

Thermal and Electrical Conductivities of Silicon in the Solid and Liquid States

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The thermal and electrical conductivities of silicon have been investigated in the solid and liquid states. The thermal conductivity has been studied in the stationary thermal regime by means of an absolute method of spherical layers. The electrical conductivity has been studied by the four-probe compensation method. It is shown that in the solid state region at temperatures close to the melting point, phonon and electron mechanisms, including the ambipolar part, are dominant in thermal conductivity. The electronic contribution, including the ambipolar part, did not exceed 20 % of the total thermal conductivity at temperatures near the melting point. The deviation in the temperature dependence of the phonon thermal conductivity from an inverse dependence on temperature observed at high temperatures can be explained in terms of the scattering of acoustical phonons by optical phonons.

The thermal and electrical conductivities of silicon increase at melting, and the magnitude of these parameters becomes close to those of metallic melts. However, the thermal and electrical conductivities of the melt of Si at temperatures near the melting point change with temperature (electrical conductivities increase and thermal conductivities decrease), unlike those in metallic melts. Using the temperature dependence of the heat capacity and the density, the molecular thermal conductivity of the melt has been calculated.

The values of the Lorentz number, L , for various temperatures have been also calculated using the experimental data on thermal and electrical conductivities and taking into account the value of the molecular thermal conductivity from the Wiedemann-Franz relation. The values of the Lorentz number and its temperature dependence (L decreases with temperature in the range of 150 K after melting) are not typical for metallic melts. The anomalous values and temperature dependence of the Lorentz number, as well as the thermal and electrical conductivities at temperatures near the melting point, are consistent with anomalous (for metallic melts) temperature variations in density, viscosity, free energy, and entropy of activation of the viscous flow of a silicon melt in the same temperature range. The anomalous behavior of these parameters in the melt of Si is explained by the inherited features of solid state structures in a certain temperature range after melting.

In our opinion, the melt of Ge just after melting has intermediate properties between metal melts and B group melts according to Mott'sTM classification.