



Purposeful scientific research is a basic pillar for the advancement of Iraq



Study the effect of pH value on structure properties of $Ni_{0.6}Zn_{0.4}Fe_2O_4$

Najat A. Dahham , Abdulsamee Fawzi Abdul Aziz , Omar Farooq Fouad

Physics Department , College of Science , Tikrit University, Tikrit, Iraq

dr.najat1970@tu.edu.iq , abdulsamee_fawzi@tu.edu.iq , Alnoaimy94@gmail.com

ABSTRACT

Nanoparticles of ferrite compound with the formula $Ni_{0.6}Zn_{0.4}Fe_2O_4$ and pH values (pH = 1.5, 7, 10, 13) were prepared using a chemical precipitation method. The shape of X-ray diffraction (XRD) pattern spectrum shows the appearance of the spin phase of zinc and an increase in the intensity of the peaks with increasing pH, which leads to the formation of nanoparticles of varying size according to the pH value. The surface morphology of $Ni_{0.6}Zn_{0.4}Fe_2O_4$ nanoparticles was obtained by Scanning Electron Microscopic (SEM), the magnetic nanomaterials showed a spherical-like agglomeration with random and slightly unclear precipitation, the morphology of Nickel Zinc ferrite appeared as a semi-cubic structure at (pH=7) and sintered at 700°C for two hours.

Keywords: Nickel ferrite ($NiFe_2O_4$), Zinc ferrite ($ZnFe_2O_4$), XRD, SEM, lattice constant.

Introduction

Recent years have seen a rise in the production of spinel ferrite by a sizeable number of researchers and scientists, mostly as a result of the many and one-of-a-kind structural, spectroscopic, and magnetic properties that it has. Spinel ferrites have a wide variety of applications, some of which are microwaves, medicine delivery (three), gas sensors (four through five), and electrical devices (six). All of these uses are linked to the kinds of transition metals that may be found in the structure of spinel ferrites [1-7]. In order for these materials to be useful for technological applications, they must have a low porosity, a high density, and a species-specific microstructure.[8].

When the under research ferrite nanopowders are allowed to crystallize, spinel is produced. The octahedral or tetrahedral locations inside the lattice are both conceivable for the divalent A cations and the trivalent B cations, respectively. The environment that each of these cations is in affects this. According to how the M^{2+} and Fe^{3+} cations are arranged, spinel ferrites are divided into two groups: conventional spinel AB_2O_4 with the formula $(A^{2+})A[Fe^{3+}Fe^{3+}]BO_2$ and the inverse type B (AB) O_4 with the formula $(A^{2+}Fe^{3+})A[A^{2+}Fe^{3+}]BO_2$. Both of these spinel ferrites have the same [9]. These two equations may both be true. According to Figure (1) [10], when spinel ferrites crystallize, the metal ion will get caught

between the two oxygen ions because its radius is smaller than that of the oxygen ions. Spinel ferrites' structural and magnetic characteristics are influenced by the presence of cations along the (A) and (B) sites. One of the various ferromagnetic soft ferrite materials is nickel ferrite, which is also one of the most adaptable and important in terms of technology [11-13]. It's typical traits, which include reduced eddy current losses, low conductivity, and strong electrochemical stability, are to blame for this. Because of their high magnetic permeability, low electrical conductivity, and exceptional performance at high frequencies, Ni-Zn spinel ferrites are particularly intriguing [14]. Numerous techniques, such as the hydrothermal method [15], co-precipitation [16], sol-gel [17], microwave combustion [18], and others [19, 20], were employed to create the Ni-Zn Nano ferrite. The sol-gel technique is one of these methods that stands out for being both useful and efficient. It was feasible to effectively achieve chemical uniformity, a high degree of purity, and substantial energy savings by employing the sol-gel technique [21]. The composition, particle size, quantity of dopant present, impurities, production process, and heating conditions are only a few of the microscopic properties of Ni-Zn ferrites [22].

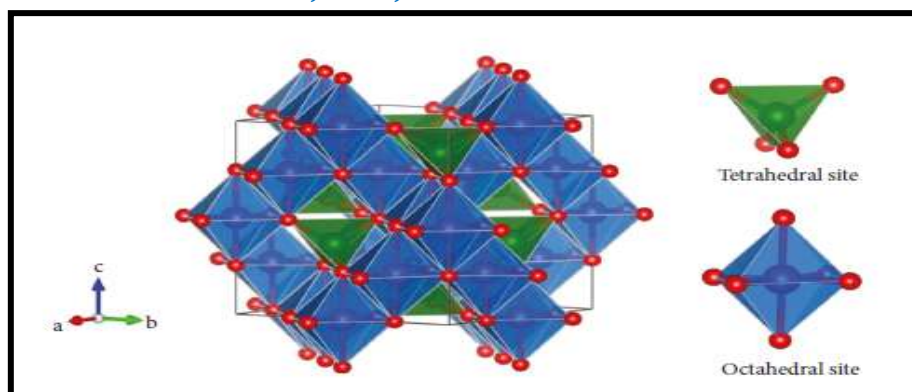


Fig. 1: the cubic spinel structure. oxygen locations are shown in red, while the tetrahedral (A-site) and octahedral cation (B-site) are indicated in green and blue, respectively [19].

Experimental details

To prepare the compounds used in experimental by chemical precipitation method, iron nitrate, zinc nitrate and nickel nitrate were dissolved in (100ml) of distilled water using a magnetic stirrer (Stirrer magnetic) at a temperature of (60 °C) and for half an hour in order for the substance to be completely and homogeneously dissolved in water, then all the solutions are mixed in a glass flask at a temperature of (60 °C) for half an hour with continuous stirring by means of the magnetic mixer.

As for the second stage, (40g) of sodium hydroxide (NaOH) was dissolved in (200 ml) of distilled water in a glass flask with continuous stirring using a magnetic mixer at a temperature of (60°C) for 15 minutes. Sodium hydroxide solution is used as a precipitating agent and to determine the pH value.

As for the third stage, it included mixing all the solutions in a glass flask at a temperature of (60°C) for half an hour with continuous stirring by means of the magnetic mixer. Then we distill the sodium hydroxide solution mixture by a burette slowly over the solution of the mixture of solutions while continuing the mixing process at a temperature (60°C) until the sodium hydroxide solution is distilled to determine the pH value.

After completing the distillation process, the solution will be clear with a pH that we determine. This solution is filtered with filter paper and then washed several times with distilled water to get rid of insoluble nitrates. Then the resulting substance is taken and dried in a drying oven at a temperature (100 °C) to obtain a dry, moisture-free compound. Then the powder we obtained is calcined at a temperature of (700 °C) for two hours

Results and discussion

1. X-ray Diffraction (XRD).

The ferrite samples were prepared based on the molar concentration and molecular weights by comparing the X-ray diffraction patterns of ferrite after sintering at a temperature of 700°C and in comparison with the standard labels it was found that they are identical to the standard label number (JCPDS 8-324).) And as shown in Figure (1-2), and from the X-ray diffraction pattern of the sample, the appearance of peaks (220),(311),(222),(400),(422),(333),(440),(533) within the angular range (20°-80°) for all the compounds prepared by chemical precipitation method, where the peaks are considered dominant, which refers to the geometric crystal structure of ferrite powder and from observe the shape of the diffraction spectrum, the appearance of the spin phase of zinc. No impurities were found for any other material, which proves that the material has a very high purity. A variation in intensity was found where the highest intensity was due to the (311) peak corresponding to the angle 35.7°, when looking at the diffraction spectrum an increase in the intensity of the peaks with increasing pH, leads to the formation of nanoparticles of varying size according to the pH value. As the pH increases, the granular size increases. The granular size has reached the value (18-48 nm) of the pH value, and the reason for the increase in size is The granularity of ferrite materials is due to the fact that magnetic materials tend to agglomerate, which leads to the increase of particles with each other, which leads to an increase in the surface area of the material, thus increasing the granular size also, justify this increase due to the recrystallization that reduced the amplitude of the lattice constant [23].

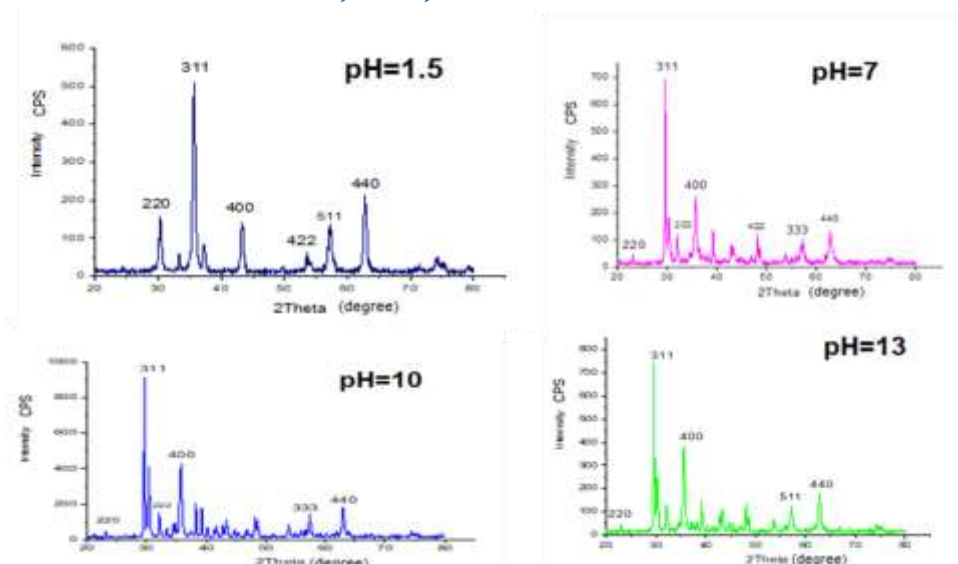


Fig. 1-2 : XRD of $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ with PH value 1.5,7,10,13

2. Lattice constant

The lattice constant based on Miller's coefficient for the highest obtained intensity and for the peak (311) shown in table (1-1), which was prominent in terms of intensity, location and granular size. It increased with the increase of the pH and also with the increase in the content of the zinc ion whose value was different between the two formulas, as it causes the increase to the migration of the triple iron ion from the tetrahedral sites to the range of the octahedral sites [24].

Table (1-1): The value of lattice constant with PH for (311) peak

pH value	Lattice constant a (Å)
7	8.382
10	8.391
13	8.373

3. Theoretical Density

The theoretical density shown in table (1-2), it was found that the theoretical density decreased with increasing pH and also with an increase in the zinc ion content, where the ratios varied between (5.32-5.42 g/cm³), where in the ferrite spinel structure, which contains the tetrahedral and octahedral

structure, it is preferred to occupy the eight-surfaced corners with Zn^{+2} ions because of the predominance of volume over mass and also because the diameters of the ions are not the same size [25].

Table (1-2): value of Theoretical density at different pH

pH value	Theoretical density (ρ_{xrd}) (gram/cm ³)
7	5.25
10	5.384
13	5.342

4. SEM analysis

The morphology and the size distribution of the NiFe_2O_4 nanoparticles were determined using SEM. Typical SEM images of NiFe_2O_4 synthesized, as for the sample with the structural formula $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ and at (pH values = 1.5, 7, 10, 13). The image of this formula and as shown in Figure 2 (a-d) where it was found that the magnetic nanomaterials showed a spherical-like agglomeration with random and slightly unclear precipitation, although the morphology of NZF has been It appeared as a semi-cubic structure as shown in Figure prepared at (pH=7) and sintered at 700°C for two hours.

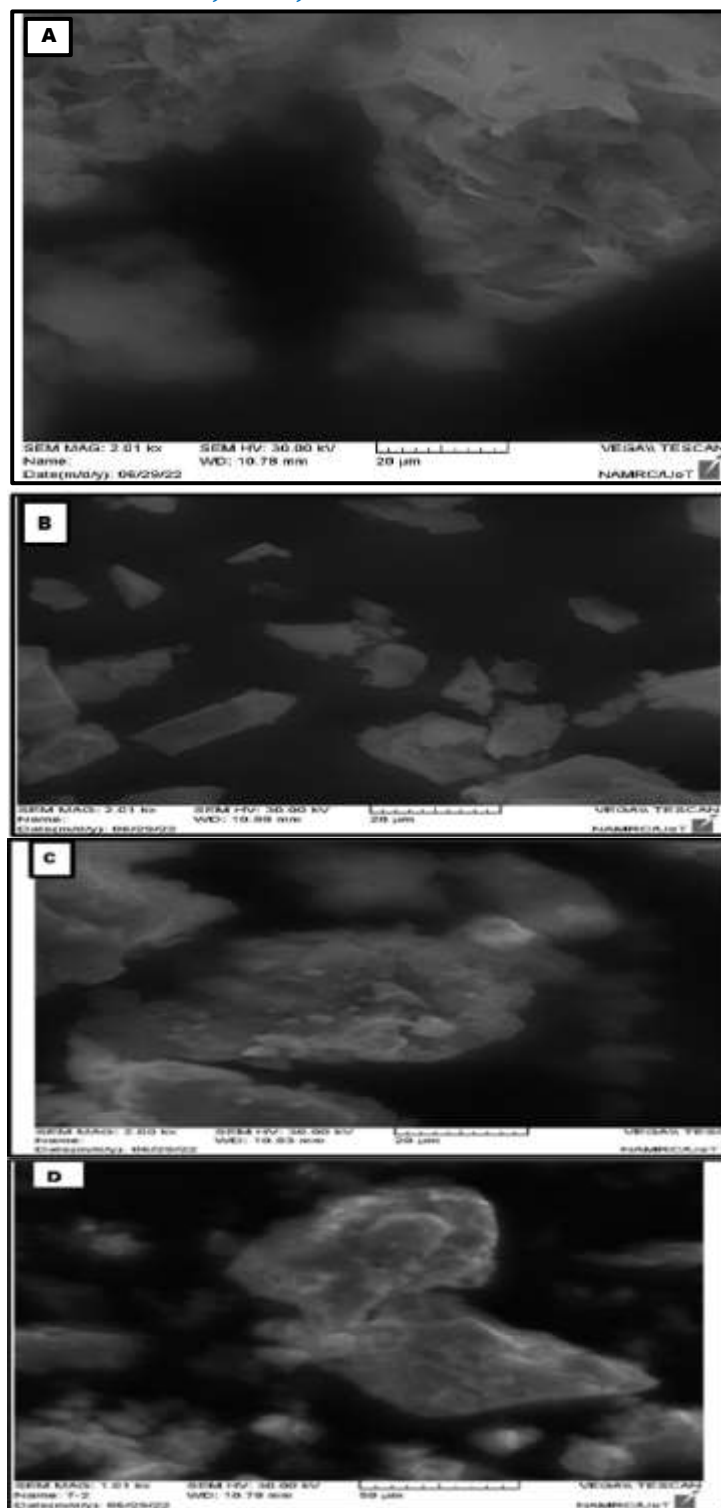


Fig. 2 (a-d): SEM for $\text{Ni}_{0.6}\text{Zn}_{0.4}\text{Fe}_2\text{O}_4$ at pH=1.5,7,10,13

Conclusion

If we put a single scientific explanation for the effect of pH on the physical properties of the prepared nanomaterials and for all chemical formulas and for all the different values of hydrogen bases in order to arrive at a single explanation commensurate with the different conditions for preparing all the models, we would find that the most appropriate explanation is that the particles exhibited behavior in terms of shape

as if they were smaller and more regular And the geometrical shape of the particles is simple cube and looks similar to spherical, and lumps were found in most of the samples as a result of surface tension and adhesion of particles with each other, in addition to that magnetic nanoparticles tend to form clusters and stick to each other according to the interaction of magnetic dipoles.

Reference

- [1]. W. D. Kingly, D.R. Uhlmann and H.K. Bowen, Introduction to ceramic, 2nd edition, John Wiley and sons, New York 1976.
- [2]. P. I. B. Clarricoats, Microwave Ferrites, Chapman and Hall Ltd., London 1961.
- [3]. C. Kittel, "Introduction to solid state physics", 5th ed., John Wiley and sons New York 1976.
- [4]. K. J. Standley; "Oxide Magnetic Materials", 2nd Ed., Clarendon Press, Oxford, 1972.
- [5]. L. L. Hench & West J. K., "Principle of Electronic Ceramic" John Wiley & sons 1990.
- [6]. M. M. Eltabey, W.R. Ajami, H.T. Mohsen "Improvement of the magnetic properties for Mn-Ni-Zn ferrites by rare earth Nd³⁺ ion substitution" J. of Advanced Research 05, PP. 601-605 (2014).
- [7]. V. A. Goel, T.C., Mediratta, R.G., and Gupta, R., "High resistivity nickel-Zinc ferrites by the Citrate precursor method", Journal of Magnetism Materials, vol. 192, pp. 271-276, 1999.
- [8]. J. G. H. and Stuijts, A. L., "Controlling the properties of electroceramic materials through their microstructure" Philips Technical Review, vol. 32, pp. 79-95, (1971).
- [9]. S. A. L. and Kooy, C., "Influence of Technological Factors on the Sintering Behavior of ferrite" in proceedings of Conference held under the auspices of British ceramic society and the Netherlands Keramische Vereniging at Noordwijk aan Zee 13-17 May, 1963, in Science of Ceramic, edited by Ste wart, G.H., vol. 2, 1965.
- [10]. Y. Chien & Y. Chaoko, J. Mater. Sci. V. 25, pp. 1771-1781, (1990).
- [11]. A. Vijayalakshmi & N.S. Gajbhiya "Magnetic properties of Single domain SrFe₁₂O₁₉ particles synthesized by citrate precursor technique" Appl. Phys., Vol. 83, No. 1, Jan. 1998.
- [12]. G. A. Hossienpour, A. Morisako, A. Saatchi, M. Salehi "Electromagnetic properties and microwave absorbing characteristics of doped barium hexaferrite" Journal of Magnetism and Magnetic Materials 302, pp. 429-435, (2006).
- [13]. Richa R, Tyagi A. K, Ahlawat D. S. Influence of pH Variation on Structural and Magnetic Properties of Ni-Zn Ferrite Nanoparticles Synthesized by Auto Combustion Method. Orient J Chem; 33(1). (2017).
- [14]. Lafta, Sadeq H. "Effect of pH on Structural, Magnetic and FMR Properties of Hydrothermally Prepared Nano Ni Ferrite" Open Chemistry, vol. 15, no. 1, pp. 53-60. (2017).
- [15]. ELSAYED, E. M., et al. "The effect of solution pH on the electrochemical performance of Nano-crystalline metal ferrites MFe₂O₄ (M= Cu, Zn, and Ni) thin films". Applied Nanoscience, 6(4): 485-494. (2016)
- [16]. Santosh S. Jadhav, Sagar E. Shirsath, B. G. Toksha, S. J. Shukla, K. M. Jadhav. "Effect of Cation Proportion on the Structural and Magnetic Properties of Ni-Zn Ferrites Nano-Size Particles Prepared By Co-Precipitation Technique" J. , 21(4): 381-386. (2008)
- [17]. Huq, M. F., Saha, D. K., Ahmed, R., & Mahmood, Z. H.. Ni-Cu-Zn Ferrite Research: A Brief Review. Journal of Scientific Research, 5(2), 215-234. (2013).
- [18]. Behrooz Shahbahrani, Sayed Mahmood Rabiee, Reza Shidpoor et al. Effect of pH Value on Synthesis and Properties of Zinc Cobalt Ferrite Nano Powders Prepared via Co-Precipitation Method, 15 May 2020, PREPRINT (Version 1) available at Research Square.
- [19]. Sarwar Hasan and Bruska Azhdar, "Synthesis of Nickel-Zinc Ferrite Nanoparticles by the Sol-Gel Auto-Combustion Method: Study of Crystal Structural, Cation Distribution, and Magnetic Properties" Advances in Condensed Matter Physics, Vol. 2022, pp. 14.
- [20]. M. Junaid, M. A. Khan, S. A. Abubshait et al., "Structural, spectral, dielectric and magnetic properties of indium substituted copper spinel ferrites synthesized via sol gel technique," Ceramics International, vol. 46, no. 17, pp. 27410-27418, 2020.
- [21]. P. P. Mohapatra, S. Pittala, and P. Dobbidi, "Temperature dependent broadband dielectric, magnetic and electrical studies on Li₁-Mg₂Fe₅-O₈ for microwave devices," Journal of Materials Research and Technology, vol. 9, no. 3, pp. 2992-3004, 2020.
- [22]. R. Jose, R. Jothi, and N. S. N. Jothi, "Synthesis and characterisation of curcumin loaded Ag_(1-x)Ni_xFe₂O₄ for drug delivery," Materials Technology, vol. 36, no. 6, pp. 339-346, 2021.
- [23]. K. K. Kefeni, T. A. M. Msagati, and B. B. Mamba, "Ferrite nanoparticles: synthesis, characterization and applications in electronic device," Materials Science and Engineering: B, vol. 215, pp. 37-55, 2017.
- [24]. R. R. Powar, V. D. Phadtare, V. G. Parale, "Effect of zinc substitution on magnesium ferrite nanoparticles: structural, electrical, magnetic, and gas-sensing properties," Materials Science and Engineering: B, vol. 262, Article ID 114776, 2020.
- [25]. P. S. Mkwae, I. Kortidis, R. E. Kroon, "Insightful acetone gas sensing behavior of Ce substituted MgFe₂O₄ spinel nano-ferrites," Journal of Materials Research and Technology, vol. 9, no. 6, pp. 16252-16269, 2020.