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INFLUENCE OF In_2O_3 ADDITION ON THE MAGNETIC AND ELECTRICAL PROPERTIES OF IRON – DEFICIENT Ni-Zn FERRITE

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ABSTRACT

The influence of low melting In_2O_3 addition on the magnetic and electrical properties of iron-deficient ferrites of composition. $Ni_{0.65}Zn_{0.35}Fe_{1.96}O_4$ + xIn_2O_3 (x = 0, 0.005, 0.01, 0.015, 0.02, 0.025, 0.03 and 0.035) was investigated. Single phase spinel structure of all sintered samples were confirmed by X-ray diffraction. The lattice parameter of the samples increased with the increment of In_2O_3. The effect of In_2O_3 (melting point 680°C) can be explained by the formation of liquid phase on the grain surface due to reaction of In_2O_3 with the spinel phase at 1250°C sintering temperature. Saturation magnetization decreased almost linearly and Curie temperature linearly with the increasing addition of In_2O_3. The decrease in magnetization was possibly due to diamagnetic In^{3+} ions occupy B-sublattice (octahedral sites) and replace Fe^{3+} ions keeping the magnetization of A-sublattice (tetrahedral sites) unchanged. When indium ions occupy B-sites and replace Fe^{3+} ions, the magnetization of B-sublattice (M_B) decreases keeping the magnetization of A-sublattice (M_A) constant which in turn weakens A-B exchange interaction ($M = M_B - M_A$). The dc resistivity of the samples increased almost linearly with the addition of In_2O_3. With the increasing addition of In_2O_3, In^{3+} ions occupy B-sites which reduces Fe^{2+} to Fe^{3+} electron hoping conduction in octahedral sites and contributes to increase in resistivity.

Key words: Ferrites, Magnetization, Curie temperature, Permeability, Resistivity, Loss factor

INTRODUCTION

Ni-Zn ferrites are widely used as soft magnetic materials for high frequency applications due to their attractive magnetic and electrical properties. Magnetic and electrical properties of these materials are sensitive to composition and preparation methodology.

Efforts have been made to improve the magnetic and electrical properties of these ferrites by adding oxides of transition elements and elements of different valence states depending on the applications of interest (Jain *et al*. 1979, Rezlescu *et al*. 1992, Caltun *et al*. 2001, Rao *et al.* 2004, Akhter *et al*. 2007). It has been reported that the choice of the

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addition of these oxides influences favorably the characteristic properties of ferrites (Rao *et al*. 1981, Pol *et al*. 1996, Bhosale *et al*. 1997). In this paper the authors presented some experimental results concerning the influence of low melting In_2O_3 addition on the magnetic and electrical properties of $Ni_{0.65}Zn_{0.35}Fe_{1.96}O_4$ ferrite.

MATERIALS AND METHODS

Polycrystalline spinel ferrites of composition $Ni_{0.65}Zn_{0.35}Fe_{1.96}O_4 + xIn_2O_3$ (x in mol unit = 0, 0.005, 0.01, 0.015, 0.02, 0.025, 0.03 and 0.035) were prepared by solid state reaction method described elsewhere (Smit and Wijn 1959a). Components of each of these mixtures were mixed by wet milling for 6 hours. After mixing the slurry was filtered, dried and the powders were pressed in a metal-die press assembly to form pellets for presintering. The pellets were presintered in air for 3 hours at 1000°C for ferritization. The presintered pellets were then crushed and subjected to milling for 6 hours to get a fine reactive powder for final densification, mixing with required quantities of In_2O_3 addition. Fine powders were compacted into discs and toroids at a pressure of 20 KN. Disc and toroid samples were sintered for 3 hours in air at 1250°C and then cooled to room temperature at the rate of 100°C/hour. Single phase spinel structure of the sintered samples were confirmed by means of X-ray diffraction (Model No. PHILIPS PW 3040 x' pert PRO) using CuKα radiation (XRD pattern (Fig. 1). Magnetization of the samples was measured by vibrating sample magnetometer (Model No.VSM 02, Hirstlab, England). The Curie temperature of the samples was determined from the permeability versus temperature curve. Magnetic initial permeability and loss factor (Q-factor) measurements were carried out using LF impedance analyzer (Model No. HP4192A). The dc resistivity of the samples was measured with the help of an electrometer (Model No. Kiethley 6514) using silver paste contact. Microphotograph of the samples was taken by a Scanning Electron Microscope (Model No. S 50, FEI Quanta Inspect, Netherland).

RESULTS AND DISCUSSION

Fig. 2 shows the variations of sintered density (d_s) and lattice parameter (a) with the increment of In_2O_3. Sintered density increases with the increasing addition of low melting In_2O_3. The inclusion of In_2O_3 (melting point 680°C) in this composition of Ni-Zn ferrite enhances the chemical reactivity of the resulting mixtures because it acts to some degree as a flux. So the effect of In_2O_3 is explained by the formation of liquid phase on the grain surface of the ferrite due to reaction of In_2O_3 with the spinel phase at 1250°C sintering temperature which promotes densification. The increment in lattice parameter can be defined on the basis of ionic radius of the additive ions. The ionic radius of In^{3+} (0.91Å) is larger than the displaced Fe^{3+} (0.64Å) ions, so the lattice bulges and the lattice parameter increases with In_2O_3 addition.

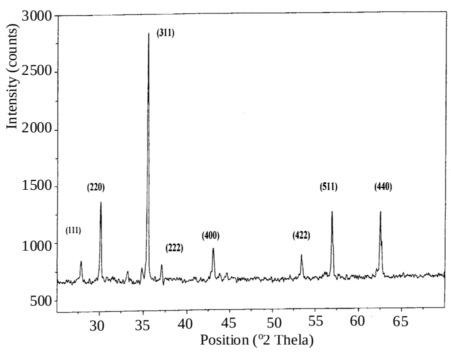


Fig. 1. XRD pattern of sintered ferrite with the addition of In_2O_3.

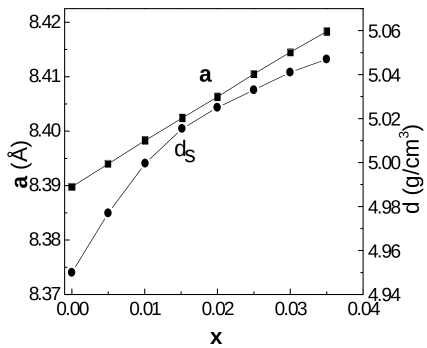


Fig. 2. Variation of d_s and a on In_2O_3 addition.

The observed variation of saturation magnetization (M_s) and Curie temperature (T_c) with the increasing concentration of In_2O_3 is shown in Fig. 3. Saturation magnetization decreases almost linearly and Curie temperature decreases linearly with the increase of In_2O_3 addition. The decrease in magnetization with increased concentration of indium is possibly because diamagnetic In^{3+} ions occupy B-sites (octahedral sites) and replace Fe^{3+} ions from the sites. When indium ions occupy B-sites and replace B-site's Fe^{3+} ions, the magnetization of B-sublattice (M_B) decreases keeping the magnetization of A-sublattice (M_A) unchanged, which in turn weakens A-B exchange interaction. Thus the resultant magnetization according to $M = M_B - M_A$ is expected to decrease, hence the magnetization decreases. It is well-known that the replacement of Fe^{3+} ions by the paramagnetic or diamagnetic ions results in the fall of Curie temperature (Lakshman *et al*. 1971). In this case it is also true because here A-B exchange interaction becomes weak, so Curie temperature decreases.

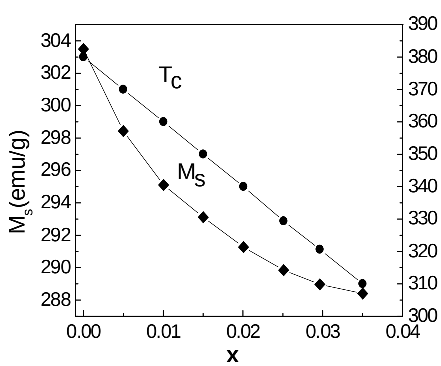


Fig. 3. Variation of M_s and T_c on In_2O_3 addition.

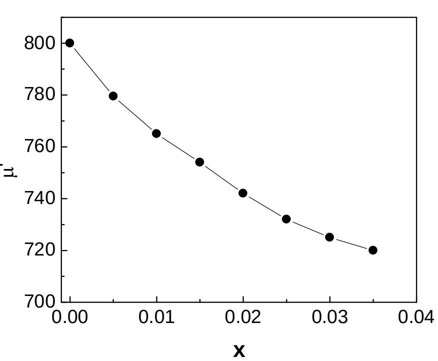
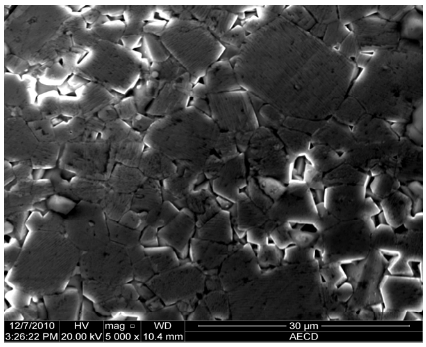
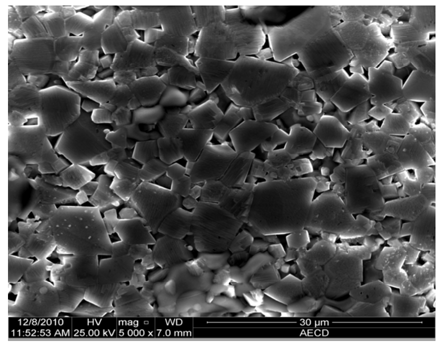


Fig. 4. Variation of μ′ at 100 kHz on In_2O_3 addition.

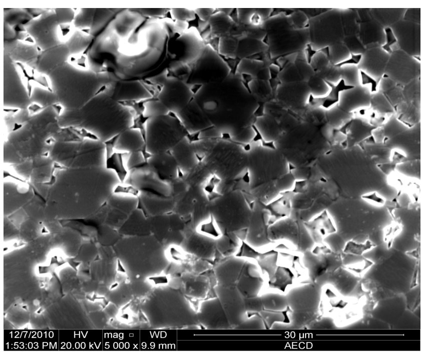
The variation of initial magnetic permeability (μ') at 100 kHz as shown in Fig. 4 decreased with increased addition of Indium concentration. The observed variation in initial permeability may be explained by the following considerations:



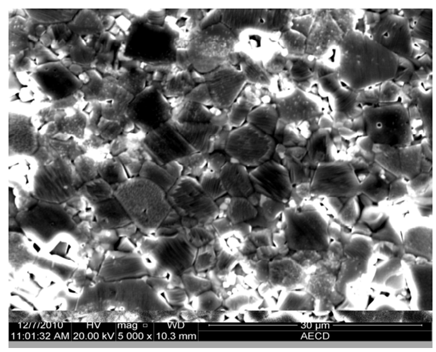
In_2O_3(x = 0.0)



In_2O_3 (x = 0.02)



In_2O_3(x = 0.030)



In_2O_3 (x = 0.035)

Fig. 5. Microstructure of Ni-Zn ferrite samples with In_2O_3 addition.

The initial permeability of a ferrimagnetic material depends on many factors like reversible displacement of domain walls, bulging of domain walls, microstructural parameters *viz.*, average grain size and intra-granular porosity (Smit and Wijn 1959a,b, Peeduijn and Peloschek 1968, Roess *et al*. 1964). The grain size variation of the material as shown in the scanning electron micrographs (Fig. 5) is significant for considerable fall in initial permeability with increasing concentration of In_2O_3.

The observed variation of normalized loss factor (1/μQ) and dc resistivity (ρ) are shown in Fig. 6. The loss factor first decreases, reaches a minimum and then increases with the addition of In_2O_3. The dc resistivity of the samples increases almost linearly with the addition of In_2O_3. As mentioned earlier In^{3+} ions occupy B-sites (octahedral sites) which reduces the degree of Fe^{2+} to Fe^{3+} electron hoping conduction in this sites and contribute to increase the resistivity.

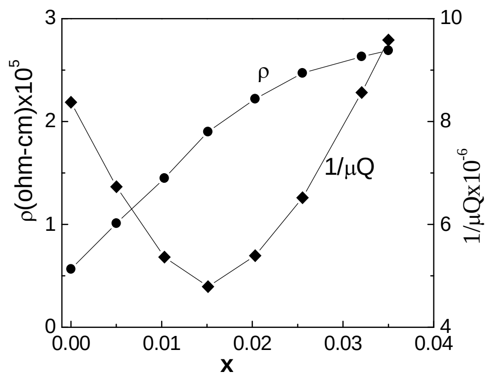


Fig. 6. Variation of 1/μQ and ρ on In_2O_3 addition.

CONCLUSION

It can be concluded from the experimental data that the density, saturation magnetization, Curie temperature, initial magnetic permeability, magnetic loss factor and dc resistivity of iron deficient Ni-Zn ferrites can be controlled by the addition of In_2O_3. The optimum content of In_2O_3 is considered to be around 4% ($x = 0.04$) to obtain better dc resistivity and loss factor to promote the properties of the ferrite materials for high frequency applications.

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