Phonon Viscosity Attenuation of Ultrasonic Waves in HgTe

ATTENUATION of ultrasonic waves arising from lattice phonon viscous drag is known in insulators such as quartz[1] and in semiconductors, notably germanium[2] and silicon[3]. Here we report that this damping effect is large in the semi-metal HgTe. When the thermal phonon mean free path is small compared with the sound wavelength ($\omega\tau_{th} \ll 1$), as in the present experiment, the lattice phonon damping for an isotropic solid is given by[4]

$$\alpha_L = 8{\cdot}68\bar{\gamma}^2\omega^2 KT/\rho\bar{v}^5 \text{ dB/cm} \qquad (1)$$

where $\bar{\gamma}$ is an average Gruneisen parameter and K the lattice thermal conductivity. For HgTe ($\Theta = 141°$ K) (ref. 5) the Debye velocity of sound $\bar{v}$ is $1{\cdot}53 \times 10^5$ cm s^{-1}, considerably less than that in germanium ($3{\cdot}55 \times 10^5$ cm s^{-1}), silicon ($5{\cdot}87 \times 10^5$ cm s^{-1}) or quartz ($4{\cdot}39 \times 10^5$ cm s^{-1}) (ref. 3). A stronger thermal wave attenuation would therefore be expected in HgTe. The effect can be observed at comparatively low frequency.

The attenuation of longitudinal ultrasonic waves between 10 MHz and 290 MHz propagated along the [100], [110] and [111] directions in HgTe has been measured by the pulse echo technique[5]. Representative curves of the temperature dependence of attenuation are given in Fig. 1. Below about 20° K, the attenuation is low and almost temperature independent; this level is taken as the residual attenuation (α_0). Above 20° K the attenuation rises approximately as T^3 to a maximum at about 40° K and then decreases slowly—a behaviour consistent with phonon viscosity attenuation as expressed by (1). The frequency dependence of attenuation (Fig. 2) approaches ω^2 above 100 MHz but deviates at low frequencies, largely because of diffraction losses. The attenuation above 200 MHz is constant; a similar effect in germanium has been attributed to dislocation damping[2].

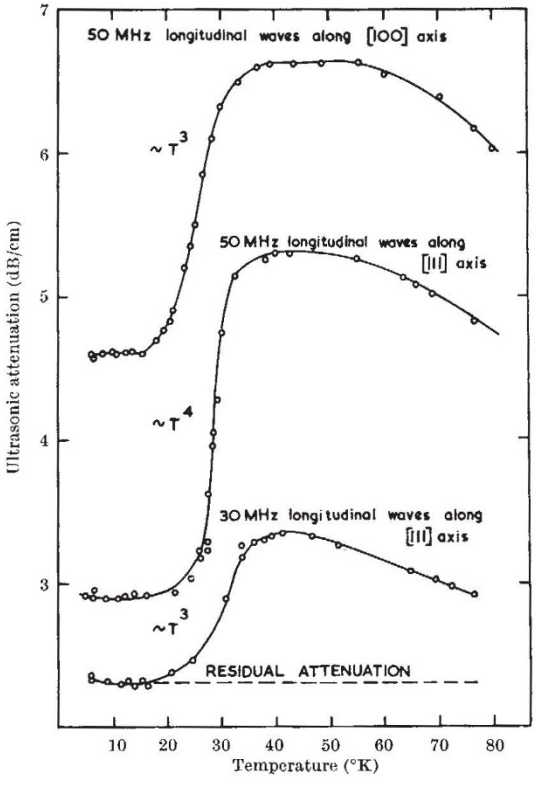

Fig. 1. The temperature dependence of ultrasonic attenuation in HgTe. The residual attenuation level is shown only for the lowest curve.

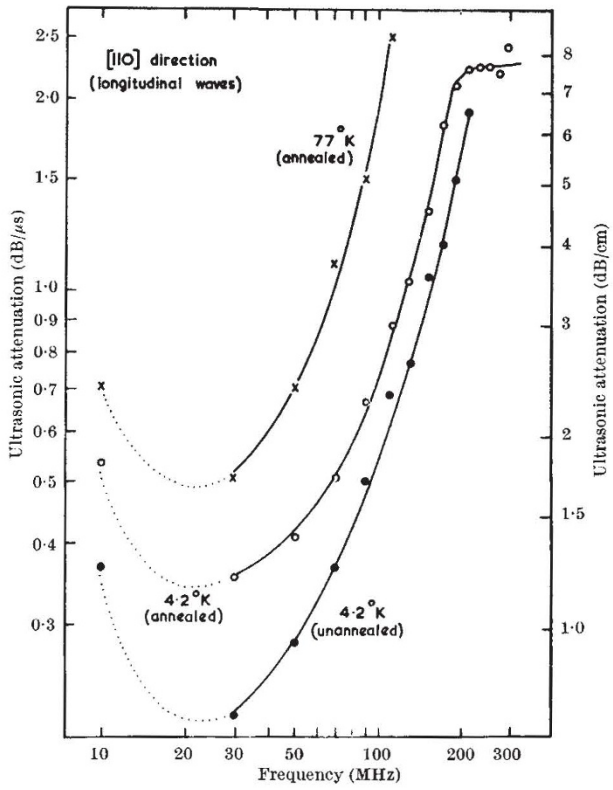

Fig. 2. Ultrasonic attenuation of longitudinal waves propagated along the [110] direction as a function of frequency in both unannealed and annealed HgTe single crystals.

Table 1. ACOUSTICAL GRUNEISEN PARAMETERS ESTIMATED FROM THE ULTRASONIC ATTENUATION OF LONGITUDINAL WAVES PROPAGATED IN HgTe SINGLE CRYSTALS

Direction of propagation	Velocity of sound at 4·2° K (cm/s)	Frequency (MHz)	Intrinsic ultrasonic attenuation $(\alpha-\alpha_0)$dB/cm	Acoustical Gruneisen parameter $\bar{\gamma}$
[111]	$3{\cdot}073 \times 10^5$	50	2·44	1·19
		30	1·02	1·28
[100]	$2{\cdot}961 \times 10^5$	50	2·04	1·07
[110]	$2{\cdot}982 \times 10^5$	70	2·48	0·86
		50	1·16	0·81

A complete quantitative assessment awaits measurements of the third order elastic constants and thermal conductivity. But it is of interest to estimate the acoustic Gruneisen parameters $\bar{\gamma}$ (Table 1) using equation (1). For comparison, the thermal expansion Gruneisen parameter is estimated as $0{\cdot}65 \pm 0{\cdot}10$.

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Recrystallization of Nickel-coated Carbon Fibres

CARBON fibres of high strength and stiffness have recently been developed at these laboratories and elsewhere[1,2]. To exploit these mechanical properties in composites at high temperatures, the fibres must remain compatible with the matrix material. In a survey of several matrix