Nanotechnology and Nanoscience, ISSN: 0976–7630 & E-ISSN: 0976–7649, Vol. 1, Issue 1, 2010, PP-01-03

# Influence of $Al^{3+}$ doping on the structural and electrical properties of nanocrystalline $Ni_{0.7}Mg_{0.3}Al_xFe_{2-x}O_4$ ferrites

**Razia Nongjai*, Khalid Mujasam Batoo and Shakeel Khan**
Department of Applied Physics, Z.H. College of Engineering & Technology,
Aligarh Muslim University Aligarh-202002, India, razianongjai@gmail.com

**Abstract -**Nanoparticles of $Ni_{0.7}Mg_{0.3}$ $Al_xFe_{2-x}O_4$ ($0.0 \le x \le 0.5$) were prepared through sol-gel method to study the effect of $Al^{3+}$ doping on structural and electrical properties using dielectric spectroscopy as a function of frequency at room temperature. The average particle size has been found between 25~30 nm. The dispersion in $\varepsilon'$, $\varepsilon''$, tanδ and $\sigma_{ac}$ with frequency shows that the dispersion is due to Maxwell-Wagner type of interfacial polarization in general and the hopping of charge between $Fe^{2+}$ and $Fe^{3+}$ as well as between $Ni^{2+}$ and $Ni^{3+}$ ions at B-sites.

## Introduction

Electric transport properties of ferrites provide information suitable for these materials for specific applications. These properties of ferrites are very sensitive to the methods of preparations, chemical composition, grain structure or size, sintering time and temperature, type and amount of additives [1]. By careful control of both composition and structure useful properties of ferrites can be achieved. In this communication, we report the detailed study of structural, dielectric and ac conductivity of Al doped Ni-Mg ferrite as a function of frequency and compositions at room temperature synthesized through sol–gel method.

## Experimental details

Nanoparticles of $Ni_{0.7}Mg_{0.3}Al_xFe_{2-x}O_4$ ($0.0 \le x \le 0.5$) ferrites were prepared by sol-gel method [2] using 'AR' grade nitrates of Ni, Mg, Al and Fe as the starting materials. To identify the product structure, powder X-ray measurement were carried out by RIGAKU X-ray diffractometer with Cu $K_\alpha$ radiation ($\lambda$=1.54056$A^0$). The dielectric measurements were carried out on the pellets by coating graphite on the opposite faces making parallel plate capacitor geometry with the ferrite samples as the dielectric medium using

LCR HITester (HIOKI 3532–50) in the frequency range of 42 Hz-5Mhz at room temperature.

## Results and discussion

The XRD patterns shown in Fig.1 confirm the single phase cubic spinel structure of all the samples. The crystallite sizes of all the samples were calculated from XRD data using Scherrer formula [3] and were found between 25 to 30 nm.

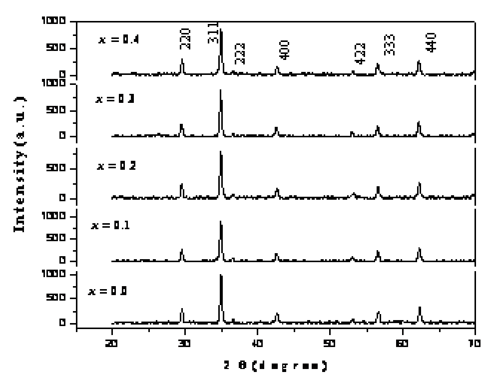


Fig. 1- XRD pattern of the $Ni_{0.7}Mg_{0.3}Al_xFe_{2-x}O_4$ ferrite nanoparticles.

## Dielectric Constant

Fig.2 shows the variation of the dielectric constant with frequency measured at room temperature. The dielectric constant decreases with increasing frequency which shows the general behavior of ferrites. The dispersion in dielectric properties can be explained in the light of Maxwell–Wagner two layer model and Koop's phenomenological theory of dielectrics [2]. It has been found that the loss tangent shows anomalous behavior with frequency (Inset Fig.2). The samples x = 0.3, 0.4, 0.5 show anomalous behavior where relaxation peak appear at lower frequency region. The behavior can be explained in the light of Rezlescue Model [4]. According to this model the peaking nature occurs when the hopping frequency matches with the applied frequency of the field. It has been found that the dielectric constant and loss tangent increase up to 10% of Al doping, thereafter, these parameters decrease, which can be explained on the basis that the $Al^{3+}$ ions prefer to occupy A-site up to x = 0.1, where the already present $Fe^{3+}$ ions are pushed to B-sites. Hence the dielectric parameters increase. The further doping of Al ions occupy B-sites depleting the $Fe^{3+}$ number and hence dielectric polarization.

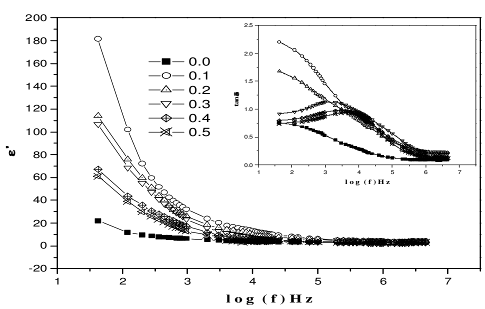


Fig. 2- with inset shows variation of έ and tanδ with frequency.

## AC conductivity

Fig.3 shows the variation of ac conductivity with frequency at room temperature. The ac conductivity increases with an increase of frequency. The conduction mechanism in ferrites is explained on the basis of hopping of charge carriers between two Fe ions at octahedral site.

The increase in frequency enhances the hopping frequency of charge carrier, resulting in an increase in the conduction process. The increase in conductivity does not mean increases in charge concentration but increase in mobility of charge carriers. The inset in Fig. 3 shows the variation of activation energy (n) with composition which shows that the conduction process in the samples are hopping type.

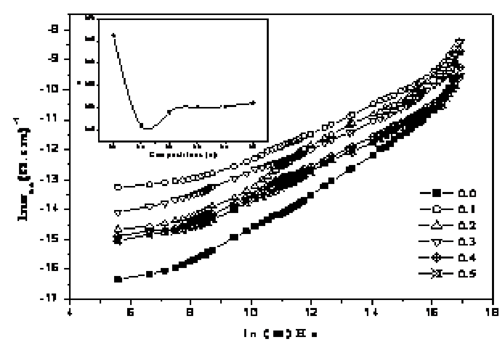

Fig. 3- with shows the variation of $\sigma_{ac}$ with frequency with inset showing variation of n with x.

## Conclusion

We have successfully synthesized the single phase nanoparticles of Al doped Ni-Mg ferrites. Dielectric constant shows normal behavior which has been explained on the basis of Maxwell–Wagner two layer model. Dielectric loss shows abnormal behavior and is explained in the light of Rezlescue Model. The ac conductivity data shows that the conduction process is hopping type.

## References

[1] B. Viswanathan, V.R.K. Murthy, Ferrite Materials: Science and

technology, Narosa Publishing House, 1990.
[2] Khalid Mujasam Batoo, Shalendra Kumar, Chan Gyu Lee, Alimuddin, Current Applied Physics 9 (2009) 826–832
[3] H.E. Schaefer, H. Kisker, H. Kronmuller, R. Wurschum, Nanostruct. Mater. 6 (1995) 533.
[4] S.S. Bellad, B.K. Chougule, Mater. Chem. Phys. 66 (2000) 58.