



ISSN: 0975-833X

Available online at <http://www.journalcra.com>INTERNATIONAL JOURNAL  
OF CURRENT RESEARCHInternational Journal of Current Research  
Vol. 9, Issue, 10, pp.59176-59179, October, 2017

## RESEARCH ARTICLE

## SYNTHESIS AND AC PROPERTIES OF MIXED LI-ZN FERRITES

\*Hussein Dawoud, Zana Abu Mosa and \*Samy Shaat

Department of Physics, Islamic University, P.O. Box 108, Gaza, Palestine

## ARTICLE INFO

## Article History:

Received 28<sup>th</sup> July, 2017

Received in revised form

15<sup>th</sup> August, 2017Accepted 25<sup>th</sup> September, 2017Published online 31<sup>st</sup> October, 2017

## Key words:

Li-Zn spinel ferrite,  
Dielectric properties,  
AC electrical conductivity.

## ABSTRACT

The mixed polycrystalline ferrites  $Li_{0.5(1-x)}Zn_xFe_{2.5-0.5x}O_4$  were prepared by the conventional solid state method using high purity metal oxides  $ZnO, Fe_2O_3$  and  $LiCO_3$  for different concentration of  $Zn^{2+}$  ions. Double probe electrode method was used to study the AC properties: the AC electrical conductivity ( $\sigma$ ), the dielectric constant: real ( $\epsilon'$ ), imaginary ( $\epsilon''$ ) and complex ( $\epsilon^*$ ), and the dielectric loss tangent ( $\tan \delta$ ) over the range of the applied frequency ( $f = 1\text{ KHz} - 5\text{ MHz}$ ) at room temperature.  $\sigma$  increased exponentially with the increasing  $f$  where the maximum value was for the sample  $Li_{0.3}Zn_{0.4}Fe_{2.3}O_4$ . The obtained results of the dielectric parameter ( $\epsilon'$ ,  $\epsilon''$ ,  $\epsilon^*$  and  $\tan \delta$ ), also, decreased exponentially with increasing  $f$ , which confirm the normal spinel ferrite behavior. The behavior of AC properties can be elucidated on the basis of the exchanged electrons between  $Fe^{3+} + e^- \leftrightarrow Fe^{2+}$ . The obtained results reveal that the AC properties change by substitution of the  $Zn^{2+}$  ions in Li-spinel ferrite matrix.

Copyright © 2017, Hussein Dawoud et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Citation: Hussein Dawoud, Zana Abu Mosa and Samy Shaat, 2017. "Synthesis and ac properties of mixed li-zn ferrites", *International Journal of Current Research*, 9, (10), 59176-59179.

## INTRODUCTION

The significant electromagnetic of ferrites enable them to have wide variety of technological applications, aiming at a better material with excellent chemical stability, low eddy current, high permeability, high electrical resistivity, microwave components, biomedical potential applications in magnetic resonance imaging. The exploration of the electric properties of ferrite materials offers valuable information about the behavior of localized electric charge carriers and can understand the mechanism of electrical conduction and dielectric polarization. The properties of spinel ferrites with the chemical formula  $D_1^{2+}T_2^{3+}O_4^{2-}$  has a cubic structure packed of oxygen ( $O^{2-}$ ) ions (Shaath, 2012; Dawoud et al., 2016; Dawoud et al., 2017; Dawoud, 1997; Dawoud and Shaat, 2006; Mazen and Dawoud, 1999), have tetrahedral ( $T_d$ ) and octahedral ( $O_h$ ) sites. These two sites that occupies by metal ions depending on their radii and the valency to form the cation distribution. It is worthy, to mention that the cations distribution among  $T_d$  and  $O_h$  sites plays an important role in controlling the electromagnetic and dielectric properties of spinel ferrite. Among of ferrite materials, *Li-Zn* spinel ferrite is, usually, used as magnetic material for different technological applications. So, *Li-Zn* ferrites have been developed for electronic applications. Even though *Li-Zn* ferrites system exhibit excellent properties and can

be used for a variety of applications. In spite of, poor detailed studied has been reported in the literature on dielectric and AC conductivity properties of *Li-Zn* ferrite. Therefore, it was interesting in the present article to investigate the dielectric and AC conductivity properties of *Li* ferrite when added *Zn* content.

## Experimental Techniques

The conventional solid state method was used to synthesize 25 grams of  $Li_{0.5(1-x)}Zn_xFe_{2.5-0.5x}O_4$  ferrites, where  $x = 0.0, 0.2, 0.4, 0.6, 0.8$  and  $1.0$ , using high pure metal oxides  $ZnO, Fe_2O_3$  and  $LiCO_3$ . A stoichiometric quantities of metal oxides were grounded for 5 hr's, then was pre-sintered at  $750\text{ }^\circ\text{C}$  for 3 hr's in a crucible using a laboratory Furnace (BIFATHERM model AC62). After that, the prefired powder was well grounded for 3 hr's. The grounded powder was pressed under constant pressure of  $3 \times 10^8$  pa, by adding a small quantity of butyl alcohol as a binding material. The pressed powder was formed into a disc shape with a radius  $0.495$  cm and thickness  $(0.4-0.7)$  cm. Then, all pressed discs were sintered at  $1150\text{ }^\circ\text{C}$  for 5 hr's. After sintering process, the pressed discs were cooled down, gradually, to room temperature. Finally, the pressed discs were polished to obtain uniform parallel surfaces to study the AC and the dielectric properties. Double probe electrode method was used to examine the AC electrical conductivity, dielectric parameters over a variable range of frequency  $1\text{ KHz} - 5\text{ MHz}$  at room temperature. The AC electrical conductivity ( $\sigma$ ) was calculated by the relation (Shaath, 2012).

\*Corresponding author: Hussein Dawoud and Samy Shaat,  
Department of Physics, Islamic University, P.O. Box 108, Gaza,  
Palestine.

$$\sigma = t / aZ \quad (2)$$

where  $Z$  the impedance of the sample,  $t$  is the thickness, and  $a$  is the cross-sectional area of a flat surface of the pressed disc.

The permittivity (dielectric constant) of the material such as the imaginary ( $\epsilon''$ ), the real ( $\epsilon'$ ), the complex ( $\epsilon^*$ ) can be calculated from (Abdul Khader et al., 2016)

$$\epsilon'' = \sigma / 2\pi f \epsilon_0 \quad (3)$$

where  $f$  is the applied frequency and  $\epsilon_0$  is the permittivity of free space.

$$\epsilon' = C / C_0 \quad (4)$$

where  $C$  and  $C_0$  are the capacitance of the filled and unfilled of the pressed disc.

$$\epsilon^* = \epsilon' - j\epsilon'' \quad (5)$$

The dielectric loss tangent ( $\tan \delta$ ) can be calculated by the following formula (Shaath, 2012)

$$\tan \delta = \epsilon'' / \epsilon' \quad (6)$$

## RESULTS AND DISCUSSION

### AC conductivity

Fig. (1) shows the variation of  $\sigma$  over the range 1 KHz – 5 MHz for the pressed disc samples. The points in this Fig. indicate to the calculated  $\sigma$ , where the red line is the fitted curve for the presented points. It is noticed that  $\sigma$  increases exponentially with increasing of  $f$ . All samples exhibit normal behavior with the variation of  $f$ . This is because of the applied force driven by  $f$ , which helps in transferring the charge carriers between the different conduction states. In line with, it may be attributed to the electron hopping or the electron exchange, i.e.  $Fe^{3+} + e^- \leftrightarrow Fe^{2+}$  which occurs by the electron transform between the adjacent  $O_h$  sites in the spinel lattice (Shaath, 2012). Based on the fitted curve, it can be deduced a mathematical expression for  $\sigma$ .

$$\sigma = B + Af^S \quad (7)$$

where  $B$  is y-axis offset,  $A$  has electrical conductivity unit and  $S$  is the universal exponential factor. Eq. (7) is similar to the equation that is introduced in Refs. (Zaki et al., 2013; Batoo and Ansari, 2012; Pervaiza and Gula, 2012).

$$\sigma = Af^S \quad (8)$$

The only difference between Equations (7) and (8) is the constant  $B$ . As a result, we suggest that Eq. (7) may be given a good description for the behavior of the  $\sigma$  in such material. The values of the fitted parameters  $B$ ,  $A$  and  $S$  for all samples are seen in the Table (1).

However,  $\sigma$  is increased for the  $Li-Zn$  spinel ferrite is explained based on Verwey mechanism (Shaath, 2012). That is, the electron hopping may be occurred between the ions of the same element that present in more than one valence state and

distributed randomly over crystallographically inequivalent lattice sites (Dawoud et al., 2010).

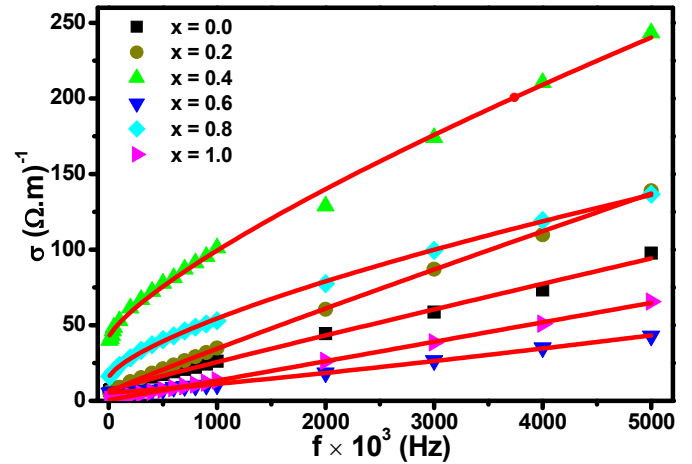


Fig. 1. Variation of  $\sigma$  with the  $f$  for all samples at room temperature, the red line is the fitted of the calculated  $\sigma$

Table 1. The values of  $B$ ,  $A$  and  $S$  derived from the fitted curve for the Fig. 1. The ratio of the increment in the  $\sigma$  for each sample

x	B	A	S	%
0.0	6.9523	0.02515	0.9571	93.27
0.2	5.6522	0.04290	0.9425	95.92
0.4	41.641	0.28868	0.7672	83.57
0.6	5.3923	0.00190	1.1628	87.78
0.8	15.001	0.32180	0.6964	88.18
1.0	0.5772	0.01259	1.0024	99.25

Depending upon the sintering conditions, the number of such ions may be produced during the preparation of the ferrite samples. It is known that, the partial reduction of the electron hopping,  $Fe^{3+} \leftrightarrow Fe^{2+}$ , can take place at an elevated firing temperature (Shaath, 2012). Thus; the hopping of electron,  $Fe^{3+} \leftrightarrow Fe^{2+}$ , occurs only by electron transform between the adjacent  $O_h$  sites in the spinel lattice formed in the  $Li-Zn$  spinel ferrite. This causes the increasing in electric conductance (Dawoud et al., 2010). Further comparison, at the highest frequency (5 MHz) for all samples, it was found that, the sample  $x = 0.4$  (Fig. (2)) showed a rapidly increasing of  $\sigma$  which is equal to  $243(\Omega.m)^{-1}$ . This indicates that the sample with  $x = 0.4$  has the high concentration of  $Fe^{2+}$  ions in the spinel structure lattice (Shaath, 2012). In the same time, the lowest value of  $\sigma$  was registered for sample  $x = 0.6$  which is  $42(\Omega.m)^{-1}$ . The ratio of the increment for each of the given samples are shown in Table 1. Such ratio may be attributed to the concentration of  $Fe^{2+}$  ions the mixed  $Li-Zn$  spinel ferrite. A similar behavior was observed in various ferrite systems by several investigators (Dawoud et al., 2010; Alwash et al., 2016). The relaxation time ( $\tau_\sigma$ ) is a characteristic time constant of ferrimagnetic materials and the angular frequency ( $\omega$ ).  $\tau_\sigma$  can be described in terms of  $\sigma$  as below (Shaath, 2012)

$$\sigma = \sigma_h + \frac{\sigma_l - \sigma_h}{1 + (\omega\tau_\sigma)^2} \quad (9)$$

where,  $\sigma_l$  and  $\sigma_h$  are  $\sigma$  at low and high applied frequency, respectively. The estimated values of  $\tau_\sigma$  at  $f = 1$  MHz for the samples,  $x = 0.0, 0.2, 0.4, 0.6, 0.8$  and  $1.0$  are, respectively,

$2.27 \times 10^{-5}s$ ,  $1.79 \times 10^{-5}s$ ,  $2.85 \times 10^{-5}s$ ,  $4.3 \times 10^{-5}s$ ,  $2.58 \times 10^{-5}s$  and  $1.48 \times 10^{-5}s$ .

hence a high value of dielectric parameter. As conductivity and relative permittivity has similar behavior.

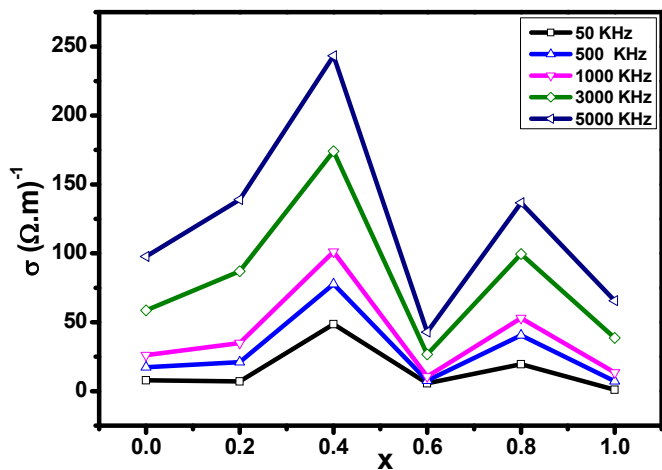


Fig. 2. Variation of  $\sigma$  with the concentration of Zn content

**Dielectric Properties**

Fig. 3(a-c) depicts the variation of the dielectric constants  $\epsilon'$ ,  $\epsilon''$  and  $\epsilon^*$  with  $f$ . From this Fig.  $\epsilon'$ ,  $\epsilon''$  and  $\epsilon^*$  for all samples decreases with increasing of  $f$ . This decrease is more rapid in the low frequency region, but ultimately this decrease becomes shiftless at higher  $f$ . This behavior is subjected to dielectric polarization under the application of AC field. The decrease of dielectric constants with an increase of  $f$  observed in the case of mixed *Li-Zn* ferrites is a normal dielectric behavior of spinel ferrites, which are reported by several investigators (Azadmanjiri, 2008; Yadoji, 2003; Kumar *et al.*, 2012; Krishna *et al.*, 2012; Chavanet *et al.*, 2013; Devmunde *et al.*, 2016; Soibam, 2016). As shown in Fig.3 the maximum value of the dispersion of the dielectric constants is for the sample with  $x = 0.4$ . Herein, the concentration of  $Fe^{2+}$  ions is expected to be higher than in other compositions of mixed *Li-Zn* ferrites. Consequently, it is possible for these ions to be polarized to the maximum possible extent. Further, as the  $f$  of the externally applied field increases gradually, though the number of  $Fe^{2+}$  ions is present in the ferrite material. The value of  $\epsilon^*$  decreases from 71732 at 1KHz to 756.45 at 5MHz. The reduction occurs because beyond a certain  $f$  of the externally applied electric field, the electronic exchange between  $Fe^{2+}$  and  $Fe^{3+}$  ions, cannot follow the alternating field. The variation of the dispersion of dielectric parameters with composition for other mixed *Li-Zn* ferrites explained by the fact that the electron exchange between  $Fe^{2+}$  and  $Fe^{3+}$  ions in an *n*-type semiconducting ferrite cannot follow the frequency of the applied alternating field beyond a critical value of the  $f$ . Such type of dielectric dispersion in ferrite system was analogous to Maxwell-Wagner model and Koops phenomenological theory, which suggested that ferrite system consist of a combination of highly conducting grains separated by poorly conducting grain boundaries (Zaki *et al.*, 2013). As dielectric polarization in ferrites magnitude depends upon the percentage of  $Fe^{2+}$  and  $Fe^{3+}$  ion pairs at  $T_d$  and  $O_h$  sites.  $Fe^{2+}$  ions concentration largely affects the conduction phenomenon and depends upon type of cation substituting, synthesis route, sintering time and sintering temperatures. In the present case  $\epsilon'$  and  $\epsilon''$  both decreases, which can be explained by low  $Fe^{2+}$  ion concentration at  $O_h$  site causing a low value of resistivity and

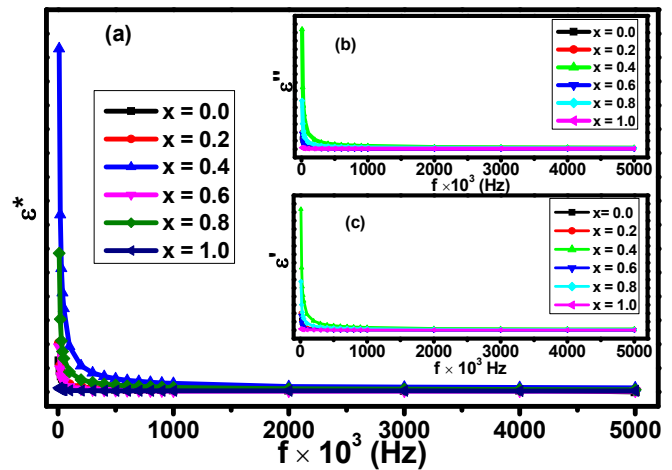


Fig. 3. Plot of (a)  $\epsilon^*$  (b)  $\epsilon''$  and (c)  $\epsilon'$  against  $f$  for all the samples at room temperature

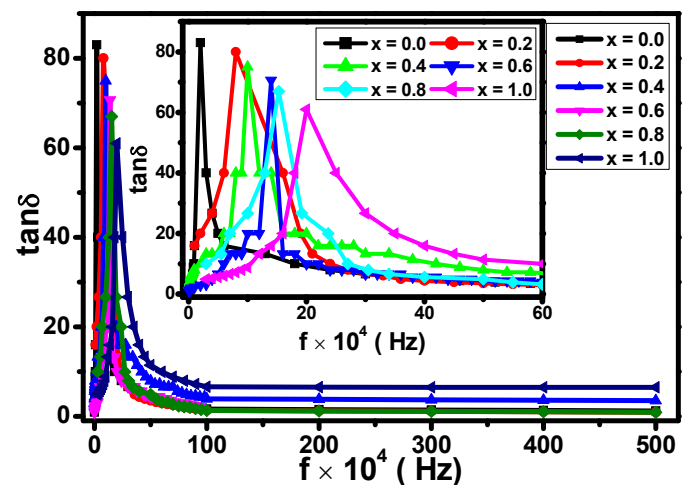


Fig. 4. A Plot of  $\tan \delta$  against the  $f$  for all the samples at room temperature, the inset shows the peaks of  $\tan \delta$

Fig. (4) shows the variation of dielectric loss tangent ( $\tan \delta$ ) with the same range of  $f$ . It can be seen that; it has the same trend as dielectric parameters. It decreases exponentially with the increase in  $f$  and becomes constant up to  $f = 5$  MHz due to the decreased polarization at high AC fields. As seen in Fig. (4),  $\tan \delta$  has a maximum value (peak values) at specific  $f$ . The peak values are found to shift towards higher  $f$  with the increasing of  $Zn^{2+}$  ions. The peak values for the samples of  $Li_{0.5}Fe_{2.5}O_4$ ,  $Li_{0.4}Zn_{0.2}Fe_{2.4}O_4$ ,  $Li_{0.3}Zn_{0.4}Fe_{2.3}O_4$ ,  $Fe_{2.2}O_4$ ,  $Li_{0.1}Zn_{0.8}Fe_{2.1}O_4$ , and  $ZnFe_2O_4$  were found at  $f = 20 \times 10^4$ ,  $15.3 \times 10^4$ ,  $12 \times 10^4$ ,  $10 \times 10^4$ ,  $8 \times 10^4$  and  $2 \times 10^4$  Hz, respectively. An qualitative explanation can be given for occurrence of the maximum in the  $\tan \delta$  versus  $f$  in the case of mixed *Li-Zn* spinel ferrite. As pointed by Iwauchi (Iwauchi, 1971) there is a strong correlation between the conduction mechanism and dielectric behavior of ferrites. The conduction mechanism in *n*-type ferrite is considered as due to hopping of electrons between  $Fe^{2+}$  and  $Fe^{3+}$ . As such, when the hopping frequency is nearly equal to that of externally applied electric field, a maximum of  $\tan \delta$  may be observed. The condition for observing a maximum in the losses of a dielectric material is given by

$$\omega' \tau = 1 \quad (10)$$

where  $\omega' = 2\pi f_{max}$  is defined as the jumping probability per unit time, i.e. hopping probability ( $P$ ). This means that  $f_{max}$  is directly proportional to  $P$  ( $f_{max} \propto P$ ).  $\tau$  is the relaxation time which is related to  $P$  by the relation  $\tau = 1/2P$ . Now a decrease of  $f_{max}$  with increasing of  $Zn^{2+}$  ions indicates that the  $P$  is decrease continuously. This behavior was, also, observed in various ferrite systems (Krishna et al., 2012; Xavier et al., 2015).

## Conclusion

Substitution of the non-magnetic  $Zn^{2+}$  ions in *Li* spinel ferrite were successfully prepared by conventional solid state technique. AC electrical conductivity showed increasing with increasing of the applied frequency. The dielectric constant (real, imaginary and complex) and dielectric loss tangent were found to decrease for all samples with increasing of the applied frequency. The substitution of  $Zn^{2+}$  ions in *Li* spinel ferrite shows remarkable influences in the AC properties.

## REFERENCES

- Abdul Khader, S., S. M. Shariff, F. Nayeem, J. Basavaraja, H. Madanakumara, M. S. Thyagaraj, 2016. Structural and dielectric properties of Ni<sup>2+</sup> doped Chromium Ferrite by Solution Combustion method, *Journal of Chemical and Pharmaceutical Sciences*, 9(2), 993-997.
- Alwash, N. H., H. K. Mohamad, M. H. Almaamori, 2016. Effect of M<sup>2+</sup> substitution on properties of the system Ni<sub>x</sub>Zn<sub>1-x-y</sub>MyFe<sub>2</sub>O<sub>4</sub>, *International Letters of Chemistry, Physics and Astronomy*, 63, 42-48.
- Azadmanjiri, J. 2008. Structural and electromagnetic properties of Ni-Zn ferrites prepared by sol-gel combustion method, *Materials Chemistry and Physics*, 109, 109-112.
- Batoo K. M. and M. S. Ansari, 2012. Low temperature-fired Ni-Cu-Zn ferrite nanoparticles through auto-combustion method for multilayer chip inductor applications, *Nanoscale Research Letters*, 7, 112, 1-14.
- Chavan, G. N., P. B. Belavi, L. R. Naik, B. K. Bammannavar, K. P. Ramesh, S. Kumar, 2013. Electrical and magnetic properties of nickel substituted cadmium ferrites, *International Journal of Scientific & Technology Research*, 2(12), 82-89.
- Dawoud H. and S. K. K. Shaat, 2006. Magnetic Properties of Zn Substituted Cu Ferrite, *An - Najah Univ. J. Res. (N. Sc.)*, 20, 87-100.
- Dawoud, H., L. A-Ouda and S. K. K. Shaat, 2016. Investigation of the Effect of Zn Ions Concentration on DC Conductivity and Curie Temperature of Ni-spinel Ferrite, *American Journal of Materials Science and Application*, 4(2), 11-17.
- Dawoud, A. 1997. "A study of Some Electric and Magnetic Properties of Li-Cu Spinel", Pd.D. Thesis, Faculty of Science Zagazig University.
- Dawoud, H. A., S. K. K. Shaat and S. S. Yassin, 2010. AC Conductivity and Dielectric properties of Cu-Zn ferrites, *Journal of Al Azhar University-Gaza (Natural Sciences)*, 12, 65-74.
- Dawoud, H., L. A-Ouda and S. K. K. Shaat, 2017. FT-IR Studies of Nickel Substituted Polycrystalline Zinc Spinel Ferrites for Structural and Vibrational Investigations, *Chem. Sci. Trans.*, 6(2), 179-188.
- Dawoud, H., L. A-Ouda and S. K. K. Shaat, 2016. Synthesis and Magnetic Properties of Ni Substituted Polycrystalline Zn-spinel Ferrites, *IJRASET*, 4(XII), 111-118.
- Devkunde, B. H., A. V. Raut, S. D. Birajdar, S. J. Shukla, D. R. Shengule and K. M. Jadhav, 2016. Structural, Electrical, Dielectric, and Magnetic Properties of Cd<sup>2+</sup> Substituted Nickel Ferrite Nanoparticles, *Journal of Nanoparticles*, 2016, 1-8.
- Iwauchi, K. 1971. Dielectric Properties of Fine Particles of Fe<sub>3</sub>O<sub>4</sub> and Some Ferrites, *Jap J Appl Phys*, 10(11), 1520-1528.
- Krishna, K. R., D. Ravinder, K. V. Kumar, U. S. Joshi, V. A. Rana, A. Lincon, 2012. Dielectric Properties of Ni-Zn Ferrites Synthesized by Citrate Gel Method, *World Journal of Condensed Matter Physics*, 2, 57-60.
- Krishna, K. R., Ravinder, D., Kumar, K. V., Joshi, U. S., Rana, V. A. and Lincon, 2012. Dielectric Properties of Ni-Zn Ferrites Synthesized by Citrate Gel Method, *J. of Condensed Matter Physics*, 2(2), 57-60.
- Kumar, G. R., Kumar, K. V., Venudhar, Y. C., 2012. Electrical Conductivity and Dielectric Properties of Copper Doped Nickel Ferrites Prepared By Double Sintering Method, *IJMERE*, 2(2), 177-185.
- Mazen S. A. and H. A. Dawoud, 1999. Structure and magnetic properties of Li-Cu ferrite, *Phys. Stat. Sol. (a)*, 172-289.
- Pervaiza E. and I. H. Gula, 2012. Structural, Electrical and Magnetic Studies of Gd<sup>3+</sup> doped Cobalt Ferrite Nanoparticles, *NPRESSCO*, 2(4), 377-387.
- Ramesh, P., Craig, G., Dinesh, A., and Rustum, R., Yadoji, P. 2003. Ultralow dielectric constant nickel-zinc ferrites using microwave sintering, *J. Mater. Res.*, 18(10), 2292-2295.
- Shaath, S. K. K. 2012. Advanced Ferrite Technology, *LAMBART Academic Publishing*.
- Soibam, I. 2016. A Study of Microwave Sintered Ni Substituted Lithium Zinc Ferrite Synthesized by Citrate Precursor Method, *International Journal of Materials Science and Engineering*, 4(1), 54-59.
- Xavier, S., Thankachan, S., Jacob, B. P. and Mohammed, E. M. 2015. Structural and electrical properties of neodymium substituted cobalt ferrite nanoparticles, *IOP Conf. Series: Materials Science and Engineering*, 73, 012093.
- Zaki, H. M., S. Al-Heniti, Ahmad Umar, F. Al-Marzouki, A. Abdel-aiem, T. A. Elmosalami, H. A. Dawoud, F. S. Al-Hazmi and S. S. Ata-Allah, 2013. Magnesium-Zinc Ferrite Nanoparticles: Effect of Copper Doping on the Structural, Electrical and Magnetic Properties, *Nanoscience and Nanotechnology*, 13, 4056-4065.

\*\*\*\*\*