STUDY OF ELECTRICAL PROPERTIES OF NANOCRYSTALITES Ca-Ni-Fe-Al FERRITES BY SOL-GEL AUTO COMBUSTION METHOD.

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ABSTRACT:

Calcium hexaferrite $CaNi_2Fe_{11-x}Al_xO_{22}$ (x=1 & x=1.5) nanoparticles were synthesized by microwave assisted sol-gel auto combustion method. The dielectric characterization such as ac conductivity, dielectric constant and dielectric loss tangent of the synthesized sample were studied. The real part of the ac conductivity σ_{ac}, dielectric constant $\acute{\varepsilon}$ and dielectric loss tangent *tan δ* were measured for different frequencies at room temperature and in the temperature range of 303K-623K. Electrical conduction in ferrite can be explained by Verway hoping mechanism of electron. Dielectric constant and dielectric loss tangent *tan δ* were explained on the basis of Maxwell interface polarization in accordance with Koops phenomenological model. The low dielectric behavior makes ferrite materials useful in high frequency applications.

Keywords: sol-gel method, hexaferrite, nanoparticles, dielectric constant, dielectric loss tangent etc.

INTRODUCTION:

In 1950, a new class of ferrites having permanent magnetic properties was discovered. They are called hexagonal ferrites with the formula $MFe_{12}O_{19}$ where M is usually Barium (Ba), Strontium (Sr), Calcuim (Ca) or Lead (Pb). Hexagonal ferrites specially Y type ferrites have been proved to be potential candidate for nanomaterials having properties by virtue of their ease of applicability in high density recording media, mircro absorption devices, magneto-optic recording media etc. Y type nanoferrites are at present very promising materials in technological application and drug delivery [1]. The dielectric properties of these ferrites vary markedly depending upon the preparation techniques. Knowledge of the dielectric properties is also important from the view point of applications at high frequencies. To improve electrical properties of Ca ferrites, divalent, depending trivalent and tetravalent ion substitution were studied [2-4]. In the present research module sol-gel auto combustion technique was used to obtain ultrafine hexagonal ferrites particles possessing in the range of nano scale. The aim of this work is to study the effect of Al^{+3} ions on the behavior of dielectric properties of calcium hexaferrites.

EXPERIMENTAL:

The Al^{+3} substituted calcium ferrites were synthesized by sol-gel auto combustion method. The Stoichiometric amount of AR grade calcium nitrate $Ca(NO_3)_2 4H_2O$ aluminium nitrate $Al(NO_3)_2.9H_2O$ were used while urea was used as fuel. The mixture of metal nitrate was dissolved in distilled water. The solutions as prepared were mixed together to form a homogeneous transparent aqueous solution. The aqueous solution was then heated and continued stirred on the magnetic stirrer at 60^oC, till aqueous solution get converted into wet gel by evaporating the water. Further, the wet gel fired in a specially designed microwave oven, to get the resultant ash powder. The ashes of raw substances obtained were grinded in a pestle mortar for 6 hrs. Finally these samples were annealed at 800 ^oC for 4 hours at a heating rate of $100^oC/hr$ to get desired nanopowder.

Result and Discussion:

Temperature dependence of σ_{ac}, ἑ and tan δ:

Figure (1-a) shows the temperature dependence of ac electrical conductivity (σ_{ac}) for different concentration of Al at constant frequency (f

=1 kHz). From the figure it is clear that σ_{ac} increases gradually with temperature. The variation of log σ_{ac} with the inverse of temperature indicates that the synthesized hexaferrite samples are having semiconducting nature.

Figure (1-b) shows the variation of έ with temperature for different Al concentration at constant frequency (f = 1kHz). The data in the figure shows that έ has a small value and is nearly independence of temperature up to T≈548 K. The constancy of έ with temperature can be attributed to the impurities in the samples which are localized at low temperature (T ≈ 550 K). Such behaviour is found in ionic solids [5]. As the temperature increases the charge carriers becomes free to move through the crystal causing a polarization and hence έ increases.

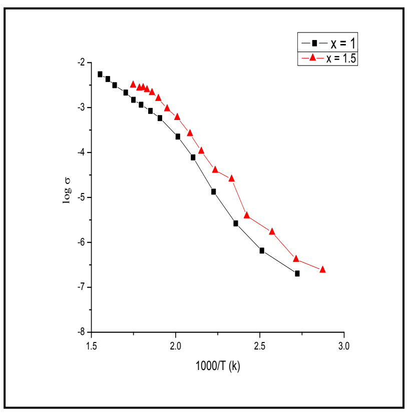

Fig (1-a) Variation of log σ_{ac} with the inverse of absolute

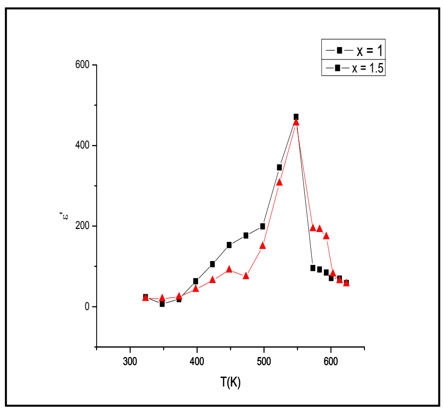

Fig (1-b) Variation of έ with absolute temperature at f=1kHz

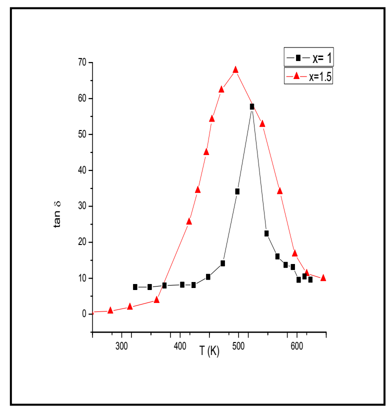

Fig.(1-c) Variation of tan δ with absolute temperature

Figure (1-c) shows the change of tan δ with temperature. In general the value of tan δ has a peak around 600 K. The appearance of a maximum in tan δ could be explained according to Koops's model [6] in which the solid is assumed to be composed of grains and grain boundaries. The observed peak in tan δ may be attributed to the contributions from the grain boundaries [7], where the impurities reside, which take part in the conduction at low temperatures. The role of the grains may appear at higher temperature.

Frequency dependence of σ_{ac}, έ and tan δ:

International Journal of Researches in Biosciences, Agriculture & Technology | January 2014 Issue-2, Volume-1 | ISSN No. (Online) 2347-517X

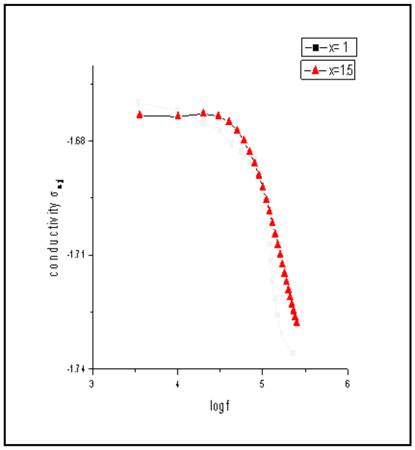

Fig.(2-a) Frequency dependence of σ_{ac}

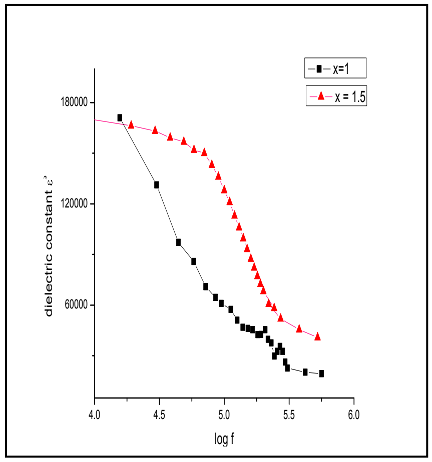

Fig.(2-b) Frequency dependence of έ

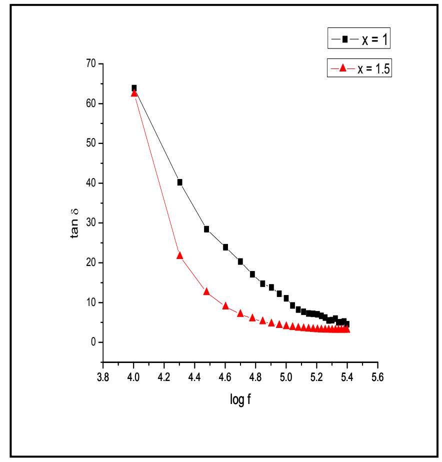

Fig.(2-c) Frequency dependence of tan δ

Figure (2-a) shows the variation of the ac conductivity σ_{ac} with the frequency at constant temperature 303 K. As a normal behaviour, σ_{ac} increases with f.

Figure (2-b) shows the decrease in dielectric constant with increasing frequency. The sharp decrease in ἐ at low frequencies and shows almost a frequency independent behaviour at high frequencies. The observed variation in ἐ is qualitatively in accordance with the Maxwell-Wagner two-layer model [8, 9], the space-charge polarization is due to the inhomogeneous structure of dielectric material. When the frequency of the applied field is increased, the probability of electrons to reach grain boundary decreases. This decreases the polarization and hence the dielectric constant with increasing frequency [10].

Figure (2-c) shows the dielectric loss tangent (tan δ) as a function of frequency was studied at room temperature. The dielectric loss tangent decreases with increasing frequency for each sample. The samples exhibit a dispersion due to the Maxwell-Wagner interfacial type polarization [11]. The value of tan δ depend upon a number of factors such as stoichiometry, structural homogeneity, which in turn depend on the composition and sintering temperature of the samples[12]. The graph indicates that the dielectric loss tangent of the prepared nanoparticles also depend upon the composition. In the low frequency region which corresponds to high resistivity, more energy is required thus the energy loss is high[13].

Conclusions:

The ac conductivity is found to be increased for higher temperature and higher frequency that reveals the semiconducting nature of ferrites.

The dielectric constant found to be increased with increasing temperature.

Abnormal dielectric behaviour (peaks) was observed on tan δ curves at relatively high temperatures.

Real dielectric constant decreases and dielectric loss tangent decreases as the frequency increases which is normal dielectric behaviour in ferrites.

The experimental result in present research module shows a trend for small polar on conduction.

The ferrite materials with lower dielectric constants are best suited for application at high frequencies such as microwave absorbers.

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