MAGNETIC FIELD EFFECTS

The electronic contribution to the K of Ge is about 40% of the total at 1175°K, a temperature 35°K below the melting point. An attempt was made to alter this electronic contribution by applying a moderate magnetic induction in a direction perpendicular to the axis of the K sample. Magnetic induction strengths (MKS units) up to 0.6 Wb/m² (6000 G) were applied, but no effect on K was observed to within ±2%. Steele[62] found that values up to 1.15 Wb/m² had no effect on the K of Ge at 278°K. Here the estimated $K_e = K_{ep} + K_{eb}$ is only 4×10^{-4}% of the total K for intrinsic Ge. His experiment was not sufficiently sensitive to see changes this small even if the magnetic induction had been sufficiently strong to suppress K_e. Magnetic effects on K have been seen in HgSe,[63] Bi_2Te_3,[64] and InSb.[65,66] The requirement on the magnetic induction is that it must be large enough so that the charge carriers will make about one cyclotron orbit before being scattered. This minimum value,[65] B_m, is approximately

$$B_m = \pi/\mu ,$$

where B is in Wb/m², and μ is the carrier mobility in m²/V-sec. The electron mobility in intrinsic Ge at 1175°K is about 0.03 m²/V-sec, the hole mobility is even lower. The minimum magnetic induction is thus about 100 Wb/m² (10^6 G). It is rather clear why no magnetic effects were seen in Ge. No experiments on Si were tried.

CONCLUSIONS

The thermal conductivity K of silicon has been measured from 3 to 300°K using a steady-state, longitudinal heat flow apparatus. By using the relaxation times for umklapp scattering, isotope scattering and boundary scattering, and Callaway's simple model, a theoretical phonon thermal conductivity was calculated and was found to agree with the experimental measurements.

A high-temperature thermal conductivity apparatus employing steady-state, radial heat flow in a cylindrical sample was designed and was found to give accurate (±5%), absolute, measurements at temperatures from 300 to 1600°K. The method does not require any correction for heat loss by radiation. The K values so obtained agree with those found for both Si and Ge using the low-temperature, longitudinal heat flow apparatus.

The results show that phonons are the dominant carriers of heat in high purity, solid Si and Ge at all temperatures from 3°K to their melting points. The phonon or lattice thermal conductivity K_g decreases faster than the T^{-1} law predicted by three phonon umklapp scattering for $T \geq \theta$, where θ is the Debye temperature. For temperatures $T > \theta$, an approximate theoretical formula has been developed for K_g which agrees with experimental results between $0.5\theta < T < 1.6\theta$. This formula is based on the assumption that three-phonon, four-phonon, and isotope scattering are important at high temperatures, and it predicts that the thermal resistivities of these three processes are additive. It is suggested that the relaxation times for both three- and four-phonon processes are comparable for $T \geq \theta$.

For temperatures above about 1.6θ an electronic thermal conductivity K_e has been found in both Si and Ge. The theoretical and experimental values of K_e agree quite well. The major part of K_e comes from the bipolar term, with some small contribution from the polar term. At the melting point the phonons contribute an average of 61% to the total K while the bipolar and polar contributions are 32% and 7%, respectively.

The thermal band gaps at the melting points are estimated from K_e as 0.6±0.1 eV for Si and 0.26±0.08 eV for Ge. They are in reasonable agreement with the linear extrapolations from lower temperatures.

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