

## Morphological Effect On Magnetic Properties Of Mo<sup>6+</sup> And Sb<sup>5+</sup> Substituted Lithium Ferrites

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**Abstract:** High valency cations of Mo<sup>6+</sup> and Sb<sup>5+</sup> substituted lithium ferrites were prepared under solid state reaction method with General formula  $[Li_{0.5+x}Sb_xFe_{2.5-2x}]O_4$ ,  $[Li_{(1+3y)/2}Mo_yFe_{2.5-5y/2}]O_4$ ; where x is varies from 0.1 to 0.5 insteps of 0.1 and y is varies from 0.05 to 0.5 insteps of 0.05. Average grain size ( $d_m$ ) of Sb<sup>5+</sup> substituted lithium ferrites were initially decreases at x=0.1 then increases maximum upto x= 0.3 then again decreases. Similarly in case of molybdenum the mean diameter initially decreases to y= 0.25 and again increases gradually with y. In both cases initial permeability shows proportionality relation with mean diameter and shows inverse relation with coercivity.

**Keywords:** Lithium Ferrites, grain diameter, magnetic parameter

### I. INTRODUCTION

Lithium ferrites belong to Inverse spinel ferrites and the class of soft ferrites which have potential applications in electrical components, memory devices over a wide range of frequencies (In GHZ range) due to their excellent rectangular loop characteristics, highest Curie temperature, high resistivity, low eddy current losses, low dielectric loss and high Neel temperatures, superior temperature stability of saturation magnetization, low intrinsic line width and low magnetic losses[1-3]. They have an excellent flat profile of permeability at high frequencies along with high dielectric constant. In addition to the properties rapidly changes with variation in composition, ease of fabrication and low cost they offer better performance over other ferrites.  $[Li_{0.5}Fe_{2.5}]O_4$  is an inverse spinel with the Li<sup>1+</sup> and three – fifths of the Fe<sup>3+</sup> ions occupying the octahedral B sites of the cubic spinel structure of the general formula AB<sub>2</sub>O<sub>4</sub> [4]. Since the number of ferric ions on A and B sites is unequal the magnetization of the sample is given by the difference in the magnetic moments of ions on A and B sites. Consequently, lithium ferrite possesses a higher Curie temperature than other spinel ferrites [5] and other advantages suitable for applications. The present paper discusses the variety of lattice constants, density, porosity and other structural parameters with substituent concentration. The lattice constant values give the information on the bond lengths which determine the exchange interactions and chemical interactions.

### II. EXPERIMENTAL DETAILS

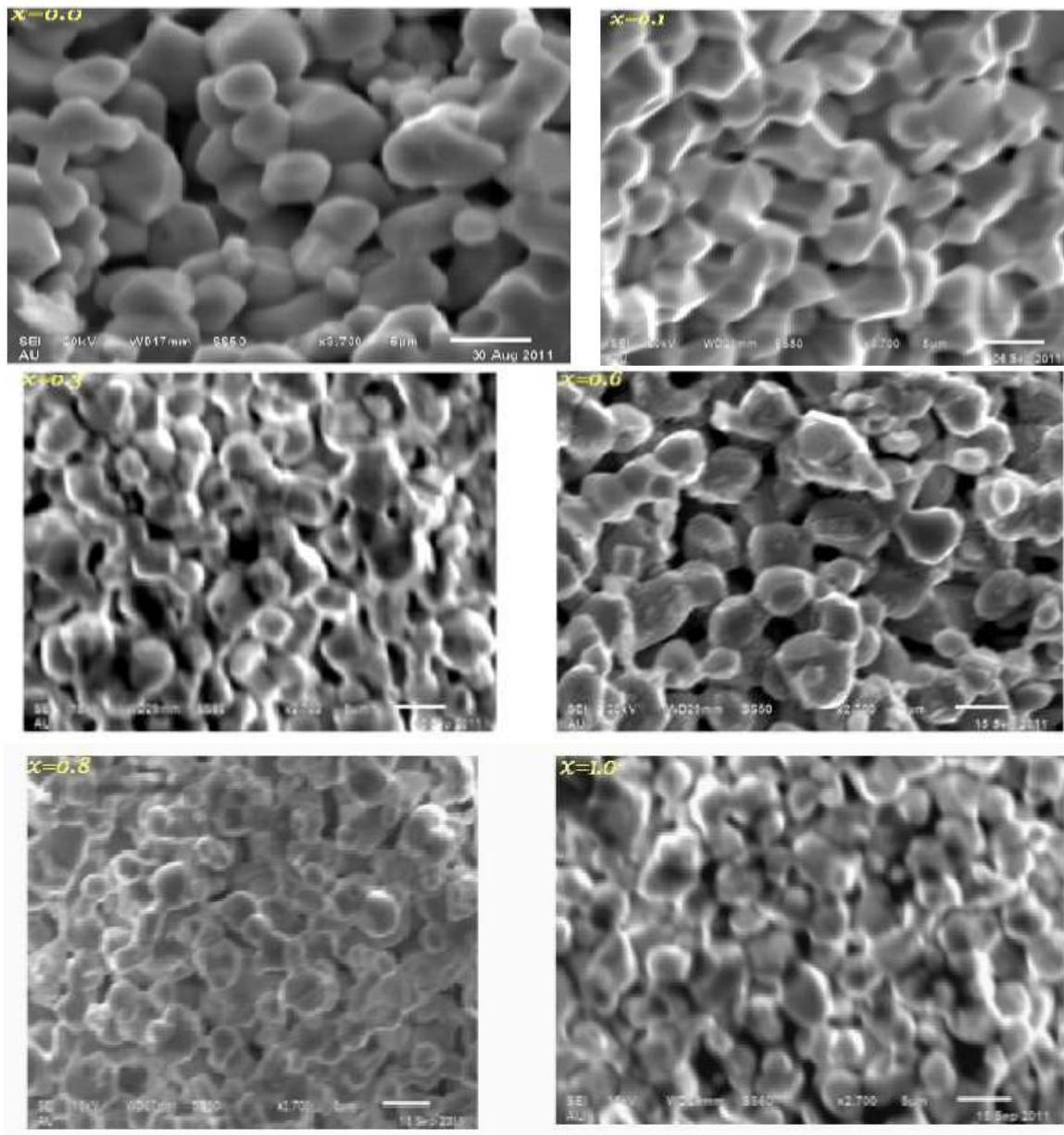
The samples were prepared with compositional formulae  $[Li_{0.5+x}Sb_xFe_{2.5-2x}]O_4$ ; (where x=0.0 to 1.0 in steps of 0.05) &  $[Li_{(1+3y)/2}Mo_yFe_{2.5-5y/2}]O_4$ ; (where y =0.1, 0.2, 0.3, 0.4 and 0.5) were prepared by Solid state reaction method. The appropriate proportions of Li<sub>2</sub>CO<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> and Sb<sub>2</sub>O<sub>5</sub> for the first series similarly second series were prepared with the same compounds of first series except MoO<sub>3</sub> in place of Sb<sub>2</sub>O<sub>5</sub>. All were taken and thoroughly mixed in an agate mortar in the presence of methanol. The dried mixture was pre-sintered at 625 °C for 4 hrs. The related powder was ground again for three hours and granulated using a small amount of PVA binder with ground for one hour. Finally a granulated powder was compressed uniaxially under pressure of 5 tons/cm<sup>2</sup> in a stainless steel die to make pellets and the samples were sintered at 1200°C for 4hrs for good densification. The samples were cooled in the furnace in air atmosphere at the rate of 3°C/min. Due to sintering at 1200 °C lithium volatility occurs and as a result Fe<sup>2+</sup> ions exist [6]. Some of the properties are more attractive when sintering at 1200 °C than sintered at 1000 °C [7-9].

The bulk density ( $d_{ob}$ ) of the samples was measured through the Archimedes principle. The lattice parameter ‘a’ of the Samples were determined using PHILIPS (X’pert: Japan) diffractometer in the range between 15° to 80° at room temperature. The Cu-K $\alpha$  radiation was used.

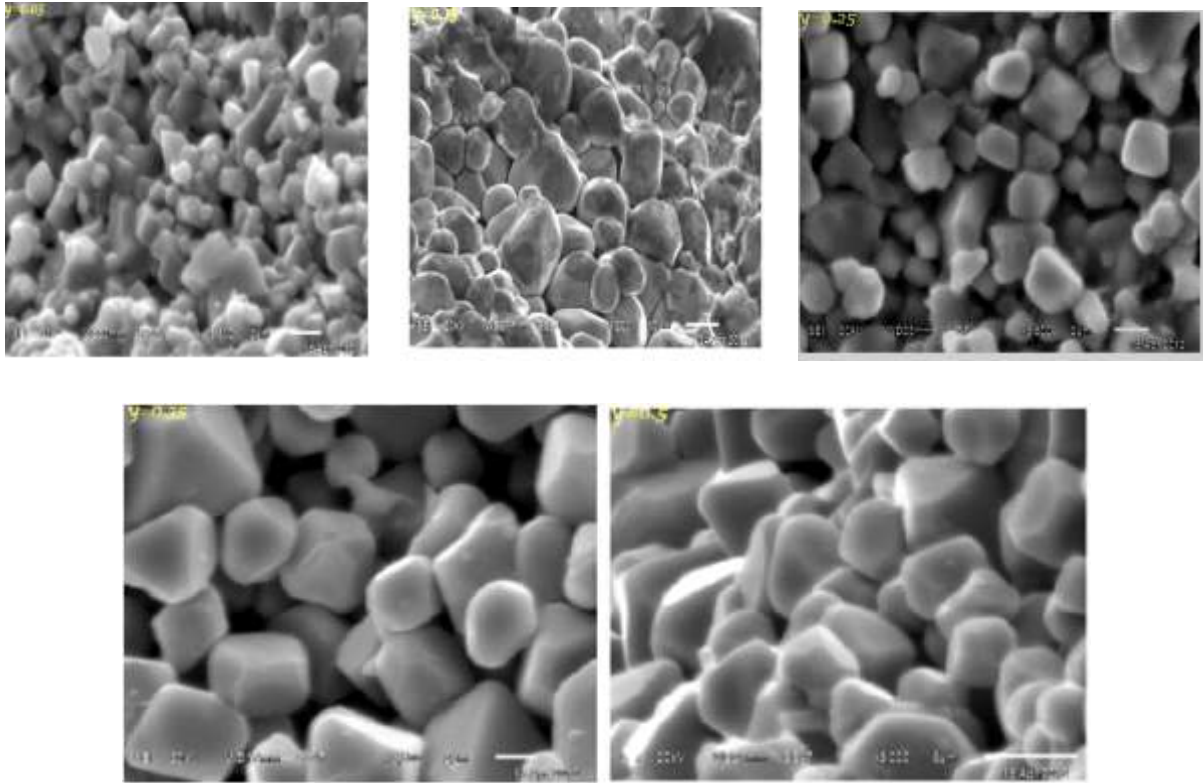
### III. Results And Discussion

From X- ray diffraction studies lithium ferrites confirm the  $\beta$ - phase with space group Fd $\bar{3}m$ . The lattice constant is found to increase in both Sb substituted and Mo substituted series with increasing

concentrations of the substitutions. It is explained on the basis that ionic radius of Li<sup>1+</sup> (0.68 Å) is greater than ionic radius of Fe<sup>3+</sup> (0.64 Å) which it replaces Fe<sup>3+</sup> ions at A site. The Sb<sup>5+</sup> ions seems to replace the Fe<sup>3+</sup> at B site. When Li<sup>1+</sup> is added, the Fe<sup>3+</sup> moves from A site to B site. Therefore, lattice constant increases. The similar behavior with Sb<sup>5+</sup>/Mo<sup>6+</sup> was observed [10] earlier.



**Fig.1** The SEM photographs of [Li<sub>0.5+x</sub>Sb<sub>x</sub>Fe<sub>2.5-2x</sub>]O<sub>4</sub> ferrites, where 'x' corresponds to antimony concentration.



**Fig.2** The SEM Photographs of  $(Li_{(1+3y)/2}Mo_yFe_{2.5-5y/2})O_4$  ferrites, where ‘y’ corresponds to molybdenum concentration can shown in figure.

The average grain size ( $d_m$ ) is initially decreased at  $x=0.1$  then increases to maximum at  $x=0.3$  then decreases again for antimony substitution. Similarly, it is initially decreasing and again increases to maximum at  $y=0.15$  and then decreases and again increases and finally decreases for molybdenum substitution series. For antimony substituted lithium ferrites, the mean grain diameter ( $d_m$ ) is found to decrease gradually except  $x=0.3$  where it shows high grain diameter in the Table 1, it shows well grown grains (completed grains) hence the average grain diameter is of this composition is greater than the diameter for other composition. The increase in the sintering temperature also decreases the crystal anisotropy. This reduces the hindrance to movement of the domain wall resulting in the increase value of grain diameter. The increased diameter also depends on the driving force for the movement of grain boundary and the homogeneity of the material [11]. Molybdenum substitution also influences the formation of relatively larger grains (except  $y=0.05$ ) than antimony substitution. This is attributed that the idea that substitution induces the driving force for the movement of grain boundary thereby increasing higher diffusion. The average grain sizes of molybdenum substituted compositions are higher than those in Sb substituted series except  $y=0.05$ .

**Table 1** The mean grain diameter of antimony (x) and molybdenum (y) substituted ferrites

S.No	Composition (x)	Mean grain Diameter (dm) $\mu m$	Composition (y)	Mean grain Diameter (dm) $\mu m$
1	0.0	2.8350	0.00	2.835
2	0.1	2.7762	0.05	1.997
3	0.3	3.0180	0.15	5.095
4	0.6	2.3993	0.25	3.096
5	0.8	2.3459	0.35	3.247
6	1.0	1.5705	0.50	3.180

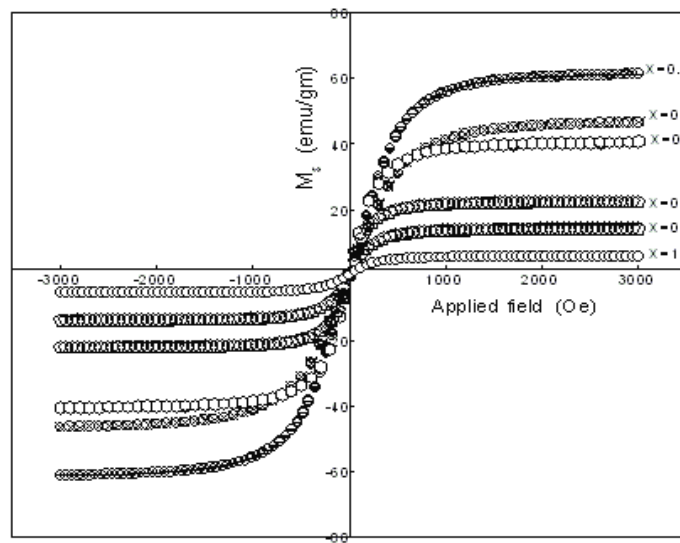
**Table 2** Magnetic measurements of  $[Li_{0.5}Sb_xFe_{2.5}]O_4$  ferrites.

S.No	Composition (x)	Saturation Magnetisation ( $M_s$ ) emu/gm	Coercive Force( $H_C$ ) Oe	Remanen Magnetisation emu/gm
1	0.0	61.70	2.62	0.282
2	0.1	46.83	2.92	0.180
3	0.3	40.40	0.84	0.138

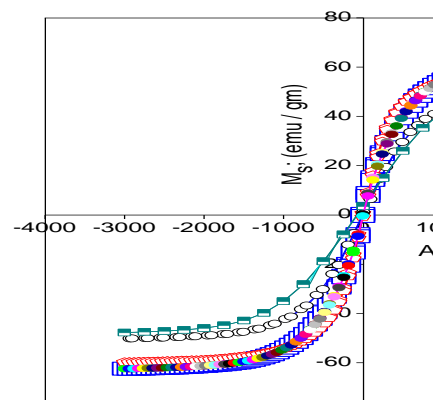
4	0.6	22.33	2.60	0.376
5	0.8	14.05	4.025	0.340
6	1.0	6.321	6.321	0.200

**Table 3** Magnetic measurements of  $[Li_{(1+3y)/2}Mo_yFe_{2.5-5y/2}]O_4$ .

S.No	Composition (x)	Saturation Magnetisation ( $M_s$ ) emu/gm	Coercive Force( $H_C$ ) Oe	Remanen Magnetisation emu/gm
1	0.05	67.40	1.527	1.70
2	0.15	59.80	2.648	0.80
3	0.25	50.42	4.929	1.77
4	0.35	55.01	7.540	3.46
5	0.40	57.35	5.353	0.31
6	0.50	62.50	7.968	0.40



**Fig.3** The Hysteresis loops of  $[Li_{0.5+x}Sb_xFe_{2.5+x}]O_4$  with 'x' varies different substitution compositions separately are shown below.



**Fig.4** The Hysteresis loops of  $(Li_{(1+3y)/2}Mo_yFe_{2.5-5y/2})O_4$  with 'y' varies different substitution compositions separately are shown below

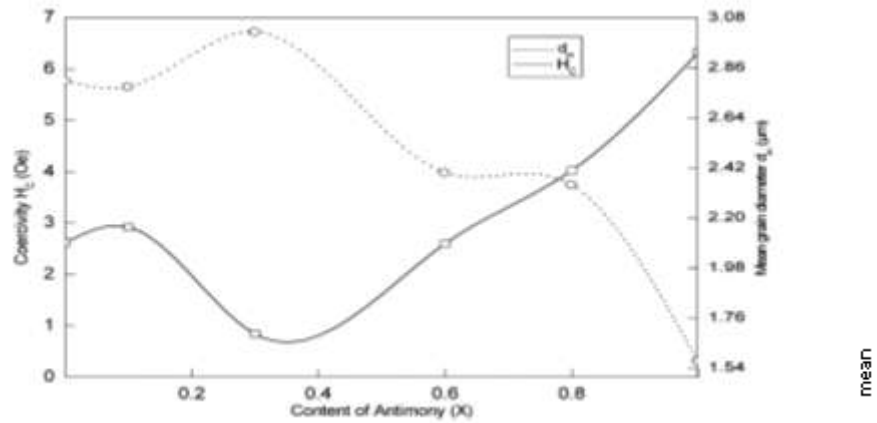
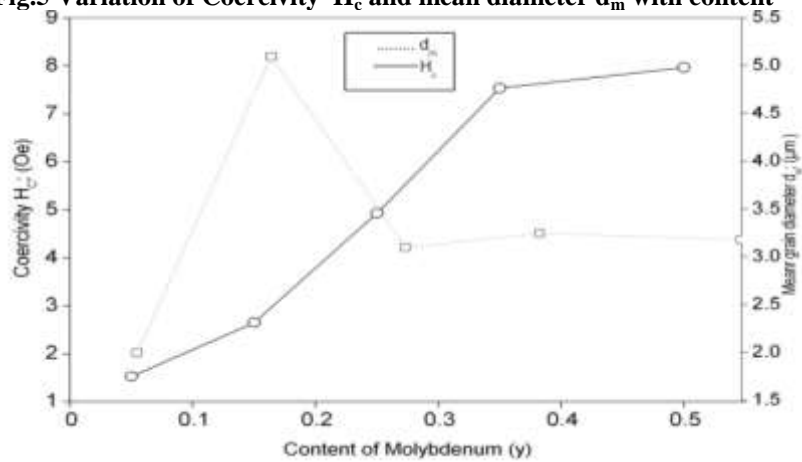


Fig.5 Variation of Coercivity  $H_c$  and mean diameter  $d_m$  with content



Sb.

Fig. 6. Variation of Coercivity  $H_c$  and mean diameter  $d_m$  with content Mo

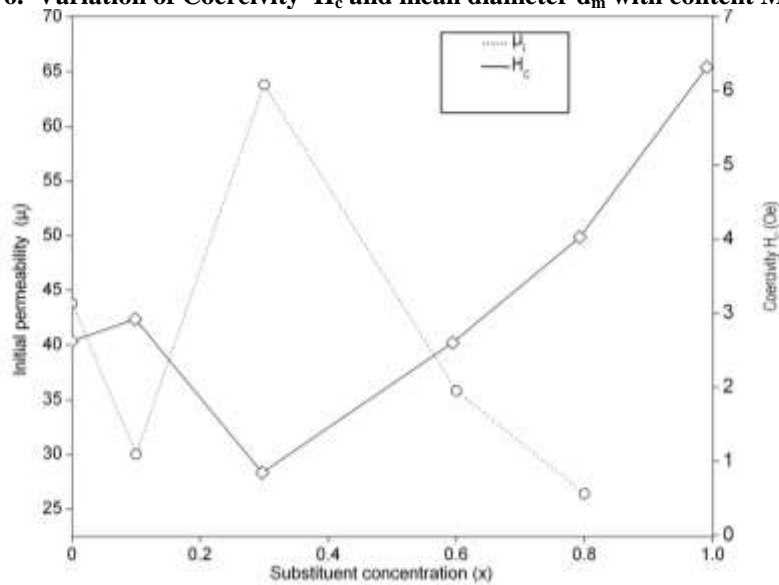
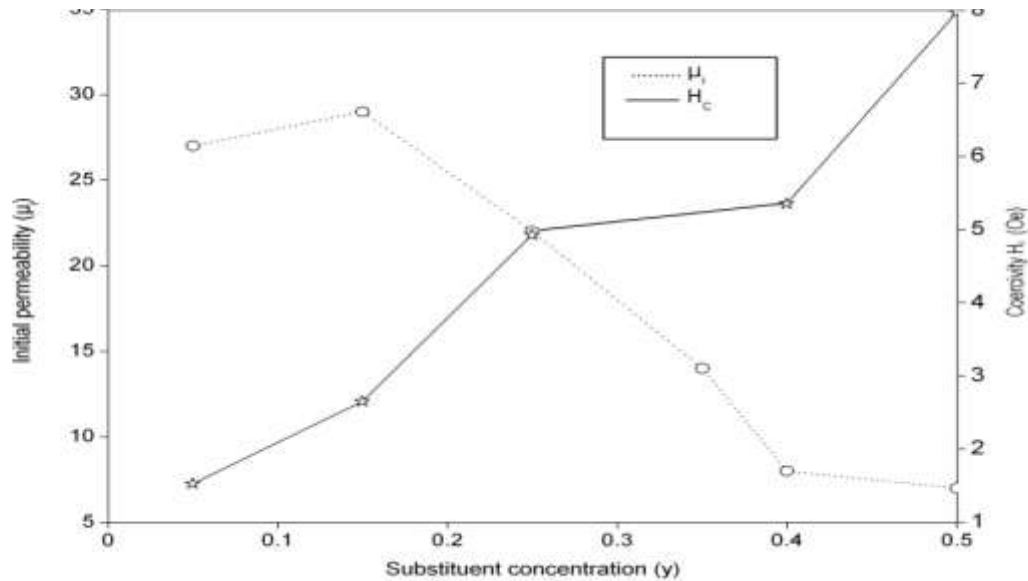


Fig. 7 The inverse relation between Coercivity ( $H_c$ ) and initial Permeability ( $\mu_i$ ) as a function of antimony substitution (x).





**Fig.8 The inverse relation between Coercivity (Oe) and initial Permeability ( $\mu_i$ ) as a function of molybdenum substitution (y).**

Saturation magnetization gradually decreases with increasing of Sb substitution in Li-Sb Ferrites can be seen in Table 2. This can be explained on the basis of exchange interactions between the sites. From the Table 3 the Saturation magnetization for molybdenum substitution decreases up to  $y = 0.25$  from where it increases to maximum, it is explained on the basis of exchange interactions and migration of ions.

The coercivity ( $H_c$ ) initially increases again at  $x = 0.1$  then decreases to lowest at  $x = 0.3$  then increases for Sb substitution series shows in Table 2. For molybdenum substitution series, it increases up to  $y = 0.35$  then decreases and again increases. It can be shown Table 3.

In two series (from Fig.7 & Fig.8), it shows Coercivity is inversely proportional to initial permeability ( $\mu_i$ ) and average grain diameter. Saturation magnetization and Curie temperature follow the same trend in both series. The initial permeability increases to maximum at  $x = 0.3$  then gradually decreases. Similarly it is initially increases to maximum at  $y = 0.10$  then gradually decreases. This can be explained based on grain size variation.

#### IV. Conclusions

A systematic and careful study of the influence of morphology of pentavalent antimony and hexavalent molybdenum substituents on magnetic properties of lithium ferrites has been carried out. Both  $\text{Sb}^{5+}$  and  $\text{Mo}^{6+}$  substituted lithium confirmed the  $\beta$ - phase with space group  $\text{Fd}\bar{3}m$ . The lattice constant is found to increase both in Sb substituted and Mo substituted series with increasing concentrations of the substitutions. Saturation magnetization gradually decreases with increasing of Sb and saturation magnetization for molybdenum substitution decreases up to  $y = 0.25$  from where it increases to maximum. The coercivity ( $H_c$ ) initially increases at  $x = 0.1$  then decreases to lowest at  $x = 0.3$  then increases for Sb substituted lithium ferrites. For molybdenum substitution series, it increases up to  $y = 0.35$  then decreases and again increases. Coercivity is inversely proportional to initial permeability ( $\mu_i$ ) and average grain diameter ( $d_m$ ). Saturation magnetization and Curie temperature follow the same trend in both series

#### References

- [1] Ernst Scholoman, Advances in ferrite microwave materials and devices, *J. Magn. Magn., Mater.* 209(1), 2000, 15-20.
- [2] Sun-Ho Kang, Han-Il Yoo, Nonstoichiometry ( $\delta$ ) and High-Temperature Thermodynamic Properties of
- [3]  $(\text{Mg}_{0.22}\text{Mn}_{0.07}\text{Fe}_{0.71})_{3-\delta}\text{O}_4$ , *J. Solid State Chem.*, 1459(2), 1999, 276-282.
- [4] M. Abe, J. Kuroda, M. Matsumoto, Granular composites containing micro-ions, permeability, and permittivity
- [5] calculated for application to microwave absorbers, *J. Appl. Phys.* 91(10), 2002, 7373-7375.
- [6] S. Verma, P.A. Joy, —Magnetic properties of superparamagnetic lithium ferrite nanoparticles, *J. Appl. Phys.* 98(12), 2005, 124312-9.
- [7] Yen-PeiFu, —Microwave induced combustion synthesis of  $\text{Li}_{0.5}\text{Fe}_{2.5}\text{xCr}_x\text{O}_4$  powder and their characterization *Mater. Res. Bull.*, 41(10), 2005, 809-816.
- [8] Yen-PeiFu, Shao-Hua Hu, —Electrical and magnetic properties of magnesium-substituted lithium ferrite, *Ceram. Int.*, 36(1), 2010, 1311-1317.
- [10] 1311-1317.

- [11] D. Ravinder, Elastic behaviour of lithium ferrites, *Mater. Lett.*, 45(2), 2000,125-127.
- [12] S.Manjura Hoque, M. Samir Ullah, F.A. Khan, M.A. Hakim, D.K. Ssha, Structural and Magnetic properties of Li-Cu mixed spinel ferrites, *Physica B*, 9 (2)2011, 1799-1804.
- [14] Nutan Gupta, Mukesh C. Dimri, Subhas C. Kashyap, D.C. Dube, Processing and properties of cobalt-substituted lithium ferrite in GHz frequency rang, *Ceram. Int.*, 30(4), 2004,1623-1628.
- [15] L ithium ferrite in GHz frequency rang, *Ceram. Int.*, 30(4), 2004,1623-1628.
- [16] K. S. Laksmi, B. Ramesh, A. D. P. Rao, P. M. RAO and S. B. Raju, *J. Solid State Che.*, 11 (1974), 239.
- [17] A. D. P. Rao, structural, magnetic and electrical studies on Sn/Nb substituted Mn-Zn ferrites, Ph. D thesis Submitted to Andhra University, Visakhapatnam, 1995.