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To Delimitating the Optimal Concentrations of Mn^{2+} Ions in Soft Ferrite System Mg – Mn during studying the Properties of Electrical and Magnetic Susceptibility

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الخلاصة

تم في هذا البحث دراسة إمكانية تحديد الخصائص الكهربائية المثلى لأنظمة الفريتات المرنة $Mg_{(1-x)}Mn_xFe_2O_4$ والمحضرة بطريقة تفاعل الحالة الصلبة في مدى من الدرجات الحرارية بين 300 K و 550 K من خلال استبدالية الأيونات Mn^{2+} بديلا عن أيونات Mg^{2+}، إذ أظهرت نتائج هذه الدراسة أن الايصالية الكهربائية لهذه الأنظمة كانت بحدود ($10^{-7}\ \Omega^{-1}\ cm^{-1}$)، تم حساب طاقات التنشيط في هذه الأنظمة والتي كانت تتراوح بين 0.224 eV و 0.243 eV، وكانت إشارات القدرة الكهروحرارية (معامل سيباك) موجبة في هذه المواد ضمن التراكيز الواطئة لاستبدالية الأيونات Mn^{2+} وسالبة ضمن التراكيز العالية لاستبدالية الأيونات Mn^{2+} .

كما أظهرت نتائج هذه الدراسة تحديد خاصية التأثرية المغناطيسية الأمثل في الفريتات المرنة $Mg_{(1-x)}Mn_xFe_2O_4$ أنها كانت قد تراوحت مابين $-86x10^{-8}$ و $-622x10^{-8}$. إن كلا الاختبارين للخصائص الكهربائية (الايصالية الكهربائية والقدرة الكهروحرارية) والتأثرية المغناطيسية تمثلت أفضل النتائج المستحصلة لهما في الفريتات المرنة أي عندما يكون تركيز الأيونات Mn^{2+} المستبدلة مساويا إلى 0.1 .

ABSTRACT

In order to study the practicability delimitating the optimal electrical properties have been studied for soft ferrite system $Mg_{(1-x)}Mn_xFe_2O_4$, which prepared by solid state method in the temperature range 300 to 550 K by substituting Mn^{2+} ions instead of Mn^{2+} ions. The resulting of this study shows that the electrical conductivity for these systems were optimal value ($10^{-7}\ \Omega^{-1}\ cm^{-1}$).

The calculation of activation energy gave of 0.224 eV and 0.243 eV. The positive sign of thermoelectric power (seeback coefficient) for these samples at lower concentrations of substitution Mn^{2+} ions , and negative sign of at higher concentrations of substitution Mn^{2+} ions .

Also the optimal magnetic susceptibility properties resulted in values $-86x10^{-8}$ و $-622x10^{-8}$. From the electrical properties (electrical conductivity and thermoelectric power) and magnetic susceptibility, the optimal results where obtained with x= 0.1 for Mn^{2+} ions .

INTRODUCTION

Magnesium ferrites have been used in high frequency applications. Due to their enormous resistivity they can withstand high frequency electromagnetic fields. Due to a combination of high specific resistance and remarkable magnetic properties, these materials become one of the best choices of microwave applications [1].

Mg-Mn ferrites are quite versatile from the point of view of their applications and the simplicity of their application. These have rectangular hystersis loop characteristics, which renders them suitable from memory and switching circuits of digital computers, phase shifters and other applications [2].

It has been shown that the electrical and magnetic susceptibility properties of ferrites can be upgraded by incorporating suitable diamagnetic impurities in these ferrites [3].

In this communication we have reported the results of measurement of thermoelectric power, the results of measurement of magnetic susceptibility in soft ferrites $Mg_{(1-x)}Mn_xFe_2O_4$, which employed for the verification of the optimal appropriated of the material .

EXPERIMENT PROCEDURE

1- Materials and Methods:

The $Mg_{(1-x)}Mn_xFe_2O_4$ soft ferrites were prepared by ceramic method according to ratio molecule concentration from each structure , in which x varied from 0 - 1.0 in steps of 0.1 . The samples were finally sintered at about 1300 C°.

The other details of the sample preparation are reported elsewhere [4].

2- Measurements of electrical conductivity and thermoelectric power (seeback coefficient) :

The electrical conductivity was measured . The sample was sandwiched between the probes of the sample holder. A temperature difference of about 20 K was maintained across the sample with each electrode [5] . The electrical conductivity σ of both surface of the sample was measured with help of copper-constant thermocouple by using the formula:

$$\sigma = WI/VA$$

Where W, I, V, A represented the thickness, area, applied voltage and the electrical current passes threw the sample respectively [6] .

Also the measurements of thermoelectric power (seeback coefficient) were carried out using the relation :

$$S = \Delta V / \Delta T$$

Where ΔV is the thermo electromotive force (e.m.f.) (in μv) developed across the sample due to a temperature difference ΔT .

A circuit digram for these measurements is shown in Fig. 1.

3- Measurements of magnetic susceptibility:

These measurements have been performed at room temperature by using magnetometer device as shown in Fig. 2. In which mainly constructed to idea of curie-faraday technique [7] .

This technique depended on the presence of perpendicular magnetic force F with nonlinear magnetic field by the partial range ($\partial H / \partial Y$) with real magnitude. This force was measured by electronic balance which is very fine and very sensitive, and can be calculated using :

$$F = m\,\chi\,[\partial H / \partial Y]$$

Where m- mass of sample (*gm*) .

χ- magnetic susceptibility (*B.M*) .

H- intensity of magnetic field (*orested*) .

This method was suggested to be indirect method in measuring the magnetic susceptibility χ for all materials .

RESULTS AND DISCUSSION

Fig.3 shows The electrical conductivity increased with increasing the preparing temperature for all $Mg_{(1-x)}Mn_xFe_2O_4$ at the temperature values (350 – 450 – 525)K . By increasing Mn^{2+} ions up to x=0.1 gave maximum increased in the conductivity , where at higher concentration the conductivity decreased, as shown in Fig.3 . This attributed to the following:

Mn^{2+} ions occupied the octahedral positions in the spinel ferrites [8] . The electrical conductivity in these ferrites is mainly due to hopping electrons between Fe^{2+} and Fe^{3+} . The increase of Mn^{2+} concentration increase the number of ferrous ions during sintering processes till to x=0.1 . Hence , a good correlation between the formation of ferrous ions and Mn^{2+} concentration exists of sintering for x=0.1 , so the small fraction of Mn^{2+} ions reacts with Fe^{3+} ions to form Mn^{3+} and Fe^{2+} as shown by following reactions :

$$Mn^{2+} + Fe^{3+} \longrightarrow Mn^{1+} + Fe^{2+}$$

For x > 0.1 , the Mn^{2+} ions imagrate to substitute the tetrahedral sites leading to a decrease in the number of ferrous ions decreases in the number of ferrous ions at the octahedral sites . The decrease of ferrous ions decreases the hopping electrons with cause the decrease of electrical conductivity .

The variation of thermelectric power (α) with different compositions , Fig.4. shows the plot of thermocouple factor α vs. temperature for all $Mg_{(1-x)}Mn_xFe_2O_4$ samples in the temperature range 300 – 550 K . It is clear that all samples are degenerate type semiconductors. Degenerate samples obey the general equation for all the temperature dependence i.e.

$$\alpha = A+B / T$$

Where A and B are constants .

It is noticed that (α) increasing by increased Mn^{2+} ions concentrations up to x=0.1 attaining maximum value 125 μv/K .Further increase of x resulted in a slight decrease in the value of seeback effect (α) . This attributed to the following :

The negative values of thermoelectric power confirmed the n-type conduction mechanism , as for samples x = 0.9 , 0.8 , this caused from the hopping electrons between Fe^{2+} and Fe^{3+} ions which is the fundamental in the conduction of these ferrites at the octahedral configuration .

The positive values of thermoelectric power confirmed the p-type conduction mechanism , as for samples x = 0.1 , 0.2 , 0.3 , 0.4 , 0.5 , 0 , but some of these samples are varied between the negative values and positive values of (α) and exhibits n- to -p type conduction mechanism , as for samples x = 0.7 , 0.6 , hence both type of carriers are taking part in the conduction process .

The existence of Mn^{2+} ions at the tetrahedral configuration must occupy spin – down positions configuring the behavior of thermoelectric power of the present samples . The increase of concentrations for x > 0.1 decreases the number of spin – down leading to a decrease in the thermoelectric power of n-type spinel ferrites [9] .
Arrhenius relationship is used to calculate the activation energy (Ea)[10], as from the following :

$$\ln \sigma\ (T) = -E_a / k_B T + \ln \sigma_o$$

Where σ_o : the final electrical conductivity at high temperature .
k_B : Boltzman constant .
T : Absolute temperature .
Fig.5 shows the plot of the values activation energy (Ea) vs. the concentrations for all $Mg_{(1-x)}Mn_xFe_2O_4$ samples , which is ranged between 0.224 eV , the lower value of (Ea) , when the ratio of substitution Mn^{2+} ions x=0.8, to maximum value of (Ea) , when the ratio of substitution Mn^{2+} ions x=0.1 .
This results indicated clearly the simplicity on the mobility of charge carriers at x=0.1 .

Other studied of the optimal concentrations the substitution Mn^{2+} ions for all $Mg_{(1-x)}Mn_xFe_2O_4$ samples have been detected by measuring the magnetic susceptibility (χ) , as shown in Fig.6 , the maximum values of (χ) is obtained at x=0.1 ($-622 \times 10^{8-}$) .This attributed to the following :
The small fraction of substitution Mn^{2+} ions increased the magnetic moment, and increased in initial permeability [2] up to high value in $Mg_{(1-x)}Mn_xFe_2O_4$, so the preference for Mn^{2+} ions occupy the octahedral positions in the spinel ferrites at x=0.1 .

CONCLUSION

According to results obtained about the electrical conductivity, thermoelectric power, activation energy, magnetic susceptibility, the optimal concentrations for all $Mg_{(1-x)}Mn_xFe_2O_4$ soft ferrite is to be there as $Mg_{0.9}Mn_{0.1}Fe_2O_4$, so Mn^{2+} ions has 0.1 and Mg^{2+} ions has 0.9 . Hence the researcher here recommended to have this structure (model) to make the development using them for many applications , as in our reported elsewhere [11].

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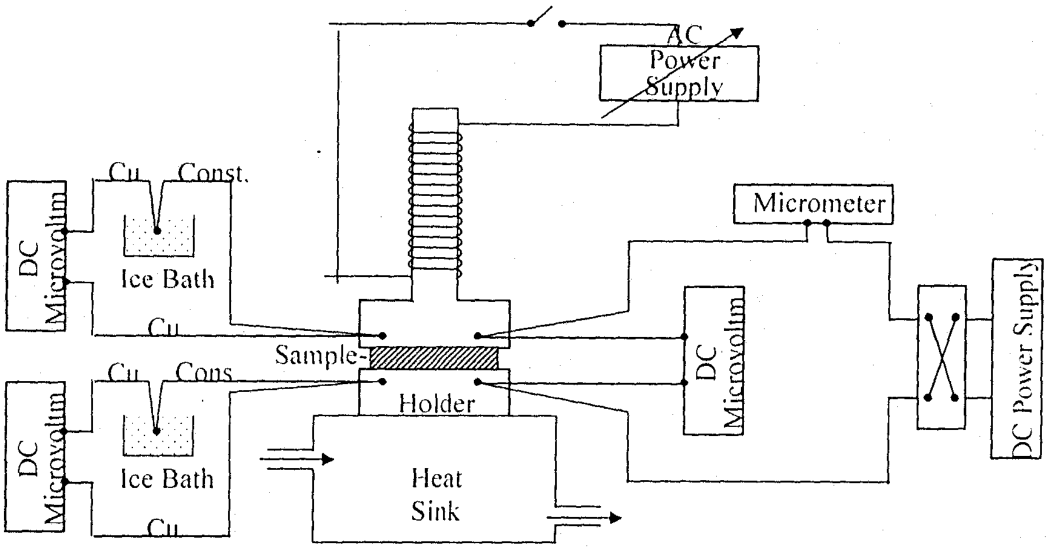

Fig. 1 : circuit of electrical conductivity & thermoelectric power

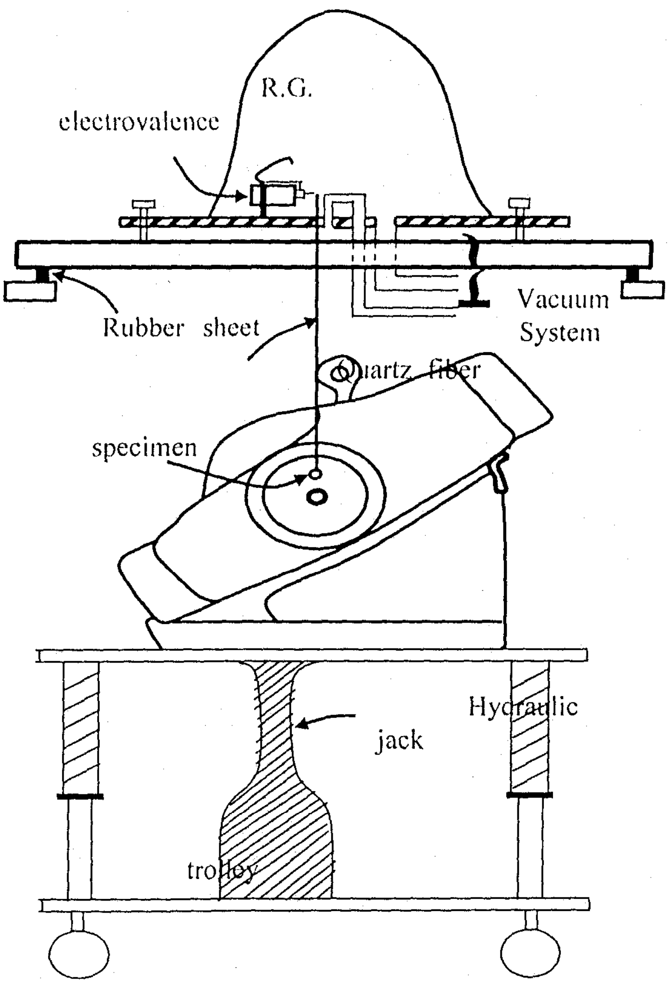

Fig. 2 : the magnetometer device

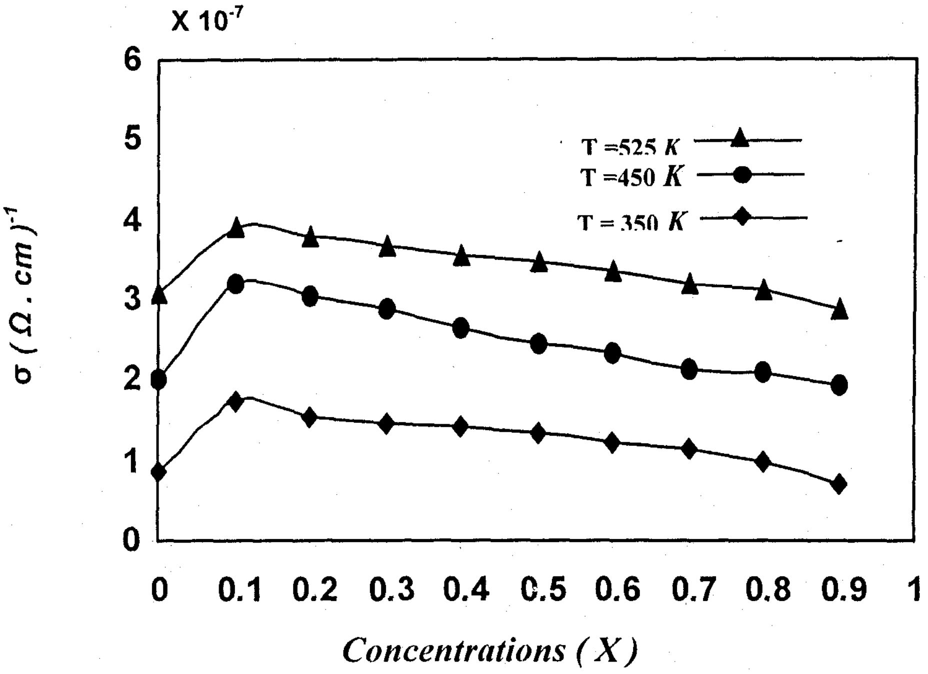

Fig. 3 : plot of electrical conductivity (σ) vs. Concentrations (X) from the ferrite system $Mg_{1-x}Mn_xFe_2O_4$

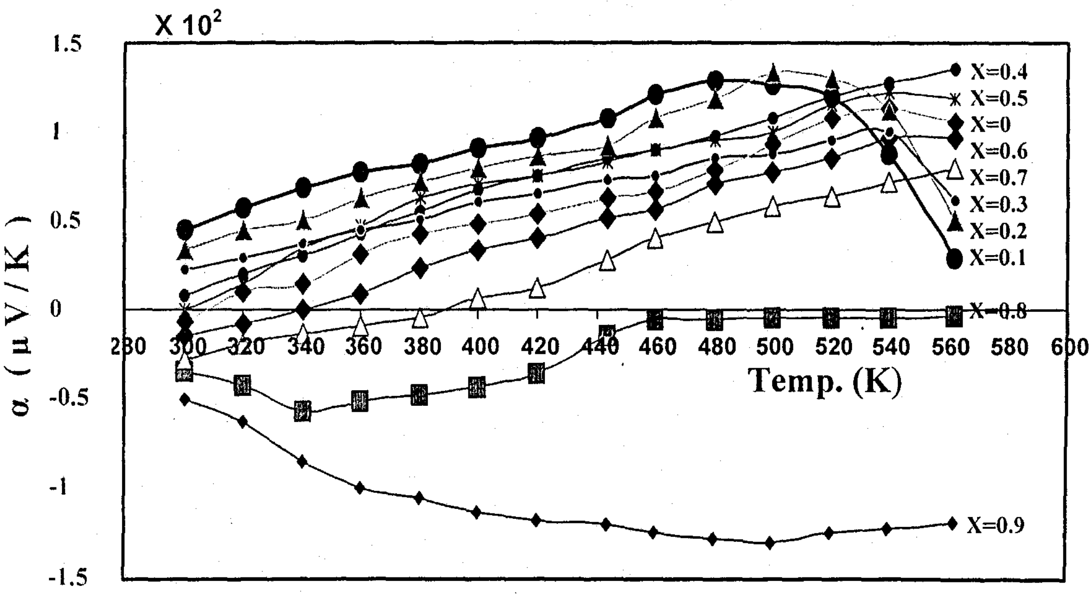

Fig. 4 : plot of thermoelectric power (α) vs. temperature (K) from the ferrite system $Mg_{1-x}Mn_xFe_2O_4$

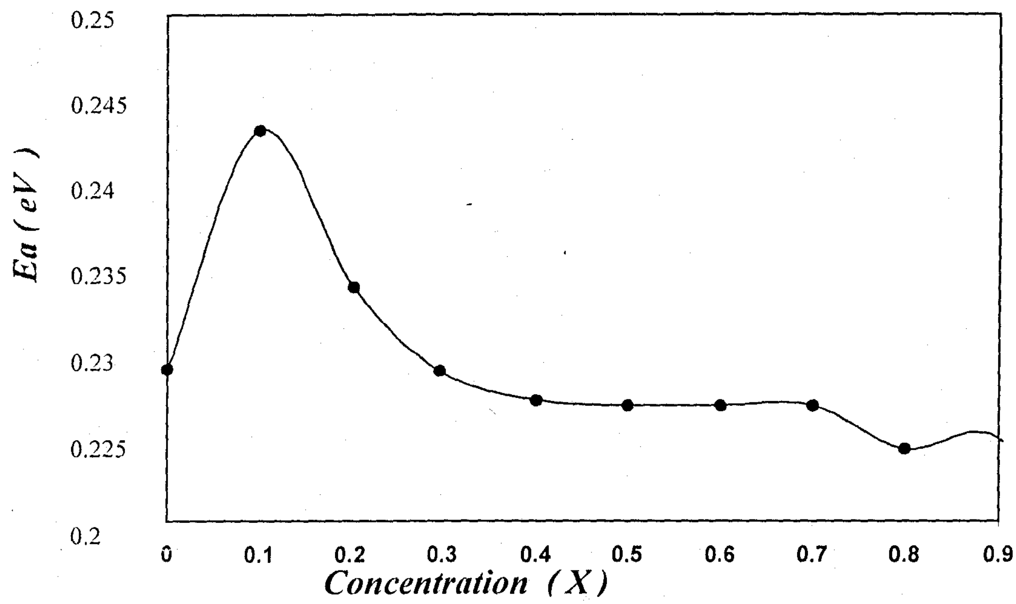

Fig. 5 : plot of activation energy (Ea) vs. concentration (X) from the ferrite system $Mg_{1-x}Mn_xFe_2O_4$

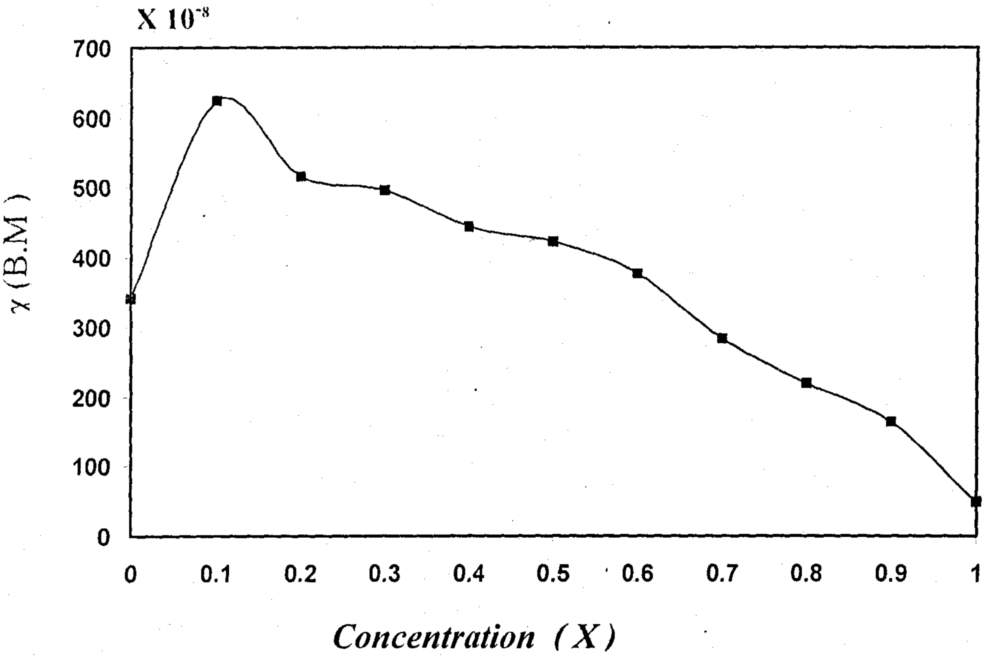

Fig. 6 : plot of magnetic susceptibility (χ) vs. concentration (X) from the ferrite system $Mg_{1-x}Mn_xFe_2O_4$