PERCOLATION EFFECTS IN THE $PBSE_{1-X}TE_X$ SOLID SOLUTIONS

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Earlier, when studying the room temperature concentration dependences of the Seebeck coefficient, electrical conductivity, microhardness, and lattice thermal conductivity of the $PbSe_{1-x}Te_x$ solid solutions, we observed peaks near $x = 0.01$ and $x = 0.99$ and attributed their presence to the percolation-type phase transition [1-3]. To confirm this assumption, it is necessary to expand the range of properties studied and the temperature interval in which they are measured.

The purpose of this study was to establish for $PbSe_{1-x}Te_x$ solid solutions in the range $x = 0–0.04$, the dependence of the exponent β in the power law temperature dependence of lattice thermal conductivity $\lambda_L = A\,T^{-\beta}$ (A is the coefficient depending on the degree of anharmonicity of the crystal lattice vibrations). The β values for different x were estimated using the temperature dependences of λ_L in the interval 150–350 K, in which the contribution of the bipolar component to λ can be ignored.

It was established that the $\beta(x)$ dependence was non-monotonic and had a clearly defined anomaly near $x \sim 0.01$, indicating the presence of a phase transition. It turned out that the behavior of the $\lambda_L(x)$ dependence is very similar to that of the $\beta(x)$ one. This indicates that the deviation from the additive dependence of both λ_L and β is caused by phase transitions that change the phonon spectrum. According to the Debye-Peierls theory, at temperatures above the Debye temperature the phonon mean free path in a defect-free crystal is limited by three-phonon anharmonic interactions and λ_L decreases inversely with temperature: $\lambda_L \sim 1/T$, which corresponds to $\beta = 1$. However, if the crystal contains defects, crystal phonon spectrum and β values change. The existence of the phase transition, leading to a sharp change in the crystal properties, should also lead to a noticeable change in β values. The formation of percolation channels leads to an increase in phonon mobility which determines the growth in β.

Thus, the non-monotonic behavior of the $\beta(x)$ dependence confirms a change in the heat transfer and phonon scattering processes at the percolation phase transition.

References:

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