Table3 Relationship between atomic weights and velocities of $[Li_{0.5+x}\ Sb_{x}Fe_{2.5-2x}]\ O_4$ 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	0.1	1.34	0.74	3614	479
3	0.2	1.31	0.70	3423	453
4	0.3	1.27	0.67	3290	433
5	0.4	1.11	0.59	2986	397
6	0.5	1.09	0.59	3006	400

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 finally slightly/slight increased at x=0.5. This behavior clearly indicates direct relationship between the acoustic parameter (average sound velocity) and the important thermodynamic parameter (Debye temperature).

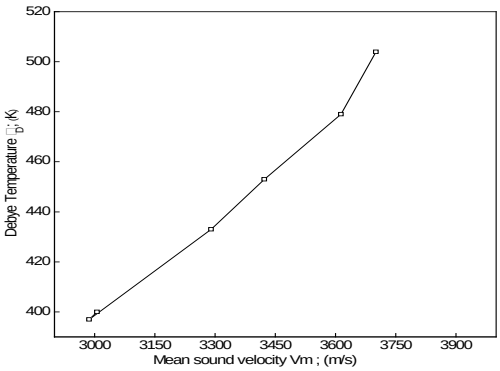

Fig 1. Variation of average sound velocity (V_m) with Debye temperature (θ_D) for antimony substituted lithium ferrites.

The elasic moduli can also be evaluated from IR study has been developed by Modi et al [7-9]. In the present study the elastic maduli were calculated only for x=0.0 and other samples are not performed due to lack of cation distribution from Mössbauer spectrometer for calculating force constants.The force constant is a second derivative of potential energy with respect to the site radius (R_A and R_B), the other independent parameter being kept constant, for tetrahedral site (K_t) and octahedral site (K_o), were calculated employing the method substituted by Waldron [10]. According to Waldron the force constants, K_t and K_o for respective sites are given by:

$K_t = 7.62 \times M_A \times \upsilon_1^2 \times 10^{-7}$ N/m (12)

$K_t = 10.62 \times M_{B/2} \times \upsilon_2^2 \times 10^{-7}$ N/m (13)

Where M_A and M_B are the molecular weights of cation on A-site and B-site calculated cation distribution $(Fe^{3+})[Li_{0.5}Fe_{2.5}]$ [11] for pure lithium ferrite (x=0). From the Fig.2 the primary absorption band ($\nu_{1)}$ is 582 cm^{-1} and the secondary absorption band ($\nu_{2)}$ is 476 cm-1.the average force constant is listed in Table 4. The elastic moduli can be evaluated using the following relation [12,13].

Bulk modulus (K) = $\frac{1}{3}(C_{11}+C_{12})$ = L — $\frac{4}{3}G$ (14)

Where C_{11} and C_{12} are the stiffness constant. But according to Waldron [10] for isotropic materials with cubic symmetry like spinel ferrites and garnets $C_{11} \approx C_{12}$. Therefore, K =C_{11}. Also, the force constant(K) is a product of lattice (a) and stiffness constant (C_{11}) i.e. K= aC_{11} [14]. And K is also average force constant (K= (K_t+K_o)/2).The value of lattice constant obtained from X-ray diffraction analysis is 8.333Å. The other elastic moduli of the ferrite specimens are calculated using following formulae [15,16] for a cubic lattice:

Stiff constant (C_{12}) = $\frac{\sigma C11}{(1-\sigma)}$ (15)

Rigidity modulus (G) = $\frac{E}{2(1+\sigma)}$ (16)

Young's modulus (E) = $2(1+\sigma)\ \rho(V_s)^2$ or

(E) = $\frac{(C11-C12)(C11+2C12)}{C11+C12}$ (17)

Poission's ratio (σ) = $\frac{3K-2G}{6K+2G}$ (18)

We have determined the value of longitudinal elastic wave velocity (V_ℓ) using the formula suggested by Waldron [10], $V\ell = \left(\frac{C_{11}}{\rho}\right)^{1/2}$ and the transverse elastic wave velocity (V_s) by general approximation [16,17] $V_l = 3^{1/2}\ V_s$. The values of $V\ell$ and V_s are further used to calculate the mean velocity and Debye temperature of the ferrite specimen using the following formula [18]:

Mean elastic Wave velocity (V_m) = $\left[\frac{v_l^3+v_s^3}{2v_l^3+v_s^3}\right]^{\frac{1}{3}}$ (19)

Debye temperature(θ_D) = $\frac{h}{k}\left[\frac{3N_A}{4\pi V_A}\right]^{\frac{1}{3}}$ (20)

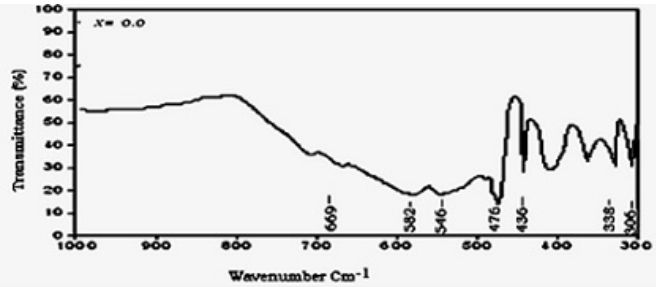

Fig.2 The IR absorption bands of $[Li_{0.5+x}\ Sb_xFe_{2.5-2x}]O_4$, where 'x' =0.0 concentration of antimony substitution

Table 4: Force constant (K), Elastic wave velocities (V_ℓ & Vs), stiffness constant (C_{ij}), Young's modulus (E), rigidity modulus (η), Bulk modulus (K), mean velocity (Vm), Poisson's ratio (σ) and Debye temperature (θ_D) of $Li_{0.5}\ Fe_{2.5}\ O_4$ ferrite.

Content x	V_ℓ (m/s)	Vs (m/s)	K (N/m^2)	η (N/m^2)	E (N/m^2)	σ	Vm (m/s)	θ_D (K)
0.0	5638.77	3255.64	8.28×10^{10}	4.97×10^{10}	12.433×10^{10}	0.25	3615.27	492

From Table 4 the calculated value of elastic moduli and Debey temperature from IR spectrum for x=0.0 are in good agreement with which are obtained from UPT technique (Table1).

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