III. SOLID STATE PHYSICS

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A. ELASTIC CONSTANTS OF MAGNESIUM

The elastic constants of magnesium were measured from 4.2°K to 300°K by an ultrasonic pulse technique. The results are given in Fig. III-1, Fig. III-2, and Fig. III-3. The constants c_{11}, c_{44}, and c_{66} are given directly by the velocity of longitudinal and transverse waves propagating in the planes perpendicular to the three-fold screw axis.

$$\rho U_\ell^2 = c_{11}$$

$$\rho U_t^2 = c_{44} \qquad \rho U_t'^2 = c_{66} = (c_{11} - c_{12})/2$$

The value of c_{33} and a check on the value of c_{44} are provided by measurements on the longitudinal and transverse waves propagating parallel to the axis.

$$\rho U_\ell^2 = c_{33}$$

$$\rho U_t^2 = c_{44}$$

To obtain c_{13}, the velocities of quasi-longitudinal and quasi-transverse waves at a 45° angle to the three-fold axis are measured.

$$\rho U^2 = \frac{1}{4}\left\{c_{11} + c_{33} + 2c_{44} \pm \left[(c_{11} - c_{33})^2 + 4(c_{13} + c_{44})^2\right]^{1/2}\right\}$$

The experimental curves when extrapolated to 0°K give for the independent elastic constants at 0°: $c_{11} = 0.634$, $c_{33} = 0.664$, $c_{44} = 0.184$, $c_{66} = 0.1875$, and $c_{13} = 0.217$, all in units of 10^{12} dynes/cm^2. The relation $c_{66} = (c_{11} - c_{12})/2$ determines $c_{12} = 0.259 \times 10^{12}$ dynes/cm^2.

The interatomic force constants obtained from the elastic constants at 0°K are as follows: α, the force constant for interaction between nearest neighbors in the basal plane, is equal to 10.59×10^3 dynes/cm; β, the force constant between nearest neighbors in adjacent planes, is equal to 10.53×10^3 dynes/cm; and γ, the force constant between second nearest neighbors in adjacent planes is 0.316×10^3 dynes/cm. The bulk modulus of the electron gas as given by the deviation from the Cauchy relation ($c_{13} = c_{44}$) is 0.033×10^{12} dynes/cm^2. The fact that α is slightly larger than β for magnesium, in which the c/a ratio is somewhat less than the ideal value for closest

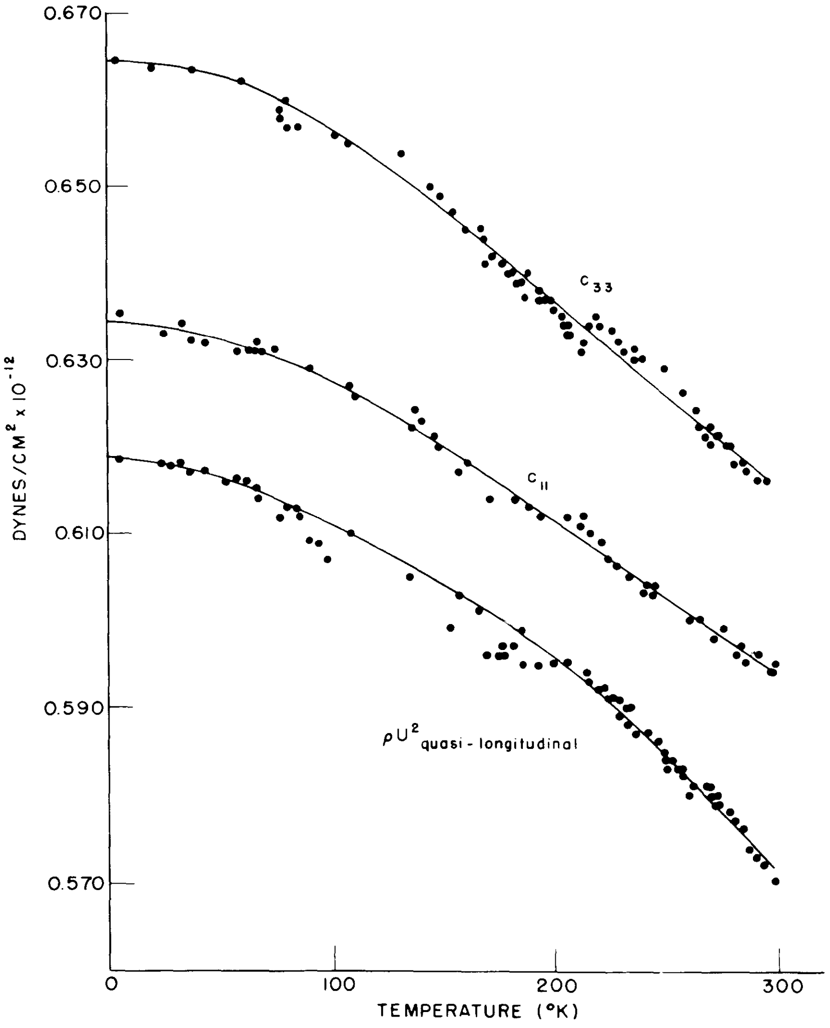

Fig. III-1. Adiabatic elastic constants c_{11} and c_{33}, and $\rho U^2_{\text{quasi-longitudinal}}$ for magnesium.

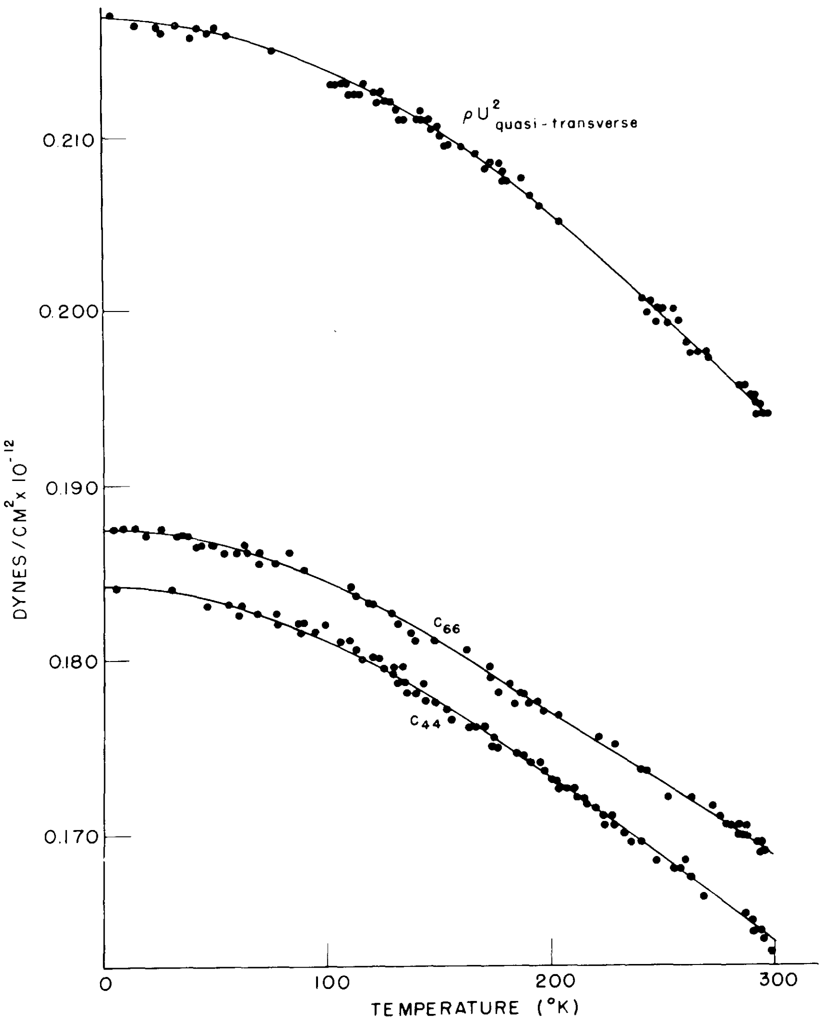

Fig. III-2. Adiabatic elastic constants c_{44} and $\rho U^2_{\text{quasi-transverse}}$ for magnesium

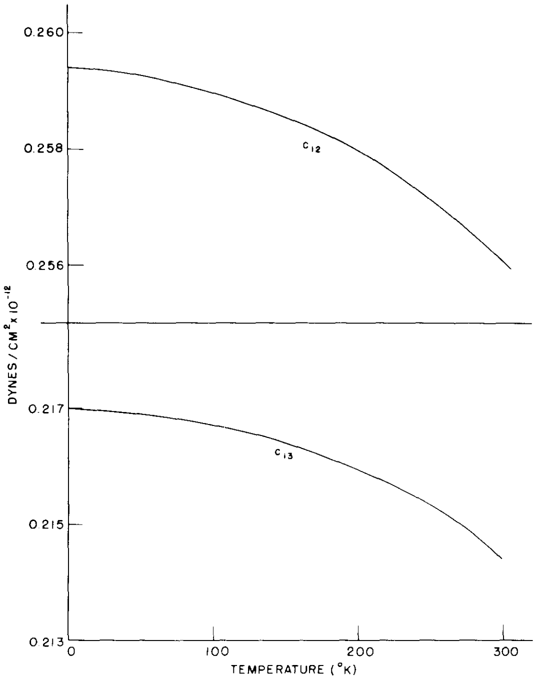

Fig. III-3. Adiabatic elastic constants c_{12} and c_{13} for magnesium.

packing, may be attributable to neglect of the next nearest neighbors in the basal plane.

A Debye characteristic temperature, θ_D, equal to 388°K, was calculated at 0°K by averaging the inverse cubed longitudinal and transverse acoustical wave velocities over all directions of propagation. The experimental value of θ_D, which was obtained from heat capacity measurements, is 406 ± 10°K (see ref. 1).

The interatomic force constants will be used in a lattice dynamical calculation of the vibrational frequency distribution function for magnesium.

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References

1. P. L. Smith, Phil. Mag., Ser. 7, 46, 744 (1955).

B. RECOMBINATION OF ELECTRONS AND DONORS IN GERMANIUM

Our aim is to measure the cross section of recombination of electrons with donor atoms in germanium.

Germanium doped with a group V impurity will have a discrete energy level at approximately 0.01 ev below the conduction band; this level is usually occupied by an electron if the sample is at liquid-helium temperature.

In these conditions, we ionize the donor levels at an instant t_o and then try to measure the decrease in the number of carriers as a function of time. To ionize the donors, we send a pulse of rf power into a cavity in which there is a sample of the material; we measure the change of the Q of the cavity as a function of time, ascribing the increased losses to the presence of the free carriers that have been excited into the conduction band of the crystal by the rf power. To measure the Q of the cavity as a function of time, we use a transient spectrum analyzer, with the help of which we can make measurements 5 μsec after the end of the magnetron pulse.

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