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“A Study of the Effect of Temperature and Frequency on Electric Conductivity of Zinc Ferrite added to it Manganese Iron Impurity”

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Abstract

In this research paper it was studied the electric behaviour of ferrite zinc material[1][3][5] [9][12][16][19][24] added to it manganese iron (Mn^{+2}) [2][4][11][13][19][20][25] according to the chemical formula: Mn_x, Zn_{1-x}, Fe_2O_4; X= 0.0, 0.2, 0.4 and 0.6, which was prepared by the traditional ceramic method. This matter is classified as one of the ferromagnetic [9][14][16][17] materials of multi-crystalline structure. X-ray diffraction technology was used for all samples and the electric conductivity [1][3][5][6][7] was measured at a certain range of temperatures and frequencies.

Keywords:- Magnetic Materials- Electric conductivity- Bragg Law- Arrhenius plots

1.Classification of Magnetic Materials

The magnetic properties of materials [2][10] differ to a great extent from each other due to the effect of external magnetic field. Temperature [17] [18] has also a significant effect on such materials. These properties arise owing to the moment and latent magnetism in a certain atom and in return it is generated from the electrons orbital movement round the atom nucleus as well as the spin movement of electron round its axis, where the magnetic behavior of atoms depends on the two movements: the orbital and the spinning of electrons in the atoms as the charged particles in the atom and its nucleus moves continuously. Electrons moves around the nucleus orbitally following certain routes and at different distances thus creating minute electric currents. These currents constitute magnetic fields. Electrons also spin round their axis and such movement generates minute electric currents in the electrons themselves thus originating magnetic fields as result of the spin movement (Magnetic Dipole Moments) [9] [18] [25][26].

According to the response of materials to an external magnetic field, materials are classified [3][6] into: **Diamagnetic Materials** When diamagnetic materials are put within an external magnetic field and as this field directs the magnetic dipoles to their atoms, in this case the total atom magnetic fields happen to be nil i.e. the atoms of these materials have no permanent magnetic moments. The orbits of such materials are envelopes totally saturated and the field inside the material is slightly less compared with the affecting external magnetic field and therefore these materials are characterized by a negative magnetic capacity and it is less than one e.g. silicon and germanium. **Paramagnetic Materials** Paramagnetic materials are materials product of spin movement of electrons characterized by the existence of naturally permanent magnetic dipole moments and the moments of these dipoles are randomly distributed in the natural state of the material. Paramagnetic property is assigned for materials having positive magnetic aptitude. **Ferromagnetic Materials** The atoms of these materials also have permanent magnetic moments. The adjacent magnetic moments are analogous and parallel to each other such that the effect of external magnetic field is enormous on them i.e. the internal field increases considerably. When an orientation of the magnetic dipoles occurs towards the external field, it is said this material has magnetized and upon removal of the external magnetic field, the material transforms into a permanent magnet but when the magnetizing field is removed the material loses its magnetism acquired; hence these materials are called transitory magnetized ferromagnetic materials. These materials lose their property when the temperature reaches a certain point called Curie temperature (T_C). When the temperature of these materials surpasses the point of Curie temperature, they behave like paramagnetic materials, for example: Fe, Ni, Co … etc. **Ferrimagnetic Materials** In these materials, the adjacent permanent magnetic moments tend to align themselves parallel and in opposite directions but their magnitudes are not equal. Ferrimagnetic materials are compounds possessing auto-polarization in room temperature. In these materials the magnetic ions occupy two types of grid sites. The property of ferrimagnetic materials disappear when their temperature reaches Curie temperature point (T_C) or Niel temperature (T_N) and beyond this point the material turns out to be paramagnetic. Ferrimagnetic materials in the industrial media are known as (Ferrite) compounds as they contain oxides of iron and other metals.[7][8][15][18][22][23]

2.Theoretical Part

Electric conductivity is considered as the most important Ferrite property that patently depends on the conditions of samples preparation such as time of construction, temperature and type of additive material. The electric conductivity (σ) is determined by the magnitude of charge that runs in the material under effect of the external electric field i.e. charge carrier density (n), its mobility (μ) .Electric conductivity of a material is expressed by the equation(1) :

$$\sigma_{ion} = n_{ion}\, q\mu_{ion} \qquad (1)$$

Where: (σ_{ion}) electric conductivity, (μ_{ion}) ionic mobility, (n_{ion}) density of moving electric charges.

Ionic kinetic ability is given by the relation(2):

$$\mu = \left\{\frac{qfa^2}{kT}\right\} e^{-\frac{E_{act}}{KT}} + 1 \qquad (2)$$

Where:

(a) Lattice constant, (T) Temperature, (k) Boltzmann constant, (f) Ions frequency.

The above equation may be converted into a linear relation by taking the natural logarithm of the two equation sides, where we can obtain the equation (3):

$$ln(\sigma T) = ln(\sigma_o) - \frac{E_{act}}{KT} \qquad (3)$$

Where (E_{act}) is the activation energy. The electric conductivity (which is the reverse of ohmic resistance capacity G= l/R) can be calculated by knowing the cross section of sample A(m^2) and its thickness d (m), by the equation (4):

$$\sigma = G\frac{d}{A} \qquad (4)$$

Activation energy can be obtained by tracing graphically the linear relation (3-35) i.e. by plotting {ln (σT)} vs. the invers of temperature (l/T); this curve is called (Arrhenius plot) by finding the straight line slope. The activation energy can be defined as the quired energy to resist the potential barrier in the lattice, and it results from the sum of energies required to move ions in addition to the energy needed to form spaces and overcome the stress barrier.

3.The Bragg Law

Two trigonometric facts should be taken into account, namely: "the incidental rays and the column constructed on the atomic levels and the parallel band, all lie in one level" and the "angle between the parallel band and the penetrating beam (non-parallel) equals to 2θ and it is called the diffraction angle" known as Bragg law which represented in equation (5) .

Where:

$$n\lambda = 2d\,sin\,\theta \qquad (5)$$

(n) represent diffraction order where (η= 1,2,3,4 …..), (θ) diffraction angle.

Bragg law is applied empirically by two methods, through using x-rays of known wave length (λ) and measuring the diffraction angle (2θ) and the distance (d) between the **successive** levels is measured or by using a crystal such that the distance between the successive levels is known (d) and then the diffraction angle is calculated (2θ). In this research, x-rays diffractions of known wave length are used together with Zinc ferrite material inoculated with Manganese (Mn, Zn_{1-x}, Fe_2O_3) in order to make sure of the materials used and extent of their purity.

4.Determination of Materials by using X-ray Diffractions:

In order to know the different materials by using x-ray diffraction techniques in the samples analyzed in this research paper using XRD happened to be samples of the compound (Mn_x, Zn_{1-x}, Fe_2O_3) where x= 0.0, 0.2, 0.4, 0.6 and they were in the form of powder, sintered at a temperature of (1100 ^oC) for a time of 2 hours.

5.Practical Part

The electric conductivity (σ) was measured for all samples in the heat range (300k – 673k) at all frequencies (1,2,3,4 MHz), by using the equation (6):

$$\sigma = d/RA \qquad (6)$$

Where: (d) sample thickness, (A) sample surface area, (R) sample resistance determined by reading current intensity (I) and reading of voltage (V) by the Oscilloscope upon changing frequency and temperature within the said range of the pure and inoculated sample. Based on the results obtained regarding the electric conductivity values by using the previous equation we proceed to plot the relation between {ln(σT) vs 1000/TK} and the inverse of temperature (Arrhenius plots). Out of this process, the activation energy can be calculated. The preceding steps may be repeated various times for the same sample so as to obtain the best reading for all frequencies.

6.Results and Calculations

The results of x-ray diffractions in all samples having the chemical formula (Mn, Zn_{1-x}, Fe_2O_3), x= (0.0, 0.2,) are illustrated in the following figures: (1), (2), (3) and (4).

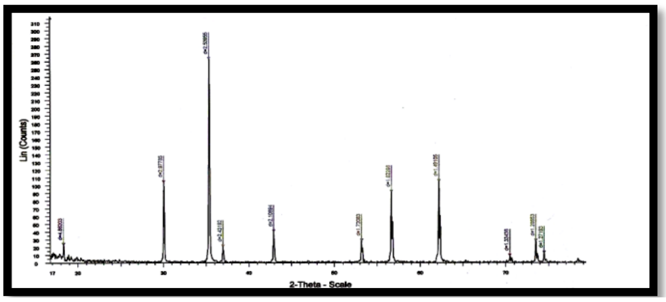

Figure (1): Pattern of x-ray diffractions for a powder sample of ($ZnFe_2O_4$), sintered at 1100 °C

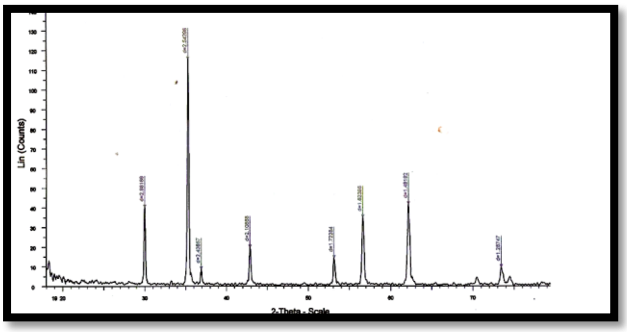

Figure (2): Pattern of x-ray diffractions for a powder sample of ($Mn_{0.2}$, $Zn_{0.8}$, Fe_2O_4), sintered at 1100 °C.

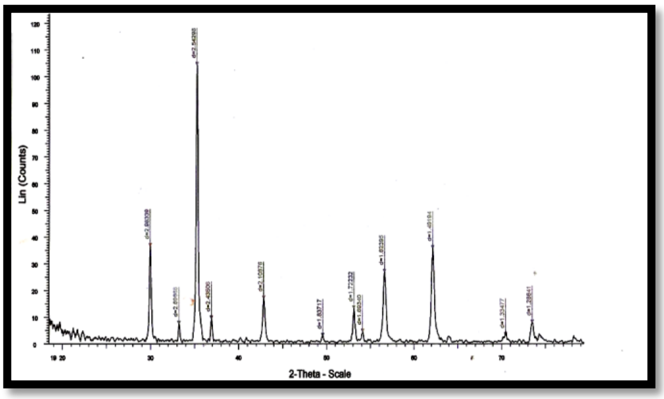

Figure (3): Pattern of x-ray diffractions for a powder sample of ($Mn_{0.4}$, $Zn_{0.6}$, Fe_2O_4), sintered at 1100 °C.

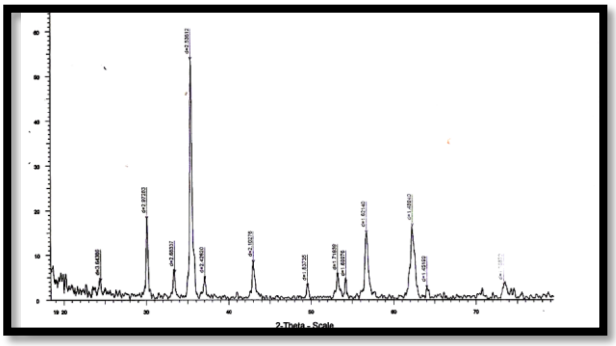

Figure (4):Pattern of x-ray diffractions for a powder sample of (Mn0.6, Zn0.8, Fe2O4), sintered at 1100 °C.

From the preceding figures the *Syntel* cubic structure revealed reflection levels (111), (220), (111), (311), (222), (400), (422), (511), (440), (620), (533), (622) and it also revealed in all sample a *Syntel* single-phased structure. These results shall be compared with the files of ((Inorganic Crystal Structure Database **ICSD**)).

Behaviour under Effect of Temperature, Frequency and Impurity Percentage on the Electric Conductivity:

Results of electric conductivity (σ) were obtained which were assessed in the range of frequencies (1, 2, 3, 4 MHz) of the compound (Mn_x, Zn_{1-x}, Fe_2O_4; x= 0.0, 0.2, 0.4, 0.6) Arrhenius plots of electric conductivity in all compounds shown in the figures: (5), (6), (7) and (8).

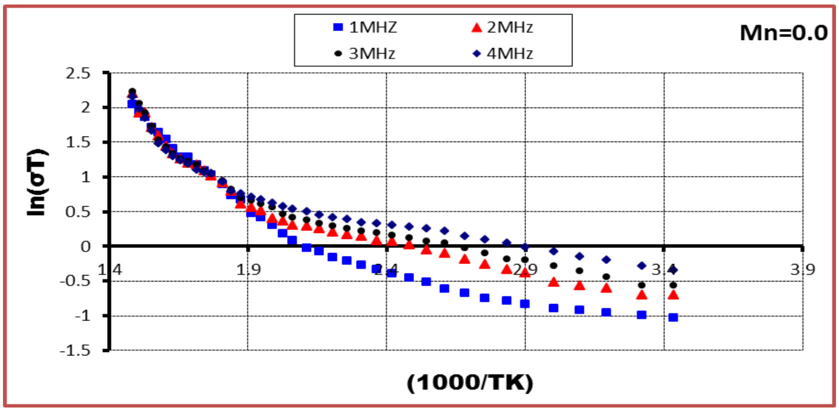

Figure (5): Behaviour of conductivity with temperature in sample (ZnFe2O4), at frequencies (1,2,3,4 MHz).

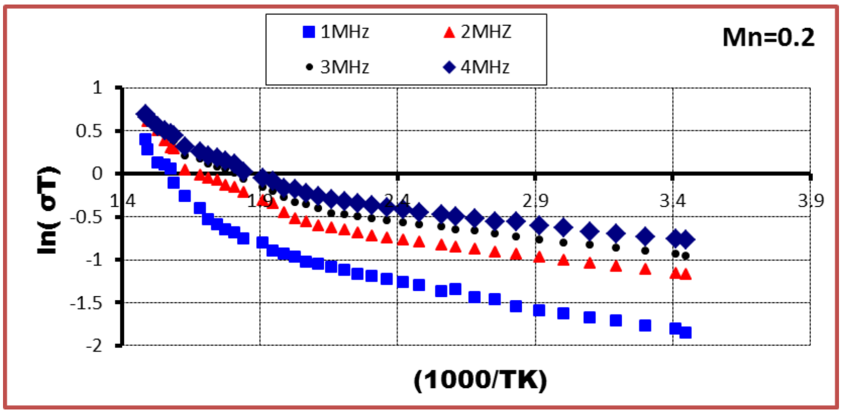

Figure (6): Behaviour of conductivity with temperature in sample (Mn0.2, Zn0.4, Fe2O4), at frequencies (1,2,3,4 MHz).

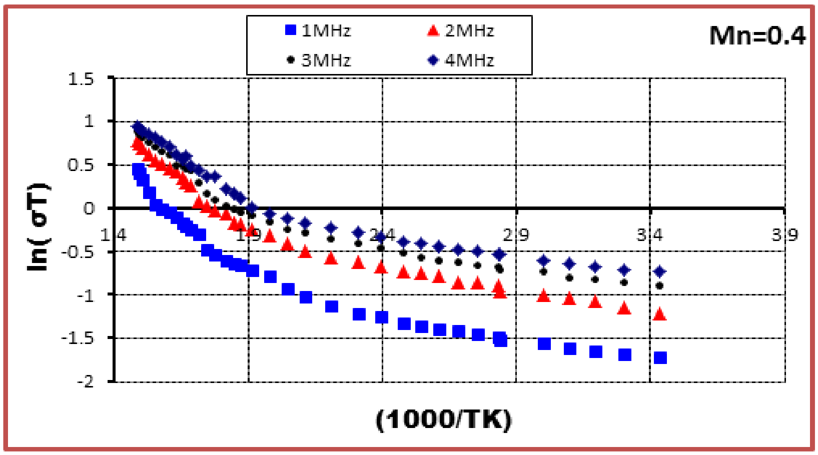

Figure (7): Behaviour of conductivity with temperature in sample (Mn0.4, Zn0.4, Fe2O4), at frequencies (1,2,3,4 MHz).

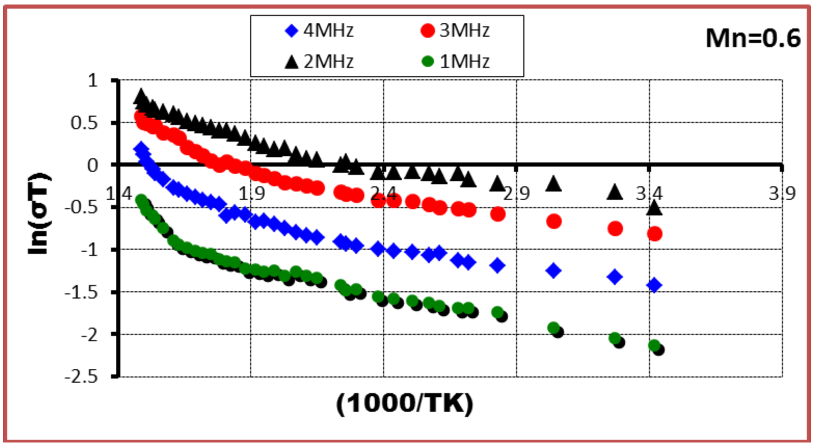

Figure (8): Behaviour of conductivity with temperature in sample (Mn0.6, Zn0.4, Fe2O4), at frequencies (1,2,3,4 MHz).

Based on Arrhenius plots of electric conductivity we realized that each sample has a negative temperature resistance factor (**NTCR**) and this evident from the behaviour of electric conductivity; whereas electric conductivity increases with the increase of temperature and we can also link this behaviour with the process of ionic transfer inside the matter as well as the electrons liable to enter the sphere of conduction. Out of theses two processes, we obtain a semi-conductive behaviour of the samples studied [7][8].

It is found that (σ_{ac}) values of in all samples at room temperature were in the range of ($10^{-3}m^{-1}\Omega^{-1}$) at frequencies (1-2-3-4 MHz) and in this study it was found in regards of Sample ($ZnFe_2O_4$) and Sample ($Mn_{0.2}$, $Zn_{0.4}$, Fe_2O_4) that they have two areas: one depends on frequency and the other do not depend on frequency where the first falls in a temperature range that could be called the transformation temperature as the electric conductivity after this degree becomes independent of on frequency. As for the samples ($Mn_{0.4}$, $Zn_{0.6}$, Fe_2O_4) and ($Mn_{0.6}$, $Zn_{0.4}$, Fe_2O_4), from the graph we notice we observe the change of electric conductivity with the change of temperature and there is no area not depending on frequency and there is transformation point in electric conductivity at all frequencies for all samples. In the area depending on frequency, we found that the electric conductivity increases with the increase of frequency in all samples subject of the study [8][9][22].

Table (1) exhibits the values of transformation temperature (T^1) of each sample.

Sample	T_t (K)
$ZnFe_2O_4$	503
$Mn_{0.2}Zn_{0.4}Fe_2O_4$	513
$Mn_{0.4}Zn_{0.6}Fe_2O_4$	523
$Mn_{0.6}Zn_{0.4}Fe_2O_4$	561

From table (1) it is observed that the transformation temperature increases with the increase of impurity content in the Samples (Mn_x, Zn_{1-x}, Fe_2O_4; x= 0.0, 02, 0.4, 0.6).

7.Conclusion

The results of x-ray diffractions also showed that all samples studied have a single phase and cubic crystalline structure of the type Syntel and the grid constant (a) increases with the increase of impurity of manganese impurity (Mn^{+2}). The value of theoretical density obtained from x-ray diffractions decreases with the increase of manganese iron content (Mn^{+2}). The electric conductivity in all samples in the presence of a frequency field increases with the increase of temperature in the range (300-673K). The behaviour of electric conductivity reveals the presence of two areas: one not depending on frequency and the other area depends on frequency. The area where the electric conductivity does not depend on frequency is denominated the high temperatures area and the area that depends on frequency is called the low temperatures area and there is a transformation point (T^1) separating the two areas that increases with the increase in the content of impurity.

8.References

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ملخص البحث:

في هذه الورقة تم دراسة السلوك الكهربي لمادة فيرايت الزنك [5][3][1] [24][19][16][12][9] والمطعمة بايون المنجنيز(Mn^{+2})حسب الصيغة الكيميائية $Mn_xZn_{1-x}Fe_2O_4$; X=0.0, 0.2, 0.4, 0.6)) والتي تم تحضيرها باستخدام الطريقة السيراميكية التقليدية[25][20][19][13][11][4][2]. وهذه المادة تصنف من المواد الفيريمغناطيسية ذات التركيب المتعدد التبلور.[17][16][14][9] استخدمت تقنيات حيود الأشعة السينية لكل العينات ، تم قياس الموصلية الكهربية عند مدى معين من درجات الحرارة والترددات[7][6][5][3][1].