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Dielectric behaviour of cobalt–zinc ferrites

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The dielectric behaviour of a number of mixed ferrites [1], has been studied in this laboratory. An extensive study of the composition and temperature dependence of the dielectric behaviour of manganese–magnesium ferrites has yielded interesting results. In continuation of this work, it was thought desirable to undertake a study of the dependence of the dielectric properties of the mixed ferrites of cobalt–zinc on the composition and temperature and the results of such a study are presented in this communication.

The dielectric constant ϵ' and the loss tangent $\tan\delta$ of the mixed cobalt–zinc ferrites were measured using a capacitance bridge (General Radio type 1615-A) with a three terminal network and a crystal holder assembly. An external oscillator (Philips PM-5100) with a frequency range of 10^2 to 10^5 Hz was used to vary the frequency continuously. The errors in the measurement of the dielectric constant and the loss tangent were 2% and 5%, respectively.

Cobalt–zinc ferrites of the formula $Co_xZn_{1-x}Fe_2O_4$ (where $x = 0$ to 1) have been prepared by the double sintering process; cobalt oxide (E. Merk, Germany, 99% pure) and zinc oxide (May and Baker, England, 99% pure) were used in the preparation of mixed ferrites. The ferrite specimens used in the present investigation were finally sintered at about 1250 to 1350° C in an atmosphere of air. X-ray diffraction patterns for all these mixed ferrites have been obtained using Fe$K\alpha$ radiation and their lattice constants are calculated. Fig. 1 shows the characteristic linear dependence of the lattice constant of Co–Zn ferrites on the zinc content. A similar variation has been observed by Murthy and Rao [2] and by Sage and Guilland [3] in the case of Ni–Zn ferrites. The bulk density of each of these ferrites is determined from volume and weight measurements in air at room temperature. They were found to be within 85% to 95% of the corresponding X-ray densities.

The dielectric constant (ϵ') and the complex dielectric constant (ϵ'') obtained at room temperature for Co–Zn ferrites are given in Table I. The values of electrical conductivity [4] are also included in the table for the sake of comparison. It can be seen from the table that the values of ϵ' and ϵ'' decrease continuously with increasing zinc content. In all the Co–Zn ferrites, the dielectric permittivity and the dielectric loss are less than 20 at room temperature at the lowest frequency studied.

Rezlescu and Rezlescu [5] have studied the composition, frequency and temperature dependence of the dielectric parameters of ferrites containing copper such as Cu–Mn, Cu–Zn, Cu–Ni ferrites. These investigations explained the composition dependence of the dielectric constant by assuming [6] that the mechanism of dielectric polarization is similar to that of the conduction process.

It can be seen from Table I that the value of electrical conductivity of cobalt ferrite is less compared to zinc ferrite and mixed cobalt–zinc ferrites. As such, the number of ferrous ions which take part in the electron exchange interaction $Fe^{27} \rightleftharpoons Fe^{3+}$ is comparatively less in cobalt ferrite and hence the polarization is less. Therefore, a comparatively low value of dielectric constant is expected for cobalt ferrite. Experimental data given in Table I are also in agreement with this result. As the zinc content in the mixed Co–Zn ferrites is continuously increased, the number of ferrous ions available for the electron exchange interaction increases and hence causes increase of polarization. This results in a continuous increase of dielectric constant with increasing zinc content.

Fig. 1 shows the variation of dielectric constant ϵ' with frequency at room temperature for Co–Zn ferrites. It can be observed from the figure that the dispersion of the dielectric constant with frequency is maximum for cobalt ferrite and

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TABLE I Dielectric data for cobalt–zinc ferrites at room temperature (303 K)

Ferrite	Dielectric constant (ϵ')	Complex dielectric constant (ϵ'')	Electrical conductivity (ohm^{-1} cm^{-1})
$CoFe_2O_4$	22	9.9	1.97×10^{-8}
$Co_{0.8}Zn_{0.2}Fe_2O_4$	18	9.0	3.1×10^{-8}
$Co_{0.6}Zn_{0.4}Fe_2O_4$	15	10.20	1.34×10^{-5}
$Co_{0.4}Zn_{0.6}Fe_2O_4$	7.5	6.60	2.35×10^{-10}
$Co_{0.2}Zn_{0.8}Fe_2O_4$	2.7	2.48	5.76×10^{-8}

decreases continuously with the addition of zinc, reaching a minimum for a specimen containing 80 mol% zinc. It can also be seen from the figure that the value of ϵ' for cobalt ferrite reduces from 23 at 1 kHz to 3.8 at 100 kHz. The same trend is also observed in all other mixed Co–Zn ferrites. A similar variation has been observed by Iwanchi [7] in the case of manganese ferrite and Josyulu and Sobhanadri [8] in the case of cobalt–zinc ferrites, Koops [9] in the case of $Ni_{0.4}Zn_{0.6}Fe_2O_4$ and Rezlescu and Rezlescu [5] in the case of certain ferrites containing copper.

Rezlescu and Rezlescu [5] interpreted their results on the basis of a combined contribution of charge carrier to polarization. If only the contribution of the n-type carrier is considered for the polarization one would find that the polarization remains constant up to a certain frequency, beyond

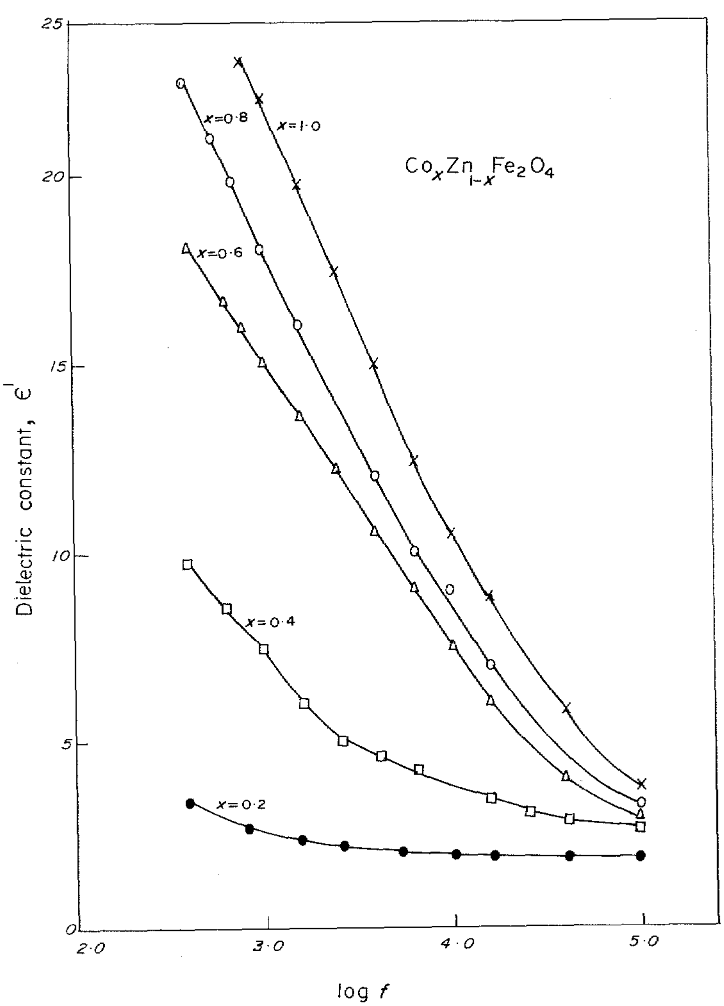

Figure 1 Plot of dielectric constant (ϵ') against frequency for cobalt–zinc ferrites.

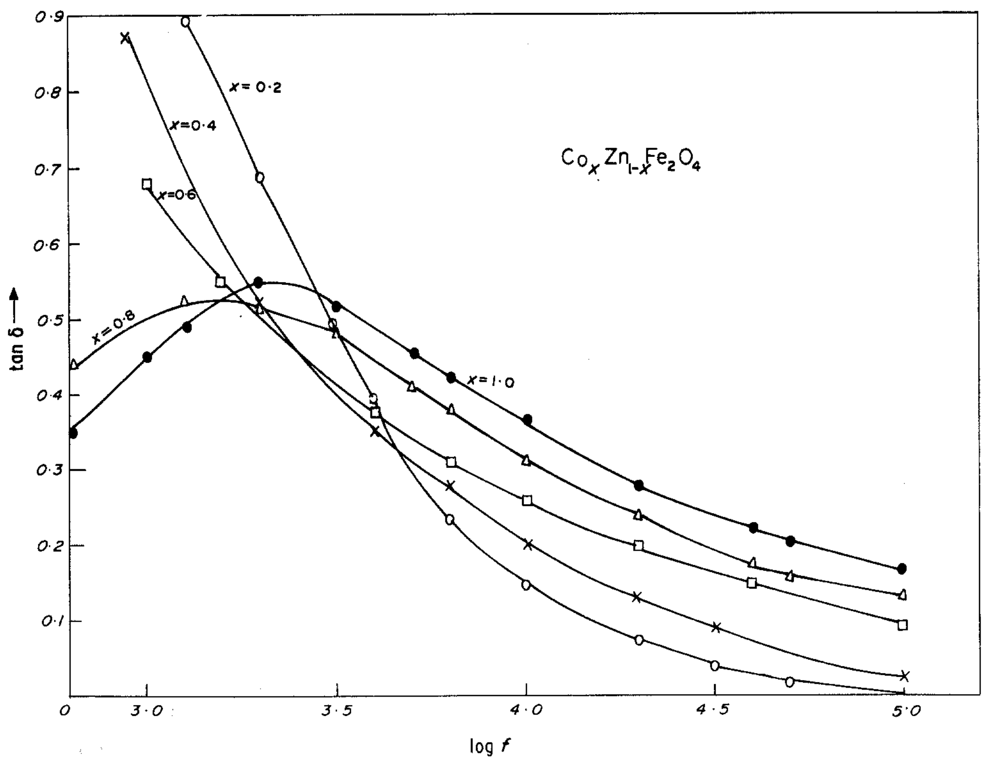

Figure 2 Plot of loss tangent (tan δ) against frequency for cobalt–zinc ferrites.

which it decreases. In the present investigation, plots of ϵ' against frequency have not shown any maximum and decrease with increase of frequency. This behaviour can be explained on the basis that in the case of the n-type Co–Zn ferrites the contribution to polarization is entirely due to an n-type carrier.

Fig. 2 shows the variation of log tan δ with frequency for all the Co–Zn ferrites. It can be seen from the figure that the curves for cobalt ferrite and $Co_{0.8}Zn_{0.2}Fe_2O_4$ show maxima at frequencies 2.05 and 1.45 kHz, respectively. But for the remaining mixed cobalt–zinc ferrites the value of log tan δ decreases with increasing frequency. These results suggest that the frequency at which the maximum occurs decreases with increasing zinc content. Thus it can be assumed that the curves for the specimens $Co_{0.6}Zn_{0.4}Fe_2O_4$, $Co_{0.4}Zn_{0.6}Fe_2O_4$ and $Co_{0.2}Zn_{0.8}Fe_2O_4$ may also show maxima below the frequency range of the present investigation.

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