Longitudinal and Transverse Phonons in the Lattice Thermal Conductivity of GaAs and InSb. A Reply

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The main contentions of Guthrie[1] for the calculations of the phonon conductivity of GaAs and InSb [2] are that it is not possible to distinguish between the contributions of longitudinal phonons and transverse phonons in the high-temperature region beyond 100 °K and that one should use $\tau^{-1}_{3\text{-phonon}} \propto T^{1.0}$ for longitudinal phonons in the high-temperature region. If one agrees with Herring's[3] calculations for the three-phonon relaxation rates, which show that longitudinal phonons and transverse phonons have different temperature and frequency dependences ($\tau^{-1}_{3\text{-phonon},L} = B_L\omega^2 T^3$, $\tau^{-1}_{3\text{-phonon},T} = B_T\omega T^4$) in the low-temperature region, the κ vs T curves for the longitudinal phonons and transverse phonons are quite distinct from each other in the low-temperature region. It may be further noted that the temperature dependence of the phonon conductivity of Si, Ge, InSb, and GaAs in the low-temperature region can be explained only if one takes the contribution of longitudinal phonons to be small in comparison with that of transverse phonons (this is also supported by the calculations of Hamilton and Parrott[4] based on a variational treatment of the three-phonon scattering processes in Ge). Whatever temperature dependence is assigned to three-phonon relaxation rates in the high-temperature region, it should explain not only the phonon conductivity data in the high-temperature region but it should also be consistent with the low-temperature results. This means that the κ vs T curve in the high-temperature region for the particular polarization branch should join smoothly with the same curve in the low-temperature region. If the temperature dependence for the three-phonon relaxation rates for the transverse and longitudinal phonons is same in the high-temperature region, the κ vs T curve on the log-log scale will be almost two parallel straight lines, the contribution of longitudinal phonons being smaller than that of transverse phonons. The smaller contribution of longitudinal phonons in the high-temperature region can be easily distinguished because of the above conditions of the consistency. However, if the phonon conductivity data is available only in the high-temperature range and if both the longitudinal and transverse phonons have the same temperature dependence, it is not possible to distinguish between the contributions of different polarization branches. The distinction is possible if one considers the high-temperature data along with the low-temperature results. In view of the fact that the contribution of longitudinal phonons is quite small in the high-temperature region, it is immaterial what temperature dependence one uses for the three-phonon relaxation rates for the longitudinal phonons in the high-temperature region.

Further, it may be noted that the high-temperature phonon conductivity data on Si or Ge cannot be explained only on the basis of the $T^{1.0}$ dependence of three-phonon relaxation rates. In order to explain the results, one has to consider four-phonon processes as has been already demonstrated by us.[5] Thus Guthrie's [1,6] temperature dependence of three-phonon relaxation rates ($\tau^{-1}_{3\text{-phonon}} \propto T^{1.0}$) is compatible only if four-phonon processes are considered.

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