Study of Electron-Phonon Interactions in III-V Semiconductors

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Experimental Investigation of the Electron-Phonon Interaction in III-V Semiconductors

Introduction

The previous progress report discussed the experimental work done on attenuation measurements in InSb at 10 Kmc and 10 mc frequencies. The present report contains the description primarily of the temperature dependence of attenuation at 10 mc. The continuation of measurements at 10 Kmc were temporarily delayed by the moving of the RIAS laboratory to its new building.

1. 10 Kmc Phonons

In the previous report it was stated that a new InSb crystal referred to as crystal C was obtained. This crystal was shown to have a very low dislocation density compared to crystal B. However, considerable unexpected difficulties have been experienced in the cutting, aligning, and polishing of crystal C. In the ultrasonic cutting, it was very difficult to obtain a complete rod without breaking during the cutting process. This difficulty was not experi-

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enced at all with crystal B although it had been experienced with crystal A. Finally two rods were obtained. However, during the coarse polishing the rods seemed to develop small triangular chips in the surface. The triangular chips were characteristic of cleavage along three (110) surfaces, each one making an angle of 35° with the (111) polished surface. This is not surprising since (110) planes are known cleavage planes in InSb. During the fine polishing, the surface became concave, as illustrated in Figure 1. This was observed when checking the surface for flatness with an optical flat. About 3 or 4 interference rings were observed on the InSb surface. All of this behavior, which was not experienced in crystal B seemed to indicate that crystal C was considerably softer than crystal B.

Several methods are being tried to overcome the development of a concave surface during fine polishing. A softer glass blank will be tried as well as, slower polishing speed and different types of polishing compounds. It is essential that this difficulty be overcome since the concavity amounts to several acoustic wavelengths across the surface. Meanwhile another crystal is being obtained in the hope that it will not suffer from the same weakness. After long discussions with J. D. Venables and Dr. E. N. Pugh of the metallurgy department at RIAS, who have had extensive experience with InSb, it became apparent that such a variability in its mechanical properties is quite common. Moreover, it has not yet been possible to correlate this variability with any other observable property of the material.

2. 10 mc Phonons

Measurements of phonon attenuation as a function of temperature at 10 mc were performed with the equipment shown in Figure 2. Crystals of GaAs and InAs were obtained for these measurements along with the InSb crystal C. The GaAs crystal is a 1 cm long slab cut from an ingot approximately 2.2 cm in diameter having at 78°K a resistivity of 0.28 Ω cm, a Hall mobility of 7.1×10^3 cm^2/(volt sec) and a net negative carrier concentration of 3.1×10^{15} cm^{-3}. The InAs crystal was also 1 cm long and cut from a roughly triangular shaped ingot approximately 2.3 cm on a side. Its electrical properties at 78°K are: resistivity = 0.007 Ω cm, Hall mobility = 3.3×10^4 cm^2/(volt sec) and net negative carrier concentration of 2.7×10^{16} cm^{-3}.

The transducers used for the measurements were x-cut quartz obtained from Valpey Crystal Company. The measurements for GaAs were made between 294°K and 78°K using a glycerin bond between the transducer and the crystal. It was found that at about 120°K the echoes suddenly became indistinct as though the transducer were ringing. However, when the system was immersed in liquid nitrogen at 78°K the echoes were again restored but with a higher attenuation. The same behavior was observed when Dow Corning's DC 200 with a viscosity of 30,000 cs was used as a bonding material.

The attenuation results for GaAs obtained from the exponential decay of the pulse echoes is given in Figure 3. These measurements will be continued down to 4°K and a further investigation of the phenomena near 120°K will be examined. It is most likely that the transducer goes into an undamped vibration and that this depends on the bonding material.

Some measurements were made with the InAs crystal also. At 294°K the attenuation measured was 0.23 ± 0.02 db/cm for 10.1 mc. For comparison the attenuation was also measured at 29.5 mc. This value was 0.83 ± 0.08 db/cm. At 78°K, the attenuation for 9.6 mc was 0.79 ± 0.07 db/cm and for 29.8 mc it was 1.97 ± 0.22 db/cm.

The attenuation measurements on the InSb had to be delayed due to breakage of the crystal. The slab which we referred to as crystal C had been cut in half so that one half could be used for these 10 mc measurements while the other half could be cut into rods and polished for the 10 kmc measurements. As was mentioned above, considerable difficulty was experienced in this cutting and polishing of the rods due to the ease with which the crystal crumbled and broke. The same difficulty plagued the half used for 10 mc measurements such that it broke at the transducer bond when cooled to 78°K. The new crystal has not been received yet but the temperature and frequency dependence of the ultrasonic attenuation in the neighborhood of 10 mcps will be measured after the crystal is received.

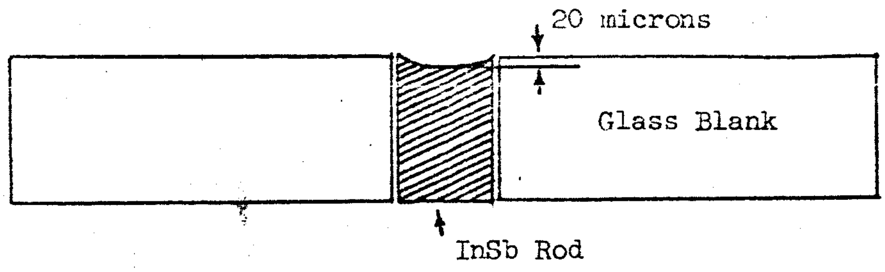

Fig. 1. Illustration of the concave polishing effect on InSb crystal C.

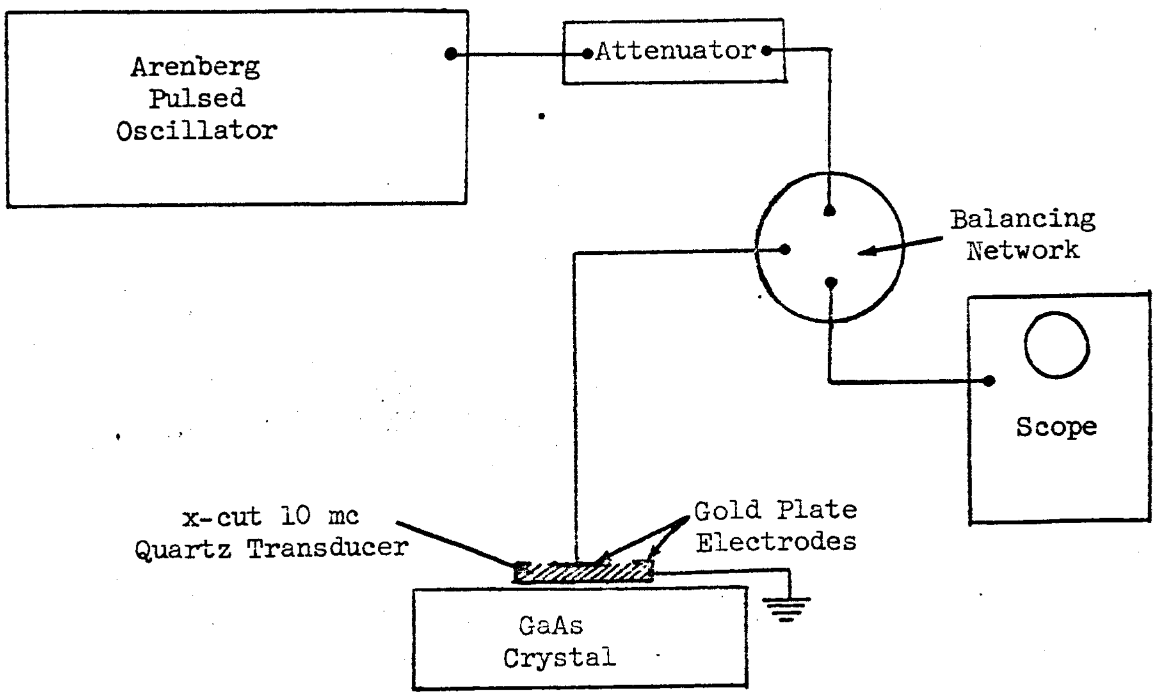

Fig. 2. Schematic diagram of equipment used in 10 mc ultrasonic attenuation measurements.

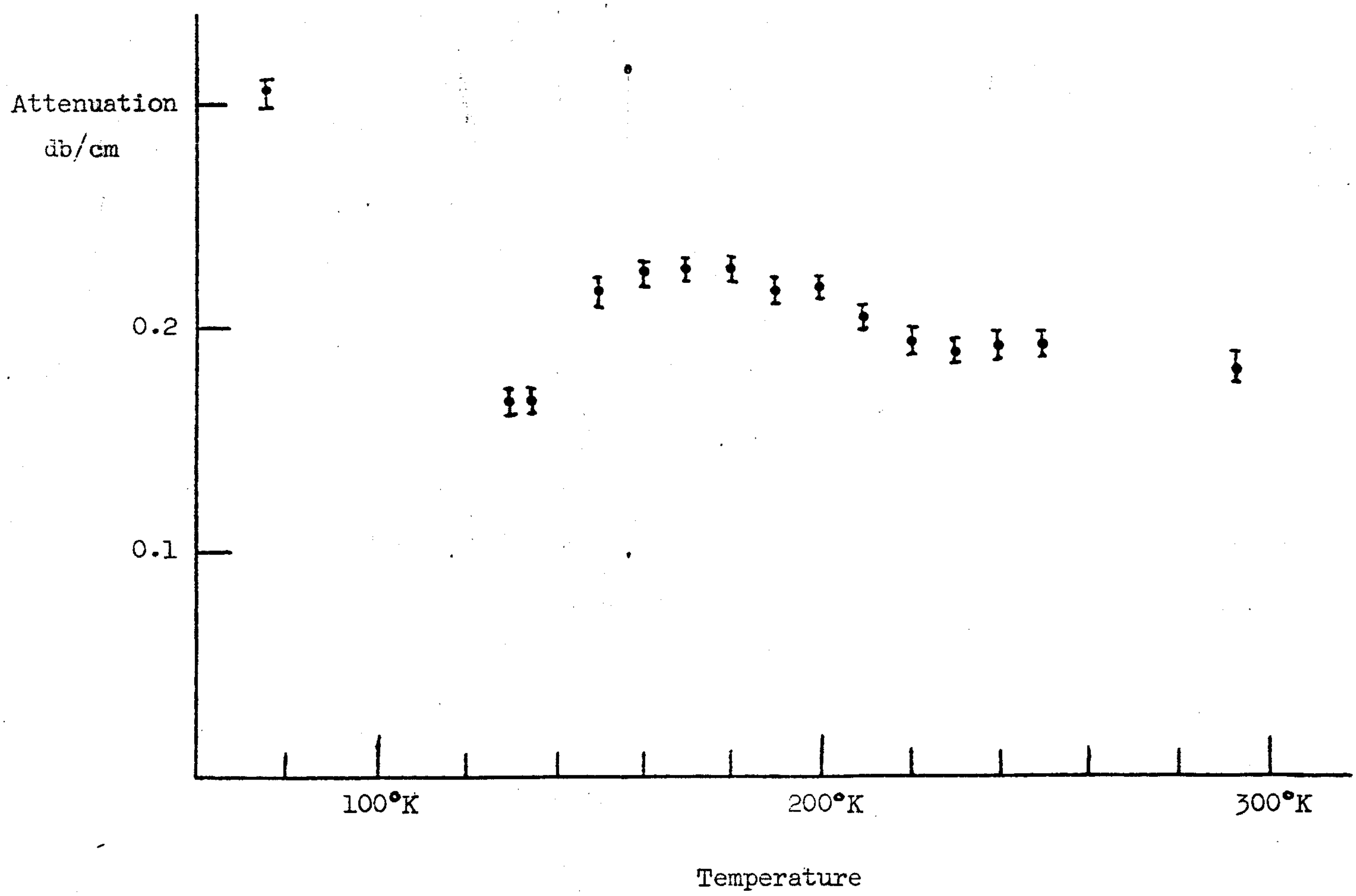

Fig. 3. Ultrasonic attenuation of GaAs as a function of temperature at 10 mcps.