Cadmium substituted high permeability lithium ferrite

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Abstract. Polycrystalline $\text{Li}_{0.5-x/2}\text{Cd}_x\text{Fe}_{2.5-x/2}\text{O}_4$ ferrites where $x = 0, 0.1, 0.2, 0.3, 0.4, 0.5$ and 0.6 were prepared by a double sintering ceramic technique and characterized by X-ray diffraction and scanning electron microscopy (SEM). The lattice parameter is found to increase monotonically with the cadmium content. It is explained in terms of the sizes of component ions. The grain size of the samples increases up to $x = 0.3$ and then it decreases for higher values of x . A similar trend is observed in the variation of M_s with Cd^{2+} content. The initial permeability (μ_i) is however found to increase continuously with x . The increase in μ_i is attributed to decrease of anisotropy constant K_1 and higher grain size of the samples.

Keywords. Lithium ferrites; initial permeability; grain size; microstructure; magnetic properties.

1. Introduction

Lithium ferrite and mixed lithium ferrites have very high potential for microwave applications, especially as replacements for garnets, due to their low cost. The squareness of the hysteresis loop and superior temperature performance are other prominent advantages that have made them very promising candidates for application in microwave devices. In particular, mixed lithium–cadmium ferrites are of much interest because of their applications in microwave devices such as isolators, circulators, gyrators and phase shifters (Ravinder 1994). Several investigations on properties of mixed Li–Cd ferrites, such as structural, electrical conductivity, thermoelectric power, elastic properties, frequency and composition dependence of dielectric behaviour, have been reported in the literature (Ravinder and Seshagiri Rao 1990; Radha and Ravinder 1995; Bellad and Chougule 1998). However, we found no such reports on the microstructure, magnetization and permeability behaviour of Li–Cd ferrites. In this communication we report our studies on these parameters.

2. Experimental

The polycrystalline lithium–cadmium ferrite samples with the chemical formula $\text{Li}_{0.5-x/2}\text{Cd}_x\text{Fe}_{2.5-x/2}\text{O}_4$ (where $x = 0, 0.1, 0.2, 0.3, 0.4, 0.5$, and 0.6) were prepared by conventional ceramic technique using AR grade component oxides. Final sintering of the samples was carried out at 1000°C for 24 h to avoid the loss of lithium. Pellets

(1 cm dia. and 0.3 cm thick) and torroids (2 cm O.D. and 1 cm I.D.) pressed at 8 tonnes/cm^2 with a hydraulic press were used in the measurements of magnetization and initial permeability, respectively. Magnetization measurements were performed with a high field hysteresis loop tracer at a constant magnetic field of 3 kOe and initial permeability measurements were performed with a LCR–Q meter (APLAB, model 4912) at a fixed frequency of 1 kHz. The microstructure was studied with a scanning electron microscope (Cambridge Stereoscan, 250 MK III). The structure formation was confirmed by X-ray diffraction using $\text{CuK}\alpha$ ($1.5418 \text{ \AA}$) radiation.

3. Results and discussion

The single-phase spinel nature of the samples was confirmed from X-ray diffraction patterns. The lattice parameter increases linearly with cadmium content obeying the Vegard's law. The increase in lattice parameter is expected due to substitutional occupancy since the ionic radii of Fe^{3+} , Li^{1+} , and Cd^{2+} in tetrahedral and octahedral sites are in the order $0.065 (\text{Fe}^{3+}) < 0.071 (\text{Li}^{1+}) < 0.084 (\text{Cd}^{2+}) \text{ nm}$ respectively (Bellad and Chougule 1998).

The variation of the mean grain diameter (d_m) obtained from SEM micrographs with content of cadmium is shown in figure 1. It is observed that the average grain diameter increases to a maximum for sample with $x = 0.3$ and then decreases slowly for further increase in x . This is due to the fact that the ions like Cd^{2+} , Zn^{2+} , Ti^{4+} do not favour grain growth when present in excess quantities (Patil *et al* 1991).

Figure 2 shows the variation of saturation magnetization with content of cadmium. The increase in magnetization with content of cadmium up to $x = 0.3$ is due to dilution of

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Figure 1. Variation of average grain diameter with content of cadmium (x).

Figure 2. Variation of saturation magnetization with content of cadmium (x).

magnetization of A-sublattice by nonmagnetic Cd^{2+} ions. This can be explained on the basis of Neel's two sublattice models. The reason for decrease of magnetization beyond $x = 0.3$ is that beyond this limit the magnetization of A-sublattice is so much diluted that the A-B interaction becomes weaker than the B-B interaction. This disturbs the parallel arrangement of spin magnetic moments on B-site paving way for canted spins. Zn^{2+} and Cd^{2+} substituted ferrites have showed similar type of canting behaviour above a certain limit of their contents.

The compositional variation of initial permeability and anisotropy constant (K_1) with cadmium content is shown in figure 3. The initial permeability (m_i) increases

Figure 3. Variation of initial permeability (m_i) and calculated anisotropy constant (K_1) with cadmium content.

continuously with increase in cadmium content up to $x = 0.6$. The values of K_1 were calculated using the relation

$$m_i = \frac{M_s^2 d_m}{K_1}, \quad (1)$$

as suggested by Globus (1963), where d_m is the mean grain diameter and M_s the saturation magnetization. The magnetocrystalline anisotropy constant (K_1) shows a continuous decreasing trend. The continuous increase in m_i with x can be attributed to rise in both M_s and d_m up to $x = 0.3$ and decrease in K_1 up to $x = 0.7$. This is also supported by the fact that the anisotropy constant (K_1) decreases in a rapid manner after this composition.

For low-frequency applications, where a high permeability is required, the crystal anisotropy and the magnetostriction must be as low as possible. It is known that the mobility of domain walls is greatly affected by the microstructure of ferrites. The large grains favour domain wall mobility, giving rise to high permeability and low coercivity. Therefore, the high values of initial permeability in the present samples can also be attributed to the high grain sizes of the samples.

4. Conclusions

The lattice parameter increases linearly with increasing cadmium content. Grain size and M_s both increase up to $x = 0.3$ and then decrease with further increase in x . The initial permeability increases continuously with x and is governed by large grain size and small anisotropy constants (K_1).

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