Executive summary of the Report

Nickel-zinc ferrite is a technologically important material system utilized in a wide variety of power electronics and radio frequency (RF) applications due to its combination of relatively high permeability and resistivity. These properties allows their use as a low loss inductor and transformer cores as well as electromagnetic interference (EMI) suppression devices at higher frequencies [1]. The effect of cobalt is generally related to an ordering of cobalt ions. In iron excess ferrites, the ordering is accomplished by vacancy (cation) diffusion. In iron excess composition, it contains only small amounts of Fe^{2+} ions. The resitivity is accordingly high and magnetic losses caused by eddy currents are negligible [2]. The study of NiCoZn ferrites is important because of their practical use at high frequencies. NiCoZn ferrites are widely used in wave absorbers to suppress the electromagnetic interference among devices up to microwave frequencies.

Ferrite samples with chemical formula $Zn_{0.35}Ni_{0.60-x}Co_xFe_{2.05}O_4$, (where x = 0.0, 0.1, 0.2, 0.3 and 0.4) were synthesized by citrate-nitrate combustion method [3, 4]. The synthesized powder was decomposed in air at 600^0C for 1hr and finally sintered at 1000^0C for 1hr. To study behavior of magnetic permeability and loss factor, the decomposed powder was mixed with small amount of polyvinyl alcohol as binder and pressed at a pressure of 7 tones into annular shaped rings having 1cm inner and 2cm outer diameter. These annular shaped rings were finally sintered at 1000^0C for 1hr. The rate of heating and cooling was maintained at 3 ^{0}C/min.

The structure of samples was studied by using XRD analysis. X- ray diffraction analysis of ferrites was carried out on a Rigaku Ultima IV (Japan) X-ray powder diffractometer with Cu-Kα radiation in the range 20^0 to 80^0. The X-ray diffraction patterns of all the samples show single phase formation of spinel structure with cubic symmetry. The lattice constant of Ni-Zn ferrites was increase with increasing cobalt content obeying the Vegard’s law. The ionic radius of the substituent ion is more than the displaced ion, the lattice tends to expands and hence lattice constant increases. This is attributed to substitution of larger ionic radii of Co^{2+} (0.78Å) ions by smaller ionic radii Ni^{2+} (0.74Å) ions.

Average crystallite size of all the cobalt substituted Ni-Zn ferrites obtained from the Debye Scherrer formula [3] by using the line broadening width of (311) peak. It is found that average crystallite sizes of all the ferrites lies in the nanocrystallite range 39 nm to 52 nm. There is no any remarkable trend was found in average crystallite sizes of cobalt substituted Ni-Zn ferrites. Similar results have been also reported by us [4] for cobalt substituted Ni-Zn ferrites prepared by oxalate precursor method.

The microstructural aspects of all the ferrites were studied with a scanning electron microscope of model JEOL-JSM-6360. Morphological observation shows agglomerated grains with different shapes and sizes which is the typical characteristics of combustion synthesis. The average grain size of the ferrites and its values lies in the range 0.26 µm to 0.48 µm. Similar results were reported earlier for Ni-Zn-Co ferrites prepared by classical ceramic method [5].

Vibrating sample magnetometer measures the magnetic properties of materials. The saturation magnetization (M_s), magnetic moment (n_B), coercivity (Hc) and retentivity (Mr) of all the ferrites were measured at room temperature by using vibrating sample magnetometer with a field of 15000 Oe. Cobalt substitution must lead to an increase of the saturation magnetization, due to Co^{2+} ions magnetic moment which is higher than the Ni^{2+} ions present in octahedral sites. But cobalt substitution does not have a significant influence on the saturation magnetization [6]. The saturation magnetization of cobalt substituted Ni-Zn ferrites is higher than pure Ni-Zn ferrite. This can be explained on the basis of cation distribution of metal ions on tetrahedral (A) and octahedral (B) sites respectively. The magnetic characteristics of ferrites are depends on chemical composition, porosity, grain size and cation distribution among the A and B sites of spinel structure etc. The saturation magnetization (Ms) is independent of grain size but coercivity is appreciably dependant on it. Coercive force (Hc) seems to be inversely proportional to grain size [7].The coercivity and retentivity of the Ni-Zn ferrites found to increases with increasing cobalt content. Similar results have been reported earlier for Ni-Co-Zn ferrites prepared by sol- gel method [8].

For measurements of magnetic permeability and loss factor the torroids were obtained by wounding a 100 turns of 30 SWG enameled copper wire. The real (µ') and imaginary (µ'') part of initial permeability were measured at various frequencies in the range 42 Hz to 1MHz by using Hioki (3532-50) LCR-Q meter. The initial permeability (μ_i) and its real part (µ') is almost independent with frequency and it is gradually increases as cobalt content increases in Ni-Zn ferrites, thereby application frequency range of material increases. Such magnetic characteristic of ferrites is useful in fast kicker magnets of accelerators. Similar behavior was reported earlier for Ni-Zn-Co ferrites prepared by ceramic technique [9]. Also such characteristics of μ_i and μ' has been observed and discussed by Mizushima [10] in Ni-Co-Zn ferrites prepared by ceramic method and Babbar [11] in Mn-Co-Zn ferrite prepared by hot pressing technique. The loss factor refers loss component and represent various losses in the material. The loss factor is ratio of loss tangent (tanδ) to initial permeability (μ_i). The loss factor is observed to increase steeply with the substitution of cobalt. It is observed that, the loss factor initially decreases suddenly with increase in frequency up to 50 KHz. Beyond 50 KHz loss factor remains constant with increasing frequency.

Dielectric properties of $Zn_{0.35}Ni_{0.60-x}Co_xFe_{2.05}O_4$, for x=0.00, 0.10, 0.20, 0.30, 0.40 was studied with frequency and composition. It is seen that both real dielectric constant (ε') and complex dielectric constant (ε") decrease as frequency increases showing usual dielectric dispersion behavior which can be explained interfacial polarization due to mechanism similar to that of conductionThis leads to local displacement of electrons or holes in the direction of the applied polarizing field [9]. A similar behavior was also observed in Ni-Zn [12] and NiCoZn [13]. It is observed that, the dielectric loss factor (tanδ) shows dispersion similar to that of dielectric constant. The values of dielectric loss depend on a number of factors such as carrier concentration and structure homogeneity. The dielectric loss arises due to the lag of the polarization behind the alternating electric field and caused by the impurities and imperfections in the crystal structure. Dielectric loss tangent (tanδ) shows maximum in lower frequency region are explained by Iwanchi etal [14].

Ferrite and a dielectric absorbing medium are combined to produce radar absorbing ferrite material [15]. For preparation of microwave absorber, NiCoZn ferrite powder was blended with silicon rubber. The prepared composite absorbers were punched into a rectangular shape with length 5 cm, breadth 4 cm and thickness 2mm. The microwave absorption properties of the samples were measured using an Agilent RF network analyzer 8714 ET in the frequency range 200 KHz to 3000 MHz. The complex permeability, permittivity and absorption coefficient of the developed ferrite obtain from scattering parameters. Scattering parameters S_{11} and S_{12} of developed ferrite were measured over a frequency range 2.3 to 2.5 GHz. All samples show absorption in the frequency range 2.3 to 2.5 GHz. It is seen that fabricated samples had reflectivities of -2.23dB, -2.55dB,-2.39dB, -2.57dB and -2.31dB for composite material x = 0.0, 0.1, 0.2, 0.3 and 0.4 in frequency range

2.3 to 2.5 GHz. A good quality absorber should have a large reflection coefficient. It is found that the composite material $Zn_{0.35}Ni_{0.30}Co_{0.3}Fe_{2.05}O_4$exhibited the best electromagnetic absorbing performance as compared to other samples. Similar results have been reported earlier for Ni-Co-Zn ferrites prepared by co-precipitation method [16]. The reflection loss of sample $Zn_{0.35}Ni_{0.30}Co_{0.3}Fe_{2.05}O_4$ is greater than other samples; therefore we found that it can be used as a best ferrite rubber composite microwave absorber.

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