Piezoresistance in *n*-Type GaAs†

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Piezoresistance and elastoresistance coefficients of *n*-type GaAs were determined at room temperature. The results are consistent with a spherical energy-band model as predicted by Callaway from theory.

I. INTRODUCTION

CALLAWAY[1] has predicted from theoretical considerations that the conduction band minimum of GaAs is in the center of the Brillouin zone. This prediction was supported by the low effective mass of $(0.043\pm005)m_0$ for the electrons, which was derived by optical experiments.[2] The present experiment was done to provide further confirmation of the spherical energy-band model for this material.

II. EXPERIMENTAL

A single crystal of *n*-type GaAs was obtained from Westinghouse Materials Engineering Department. The electron concentration, calculated from Hall measurements at 77°K, was $8\times10^{16}/\mathrm{cm}^3$. The resistivity at 77°K was 0.021 ohm-cm.

The experimental arrangements used were similar to the arrangements A and C used by Smith,[3] in which longitudinal measurements were made in the directions [100] and [110]. All samples were oriented by Laue back-reflection x-ray method. The error in orientation was $\pm2°$. The experimental apparatus used was similar to that used by Pollak.[4] Stresses applied were of the order of 5×10^7 dynes/cm^2. No transverse measurements, as in Smith's arrangements B and D, were made because of the difficulty of making good large-area low-resistance electrical contacts. Instead, a hydrostatic pressure measurement was made to complete the information on the three piezoresistance coefficients, Π_{11}, Π_{12}, and Π_{44}. The maximum hydrostatic pressure applied was 5×10^9 dynes/cm^2. The resistance increased linearly with hydrostatic pressure throughout the range of pressure applied. Measurements by hydrostatic pressure experiment are isothermal, whereas the longitudinal measurements are adiabatic. No correction has been made to take this into account, as its effect is quite small and does not affect our conclusions. Corrections due to dimensional changes were made using the elastic-constant values supplied by McSkimin.[5]

All measurements were made at room temperatures. Electrical contacts were made with tin solder.

TABLE I. Experimental data.

Current and stress direction	$\frac{1}{X}\frac{\delta R}{R}$ (10^{-12} cm^2/dyne)	Correction term[a] K (10^{-12} cm^2/dyne)	Quantity measured	$\frac{1}{X}\frac{\delta\rho}{\rho}$ (10^{-12} cm^2/dyne)
[100]	-0.3 ± 0.3	$(2S_{12}-S_{11})=-1.9$	Π_{11} (adiabatic)	-2.2 ± 0.3
[110]	-3 ± 0.3	$(S_{12}-\frac{1}{2}S_{44})=-1.2$	$\frac{1}{2}(\Pi_{11}+\Pi_{12}+\Pi_{44})$ (adiabatic)	-4.2 ± 0.3
Hydrostatic pressure	-10.2 ± 0.5	$(S_{11}+2S_{12})=0.4$	$\Pi_{11}+2\Pi_{12}$ (isothermal)	-9.8 ± 0.5

[a] Values used for elastic constants at room temperature (see reference 5): $C_{11}=1.195\times10^{12}$ dynes/cm^2; $C_{12}=0.541\times10^{12}$ dynes/cm^2; $C_{44}=0.597\times10^{12}$ dynes/cm^2.

III. RESULTS

The results are shown in Table I. The uncorrected values of the fractional change of resistance per unit stress are given in the second column. The dimensional correction terms K, expressed in terms of elastic compliances S, are given in the third column. The last column gives the fractional change of resistivity per unit stress.

The principal elastoresistance coefficients are given in Table II and for comparison corresponding numbers for extrinsic *n*-type InSb at 77°K are also given from the results of Potter.[6] The shear coefficients for GaAs are quite small and are comparable to those for InSb.

IV. CONCLUSIONS

The small values of shear coefficients are consistent with a spherical energy band model for this material, which is suggested by the theoretical calculation of Callaway[1] and the low effective-mass value derived from optical experiments.[2]

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TABLE II. Shear and volume dilation coefficients for GaAs and InSb.

Material	Temp. (°K)	Carrier concentration at 77°K (cm^{-3})	$\frac{1}{2}(m_{11}-m_{12})$	m_{44}	$\frac{1}{3}(m_{11}+2m_{12})$
n-GaAs	300	8×10^{16}	0.5	−1.4	−7.4
n-InSb[a]	77	$(3\sim4)\times10^{15}$	−1.1	−1.3	−16

[a] See reference 6.

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