Elastic behavior of Mo^{6+} substituted lithium ferrites

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Abstract- The elastic properties of Molybdenum - lithium ferrites [Li(1+3y)/2MoYFe2.5-5y/2]O4 of various compositions sintered at 1200°C were measured at room temperature using the ultrasonic pulse transmission technique. Elastic properties of the specimens were investigated as a function of composition. From the experimentally observed values of longitudinal (Vℓ) and shear (Vs) wave velocities, Young's (E), Rigidity (n) and Bulk (k) moduli are calculated and found to decrease with increase of Molybdinum content. As the ferrites under investigation are porous, the elastic moduli have been corrected to zero porosity using Hassel man and Fulrath's formulae. The Poisson's ratio is maximum at y=0.1 then gradually decreasing with increasing Molybdenum. Debye temperatures (θD) of these specimens are calculated using Anderson's formula and it is found that decrease with increase Molybdenum. The elastic moduli with compositions were interpreted in terms of the binding force between the atoms. The average sound velocity (Vm) is found to decreases linearly with Debye temperature (θD).

Index Terms- Elastic behavior, Li – Mo ferrites, sound velocity, Debye temperature

I. INTRODUCTION

Lithium ferrites are important components of microwave devices such as isolators, circulars, gyrators, and phase shifters and memory cores owing to their high Curie temperature, high saturation magnetization, and hysteresis loop properties, which offer performance advantage over other spinel structures. The lithium ferrite which is an inverse spinel has excellent rectangular hysteresis loop properties which can be suitably tailored by appropriate substitutions of cations to use the material for some specific application. In view of the wide ranging applications lithium ferrites has been chosen for the present study with special reference to the dependence of its elastic behavior on sintered at high temperature. The elastic properties of ferrites are important in industry because of their elastic data are very much useful to determine the strength of the materials under various strained conditions while in basic research, the data are useful obtaining an insight into the structure of the inter-atomic and inter-ionic forces in solids especially of the long-range type forces. A systematic study of the elastic properties of Molybdenum substituted lithium ferrite as a function of composition has been undertaken at rom temperature and the results are presented in this paper.

II. EXPERIMENTAL METHOD

The ferrite samples with compositional formula $[Li_{(1+3y)/2}Mo_YFe_{2.5-5y/2}]O4$, (where y = 0.00,0.10,0.20,0.30,0.40 and 0.50), were prepared by double sintering technique. Appropriate proportion of AR grade Li_2CO_3 , MOO_3, Fe_2O_3 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 grained again and granulated using a small amount of PVA binder. Finally samples were pressed at 5 tones / cm^2 and sintered at 1200°C for 4hrs. The samples were cooled in the furnace in air atmosphere at the rate of 3^0C/min. The ultrasonic longitudinal (V_ℓ) and shear (V_s) wave velocities of all the ferrite samples were determined by the ultrasonic pulse transmission technique. In this method 1MHz PZT crystals and calibrated range of oscilloscope (Tektronix Model No 2221) were used with an accuracy of error +1% in velocity measurements.

III. RESULTS AND DISCUSSION

The values of longitudinal (V_ℓ) and shear (V_s) wave velocities of all the samples were determined by using Ultrasonic pulse transmission technique method [1] at room temperature and these values are given in Table 1. The Young's modulus (E), Rigidity modulus (n), Bulk modulus (K),Longitudinal modulus (L) and Poission's ratio have been calculated using the experimental values V_ℓ and Vs with the help of the formulae;

$$\sigma = (V_\ell^2 - 2V_s^2) / 2(V_\ell^2 - V_s^2) \qquad (1)$$

$$L = \rho V_\ell^2 \qquad (2)$$

$$K = L - (4/3)n \qquad (3)$$

$$n = \rho V_s^2 \qquad (4)$$

and

$$E = 2n(1+\sigma) \qquad (5)$$

The calculated values of E, n, σ are given in table (1). It can be observed from the table that the values of E, n, K are decreasing continuously with increasing Molybdenum content. These values are slightly higher than the reported values [2] for concentration Y = 0 because of samples are sintered at high temperature (1200°C). It is observed that the Poission's ratio (σ) for y=0.10 is maximum then it is decreasing gradually with increasing Molybdenum .The elastic moduli of samples depend on density of the material, after confirmed the spinel formation and calculated X-ray density, the porosity to be known with density of the sample. The X-ray density and bulk density of the samples are given in Table 1.

In this approach combine all your researched information in form of a journal or research paper. In this researcher can take the reference of already accomplished work as a starting building block of its paper.

Table 1: Elastic data (uncorrected) of $[Li_{(1+3y)/2}Mo_YFe_{2.5-5y/2}]O_4$ ferrites

Sl.no	*y*	*Bulk density* $(10^3\ Kg/m^3)$	*Porosity* *(%)*	V_ℓ	V_s (m/s)	V_m	E	n	K $(10^{10} N/m^2)$	σ
1	0.00	4.6924	1.3	5983	3323	3701	13.233	5.181	9.888	0.28
2	0.10	4.3087	7.4	6000	3157	3527	11.238	4.294	9.785	0.30
3	0.20	3.9702	12.9	5200	2810	3134	8.111	3.134	6.555	0.29
4	0.30	3.7116	18.3	4500	2542	2825	6.071	2.398	4.318	0.26
5	0.40	3.5151	19.5	4240	2436	2703	5.229	2.085	3.538	0.25
6	0.50	3.0067	29.5	3903	2297	2544	3.918	1.586	2.465	0.23

The percentage of porosity is varying from 1.3% to 29.5 %, so that the elastic moduli of the measured samples will be less than non – porous samples. Hence, the observed elastic moduli of the samples have been corrected to zero porosity using Hasselman and Fulrath's formulae [3] given by ;

$$n / n_0 = 1 - 15p(1-\sigma) / (7-5\sigma) \qquad (6)$$

and

$$E / E_0 = 1 - 3P(1-\sigma)(9+5\sigma) / 2(7-5\sigma) \qquad (7)$$

Where n_0 = corrected value of rigidity modulus, E_0 = corrected values of Young's modulus and P = volume fraction of the pores.

From the values of E_0 and n_0, the corrected values of Bulk modulus (K_0) and Poisson's ratio (σ_0) have also been obtained using the following relation;

$$K_0 = E_0 n_0 / 3(3n_o - E_0) \qquad (8)$$

and

$$\sigma_o = (E_0 / 2n_o) - 1 \qquad (9)$$

The corrected values of E_0, n_o, K_0 and σ_o are given in Table (2) . It can be seen from the table that the values of E_0, and n_o, are decreasing up to y=0.40 then increased at y=0.50 with gradual increasing of Molybdinum content. Similarly K_0 is increased at y=0.10 then gradually decreasing , increased at y=0.50.

Table 2: Elastic data of $[Li_{(1+3y)/2}Mo_YFe_{2.5-5y/2}]O_4$ corrected to Zero porosity

Sl.no	y	E_o	n_0 (10^{10} N/m^2)	K_o	σ_o
1	0.00	13.597	5.320	10.022	0.28
2	0.10	13.226	5.008	12..276	0.32
3	0.20	10.940	4.164	9.795	0.31
4	0.30	9.592	3.721	7.568	0.28
5	0.40	8.617	3.380	6.371	0.27
6	0.50	9.588	3.787	6.822	0.26

Following Woostr's work [4], the variation of elastic moduli with composition may be interpreted in terms of binding forces between the atoms. Debye temperatures (θ_D) for Li – Mo ferrites have been calculated using the simple method given by Anderson formula [5,6];

$$\text{Debye Temperatures } (\theta_D) = \left(\frac{h}{k}\right)\left(\frac{3qN\rho}{4\pi m}\right)^{1/3} V_m \qquad (10)$$

Where h =Planck's constant, k = Boltzman's constant, N = Avagadro's Number, m = Molecular weight of the specimen, q = Number of atoms in molecule, ρ = Density of the Specimen and V_m = Average sound velocity which is given by:

$$V_m = \left[\frac{1}{3}\left(\frac{1}{V_\ell^{\,3}} + \frac{2}{V_s^{\,3}}\right)\right]^{-1/3} \qquad (11)$$

The values of V_ℓ / ρ, V_s / ρ are calculated and shown in Table 3. The calculated values of θ_D, using Eq. (10) are given in Table 3. It is evident from the table that, like the elastic moduli, the Debye temperature is also decreasing with increasing Molybdenum content. This variation also can be interpreted in terms of the binding forces between atoms. The average sound velocity (V_m) for all the samples have been calculated using Eq. (11) and are also given in Table 3.

Table 3: Relationship between atomic weights and velocities of $[Li_{(1+3y)/2}Mo_YFe_{2.5-5y/2}]O_4$ ferrites

Sl. no	X	V_ℓ / ρ	V_s / ρ	V_m (m/s)	θ_D (K)
1	0.0	1.28	0.71	3701	504
2	0.10	1.39	0.73	3527	469
3	0.20	1.31	0.71	3134	408
4	0.30	1.21	0.68	2825	361
5	0.40	1.21	0.69	2703	342
6	0.50	1.30	0.76	2544	307

A plot of average sound velocity (V_m) against Debye temperature is shown in Fig. 1. It is interesting to note from the figure that the average sound velocity decreases linearly with the Debye temperature. This behaviour clearly indicates the direct relationship between the acoustic parameter (average sound velocity) and the important thermodynamic parameter (Debye temperature).

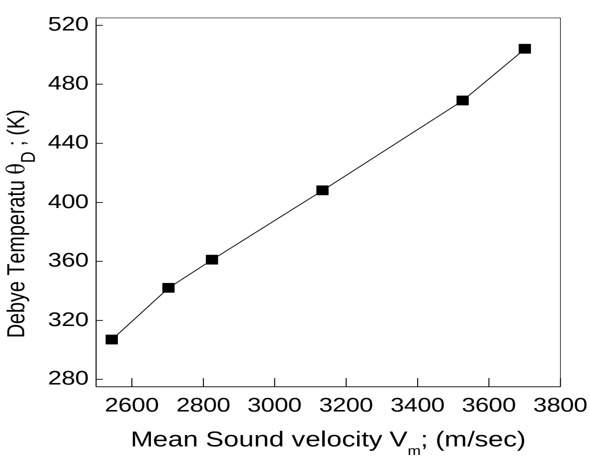

Fig 1: Variation of average sound velocity (V_m) with Debye temperature (θ_D) for Molyddenum substituted lithium ferrites.

IV. CONCLUSION

In conclusion,Mo^{6+} substitute lithium ferrites were synthesized by double standard ceramic method. The elastic properties were studied through ultrasonic pulse technique method.Experimentally the elastic moduli and Debye Temperature are found to decreasing with increasing Molybdenum.The specimen are porous hence corrected to zero porosity ,corrected elastic moduli i.e Young's modulus, Rigidity moduus are gradually decresing with increasing Molybdenum but Bulk modulus Increased at Y=0.10 then gradually decreasing and finally increased.The varation in Debye Temperature can be interpreted interms of binding forces between atoms.

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REFERENCES

[1] Y.V.Ramana, "Elastic behavior of some indian rocks under confined pressure" Int. J. Roc. Mech. Min. Sci. 6 (1969) 191. URL; http://www.sciencedirect.com/science/article/pii/0148906269900345

[2] Y. C. Venudhar, K. Satya Mohan, "Elastic behaviour of lithium–cobalt mixed ferrites" Mater. Lett. 55 (2001) 196. URL; http://www.sciencedirect.com/science/article/pii/S0167577X01006450

[3] D.P.H. Hasselman. R .M. Fulrath, "Effect of Small Fraction of Spherical Porosity on Elastic Moduli of Glass" J. Am. Ceram. Soc. 47 (1964) 52. URL; http://onlinelibrary.wiley.com/doi/10.1111/j.1151-2916.1964.tb14644.x/abstract

[4] W. A.Wooster, " Physical properties and atomic arrangements in crystals" Rep. Prog. Phys. 16 (1953) 62. URL; http://iopscience.iop.org/0034-4885/16/1/302

[5] O.L.anderson, in: W.P. Mason (Ed.), "Physical Acousics,vol. 3B, Academic Press, New York, 1965, p. 43.

[6] O.L.anderson, "A simplified method for calculating the debye temperature from elastic constants" J.Phy. Chem.solid. ,24 (1963) 909 URL; http://www.sciencedirect.com/science/article/pii/0022369763900672.

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