

Crystallographic and Magnetic Properties of Al³⁺-co-doped NiZnFe₂O₄ Nano-particles Prepared by Sol-gel Process

Amany M. El Nahrawy¹, Heba Salah El-Deen², Aisha A. Soliman³, Wafaa M.M. Mosa⁴

¹Solid State Physics Department, Physics Research Division, National Research Centre (NRC)-33 El Bohouth st, P.O.12622, Dokki, Giza, Egypt. (Affiliation ID:60014618)

²Department of Physics and Chemistry, Faculty of Women for Arts, Science and Education, Ain Shams University, Cairo, Egypt.

³Department of Solid State Physics, Faculty of Women for Arts, Science and Education, Ain Shams University, Cairo, Egypt.

⁴Department of Spectrum Physics, Faculty of Women for Arts, Science and Education, Ain Shams University, Cairo, Egypt.

Al₂O₃ SUBSTITUTED nickel zinc nano-ferrite Al_xNi_{0.5-x}Zn_{0.5}Fe₂O₄ (x = 0.0, 0.1, 0.2, 0.3) was prepared by the citrate sol-gel method using nickel, zinc, iron and aluminum nitrates and sintered at 800°C for 3 h in air. Prepared nano-sized ferrites were characterized by X-ray diffraction, High resolution transmission and scanning electron microscopy and Fourier transforms infrared spectroscopy. The estimated crystallite sizes were in the range of 24.7–32.9 nm. HR-TEM data appears that all nano-ferrite samples are composed of more or less agglomerated nanoparticles with the average particle size of nanocrystallites is ~31 nm. The impact of introducing Al ions by Ni on the magnetic properties of the prepared nano-ferrite was investigated utilizing magnetic measurements at room temperature. The changing of crystallite sizes, lattice parameter and the surface area with increasing the Al content were determined. The saturation magnetization (Ms) and coercivity (Hc) values vary from 47.894-32.314 and 70.37-60.117 G; respectively.

Keywords: Nano-crystalline ferrites, Nickel zinc ferrite, Sol-gel process, Spinel ferrite, Magnetic properties.

Introduction

Recently, soft ferrites are most versatile due to their technological applications, especially prepared by chemical methods [1]. Chemical methods as sol gel process provide high purity and homogeneity, uniform distribution of dopants ions at the molecular level and high efficiency [2]. Ni-Zn ferrites are known and have been applied in various the electrical and electronic industries, due to their interesting electrical and magnetic properties [3,4]. Nickel zinc ferrites as spinel-type structures, have a particular interest from the researchers much due to its using in various industrial electronic applications, such as communication devices (mobile phones), drug delivery, TVs, sensors, data storage, radios, microwaves,... etc. [4-6]. The spinel structure name is offered due to its structure arrangement in which metal ions are distributed between (A site)

tetrahedral and (B site) octahedral sites formed through the oxygen ions in a unit cell [7,8]. So, the distribution of metal ions through the A site and B site affects the magnetic properties of M-Fe₂O₄, which may be controlled by thermal treatment and crystallite size [9]. Nickel zinc ferrite belongs to the soft magnetic materials group, which is easily magnetized and demagnetized. Most electronic and magnetic applications require polycrystalline ferrite materials to be pressed into larger shapes, which is difficult to produce if the particles have wide-size distribution [10,11]. The variation in the starting composition of Ni-Zn-ferrite results in the rearrangement of metal ions through A and B sites, which can modify the properties of these ferrites. Thus, more investigations are still required to be done to produce Ni-Zn ferrite with narrow grain size distribution, high surface and controlled porosity leading to better structural, magnetic and electrical properties [12, 13]. The

*Corresponding author e-mail: amany_physics_1980@yahoo.com

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properties of ferrite materials change as their nanoscale size and as the level of atoms at the surface of a material become important. The superior properties of ferrites nanoparticles are therefore largely due to the large fraction of atoms that occupies the grain boundary area [14]. The synthesis of new magnetic systems, such as iron-based, led the modification of metallic materials with a nano-crystalline structure and non-classical properties. The production process progression in the size control and characterization of these magnetic systems has entailed to numerous benefits, both in the scientific and technological fields [14,15]. Considerable interest in chemical methods for the synthesis of nano-ferrite nanoparticles has been controlled to explore better materials with controllable shape, nano-scale, and stability for multi-applications sol-gel methods [15,16].

The sol-gel method as a one of the low temperature chemical methods was used for synthesis ferrites nano materials, which allows to introduce different modifiers such as Zn, Al, Ce and Cu ions in the ferrite materials could also enhance their structural and magnetic properties [15-17].

The main idea behind using the sol-gel process is to “dissolve” the compounds in a liquid in order to bring it back as a solid in a controlled manner at nano-scale. In this study, according to the importance of Al_2O_3 -nanoferrites, this attempt has been made to study the effect of substitution Ni ions by Al_2O_3 ions on the structural and magnetic properties of $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ nano-crystalline. The nano-magnetic samples with the composition $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x = 0.0, 0.2, 0.5, 0.8$) were prepared via citrate sol gel method and calcined at 800°C for 3h in air. This method involves the hydrolysis and poly-condensation reactions of the nickel, zinc, iron and aluminum nitrates, in aqueous citrate acid producing xerogel at 100°C . The structural and magnetic behavior of these samples was studied. The produced nano-ferrite was characterized by X-ray diffraction (XRD), high resolution transmission and scanning electron microscopy (HRTEM/SEM), Fourier Transforms Infrared (FTIR) and vibrating sample magnetometer (VSM) techniques.

Experimental

$\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ nano-crystalline was prepared using citrate sol gel method at room temperature. Nickel, zinc, aluminum nitrates and

ferrous nitrates were used as starting materials. The preparation process was carried out at room temperature, in which distilled water (H_2O) was taken and nitrates of nickel (Ni), zinc (Zn), aluminum (Al) and iron as starting materials were added in stoichiometry proportion to the water. The citric acid was added drop by drop on the mixture and stirring for 2 h and dried at 100°C until all solvents were continuously dried to obtain uniform gel and produce the precipitate. The previous stapes were repeated with different concentration of ($x = 0.0, 0.2, 0.5, 0.8$) Al_2O_3 ions. The obtained brownish powder was calcined at 800°C for 3h in a muffle furnace with heating rate $5^\circ\text{C}/\text{min}$ in air. X-ray diffraction (XRD) patterns of the prepared sample were recorded with an X-ray diffractometer using monochromatized $\text{CuK}\alpha 1$ radiation of wavelength = 1.54056 \AA . Crystallite sizes G were determined from the Scherer's equation ($G = K\lambda / D \cos\theta$), where K is the Scherer constant (0.9), λ : is the wavelength, and D is the full width (in radians) of the peak at half maximum (FWHM) intensity. The morphological features were studied using JEOL (JEM-2100) transmission electron microscope (HRTEM) and high resolution scanning electron microscope (HRSEM). Fourier Transforms Infrared, were used to determine the individual frequencies and their intensities, in the range of 400 cm^{-1} to 4000 cm^{-1} , using the KBr pellet method. The magnetic properties were measured using a vibrating sample magnetometer (VSM Model Lakeshore).

Results and Discussion

X-Ray Diffraction (XRD) Studies:

Figure 1 represents the XRD pattern of $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ doped with different concentrations of Al_2O_3 ions (0.1, 0.2 & 0.3) after calcination at 800°C , to analyze the formation of the crystalline phases. All the prepared samples show characteristic peaks assigned to the homogeneous cubic spinel structure (JCPDS No.08-0234) with a lattice parameter changes from 8.42 \AA to 8.63 \AA with introducing Al ions and corresponding planes of (111), (220), (311), (222), (400), (422), (511), (531), (620), (533) and (444), representing the ferrite lattice [18,19]. From the figures the sharpness and broadening of Bragg's peaks indicate the good and complete formation of pure and doped $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ using the citrate sol gel process. The Lattice constant, X-Ray density and the induced strain is calculated from the Williamson-Hall method [20], as shown in Table

1. There is a small shifting of the diffraction peak towards higher (2θ); this may be due to replacement of Ni by Al ions as shown in Fig. 1. The average crystallite size of the prepared nano-ferrite samples (D) is determined from the broadening of the high intensity peak (311) using the Debye-Scherrer's equation [20]. The crystallite size increases from 24.67 nm for the $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ to 30.85 nm with increasing Al_2O_3 content. This means that the crystallite sizes are increased due to the decrease in the induced strain as shown in Table 1. The observed broadening of XRD pattern for doped nickel zinc ferrite nanocrystalline is ascribed to the crystallite size-induced or strain

induced broadening. From the table it is note that the experimental lattice parameter and density decreases with increasing Al content in the spinel structure $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$. This can be attributed to the change of the relative ionic radii of Ni^{2+} , Al^{3+} , and Fe^{3+} ions where Ni^{2+} ions have greater ionic radii (0.69 \AA), than Al^{3+} ions (0.67 \AA) in the octahedral sites [21]. So, the partial substitution of the Ni ions by the Al ions causes little shrinkage of unit cell dimensions, thereby decreasing the lattice parameter, as shown below in Table 1.

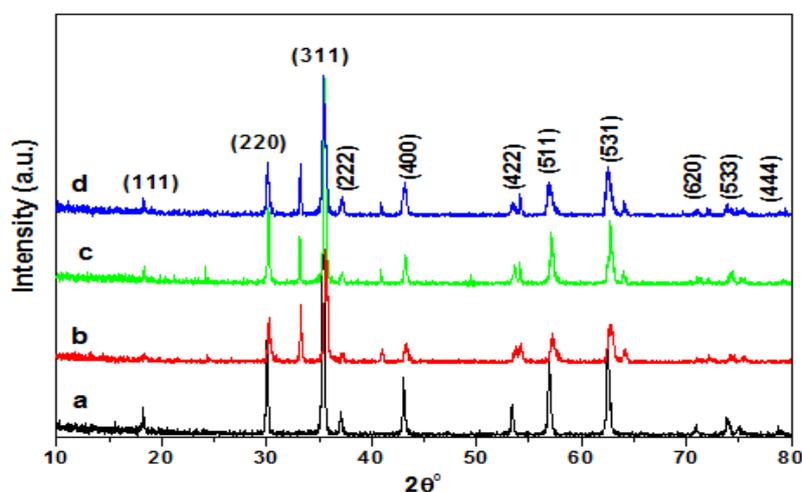


Fig. 1. X-ray diffraction patterns of $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1, 0.2$ & 0.3) nano-crystalline calcined at 800°C for 3h.

TABLE 1. Variation of crystallite size, Lattice constant, D-spacing and X-Ray density with $\text{Ni}_x\text{Zn}_{1-x}\text{Fe}_2\text{O}_4$ doped with Al_2O_3 ($x=0.0, 0.1, 0.2$ & 0.3).

Al_2O_3 content (x)	Crystallite size (nm)	Theoretical Lattice constant (\AA)	Experimental Lattice constant (\AA)	X-Ray density (g/cm^3) $\times 10^{-23}$	d-spacing (\AA)	Surface area (nm)	Strain (ϵ)
0.0	24.67	8.4258	8.4260	2.02371141	2.54050	1201.80	0.50910
0.2	30.00	8.3950	8.3950	2.04601266	2.53120	9775.11	0.31301
0.5	32.9	8.360	8.3610	2.07128244	2.52090	8804.73	0.23370
0.8	30.85	8.360614	8.360	3.10829593	2.52082	6256.44	0.24905

Scanning and transmission electron microscopy (HRSEM/HRTEM)

HR-SEM images revealed that aggregate nanostructures with spherical shapes and particle sizes in nano-scales are bonded in the prepared nano-ferrites (Fig. 2a–c). From the HR-SEM images, it is clear that the surface morphology of these samples shows dense nanostructure

particles assembly of fine nanoparticles and agglomerated as non-uniform sheets for the $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ doped with (0.1 and 0.3) Al_2O_3 ions. Figure 2(B) appears the HR-TEM images for the prepared ferrite nano-particles, obtained at 800°C . All samples reveal that the ferrite nanoparticles of nearly spherical shape and the size about 7–29 nm are uniformly distributed. For the doped

samples with (0.1, 0.3) Al_2O_3 ions, Fig. 2 B (b, c) shows a denser distribution of nanoparticles and agglomeration. The established nanoparticles

size from the HR-TEM images is agreement to the values evaluated from XRD results.

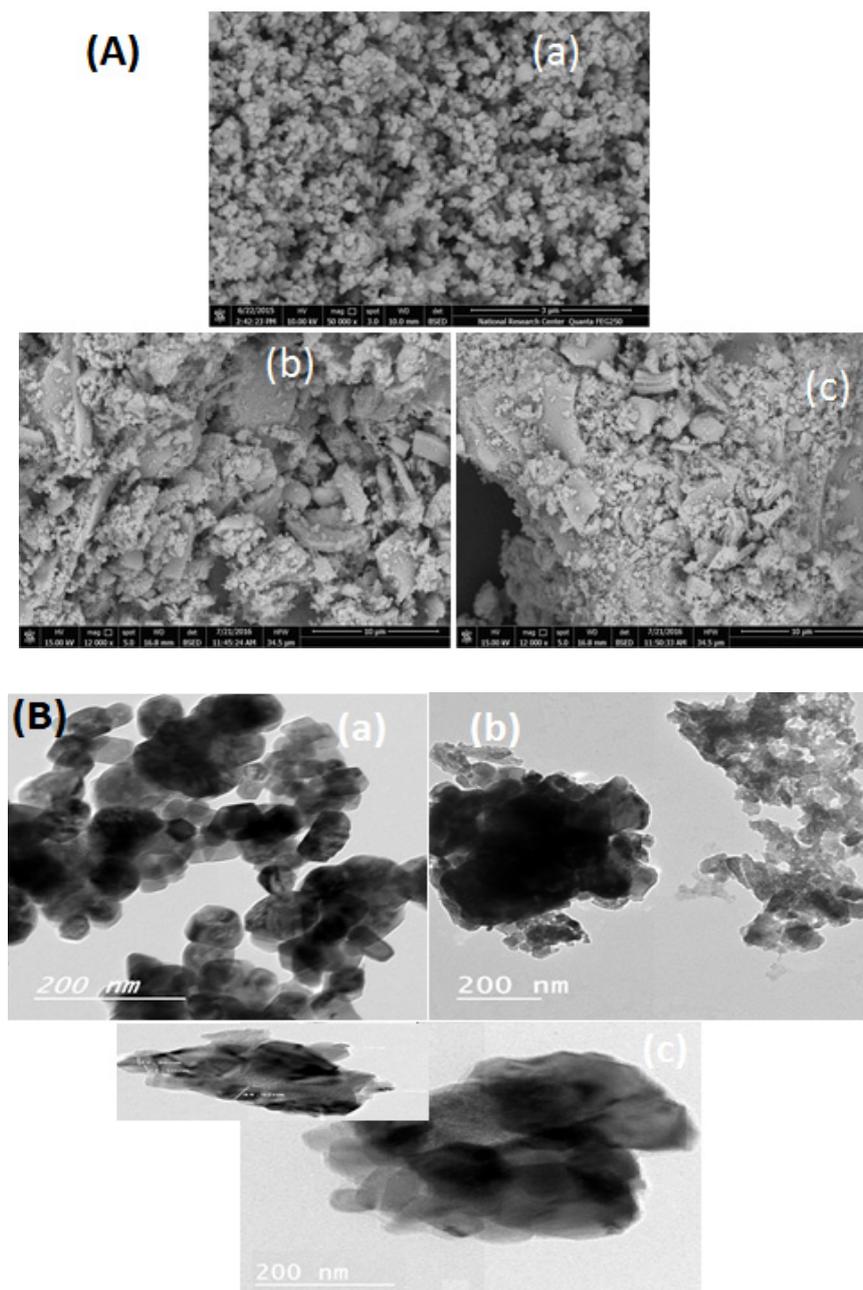


Fig. 2 (A, B). HR-SEM and HR-TEM images of $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1$ & 0.3) nano-crystalline calcined at 800°C for 3h.

FTIR Analysis

Figure 3, shows the FTIR spectra of spinel $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1, 0.2$ & 0.3) nano particle prepared by citrate sol-gel method, in the rang $400\text{--}4000\text{ cm}^{-1}$. The observed FTIR peaks are at 3461 cm^{-1} and 2357 cm^{-1} assigned to stretching vibrations of (O-H) groups and stretching (C-H) respectively [22]. The sharp peak at 1621 cm^{-1} and

1122 cm^{-1} is corresponding to stretching vibration of (M-O), which confirm the formation of the metal-oxygen in ferrite-based. The absorption band at 1386 corresponding to the nitrates from which the Ni, Zn and Fe functional groups and their linkages and disappeared with introducing the Al_2O_3 ions in $\text{NiZnFe}_2\text{O}_4$ [23]. The spectra for the prepared samples give characteristic bands at 457 cm^{-1}

(metal ion– oxygen ($M_{\text{octa}}\text{-O}$) at octahedral-site) and 605 cm^{-1} (metal ion– oxygen ($M_{\text{tetra}}\text{-O}$) at tetrahedral-site), which are the significant bands of

$\text{-Fe}_2\text{O}_4$ groups, which is due to the formation of $\text{NiZnFe}_2\text{O}_4$ nano-structure [24].

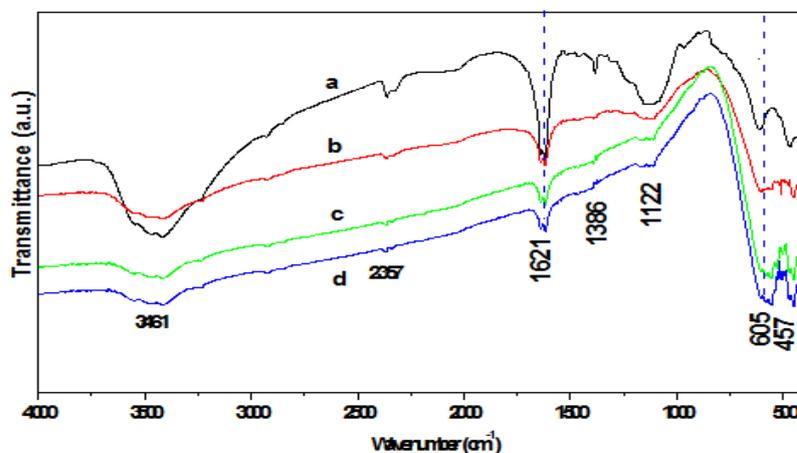


Fig. 3. FTIR spectra of $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1, 0.2$ & 0.3) nano-crystalline calcined at 800°C for 3h.

Magnetic studies

Magnetic measurements were done in room temperature of the $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1, 0.2$ & 0.3) nano-crystalline showed typical magnetic behavior for the nano-ferrite calcined at 800°C for 3h, as observed in Fig. 4. The internal area for the M-H hysteresis loop illustrates amagnetic energy loss. This area for pure and doped $\text{NiZnFe}_2\text{O}_4$ is small which a particular feature for a soft ferrite. Different magnetic

parameters as saturation magnetization (M_s), coercivity (H_c) and remnant magnetization (M_r) are specified of the room temperature hysteresis loop for various concentrations of Al^{2+} ions and are evaluated in Table 2. The observed changes in values of M_s , H_{ci} and M_r with increasing of Al concentrations can be proved to the specific basis of exchange interactions between difference ions at tetrahedral (A) and octahedral (B) sites in ferrites [25].

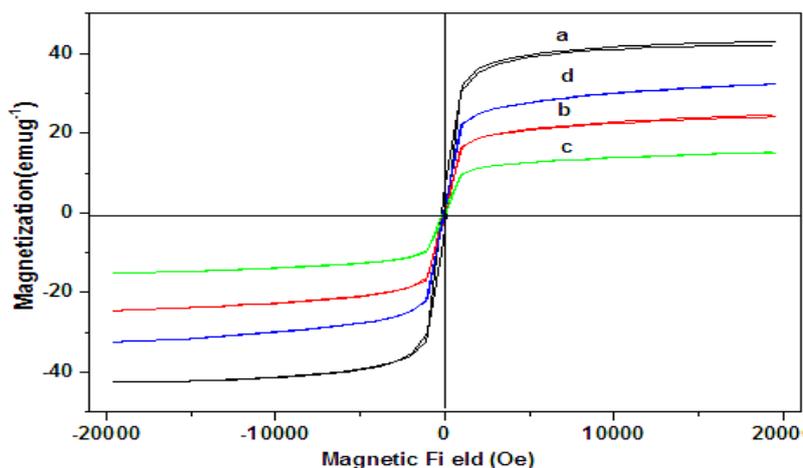


Fig. 4. Room temperature M-H curves of $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ ($x=0.0, 0.1, 0.2$ & 0.3) nano-crystalline calcined at 800°C for 3h.

TABLE 2. Values of Saturation magnetization (Ms), Remnant (Mr), Coercive field, Squarness for $\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ (x=0.0, 0.1, 0.2 & 0.3) nano-crystalline

Sample	M_s (emu/g)	M_r (emu/g)	H_{ci} (G)	Squarness (Mr/Ms)
$\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$	47.894	1.347	70.37	28.125E^{-3}
$\text{Ni}_{0.4}\text{Al}_{0.1}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$	15.194	1.1394	104.34	74.991E^{-3}
$\text{Ni}_{0.3}\text{Al}_{0.2}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$	24.562	1.2568	69.226	51.166E^{-3}
$\text{Ni}_{0.2}\text{Al}_{0.3}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$	32.314	1.4133	60.117	43.735E^{-3}

Where, the replacement of nonmagnetic Al^{2+} ions with the magnetic Ni^{2+} ions changes the magnetization behavior of the octahedral site. The effect of Al-replacement is the gradual increase in the values of M_s , H_{ci} and M_r . Also, the decrease in the M_s and M_r in the case of doped $\text{Ni}_{0.5}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ may be due to the basis of canted spin or spin of the nonmagnetic Al cation at the surface of nano-ferrites [26].

Conclusion

$\text{Al}_x\text{Ni}_{0.5-x}\text{Zn}_{0.5}\text{Fe}_2\text{O}_4$ (x = 0.0, 0.1, 0.2, 0.3) nano-crystalline were successfully prepared by the citrate sol-gel method and calcined at 800°C. The formation of single phase cubic spinel structure was observed by X-ray diffraction powder. The obtained crystallite sizes of the prepared nano-ferrites investigated by XRD line broadening was are in the range of 24-32 nm and in good agreement with HR-TEM analysis. The FT-IR spectra confirmed the successful formation of the metal oxide bonds in the prepared nano-ferrites. The saturation magnetization (M_s) and coercivity (H_c) values vary from 47.894-32.314 and 70.37-60.117 G; respectively. The decrease of M_s and H_{ci} values with increasing the Al_2O_3 content due to the weakening of sub-lattice interactions from the nonmagnetic Al_2O_3 with the nano-ferrites which lowers the magnetic moment of the unit cell.

Conflicts of Interest

The authors declare no conflict of interest.

References

- Kumar G., Shah J., Kotnala K. R., Singh P.V., Garg S. G., Shirsath E. S., Bato M. K., Singh M., Superparamagnetic behaviour and evidence of weakening in super-exchange interactions with the substitution of Gd^{3+} ions in the Mg-Mn nanoferrite matrix, *Mater. Res. Bull.* **63**, 216–225 (2015).
- El nahrawy M. A., Ali I. A., Abou Hammad B. *Egypt.J.Chem.* **62**, No. 3 (2019)
- A., Mbarek A., Structural and optical properties of wet-chemistry Cu co-doped ZnTiO_3 thin films deposited by spin coating method, *Egyptian J. of Chemistry*, **61**, 770-780 (2018).
- Rao P. B., Rao H. K., Asokana K., Caltunb F. O., Influence of titanium substitutions on the magnetic properties of Ni-Zn ferrites, *J. of Optoelect. and Advanced Materials*, **6**, 959 – 962 (2004).
- Raut V. A., Khirade P. P., Humbe A, Jadhav A. S., Shengule R. D., Structural, Electrical, Dielectric and Magnetic Properties of Al^{3+} Substituted Ni-Zn Ferrite, *J Supercond Nov Magn.* **29**, 1331–1337 (2016).
- Gaffoor A., Ravinder D., Characterization of magnesium substituted nickel nano ferrites synthesized by citrate-gel auto combustion method, *Eng Res Appl* **4**, 60–66 (2014).
- Tholkappiyan R., Vishista K., Combustion synthesis of Mg-Er ferrite nanoparticles: Cation distribution and structural, optical, and magnetic properties, *Mater Sci Semicond Process.* **40**, 631–642 (2015).
- Kumar G., Shah J., Kotnala K. R., Singh P.V., Garg S.G., Shirsath E. S., Bato M. K., Singh M., Superparamagnetic behaviour and evidence of weakening in super-exchange interactions with the substitution of Gd^{3+} ions in the Mg-Mn nanoferrite matrix, *Mater. Res. Bull.* **63**, 216–225 (2015).
- Goldman A., *Modern Ferrite Technology*, 2nd edn. Springer, Pittsburgh, 51–61 (2006).
- Atif M., Nadeem M., Sol-gel synthesis of nanocrystalline $\text{Zn}_{1-x}\text{Ni}_x\text{Fe}_2\text{O}_4$ ceramics and its structural, magnetic and dielectric properties, *J. Sol-Gel Sci. Technol.* **14**, 3484-3488 (2014).
- Morriso A. S., Cahill L. C., Carpenter E. E., Calvin S., Swaminathan R., McHenry E. M., Harris G V., Magnetic and structural properties of nickel zinc ferrite nanoparticles synthesized at

- room temperature, *J. of Applied Phys.* **95**, 6392-6398 (2004).
11. Knobel M., Os superpoderes dos nanomagnetos. *Ciência Hoje* **159**, 33-37 (2000).
 12. Shrotri J. J., Kulkarni D. S., Deshpande E. C., Mitra A., Sainkar S. R., Anil Kumar S. P., Date K. S., Effect of Cu substitution on the magnetic and electrical properties of Ni-Zn ferrite synthesized by soft chemical method, *Mater. Chem. Phys.* **59**, 1-5 (1999).
 13. Moghsoudi I., Shokrollahi H., Hadianfard J. M., Amighian J., Synthesis and characterization of NiAl_xFe_{2-x}O₄ magnetic spinel ferrites produced by conventional method Powder Technol, *Powder Technol.* **235**, 110-114 (2013).
 14. Bhukal S., Namgyal T., Mor S., Bansal S., Singhal S., Structural, electrical, optical and magnetic properties of chromium substituted Co-Zn nanoferrites Co_{0.6}Zn_{0.4}Cr_xFe_{2-x}O₄ (0 ≤ x ≤ 1.0) prepared via sol-gel auto-combustion method, *J. of Molec. Struct.* **1012**, 162-167 (2012).
 15. Lin Leng P., Saion E., Naseri G. M., Mehdipour A. L., Shaari H. A., Kamaruddin M.A., A simple thermal treatment synthesis and characterization of Ni-Zn Ferrite (Ni_{0.5}Zn_{0.5}Fe₂O₄) nanocrystals, *J. of Applied Physics (IOSR-JAP)*, **4**, 30-36 (2013).
 16. Sileo E. E., Rotelo R., Jacobo E. S., Nickel-zinc ferrites prepared by the citrate precursor method, *Journal of Electromagnetic Analysis and Applications, Physical: B*, **320**, 257-260 (2002).
 17. Babu B. R., Prasad R. S. M., Ramesh V. K., Effect on structural and magnetic properties of aluminum substituted Ni-Zn Nano ferrite system prepared via citrate-gel route, *Int. J. Mod. Phys. B* **29**, 1550032-1550044 (2015).
 18. Al-Qubaisi S. M., Rasedee A., Flaifel H. M., Ahmad H. S., S. H. Al-Ali, Hussein Z. M., Eid E. E., Zainal Z., Saeed M., Ilowefah M., The nanohybrid is of mesopores type with 58.8% drug loading and enhanced thermal stability, *Int J Nanomedicine*, **8**, 2497-2508 (2013).
 19. Adriana A. S., Jose A. D., Waldermar M. A. A., Nanosized powders of NiZn ferrite: Synthesis, structure, and magnetism, *J. Appl. Phys.* **87**, 4352-4357 (2000).
 20. Prabhul T. Y., Rao V. K., Kumar S. S. V., Kumari S. B., X-Ray analysis by Williamson-Hall and size-strain plot methods of ZnO nanoparticles with fuel variation, *Nano Sci Eng.* **4**, 21-28 (2014).
 21. Kingery D. W., Bowen K. H., Uhlmann R. D., *Introduction to Ceramics*, 2nd edn. Wiley, New York, p 131 (1976).
 22. Naik S., Parveez A., Chaudhuri A., Abdul Khader S., Structural, dielectric and electrical properties of Ni (Cd, Zn) Fe₂O₄ by Auto Combustion method, *Materials Today: Proceed.* **4**, 12103-12108 (2017).
 23. Braber M. A. V., Infrared Spectra of Cubic and Tetragonal Manganese Ferrites, *Physics. Status Solidi* **33**, 563 (1969).
 24. Socrates G., *Infrared and Raman Characteristic Group Frequencies*, John Wiley and Sons, New York (2001).
 25. Deraz M. N., Effects of magnesia addition on structural, morphological and magnetic properties of nanocrystalline nickel ferrite system, *Ceram. Int.* **38**, 511-516 (2012).
 26. Obaidat M. I., Issa B., Haik Y., Magnetic properties of magnetic nanoparticles for efficient hyperthermia, *Nanomater. Nanotechno.* **5**, 63-89 (2015).

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الخواص التركيبية والمغناطيسية للنikkel زنك فريت المطعمة جسيمات الالومنيوم النانومترية و المحضرة بطريقة السائل الجيلاتيني

أمانى محمد النحراوى^١، هبة صلاح الدين^٢، عائشة سليمان^٣ و وفاء موسى^٤

^١قسم فيزياء الجوامد - المركز القومى للبحوث - الجيزه - مصر.

^٢قسم الفيزياء والكيمياء - كلية البنات للاداب والعلوم والتربية - جامعة عين شمس - مصر.

^٣قسم فيزياء الجوامد - كلية البنات للاداب والعلوم والتربية - جامعة عين شمس - مصر.

^٤قسم فيزياء الطيف - كلية البنات للاداب والعلوم والتربية - جامعة عين شمس - مصر.

المواد المغناطيسية القائمة على النikkel زنك فريت النانومترية المطعمة بتركيزات مختلفة من الالومنيوم و المحضرة بطريقة السائل الجيلاتيني باستخدام مواد اولية فى صورة نترات ولبدت العينات عند ٨٠٠ درجة مئوية. اختبرت الخواص التركيبية والضوئية للمواد المغناطيسية باستخدام كل من اشعة الحيويد السيني، الميكروسكوب الالكتروني الماسح و الميكروسكوب الضوئي، و اطيف الاشعة الحمراء. و أظهرت النتائج تكون المادة فى طور المكعب للسداسى تحت تأثير زيادة ايونات النحاس. تغير الحجم الذرى من ٢٤,٧ نانومتر الى ٣٢,٢١ نانومتر مع وجود بعض التكتلات فى المواد المحضرة. أظهرت الخواص المغناطيسية نقص فى قيم المغناطيسية (٤٧,٨٩٤-٣٢,٣١) و ذلك يرجع الى ان الالومنيوم نانومتري مادة غير مغناطيسية.