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Preparation and characterization of Al doped nano crystalline Ni ferrites

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ABSTRACT
The Ni-Al nano ferrites having compositional formula $NiAl_xFe_{2-x}O_4$ (where x= 0.2, 0.4, 0.6, and 0.8) were synthesized by citrate gel auto combustion method. The XRD studies reflected that the fabricated powders were single phase spinel structure with crystallite sizes in the range of 17-26nm. The values of lattice parameter and X-ray density decreases with the decrease of composition. The observed results can be explained on the basis of composition.
Key words: Ni-Al nano ferrites, Citrate gel auto combustion method, XRD

I. INTRODUCTION

Nano crystalline spinel ferrites have been the subject of many studies due to their enhanced optical, structural, electrical and magnetic properties, when compared with their bulk counterparts, rendering such nano particles of interest for a variety of applications. These have potential applications in electronics, optical devices, magnetic storage devices, coolants, MLCI applications, and these nano crystalline magnetic ferrites also used as permanent magnets in many devices instead of pure metals because of their high resistivity, low eddy current loss, low magnetic loss and low cost. Many researchers has focused on investigating the effect of transition metal ion doping on the spinel ferrite crystal lattice, since it was well known that properties of the spinel ferrites were sensitive to the presence of doped cations and amount of doping and preparation conditions. The substitution of small amount of impurities has changes the electrical and magnetic properties of ferrites. According to their crystal structure, spinel ferrites were naturally super-lattices, they have tetrahedral (A) sites and octahedral (B) sites in AB_2O_4 crystal structure. It shows various different magnetic properties depending on their composition and cation distribution. Various metal cations occupied in tetrahedral site and octahedral site were tune its magnetic and dielectric properties. Depending upon occupation of tetrahedral and octahedral site, it can exhibit ferri-magnetic, anti-ferromagnetic, spin clusters and paramagnetic behavior **[1].**

Nickel substituted aluminum nano-ferrites were promising material for the microwave device applications since these were less sensitive to the stress and have higher Curie temperature (T_c). The application of nano- ferrites ferrites is restricted due to the difficulties experienced in sintering the prepared samples at the high temperatures. The irreversible loss of lithium and oxygen during sintering was the main cause that made lithium ferrites difficult to fabricate **[2]**.

Spinel ferrites have been studied extensively due to easy to synthesis and abundant uses in technological and industrial applications [3]-[4].The useful properties of the spinel ferrites mostly depend upon the chemical composition, preparation methods, sintering temperature, nature of the additives and their distribution i.e. tendency to occupy tetrahedral (A) or octahedral (B) site [5,6].

Among the spinel structures, nickel ferrite has been widely used in different kinds of magnetic devices, such as inductors, magnetic heads, and magnetic devices, such as inductors, magnetic heads, magnetic refrigeration and magnetic resonance imaging. Thus, the magnetic and electric properties of nickel ferrite have been researched and improved.

Ni-Al ferrites are low cost materials and have important magnetic and electrical properties for technological applications. Therefore a systematic study of the preparation and characterization of the mixed Ni-Al nano- ferrite have been undertaken. The sol-gel auto combustion method provides an easy alternative for the fabrication of Ni-Al nano crystalline ferrites at low temperature sintering. In the present study we fabricate the nano crystalline aluminum substituted nickel ferrites by using low temperature sol-gel auto combustion method and characterized by the x-ray diffraction studies.

II. EXPERIMENTAL TECHNIQUES

The properties of ferrites are deeply influenced by the preparation conditions. Nano crystalline cobalt substituted lithium ferrites having formula $[Li_{0.5}Fe_{0.5}]_{1-x}\,Co_x\,Fe_2O_4$ (where x=0.0, 0.2, 0.4, 0.6, 0.8 and 1.0) were prepared by low temperature solution-combustion method.

2.1 Materials to be used

(i) Ferric nitrate ($Fe(NO_3)_29H_2O$)
(ii) Cobalt nitrate ($Co(NO_3)_26H_2O$)
(iii) Lithium nitrate ($LiNO_3$)
(iv) Citric acid ($C_6H_8O_7.H_2O$) and
(v) Ammonia solution (NH_3).
All raw materials are 99.0 % purity Sigma Aldrich Company chemicals and these are used without any further purification.

2.2 Method of synthesis

To synthesize the above said ferrite materials, we use sol-gel auto combustion method. The detailed flow chart for this method was explained in our earlier publication **[7-8]**.

2.3 XRD Studies

The prepared samples were powdered for structural characterization by using x-ray diffraction studies. Part of the prepared samples was x-ray examined by Phillips x-ray diffractometer (Model 3710) using Cu-K_α radiation having wavelength 1.5405A^o. The scanning step was 0.02 and scanning rate was 2^o/min. 1D detector was used for the x-ray diffraction analysis. The x-ray generator was operated at 40 kV and 30 mA.

III. RESULTS AND DISCUSSIONS

The X-ray diffraction analysis is a powerful noninvasive technique for characterizing crystal structure of the materials. Thus in order to investigate the phase formation and micro structural studies, the XRD analysis was conducted on the synthesized samples. X-ray diffraction pattern of the prepared samples was shown in **fig (1).** All Bragg's reflections have been indexed as (220), (311), (400),(422), (511) and (440) which confirmed the formation of well-defined single phase cubic spinel structure. The strongest reflection peak has resulted from the (311) plane that indicates the spinel phase. Crystallite size and values of Lattice paramter and X-ray density are given in Table1. From the table we observed that average crystallite size of the prepared samples was in the range of 17-25 nm. The plot of lattice parameter with composition is shown in Fig.2. It can be seen from the figure that the value of lattice parameter decreases with the increase of composition. Fig.3 also shows the similar trend with composition.

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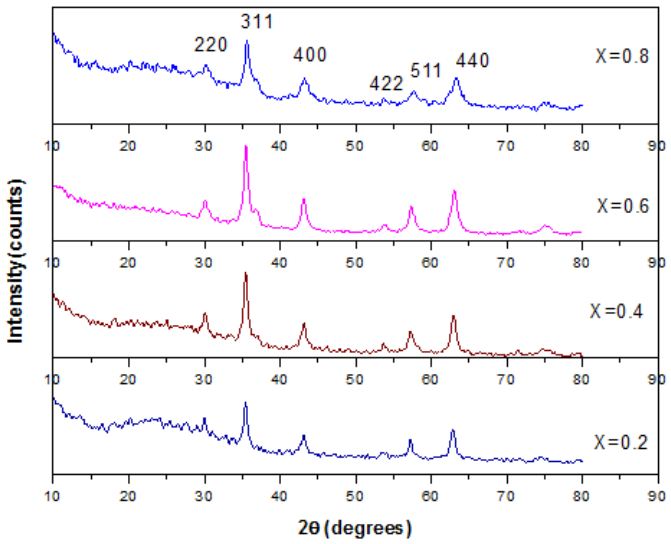

Fig. 1. XRD patterns for Ni-Al Nano-ferrites.

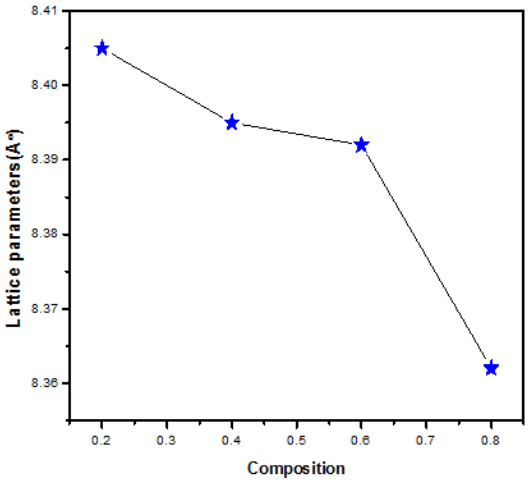

Fig.2. Plot of lattice parameter with composition.

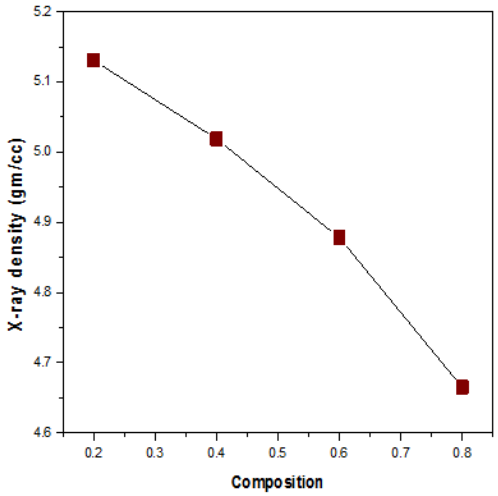

Fig.3. Plot of X-ray density with composition.

Table 1. Lattice parameter, crystal size, and X-ray density

$NiAl_xFe_{2-x}O_4$	2theta	D	a	d_x	d-space	fwhm
0.2	35.4198	26.75	8.405	5.131	2.53433	0.3149
0.4	35.4625	17.85	8.395	5.019	2.53137	0.4723
0.6	35.4754	26.75	8.392	4.878	2.53049	0.3149
0.8	35.6058	26.70	8.362	4.665	2.52151	0.3149