

Effect of Temperature on Non-Destructive Wave Propagation in Uranium Monopnictides

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Acoustic attenuation due to phonon–phonon interaction, thermoelastic mechanism and dislocation damping were evaluated in uranium monopnictides (viz. UN, UAs and USb) in the temperature range 50–500 K, along the three crystallographic directions of propagation, viz. [100], [110] and [111] for longitudinal and shear modes of propagation. Due to antiferromagnetic property of these compounds ultrasonic attenuation due to magnon–phonon interaction was also obtained. The second- and third-order elastic moduli of *B1*-type uranium monopnictides were obtained using electrostatic and the Born repulsive potentials. Grüneisen numbers and acoustic coupling constants were evaluated for longitudinal and shear waves along different directions of propagation and polarization. Results were discussed and compared with available data. It was found that the temperature dependence of attenuation due to phonon–phonon interaction and thermoelastic loss mechanisms follow the third and fourth order polynomial fit laws, respectively, and acoustic attenuation is mainly governed by phonon–phonon interaction in this temperature range.

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1. Introduction

The NaCl-type uranium monopnictides (UX, X = ⁷N, ³³As, ⁵¹Sb) exhibit a great variety of anomalous behavior as far as their elastic, electronic, lattice dynamical and magnetic properties [1–11] are concerned. Uranium monopnictides show antiferromagnetic ordering at T_N or T_C (53, 124, and 213 K for UN, UAs, and USb, respectively), which increases with increasing anion atomic number. The electronic structure of uranium monopnictides is characterized by *5f* and *6d* electrons in addition to conduction electrons close to the Fermi energy. These groups of electrons give the compounds, their metallic character and high electronic specific heat [12, 13]. The lattice dynamical properties for these compounds have been studied using rigid ion and shell models [7], three-body force rigid ion model [8] and three-body force shell model [9]. But results on acoustical studies are not available for these compounds.

Different causes can be attributed to the attenuation of acoustic wave propagating through solids. Some important causes of acoustical dissipation are: electron–phonon interaction, phonon–phonon interaction, thermoelastic loss, losses due to lattice imperfections (viz. dislocation damping due to screw and edge dislocations), and in ferromagnetic and antiferromagnetic materials,

magnon–phonon interaction also produces acoustical dissipation in lower temperature range ($T < 50$ K). In dielectric crystals, interaction of acoustic phonons and thermal phonons is the dominant cause of acoustical dissipation at higher temperatures [14], while in ferromagnetic and antiferromagnetic compounds, in presence of external magnetic field, magnon–phonon interaction is the principal cause in the lower temperature range [15]. Such types of studies are essential for assessing the suitability of materials for several practical problems, such as the design of optimum sound transmission systems for ultrasonic delay lines [16]. From microstructure characterization point of view, it is well known that acoustic properties of materials are very important. Therefore, in the present paper we have studied the acoustic attenuation due to different causes. Second and third order elastic moduli, the Grüneisen parameters, acoustic coupling constants, and viscous drag coefficients due to screw and edge dislocations have also been evaluated for uranium monopnictides.

2. Theoretical approach

2.1. Elastic moduli

Elastic moduli of *n*-th order is defined as [17]:

$$C_{ijklmn\dots} = (\partial^n u / \partial \varepsilon_{ij} \partial \varepsilon_{kl} \partial \varepsilon_{mn} \dots), \quad (1)$$

where *u* is the crystal free-energy density and ε_{ij} is the strain tensor.

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Second- and third-order elastic moduli (SOEM and TOEM) at absolute zero temperature viz. C_{ij}^0 and C_{ijk}^0 are given as [18]:

$$\begin{aligned}
 C_{11}^0 &= 1.56933 \frac{z^2 e^2}{r_0^4} + \frac{1}{qr_0} \left(\frac{1}{r_0} + \frac{1}{q} \right) Q(r_1) \\
 &\quad + \frac{2}{qr_0} \left(\frac{1}{\sqrt{2}r_0} + \frac{1}{q} \right) Q(r_2), \\
 C_{12}^0 &= C_{44}^0 = 0.344778 \frac{z^2 e^2}{r_0^4} + \frac{1}{qr_0} \left(\frac{1}{\sqrt{2}r_0} + \frac{1}{q} \right) Q(r_2), \\
 C_{111}^0 &= 10.26390 \frac{z^2 e^2}{r_0^4} - \left(\frac{3}{qr_0^2} + \frac{3}{q^2 r_0} + \frac{1}{q^3} \right) Q(r_1) \\
 &\quad - \left(\frac{3}{\sqrt{2}r_0^2 q} + \frac{3}{q^2 r_0} + \frac{\sqrt{2}}{q^3} \right) Q(r_2), \\
 C_{112}^0 &= C_{166}^0 = -1.209625 \frac{z^2 e^2}{r_0^4} \\
 &\quad - \left(\frac{3}{2\sqrt{2}r_0^2 q} + \frac{3}{q^2 r_0} + \frac{\sqrt{2}}{q^3} \right) Q(r_2), \\
 C_{123}^0 &= C_{144}^0 = C_{456}^0 = 0.678375 \frac{z^2 e^2}{r_0^4},
 \end{aligned}$$

where Z is atomic number, r is nearest neighbor distance, q is hardness parameter

$$Q(r_1) = A \exp\left(-\frac{r_0}{q}\right)$$

and

$$Q(r_2) = A \exp\left(-\frac{r_0 \sqrt{2}}{q}\right).$$

Second- and third-order elastic moduli at temperature, T are the sum of elastic moduli at absolute zero temperature and vibrational contribution to second- and third-order elastic moduli at corresponding temperature [19–22] viz. C_{ij}^0 and C_{ijk}^0 , i.e.

$$C_{ij}(T) = C_{ij}^0 + C_{ij}^{\text{vib.}}, \quad (2)$$

$$C_{ijk}(T) = C_{ijk}^0 + C_{ijk}^{\text{vib.}}, \quad (3)$$

where $C_{ij}^{\text{vib.}}$ and $C_{ijk}^{\text{vib.}}$ are vibrational contribution to elastic moduli given by

$$\begin{aligned}
 C_{11}^{\text{vib.}} &= f^{1,1} G_1^2 + f^2 G_2 : C_{12}^{\text{vib.}} \\
 &= f^{1,1} G_1^2 + f^2 G_{1,1} : C_{44}^{\text{vib.}} = f^2 G_{1,1},
 \end{aligned}$$

$$C_{111}^{\text{vib.}} = f^{1,1,1} G_1^3 + 3f^{2,1} G_2 G_1 + f^3 G_3,$$

$$C_{112}^{\text{vib.}} = f^{1,1,1} G_1^3 + f^{2,1} (2G_{1,1} + G_2) G_1 + f^3 G_{2,1},$$

$$C_{123}^{\text{vib.}} = f^{1,1,1} G_1^3 + 3f^{2,1} G_1 G_{1,1} + f^3 G_{1,1,1},$$

$$C_{144}^{\text{vib.}} = f^{2,1} G_1 G_{1,1} + f^3 G_{1,1,1},$$

$$C_{456}^{\text{vib.}} = f^3 G_{1,1} : C_{166}^{\text{vib.}} = f^{2,1} G_1 G_{1,1} + f^3 G_{2,1},$$

where

$$G_3 = 2Q(r_1) (30 + 30q_0 + 9q_0^2 - q_0^3 - q_0^4) H + 2G_{2,1},$$

$$G_{2,1} = Q(r_2) \left(15\sqrt{2} + 15q_0 + \frac{9}{q_0^2 \sqrt{2}} - q_0^3 - \sqrt{2}q_0^4 \right) H,$$

$$G_2 = 2Q(r_0) (-6 - 6q_0 - q_0^2 + q_0^3) H + 2G_{1,1},$$

$$G_{1,1} = Q(r_2) (-3\sqrt{2} - 6\sqrt{2}q_0 - \sqrt{2}q_0^2 + 2q_0^3) H,$$

$$\begin{aligned}
 G_1 &= 2Q(r_0) (2 + 2q_0 - q_0^2) \\
 &\quad + Q(r_2) (\sqrt{2} + 2q_0 - \sqrt{2}q_0^2) H,
 \end{aligned}$$

where

$$Q(r_1) = A \exp\left(-\frac{r_0}{q}\right)$$

and

$$Q(r_2) = A \exp\left(-\frac{r_0 \sqrt{2}}{q}\right),$$

$$f^2 = f^3 = \frac{\hbar w_0}{8r_0^3} \coth X,$$

$$f^{1,1} = f^{2,1} = -\frac{1}{2r_0^3} \frac{\hbar w_0}{48} \frac{X}{\sinh^2 X} + \coth X,$$

$$\begin{aligned}
 f^{1,1,1} &= \left(\frac{\hbar w_0}{384r_0^3} \right) \left[\left(\frac{\hbar w_0}{kT} \right)^2 \frac{\coth X}{6 \sinh^2 X} \right. \\
 &\quad \left. + \frac{X}{\sinh^2 X} + \coth X \right],
 \end{aligned}$$

$$X = \frac{\hbar w_0}{2kT}, \quad \hbar = \frac{h}{2\pi}, \quad k \text{ is Boltzmann constant,}$$

$$H = \left[\left(\frac{r_0}{q-2} \right) Q(r_1) + 2 \left(\frac{r_0}{q} - \sqrt{2} \right) Q(r_2) \right]^{-1}.$$

2.2. Acoustic attenuation

Acoustic attenuation due to interaction of acoustical phonons and lattice phonons (i.e. phonon–phonon interaction) for longitudinal and shear wave are given by [23–26]:

$$[(\alpha)_{\text{p-p}}]_l = \frac{E_0 \omega^2 (\Gamma_l/3) \tau_l}{2\rho V_l^3}, \quad (4)$$

$$[(\alpha)_{\text{p-p}}]_s = \frac{E_0 \omega^2 (\Gamma_s/3) \tau_s}{2\rho V_s^3}, \quad (5)$$

where ω is angular frequency, E_0 is energy density, Γ is acoustic coupling constant, τ is thermal relaxation time, ρ is density and V_l and V_s are the velocities for longitudinal and shear wave, respectively.

Attenuation due to thermoelastic loss is given by [23–26]:

$$[(\alpha)_{\text{th}}]_l = \frac{\omega^2 \langle \gamma_i^j \rangle^2 KT}{2\rho V_l^5}. \quad (6)$$

This type of attenuation occurs due to longitudinal wave only, because, due to shear wave propagation, the volume remains unaltered and there is no heating effect.

Acoustic coupling constant is given by [23–26]:

$$\Gamma = 9 \left\langle \left(\gamma_i^j \right)^2 \right\rangle - \frac{3 \left\langle \gamma_i^j \right\rangle^2 C_v T}{E_0}. \quad (7)$$

$\left\langle \left(\gamma_i^j \right)^2 \right\rangle$ and $\left\langle \gamma_i^j \right\rangle^2$ are square average and average square Grüneisen parameters corresponding to a particular direction of propagation and polarization.

Thermal relaxation time is given by [23–26]:

$$\tau = \tau_s = \frac{\eta}{2} = \frac{3K}{C_v \langle V \rangle^2}, \quad (8)$$

where K is thermal conductivity, C_v is specific heat per unit volume and $\langle V \rangle$ is the Debye average velocity.

The Debye average velocity is given by

$$\frac{3}{\langle V \rangle^3} = \frac{1}{V_l^3} + \frac{2}{V_s^3}. \quad (9)$$

Viscous drag coefficients due to screw and edge dislocations are given by [23–26]:

$$\delta_{\text{screw}} = 0.071\chi, \quad (10)$$

$$\delta_{\text{edge}} = 0.053\chi(1 - \sigma^2) + 0.0079/(1 - \sigma^2)(\zeta/\lambda)\eta \quad (11)$$

where $\eta = \chi_l - (4/3)\chi_s$, $\chi_l = E_0\Gamma_l\tau/3$, $\chi_s = E_0\Gamma_s\tau/3$, $\lambda = (C_{11} + 2C_{12})/3$, $\zeta = (C_{11} - C_{12} + C_{44})/3$, and $\sigma = C_{12}/(C_{11} + C_{12})$, and where λ , ζ , η , σ and χ are the bulk modulus, shear modulus, phonon viscosity, Poisson's ratio and compressional viscosity, respectively.

In presence of external magnetic field, magnon–phonon interaction also produces the acoustical dissipation in ferromagnetic and antiferromagnetic materials. Acoustic wave attenuation due to magnon–phonon interaction for longitudinal and transverse waves are given by [15]:

$$\begin{aligned} \alpha_{(m-p)l} = & \frac{1}{2^5} \frac{\hbar\omega}{\pi\rho V_l} \frac{1}{\Theta_C^3 a^4} \left[\beta_2^2 \left(\frac{\Theta_0^2}{4\Theta_C} + \hbar\gamma H_0 \right) \right. \\ & + 2\beta_1\beta_2 \frac{\Theta_0^2}{4\Theta_C} \left(\frac{\Theta_0^2}{4\Theta_C} + \hbar\gamma H_0 \right) \\ & \left. + \beta_1^2 \frac{\Theta_0^4}{2^4 \Theta_C^2} \right] e^{-\left(\frac{\Theta_0^2}{4\Theta_C T} + \frac{\hbar\gamma H_0}{T} \right)}, \quad (12) \end{aligned}$$

$$\alpha_{(m-p)t} = \frac{1}{2^7} \frac{\beta_1^2}{\pi\rho V_t a^3} \frac{\Theta_0^3}{\Theta_C^3} \omega T e^{-\left(\frac{\Theta_0^2}{4\Theta_C T} + \frac{\hbar\gamma H_0}{T} \right)}, \quad (13)$$

where H_0 is the magnitude of applied field, $\gamma =$ gyromagnetic ratio, ρ is the density, Θ_0 and Θ_C are temperatures evaluated using expressions given in Ref. [15], β_1 and β_2 are some constants. V_l and V_t are ultrasonic velocities of longitudinal and transverse wave, a is lattice parameter, $\omega = 2\pi f =$ angular frequency of acoustical wave.

3. Results and discussions

SOEM and TOEM and bulk modulus of uranium monopnictides were evaluated using electrostatic and the Born repulsive potentials. Nearest neighbor distance and hardness parameter were used as input data. SOEM and bulk modulus and TOEM thus obtained, have been given in Tables I and II, respectively. SOEM and bulk modulus have been compared with available values in literature [7, 11, 27, 28]. Our values are in good agreement with the available values. However, TOEM could not be compared due to lack of available values in literature. TOEM have been evaluated for LiF using present approach and values so obtained have been compared with available values in literature for LiF [22]. From Table II, it can be seen that the TOEM for LiF obtained using present approach are in good agreement with available values. Therefore, present approach of calculation for SOEM and TOEM for uranium monopnictides is justified.

TABLE I

Calculated, experimental and other papers second-order elastic moduli and bulk modulus (10^{11} dyne/cm²) of uranium monopnictides.

Comp.	C_{11}	C_{12}	C_{44}	λ
UN				
present	42.00	4.90	5.23	17.3
other	42.0±0.4 ^a	9.0±0.5 ^a	7.9±0.08 ^a	20±0.3 ^a
papers	–	–	–	20 ^d , 19 ^d , 21 ^d
UAs				
present	25.04	2.39	2.64	9.94
other	25.0±1 ^a	1.0±1.5 ^a	2.6±0.5 ^a	9.0±1.3 ^a
papers	25.0±1 ^b	1.0±0.15 ^b	2.6±0.5 ^b	10 ^d , 9 ^d
	25.0±1 ^c	1.0±0.5 ^c	2.6±0.5 ^c	10.6 ^d
USb				
present	16.03	1.88	2.04	6.59
other	16.0±1 ^a	0.7±1.5 ^a	2.0±1 ^a	5.8±1.3 ^a
papers	16.0±1 ^b	2.0±1 ^b	0.7±0.15 ^b	6.2 ^d , 7.3 ^d
	16.0±1 ^c	0.7±0.15 ^c	2.0±1.0 ^a	5.5 ^d , 8.4 ^d

^aRef. [7]; ^bRef. [11]; ^cRef. [26]; ^dRef. [27]

Lattice energy density (E_0) and specific heat (C_v) were obtained as function of the Debye temperature, Θ_D [29, 30] and are given in Table III. Square average Grüneisen parameters, average square Grüneisen parameters and acoustic coupling constants along [100] and [110] directions of propagation (along [001] and $[1\bar{1}0]$ directions of polarization for shear modes) are presented in Table IV. These values are similar to other fcc crystals [31–33]. Viscous drag coefficient due to screw and edge dislocations was evaluated using Eqs. (10) and (11) and is given in Table V.

Attenuation coefficient due to magnon–phonon interaction for longitudinal and transverse waves has been evaluated by taking the value of $\gamma = 1.76 \times 10^7 \text{ Oe}^{-1} \text{ s}^{-1}$

TABLE II
Third-order elastic constants (10^{12} dyne/cm²) of the materials at 300 K.

Comp.	C_{111}	C_{112}	* $C_{123} = C_{144}$	C_{166}	C_{456}
UN	-88.61	-1.45	0.98	-1.95	0.91
UAs	-56.69	-0.56	0.50	-0.96	0.50
USb	-33.53	-0.53	0.43	-0.76	0.31
LiF	-6.75	-2.60	1.01	-2.80	0.98
Ref. [21]	-5.97	-2.61	0.91	-2.64	0.88

* $C_{123} = C_{144}$, since vibrational part is the same

TABLE III
Debye temperature Θ_D , phonon energy density E_0 (10^8 erg/(mol K)), specific heat C_v (10^7 erg/(mol K)), and Debye average velocity $\langle V \rangle$ (10^5 cm/s) for uranium monopnictides.

Comp.	Θ_D [K]	E_0	C_v	$\langle V \rangle$
UN	249	5.56	2.41	2.1742
UAs	221	5.80	2.42	1.7844
USb	168	6.02	2.45	1.6185

TABLE IV
Square average and average square Grüneisen number for longitudinal $\langle \gamma_i^j \rangle_l$, $\langle \gamma_i^j \rangle_l^2$ and shear $\langle \gamma_i^j \rangle_s$, $\langle \gamma_i^j \rangle_s^2$ waves, acoustic coupling constants Γ_l , Γ_s , and Γ_{s^*} at 300 K for uranium monopnictides.

	Dir ⁿ	$\langle \gamma_i^j \rangle_l$	$\langle \gamma_i^j \rangle_l^2$	$\langle \gamma_i^j \rangle_s$	$\langle \gamma_i^j \rangle_s^2$	Γ_l	Γ_s	Γ_{s^*}
UN	[100]	8.22	1.66	0.08	-	67.62	0.78	-
	[110]	7.72	2.12	0.25	16.94	58.66	2.27	152.52
UAs	[100]	9.95	1.77	0.08	-	82.91	0.74	-
	[110]	8.96	2.25	0.18	20.74	72.15	1.70	186.72
USb	[100]	8.02	1.64	0.08	-	66.24	0.78	-
	[110]	7.22	2.04	0.26	16.59	57.41	2.40	149.35

^lfor longitudinal wave; ^sfor shear wave, polarized along [001]; ^{s*} for shear wave, polarized along [1 $\bar{1}$ 0]

TABLE V
Viscous drag coefficient due to screw and edge dislocation for uranium monopnictides at 300 K for longitudinal (in cp) and shear (in mp) waves.

Comp.	Dir ⁿ	$(\delta_{\text{screw}})_{\text{long}}$	$(\delta_{\text{screw}})_{\text{shear}}$	$(\delta_{\text{edge}})_{\text{long}}$	$(\delta_{\text{edge}})_{\text{shear}}$
UN	[100]	3.37	0.38	2.85	3.52
	[110]	2.92	1.13	2.46	3.41
UAs	[100]	3.34	0.29	2.82	3.36
	[110]	2.91	0.68	2.45	3.19
USb	[100]	2.26	0.26	1.19	2.25
	[110]	1.96	0.82	1.65	2.32

at $f = 1$ GHz and $T = 10$ K using Eqs. (12) and (13) for these materials and values are shown in Table VI along with attenuation values for yttrium iron garnet (YAG). V_l and V_t have been evaluated using elastic constants, density and lattice parameters ($a = 4.89, 5.779, \text{ and } 6.19 \text{ \AA}$ for UN, UAs, and USb, respectively). These values for uranium monopnictides are smaller than that of YAG. From Table VI and values of (α/f^2) shown in Figs. 1 and 2, it can be seen that contribution to the attenuation by magnon-phonon interaction for longitudinal and transverse waves is negligible compared to contribution due to phonon-phonon interaction.

TABLE VI
Attenuation due to magnon-phonon interaction (dB/ μ s) for longitudinal and shear wave for UN, UAs and USb along with YAG.

Comp.	Longitudinal	Shear
UN	1.03×10^{-8}	3.47×10^{-9}
UAs	1.08×10^{-8}	4.32×10^{-10}
USb	7.76×10^{-9}	3.39×10^{-10}
YAG	1×10^{-8}	6×10^{-6}

Figures 1 and 2 show the temperature variation of acoustic attenuation, (α/f^2) for longitudinal and shear waves, respectively. From these figures it can be seen that

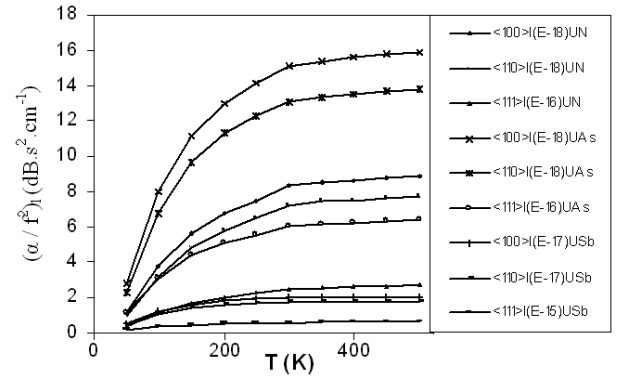


Fig. 1. Temperature variation of $(\alpha/f^2)_l$ along different directions of propagation for uranium monopnictides.

at lower temperatures, acoustic attenuation increases with temperature at faster rate and at higher temperatures rate of variation becomes nearly constant. The factor $V^2\tau$ (called diffusion coefficient) measures the ability of thermal phonons to absorb energy from a sound wave of velocity V (in crystals energy is carried by phonon wave packets with group velocity V) [34, 35]. From Fig. 3 it can be seen that $V^2\tau$ has larger value at lower temperature and decays exponentially. Therefore, at lower temperature range, the rate of absorption of sound en-

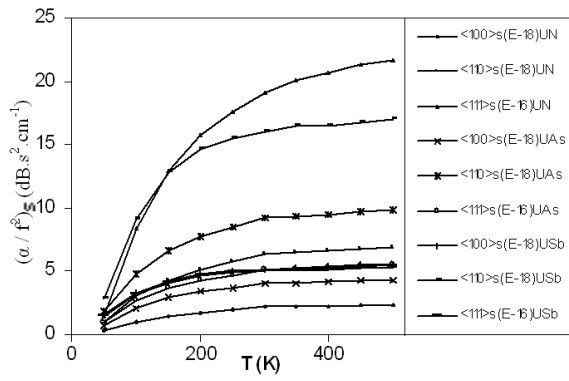


Fig. 2. Temperature variation of $(\alpha/f^2)_s$ along different directions of propagation for uranium monopnictides.

ergy (hence ultrasonic attenuation) is large and at higher temperatures it decreases and becomes nearly constant.

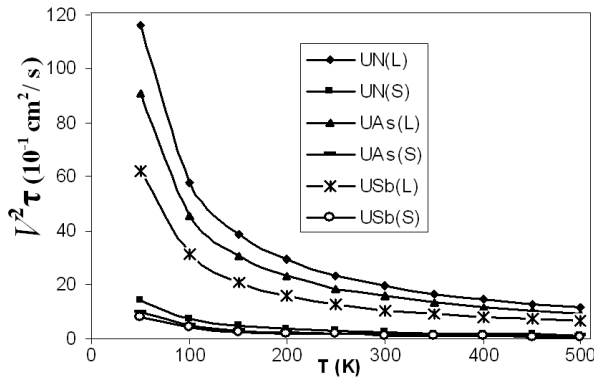


Fig. 3. Temperature variation of $V^2\tau$ for uranium monopnictides for longitudinal and shear waves.

The temperature variation of acoustic attenuation due to thermoelastic loss, $(\alpha/f^2)_{th}$ has been shown in Fig. 4. At lower temperatures, $(\alpha/f^2)_{th}$ increases with temperature and then becomes nearly constant.

Figures 5–8 show the temperature variation of acoustic coupling constant for longitudinal and shear modes, along [100] and [110] directions of propagation. From Figs. 5 and 6, it can be seen that acoustic coupling constant (which is the measure of the anharmonicity of crystal) for longitudinal wave increases with temperature at slower rate in the temperature range 50–200 K, and beyond 200 K, rate of temperature variation becomes nearly constant. Acoustic coupling constant for shear wave (Γ_s) remains almost constant (Figs. 7 and 8). Thus total acoustic attenuation is mainly affected by longitudinal wave attenuation due to larger values of Γ_l .

Ultrasonic attenuation due to phonon–phonon interaction for longitudinal and shear waves, i.e. $(\alpha/f^2)_l$ and $(\alpha/f^2)_s$ increase from UN to USb due to increase in the molecular weight or increase in the anion atomic num-

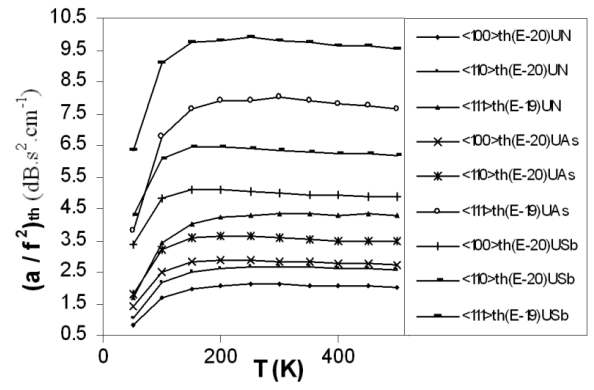


Fig. 4. Temperature variation of $(\alpha/f^2)_{th}$ along different directions of propagation for uranium monopnictides.

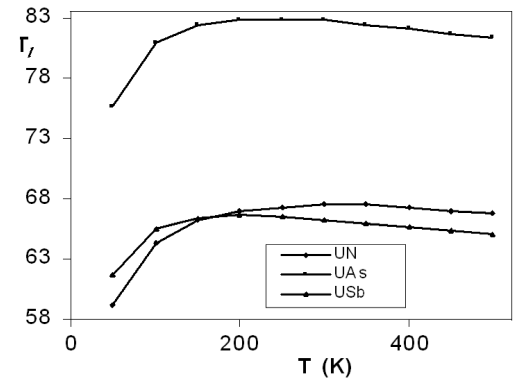


Fig. 5. Temperature variation of acoustic coupling constant (Γ_l) for longitudinal wave along [100] direction of propagation for uranium monopnictides.

ber. As molecular weight increases, the velocity of anion reduces. Thus the Debye average velocity decreases from UN to USb (Table III).

From Table III, it can be seen that the Debye temperature decreases from UN to USb. Therefore, we can say that the larger the Debye temperature, the smaller will be attenuation. The Debye temperature depends on SOEM

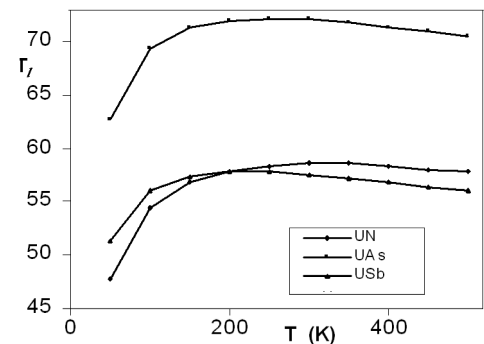


Fig. 6. As in Fig. 5, but along [110] direction.

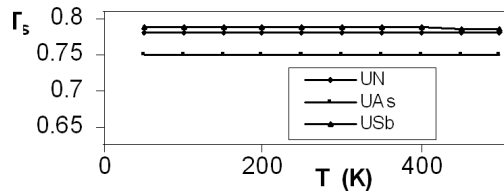


Fig. 7. Temperature variation of acoustic coupling constant (Γ_s) for shear wave along [100] direction of propagation for uranium monopnictides.

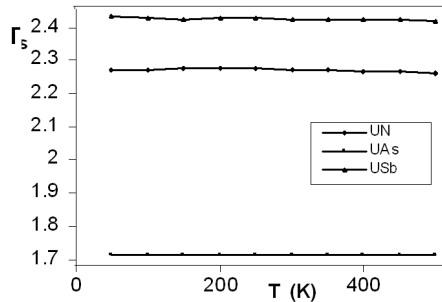


Fig. 8. As in Fig. 7, but along [110] direction.

values (through the Debye average velocity) hence, the larger the SOEM, the smaller the attenuation (because SOEM of the material are the measure of elasticity (or softening) of the crystal). Thus, it may be stated that USb is the most stable and has the least imperfections than the other two members of the group.

4. Conclusion

Total attenuation in these monopnictides in the present temperature range is the sum of attenuation due to phonon–phonon interaction, thermoelastic loss and dislocation damping due to screw and edge dislocations. Attenuation due to thermoelastic loss, dislocation damping and magnon–phonon interaction is negligible in comparison to the loss due to phonon–phonon interaction mechanism (Figs. 1 and 2, Table V and Table VI). Thus, phonon–phonon interaction is the principal cause dominating the acoustic attenuation due to larger value of Γ_l .

Using the polynomial fit law for (α/f^2) , it has been found that attenuation due to phonon–phonon interaction and thermoelastic loss follow the fourth- and third-order polynomial temperature dependent fits, respectively in the temperature range 50–500 K, i.e.

$$(\alpha/f^2)_{p-p} = A + B_1T + B_2T^2 + B_3T^3 + B_4T^4,$$

$$(\alpha/f^2)_{th} = C + C_1T + C_2T^2 + C_3T^3,$$

where A, B_1, B_2, B_3, B_4 and C, C_1, C_2, C_3 are constants.

To the best of our knowledge, no experimental or theoretical data is available on attenuation for these uranium compounds, however, comparison has been made for SOEM and TOEM for LiF obtained using present

approach and values available in literature. On the basis of good agreement for SOEM and TOEM data, it can be concluded that present approach for temperature dependence of acoustic attenuation is valid.

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