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Acoustical Investigations in some Cubic Crystals

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ABSTRACT

Variations and damping of sound waves are dependent upon the material properties of materials and its acoustic inspection has gained significant status more recently in the study of nanomaterials.The author has studies acoustic attenuation in materials of different kinds such as materials, dielectrics, semiconductors under extreme conditions of temperature and frequency along various crystallographic directions of the propagated wave using theoretical models and pulse echo technique. Such investigations have revealed that electron-phonon interactions at low temperatures and phonon-phonon interactions in the high temperature domain are the dominant factors contributing towards acoustic attenuation in all types of materials excepting the superconducting transition ones where drastic changes in theoretical models need support. The acoustical investigations were made via phonon gas interactions and thermoelastic factors using ultrasonically measured Third Order Elastic Constants. The nonlinear parameters and the absorption coefficients were studied along <100>, <110> and<111> directions of the propagated wave.

INTRODUCTION

Vibrations and the damping of sound waves are dependent upon the material properties of materials and to yield information on solids, the studies of acoustic attenuation [1] has remained an important area of interest and various experimental and theoretical methods have been used as tools to estimate it as a function of temperature and frequency etc.The measurement of attenuation is easily done using the Pulse echo Method by monitoring the experimental decay of the echo amplitudes.

Several investigators [2] viz. Akhieser, Woodruff and Ehrenreich, Mason and Bateman have attempted to explain the attenuation and its dependence on parameters like temperature, frequency etc.using different approaches.However; it was found that in dielectric crystals attenuation at ultrasonic frequencies arises mainly due to interaction of acoustic and thermal phonons. In metals and semiconductors, particularly at low temperatures, electrons play a vital role and the electron lattice interaction become dominant.Anisotropy, elastic relaxation and thermal parameters [3] co-exist with thermoelasticity and is a common happening in most of the industrial phenomenon. This technique for material analysis allows direct and non destructive measurements of the intrinsic properties of the materials and can be used to monitor chemical and structural transformations in the samples. Advance in the modern principles of ultrasonic measurements, electronics and digital processing.

THEORY

In present communications, a superconducting transition metal, the results of present investigations are compared with the experimental findings and the behavior [4] of acoustic attenuation [5] with temperature in Vitreous Silica nad Neobium.At low temperatures ~ 10 K, The acoustic variations arises mainly from the coupling between conduction electrons and acoustic phonons.This type of attenuation is observed both for longitudinal waves and shear waves.

RESULT AND DISCUSSIONS

The average Gruneisun number $<\gamma_i^j>$ and the average square Gruneisun number $<(\gamma_i^j)^2>$ have been evaluated over 39 pure modes using Mason's approach via. Third order elastic constants and other thermodynamical parameters in Vitreous Silica for longitudinal waves propagated along <111> and Shear waves along <110> and in Neobium for longitudinal waves along <100> and for shear waves along <110> directions.The acoustic coupling constants D are then evaluated along different modes of propagated wave and used in estimating the temperature dependent behavior of the acoustic attenuation. In case of Neobium we have extended our investigations to low temperatures; the electron lattice interactions good contribute predominantly and one can correlate electron shear viscosity to the electrical resistivity to examine the temperature dependent behavior of acoustic attenuation at low temperatures. It is seen from **Table 1** that the acoustic attenuation is unequal along various modes and the thermo elastic attenuation is only 1% of the total attenuation-establishing the fact that major portion of the absorb acoustic energy is used in achieving thermal equilibrium among various phonon branches in each direction. A part of energy dissipates due to interaction among the attenuated refracted waves. The attenuation, however, shows an appreciable increase as the temperature is lowered to 10 K as shown in **Figure 1** reflacting and increase in electron mean free path dominated by phonon scattering. The variation of the attenuation in Figure 1 and 2 reflects the interactions with normal electrons. At lower ultrasonic frequencies energy is feed back into the system from the crystal itself. The estimated values are in consonance with experiment by Perz and Dobbs.

We also find that the phenomenon of rapid fall of attenuation in Nb is not seen as the temperature is lowered through the critical temperature though; there is a very sharp change at Tc. Again the agreement between temperature dependence of Nb and that predicted by BCS theory is good as also explained by Ikushima et al. The absence of rapid fall region in Nb is contrary to earlier findings like those of Bommel and

Mackinnon and others. However, Leibowitz et al have reported a similar finding and have also explained as to how the high frequency breakdown of electromagnetic screening is inadequate enough to explain the reported absence of rapid fall region in Nb. In Vitreous Silica was find that the attenuation for shear waves is greater than that for longitudinal waves, but it is not due nonlinear behavior of Vitreous Silica.

At higher temperatures the acoustic attenuation due to phonon viscosity mechanism is dominating as in other crystals. The attenuation [6] increase from 77k to 193k as usual but from 193K to 253K it decreases and rises again between 273K and 293K as shown in **Figure 2** and as expected. This temperature dependent behavior is due to anharmonicity of the material except in the interval 193K- 293K, which has been explained by classical, thermally activated relaxation process in double walled asymmetric potentials. The kinks seen in the graph for shear wave and longitudinal wave attenuation are due to dislocation.

Table1. Attenuation of longitudinal and shear acoustic waves in Nb along <100> and <110> direction of propagation (For shear waves the polarization is along <110>)

Direction	**$(\alpha/f^2)_{Akh}.10^{-15}$ or $(\alpha/f^2)_{therm}.10^{-15}$ (dB s^2/cm)**		
	Long	**Shear**	**Long**
<100>	0.215	0.293	0.002
<110>[a]	0.182	1.350	0.003

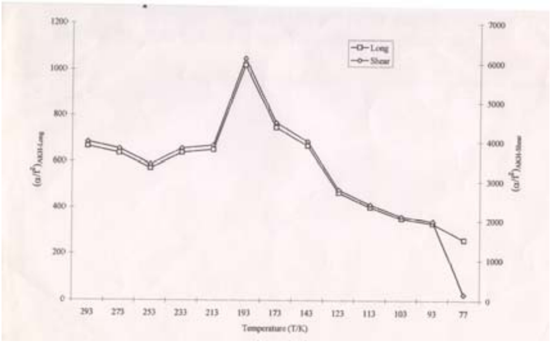

Figure 1. Ultrasonic attenuation owing to electron-phonon interaction in Nb.

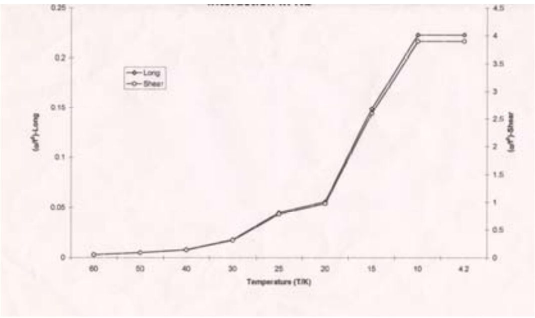

Figure 2. Temperature dependence of ultrasonic absorption coefficient for vitreous silica.

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REFERENCES

1. P. Leclaire et al, *Ultrasonic Attenuation in solids*, Proc. 15 ICA, vol.I, pp. 377-380. (1995).
2. C. Kittle, *Quantum Theory of Solids*, 2nd ed, Willeys Pub. (2001).
3. E. Thompsom et al., *Phys. Rev.* B **62**, 11437 (2000).
4. M.D. Sharma, Sadharia, 34(6), pp.1017-1032 Dec, (2009).
5. M.D. Sharma, *Int.G. Solids and struct*, 45, pp.1483-1496, (2008).
6. V. Buckin and B. Driscoll, *J Lab Plus Intertnational*, June, (2002).