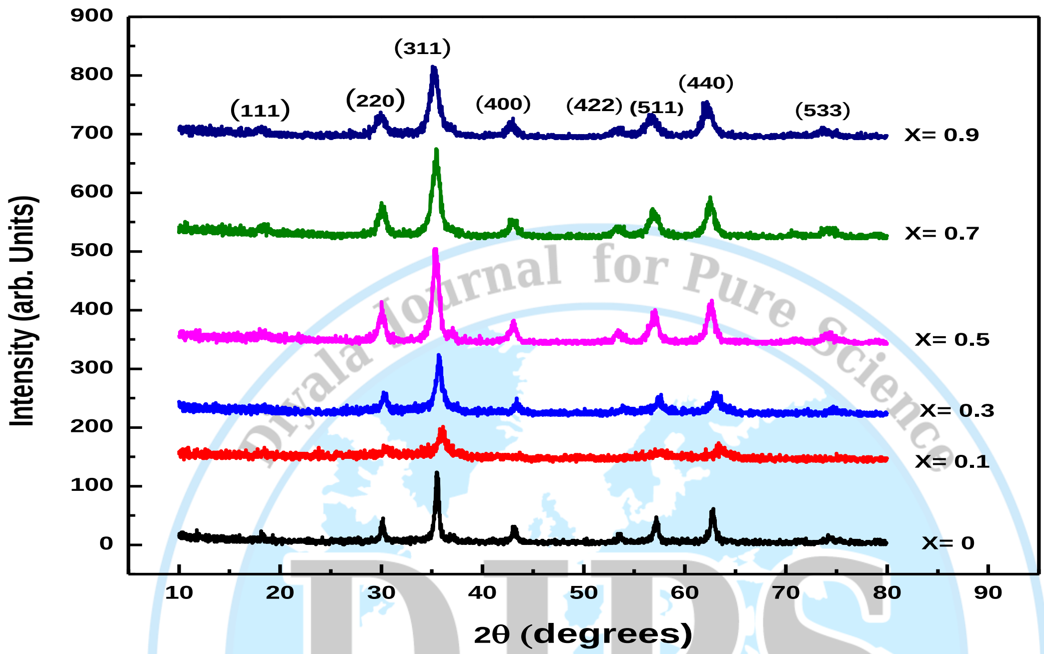

Figure 1: X-ray diffraction spectroscopy of Cobalt Zinc Freight samples

The FESEM morphology of the prepared particles of $CoZnFe_2O_4$ compound were studied, which gave an evidence of the formation of the nanoparticles for all ratios. The results showed that the particles have a narrow distribution of the nanoparticles size with round shape figure 2. It is also noted that the nanoparticles have a homogeneous agglomeration, and shave permanent magnetization, therefore each particle have permanent magnetization, which appears from the agglomeration and aggregation of the nanoparticles figure 2. Also, FESEM test displays the results of the X values (0, 0.1, 0.3. 0.5, 0.7, and 0.9). Most of the samples appear within the Nano scale and this is due to the method of Preparation in addition to the purity of the materials used in the Preparation.

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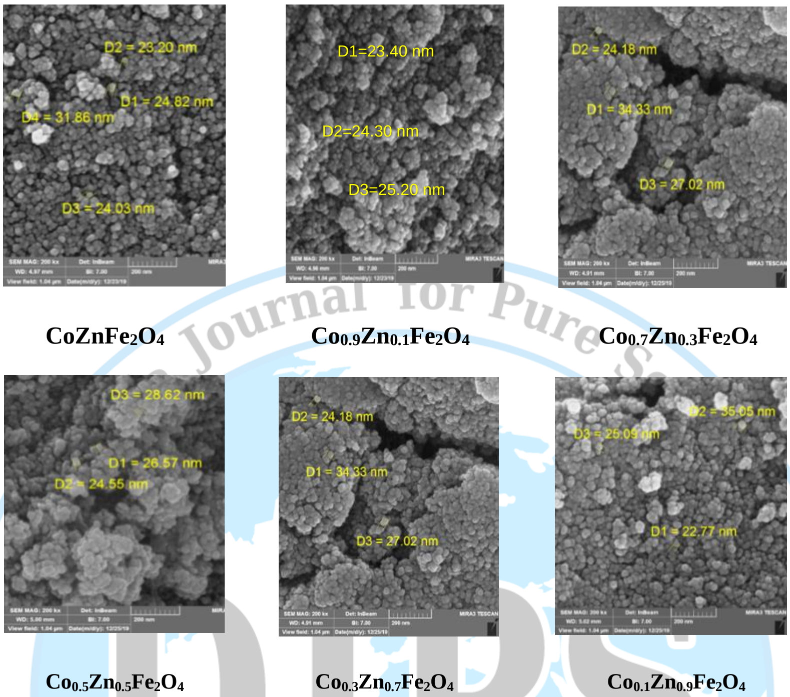

Figure 2: Images of FESEM results of Cobalt Zinc Ferrite

The magnetic properties of the prepared materials were studied by using VSM device at room temperature at an applied magnetic field of 15 KOe. Figure 3 shows MH curves of the samples prepared by the co-precipitation method at the ratios of X values (X = 0, 0.1, 0.3, 0.5, 0.7 and 0.9) at 300^{o}C. The preparation of the material at low temperatures shows us the properties of magnetism, as the variation in the magnetic properties as shown by the hysteresis ring with an increase in the proportion of zinc in the ferrite, and the narrowing of the hysteresis ring gives the properties of the soft ferrite, and some ratios also showed a hysteresis ring in the form of a line indicating the transformation of the material into the super magnetic state, and this confirms the lack of high energy consumption and this is in agreement with the research [13].

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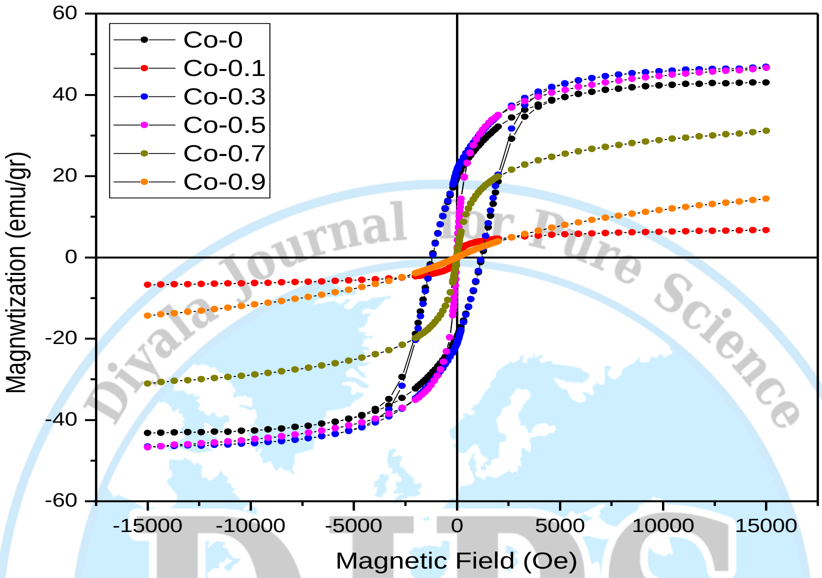

Figure 3: hysteresis loop of Cobalt Zinc Ferrite at a temperature of 300°C

Conclusions

This study showed the possibility of preparing nano-magnetic cobalt zinc ferrites with high purity by co-precipitation method at (300 ^{O}C) with saving energy consumed in the preparation. XRD test proved that the ferrites have a cubic spinal structure with nano scale sizes in the range of (8.5-20.2 nm), The FESEM results showed that the particles have a single shape, which is round shape with a narrow distribution of the nanoparticles size of the nanoparticles through the homogeneous agglomeration of the micro spherical particles. Most of the specimens are brittle ferrites with a narrow hysteresis ring and high magnetic saturation.

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