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DIELECTRIC CHARACTERIZATION OF Co_xZn_{1-x}Fe₂O₄ NANO-FERRITES SYNTHESIZED BY CHEMICAL CO-PRECIPITATION METHOD

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KeyWords

Co-precipitation method, Cobalt substituted zinc ferrite, dielectric properties, AC conductivity

ABSTRACT

In this research work Cobalt substituted Zinc ferrite ($Co_XZn_{1-X}Fe_2O_4$) for x= 0, 0.1, 0.4, 0.7, 0.9, 1 nano-particles were prepared by chemical co-precipitation method due to its low cost and short reaction time. X-ray Diffraction was carried out to confirm the phase characterization and dielectric properties were investigated under frequency range of 1 kHz to 2MHz while voltage across plates of capacitors was kept constant. The change in dielectric constant, tan loss and ac conductivity of prepared nano-particles were observed with doping concentration.

1. INTRODUCTION

Nanocrystalline ferrites are of considerable attention due to its wide range of application in electronic and magnetic field [1]. Among diverse ferrites, $ZnFe_2O_4$ and $CoFe_2O_4$ have been maximum appreciably studied structures, due to the fact they show off the inverse spinel structure. Below the Neel temperature ($T_N = 10k$) zinc ferrites are antiferromagnetic and turns to ferromagnetic or fantastic paramagnetic when particle length reduces to a nanoscale. $CoFe_2O_4$ exhibits inverse spinel structure where Co^{2^+} ions occupy the octahedral sites and Fe^{3^+} ions are similarly distributed in tetrahedral and octahedral sites. $ZnFe_2O_4$ shows spinel structure, where Zn^{2^+} ions occupy the tetrahedral sites and all Fe^{3^+} ions occupy the octahedral sites. Consequently, a distorted spinel structure emerges depending upon the concentration of zinc ferrite [2]. Co-Zn mixed ferrite has attracted great attention due to the tuneable changes in properties with substitution of Zn ions [3]. Cobalt ferrites are reverse spinel ferrite with exceptional magnetic and electric properties [4].

These ferrites are soft ferrites used in electronic devices such as transformer cores, electric motors and generators. In its applications, it is subjected to alternating magnetic fields, and should therefore present low energy losses [5].Cobalt–Zinc ferrite nanoparticles are broadly used in several technological fields, including electronic devices and ferrofluids, prospective material for biomedical applications in diagnostics and cancer therapy, magnetic drug delivery, microwave devices, crystal photonics, and high-density information storage systems [6].

In this particular study $Co_xZn_{1-x}Fe_2O_4$ (x= 0, 0.1, 0.4, 0.7, 0.9, 1) has been synthesized via chemical co-precipitation method and subsequently characterized with X-ray diffraction analysis to confirm the cubic spinel structure and further determine the dielectric properties and AC conductivity.

2. EXPERIMENTAL METHODS

Ferrite nano-particles, $Co_x Zn_{1-x} Fe_2O_4$ (x= 0, 0.1, 0.4, 0.7, 0.9, 1) were prepared by chemical co-precipitation path. In order to attain the desired compositions, stoichiometric amount of nitrides were dissolved in distilled water with constant stirring. Precipitates were formed under reaction with NaOH solution at 90°C, centrifuged at 3600rpm and dried in an oven for dehydration. Annealing was done and pallets were formed by Hydraulic press. Structure was confirmed by X-ray diffraction (XRD) using CuK α radiations with λ =1.5418Å wavelength and the effect of dielectric constant and dielectric loss tangent is explored by sintering the samples at different temperatures.

3. RESULTS AND DISCUSSION

The X-ray diffraction (XRD) analysis confirms the formation of single phase by using CuK α radiations with λ =1.5418Å wavelength as shown in Fig. 1 and the effect of dielectric constant is calculated by the following relation;

'∃=C_p .d /A. ⊡_o..... (i)

Where, C_p is capacitance of sample, d is spacing between plates, A represents area occupied by the sample between plates and \mathbb{D}_0 =8.85 x 10⁻¹²Fm⁻¹ called permittivity of free space.

Dielectric loss factor (ϵ'') is calculated with the following formula;

2''= 2'.tanδ...... (ii)

3.1 Variation of dielectric constant (2) and dielectric loss (2") with Co concentration

Both dielectric constant and dielectric loss depend upon ferromagnetic behaviour exhibited by frequency i.e. have lower value at high frequency and larger at lower value of frequency. The comparison of dielectric constant and dielectric loss (D) and D) depending

upon frequency for different Co concentration is shown similar behaviour as mentioned in Fig. 1(a, b). At lower frequency, the higher values of dielectric constant may be explained by Maxwell-Wagner model. This model suggests that ferrites possess high conducting particles separated by thin weakly conducting grain boundaries [7-9]. Due to presence of Fe³⁺ and Fe²⁺, ferrites become dipolar. Electron hopping between these ions in lattice results dielectric polarization. Dielectric constant is a combined effect of electronic, dipolar, ionic and interfacial polarization. At higher frequencies, hoping frequencies cannot follow variation in AC field, which results constant behaviour of permittivity. Dielectric constant of sample decreased with Co doping, decreasing grain size. At higher values of frequency dielectric constant is not affected, it is due to the point that electron exchange between Fe³⁺ and Fe²⁺ in n-type ferrite.



Fig1 variation of dielectric constant (□') and dielectric loss (□'') with Co concentration

3.2 Variation of tan loss with frequency and Co concentration

Tan loss describes the loss in the sample material. The angle between charging current and total current vector is taken as angle loss δ which is always less than 90° and is calculated as;

Value of tan δ depends on structure homogeneity, stoichiometry and Fe²⁺ content. Fig. 2(a, b) shows variation of tan loss with Co doping at 100 kHz, 1000 kHz and 2000 kHz, which can be explained on basis of cationic mixed distribution at octahedral and tetrahedral sites.



Fig. 2 variation of tan loss with frequency and Co concentration

3.3 Variation of AC conductivity with frequency and Co concentration

AC conductivity is calculated from the relation;

Where; ε_0 = permittivity in free space, εr = relative permittivity, ω =angular frequency.

The variation of AC conductivity with frequency and dopant concentration is shown in Fig. 3 (a, b). All samples show increase AC

conductivity with increase in frequency and chase the dynamical law. Presence of Co on octahedral sites results conduction mechanism which is predominant in Co-Zn ferrites. Conduction mechanism is due to hopping of electrons from Fe²⁺ to Fe^{3+.} Increase in ac conductivity at higher values of frequency may be due to enhancement in conduction mechanism.



Fig. 3 Variation of AC conductivity with frequency and Co concentration

Conclusion

Nanoparticles of Co-Zn ferrites have been prepared using chemical co precipitation method. XRD confirmed the formation of cubic phase crystal. Dielectric constant (ϵ'), dielectric loss (ϵ''), and tangent loss (tan δ) decreased with frequency showing dispersion in low frequency region and remained steady state in high frequency region. Dielectric loss depends on conduction loss and electric polarization of the samples. The AC conductivity (σ) of prepared samples exhibited increasing trend with increase in frequency. Dependence of all these parameters on composition was also investigated. Maxwell-Wagner model was used to clarify dielectric polarization of synthesized material.

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