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Magnetic, dielectric and complex impedance spectroscopic studies of nanocrystalline Cr substituted Li-ferrite

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ABSTRACT

Nanocrystalline $Li_{0.5}Fe_{2.5-x}Cr_xO_4$ ($2.5 \leq x \geq 0$) ferrites were prepared by a sol–gel autocombustion route. X-ray diffraction was employed to confirm the cubic spinel phase formation of the ferrites. The lattice parameter decreases with increase in Cr content. The saturation magnetization, coercivity and remanance were studied as a function of Cr content. The dielectric constant and dielectric loss were measured as a function of frequency in the frequency range 20 Hz–1 MHz. Frequency dependence of dielectric constant shows dielectric dispersion due to the Maxwell–Wagner type of interfacial polarization. In order to understand the conduction mechanism, complex impedance measurements were carried out. The substitution of chromium plays an important role in changing the dielectric and magnetic properties of lithium ferrites.

1. Introduction

Mixed spinel ferrites have gained a prime importance in the study of solid materials because of their various potential applications. Attempts are being made to monitor the preparative parameters of these materials so as to get reproducible and tailor made physical properties [1–4]. $Li_{0.5}Fe_{2.5}O_4$ is an inverse spinel ferrite in which Li^+ ions occupy the octahedral (B) sites and Fe^{3+} occupy the tetrahedral (A) sites of the spinel lattice [5]. Lithium and substituted lithium ferrites are useful for microwave devices such as isolators, circulars, gyrators, phase shifters, cathode materials and memory cores owing to their high Curie temperature, high resistivity, low eddy current losses, high saturation magnetization and hysteresis loop properties, which offer better performance advantage over other spinel structures [6–9].

Large number of mixed ferrites like Li–Mn [10], Li–Ni [11], Li–Co [12], Li–Ge [13], Li–Ti [14], etc. have been prepared by ceramic method and their structural, electrical and magnetic properties have been reported. Fu et al. [15–17] have studied the structural, electrical and magnetic properties of chromium substituted Li-ferrites synthesized by conventional ceramic method. Sellai and Widatallah [18] have discussed the electrical characteristics of Li–Cr ferrite spinel structure. Mazen [19] have studied infrared and dielectric properties of Li–Cu ferrite. Laishram and Prakash [20] have reported magnetic properties of chromium substituted Li–Sb ferrites.

However, ferrites prepared by a ceramic method involve high-temperature synthesis for the completion of solid-state reaction between the constituent oxides or carbonates. The particles obtained by this method are rather bigger and non-uniform in size. These non-uniform particles, on compacting, result in the formation of voids and subsequently the low density ferrites. In order to overcome these difficulties, wet chemical methods, viz. co-precipitation, hydrothermal processing, combustion, etc., have been used for production of homogeneous, fine and reproducible ferrites [21–23].

Literature survey shows that there are no reports on magnetic, dielectric and complex impedance properties of the nanocrystalline chromium substituted Li-ferrites prepared by sol–gel autocombustion method. We report here the synthesis of nanoparticles of $Li_{0.5}Fe_{2.5-x}Cr_xO_4$ (where $x=0.0$, 0.5, 1.0, 1.5, 2.0 and 2.5) ferrite system by sol–gel autocombustion method and their structural, magnetic and electrical properties.

2. Experimental details

2.1. Synthesis

The compositions of $Li_{0.5}Fe_{2.5-x}Cr_xO_4$ ($x=0.0$, 0.5, 1.0, 1.5, 2.0 and 2.5) system were synthesized by sol–gel autocombusion method.

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High purity AR grade [Cr $(NO_3)_3 \cdot 9\,H_2O$], [Fe $(NO_3)_2 \cdot 9\,H_2O$], [$LiNO_3$] and [$C_6H_8O_7 \cdot H_2O$] were used for the synthesis. The metal nitrate solutions were mixed thoroughly in the required stoichiometric proportions in distilled water to improve homogeneity. The pH value of the resultant solution was adjusted between 9.0 and 9.5 by adding dilute ammonia solution drop by drop. The mixture was slowly heated with constant stirring to obtain a fluppy mass. The precursor powder was sintered at 973 K for 8 h. The sintered powder was pressed to form pellets using 2% polyvinyl alcohol as a binder under uniaxial pressure of 8 tons/cm^2. These pellets were gradually heated to about 773 K to remove the organic binder material.

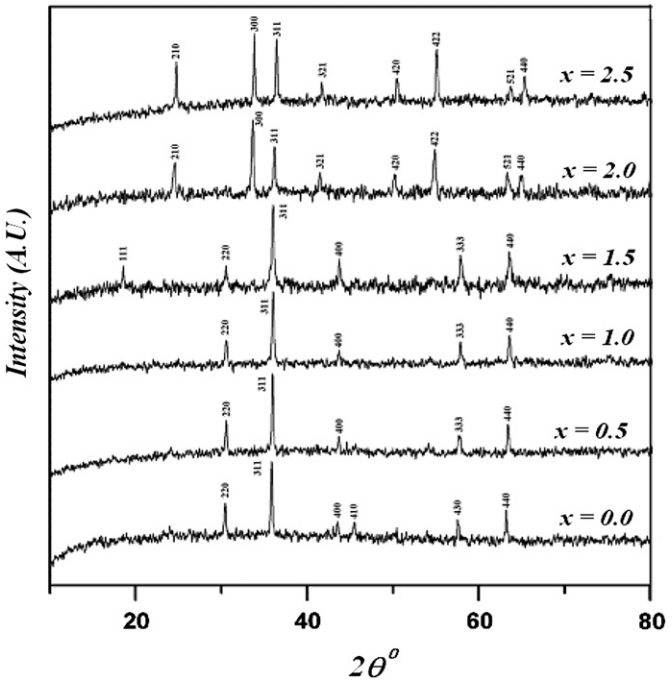

Fig. 1. X-ray diffraction patterns of $Li_{0.5}Fe_{2.5-x}Cr_xO_4$ samples.

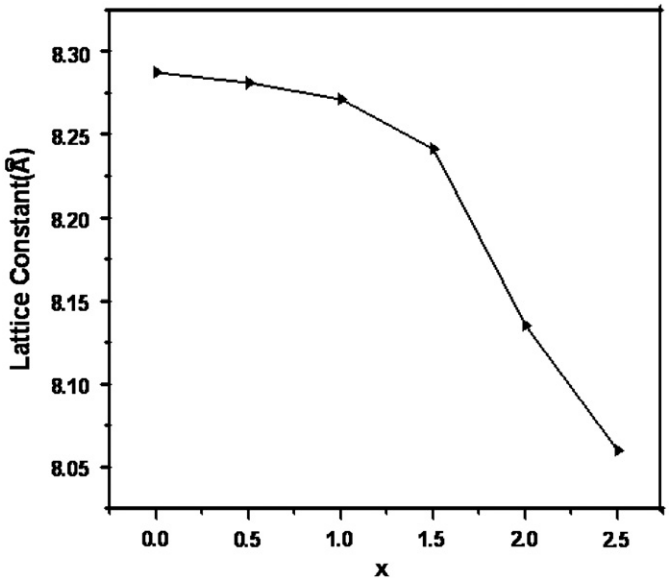

Fig. 2. Variation of lattice constant as a function of x in $Li_{0.5}Fe_{2.5-x}Cr_xO_4$.

2.2. Characterizations

X-ray diffraction technique (Philips model PW-1710) was used to identify the crystalline nature of the samples and to calculate lattice parameter, X-ray density and cell volume. The room temperature magnetic measurements for all the compositions were performed by using a computerized high field hysteresis loop tracer (Magenta, Mumbai) at a magnetic field strength of 2.5 kOe. The frequency dependence of dielectric constant, dissipation factor and complex impedance carried out using a precision LCR meter is in the frequency range from 20 Hz to 1 MHz.

3. Results and discussion

3.1. Phase identification

Fig. 1 illustrates the X-ray diffraction patterns of chromium-substituted lithium ferrite samples. The patterns indicate that the

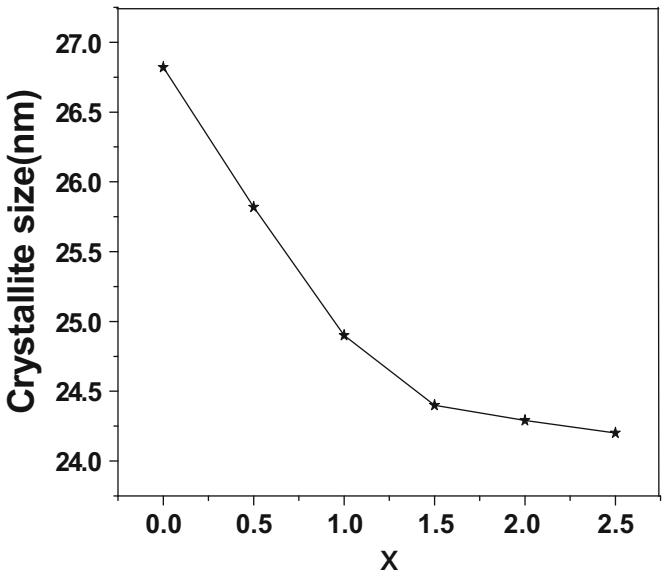

Fig. 3. Variation of crystallite size with x in $Li_{0.5}Fe_{2.5-x}Cr_xO_4$.

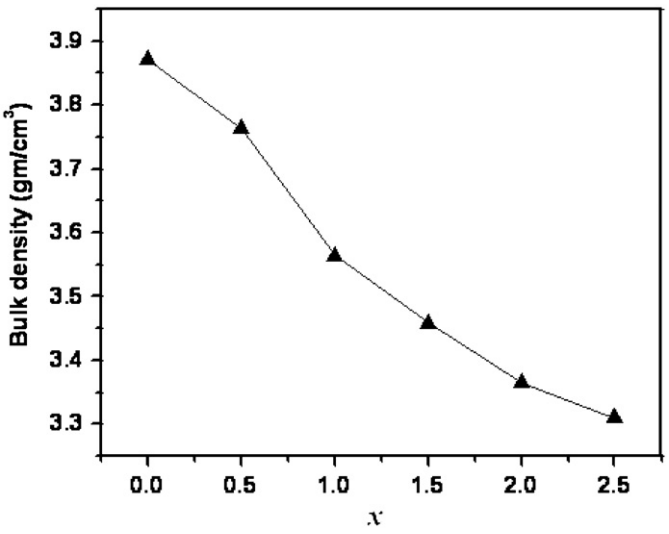

Fig. 4. Variation of bulk density vs composition.