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DISORDER ACTIVATED RAMAN SCATTERING IN InAs

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We present Raman measurements made on pure InAs alterated by a rough mechanical polish. Besides the 2TA scattering reminiscent of perfect crystalline InAs two bands appear in the low frequency region. We show that they correspond to first order disorder activated processes.

1. Introduction

The wavevector conservation is the most important selection rule for light scattering by phonons in perfect crystals. When this condition is not fullfilled new modes become first order Raman active. We induce such modes by alterating the surface of a pure InAs sample. We used an undoped single crystal. The (110) scattering face was only roughly mechanically polished with 0.3 μ alumina powder and then rinced in methanol. As we did not work in a true backscattering configuration, the spectra were not analyzed.

2. Results

Figure (1b) shows the spectrum obtained at 100 K. For comparison we display in Fig. (1a) the spectrum obtained by Carles et al [1] with the same sample carefully mechanically polished (0.05 μ alumina powder) and then etched with Syton. Figure (1c) corresponds to amorphous InAs [2]. In Fig. (1b), one distinguishes clearly the 2TA(L), 2TA(Δ → K), 2TA(W) and 2IA(K) bands characteristic of second order scattering in crystalline InAs [1]. Besides this 2TA scattering, two broad features appear in Fig. (1b) located at 54 cm^{-1} and 143 cm^{-1}. Anticipating we label them DATA and DALA (disorder activated transverse acoustical and longitudinal acoustical respectively).

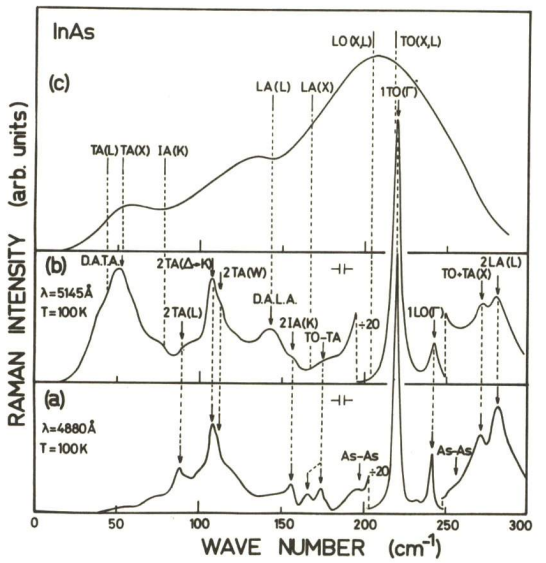

Fig.1 Raman spectra of (a) perfect crystalline InAs [1] ; (b) InAs alterated by a rough mechanical polish ; (c) amorphous InAs [2]

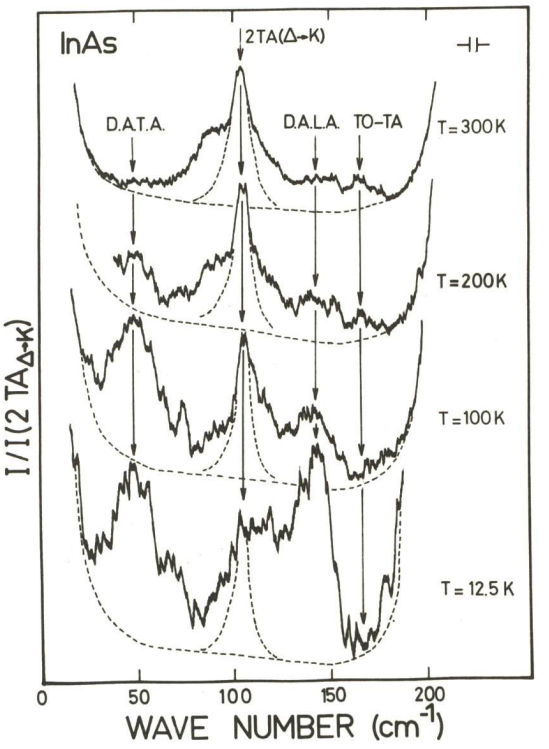

Fig. 2 Evolution with temperature of the spectrum of Fig. (1b). All intensities normalized to I(2TA Δ → K)

Figure (2) displays the evolution with temperature of the spectrum of Fig. (1b). The intensities of the different bands are normalized to that of the 2TA(Δ → K) peak. As temperature decreases the intensities of the DATA and the DALA become stronger than that of the 2TA(Δ → K) indicating that they correspond to first order processes.

3. Discussion

In crystalline InAs, the 2TA scattering, of Γ_1 symmetry, consists mainly of overtones [1]. Away from resonance, the corresponding Raman cross section is well accounted for using the following simplified expression [1]

$$I = C(\omega)\ g(\frac{\omega}{2})\ [\bar{n}(\frac{\omega}{2},T) + 1]^2 \quad (1)$$

$\bar{n}$ is the Bose-Einstein population factor, g the one phonon density of state of crystalline InAs [3] and $C(\omega)$ a factor which corrects for the optical properties of the sample, the spectral ω^4 law. (It turns out that between 0 and 300 cm^{-1} the variation of $C(\omega)$ is negligible).

We try to reproduce the Raman cross sections of the DATA and the DALA with a similar expression involving only the one phonon density of states and the corresponding population factor. To account for the broadening of the structures, we had to convolute the one phonon density of states of crystalline InAs with a gaussian. A similar procedure was already prescribed by Smith et al [4] to interpret the Raman spectra of amorphous tetrahedrally bounded semiconductors.

Figure (3) shows the experimental spectra of Fig. (2), with the residual background removed, together with the graphs of I_1 and I_2 :

$$I_1 = C_1\ g'(\omega)\ [\bar{n}(\omega,T) + 1] \quad \text{and} \quad I_2 = C_2\ g(\frac{\omega}{2})\ [\bar{n}(\frac{\omega}{2},T) + 1]^2 .$$

$g'(\omega)$ is the convoluted density of states. C_1 and C_2, which refer to first and second order processes, were used as adjustable parameters to fit the intensities of the DATA and the 2TA(Δ → K). We did not add, for clarity, the two histograms but one should keep in mind that the sum of I_1 and I_2 has to be compared with the experimental data. For a given temperature, C_1 and C_2 were taken as constants. The fit is very good between 12.5 K and 300 K. This demonstrates that the DATA and the DALA coincide, respectively, with the density of states of the transverse and longitudinal acoustical phonons. These phonons become first order Raman active because the disorder, induced by the rough polish, leads to a breakdown of the wavevector conservation rule. The frequencies of the DATA and the DALA are respectively half those of the 2TA(Δ → K) and of

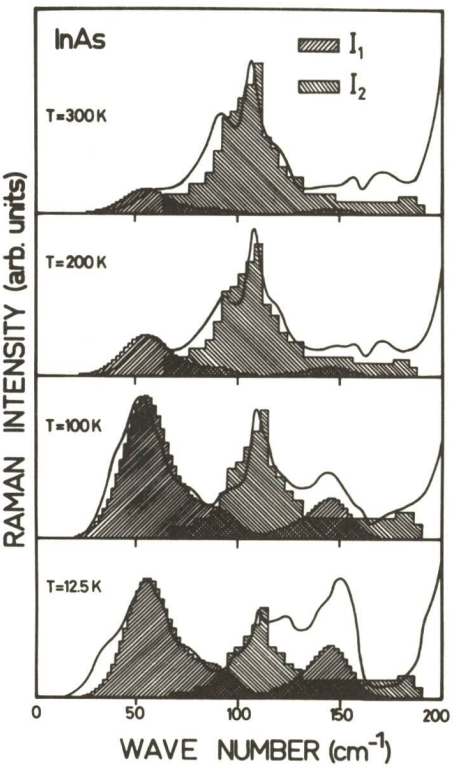

Fig. 3 Comparison of the experimental spectra of Fig.(2) with the sum of I_1 and I_2 (see text)

2LA(L) -Fig.(1a)- which corroborates our assignments. We found similar bands in InSb samples prepared in the same manner. Here too, the DATA and the DALA correspond to the density of states of transverse and longitudinal acoustical phonons of perfect crystalline InSb. This supplements also our interpretation of these bands.

We point out that the DATA and the DALA can also be induced by a configurational disorder obtained by substitution of P in InAs [5].

The ratio C_1/C_2 was found almost temperature independant showing that the population factors account for the temperature dependence of the cross sections. This ratio, equal to

$$\frac{I\,[2TA(\Delta \rightarrow K)]}{I\,(DATA)}$$

at low temperature, is a measure of the disorder. The width of the gaussian, which reflects also the degree of disorder, was taken equal to 18 cm^{-1}. This value is smaller than the one quoted by Smith **et** al. [4] in the case of amorphous Si(50 cm^{-1}) leading to the conclusion that our system is partially disordered compared to an amorphous material. This is emphasized by the presence of the TO(Γ) and LO(Γ) bands in Fig. (1b) whereas they do not show up in Fig. (1c). Also we remark that the frequencies of the different modes are unshifted compared to amorphous InAs -Fig.(1)-.

Finally, we notice that the non dispersion of C_1 contrasts with the ω^2 law followed by amorphous materials [6].

References

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