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Thermal Conductivity of Bi_2Te^3

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Abstract: This article discusses the thermal conductivity of Bi2Te3, the presence of a maximum in the thermal conductivity curve, the scattering of phonons by crystal boundaries, and its dependence on temperature.

Key words: thermal conductivity, phonon, crystal, thermoelectric material.

Introduction

Semiconductor thermoelectric materials are widely used in generators, refrigerators, thermostats, air conditioners and other devices to convert heat energy directly into electricity. Among these materials, solid solutions based on bismuth telluride (Bi2Te3) have the best thermoelectric properties in the temperature range of 200-600 K. The main energy characteristics of thermoelectric devices (temperature difference in thermopile, cooling coefficient of thermostats, air conditioners and refrigerators, efficiency of thermoelectric generators) are determined by thermoelectric efficiency.

$$ZT = \left(\frac{|\propto_n| + |\propto_p|}{\left(\frac{\chi_n}{\sigma_n}\right)^{1/2} + \left(\frac{\chi_p}{\sigma_p}\right)^{1/2}} \right)^2 T$$

where α is termo-e.yu.k. coefficient, σ - electrical conductivity, χ - thermal conductivity, T - absolute temperature, n and p indices refer to the n- and p-networks of the thermocouple.

Method and material

As the thermoelectric efficiency increases, the energy characteristics of devices improve. The values of α, σ and χ, in turn, depend on the main physical parameters of the substance, for example, lattice thermal conductivity χ_p, mobility m and effective mass of charge carriers m*, and these parameters are included as a first approximation. in the expression for Z in the form of complexes $\mu_0 \frac{(m^*/m_0)^{3/2}}{\chi_p}$ for electrons and holes (μ_0 is the mobility of non-degenerate carriers).

Due to the layered structure of Bi2Te3, its thermal conductivity is highly anisotropic. Its thermal conductivity is determined according to the following equation. Figure 1 shows the thermal conductivity of the crystal lattice.

$$\chi_p = \chi_{um} - \chi_e \qquad (1)$$

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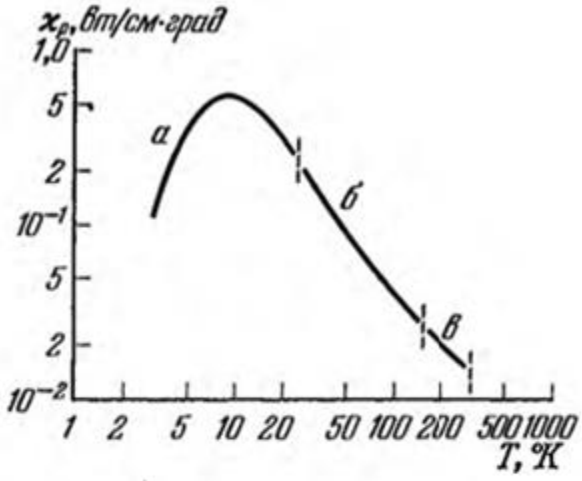

Figure 1. Temperature dependence of the thermal conductivity of the Bi_2Te_3 crystal lattice

With an increase in temperature, the lattice thermal conductivity passes through a flat maximum at about 6-8 K, reaches a value of 0.6 W/cm·grad, and then decreases first according to the law, starting from T^{-1} at 50 K to $T^{-3/2}$ approaches.

The presence of a maximum in the heat transfer curve cannot be explained by the scattering of phonons by crystal boundaries, since the calculated free path for them at a temperature of 6-8 K is several times smaller than the size of the sample. The absolute value of the thermal conductivity of the p- and n-type samples was 4-5 times higher than that shown in Fig. 1 at its maximum point.

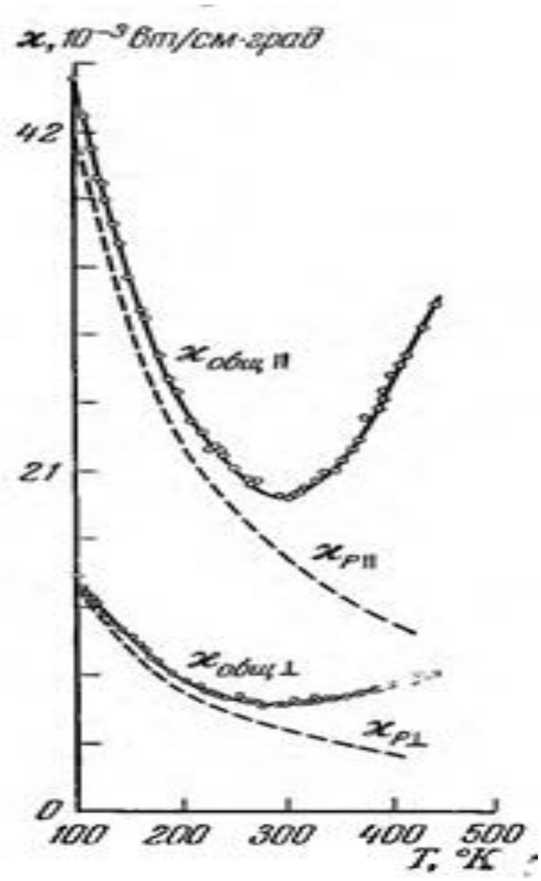

Figure 2. Results of the thermal conductivity of the Bi2Te3 crystal lattice along cleavage planes and along crack planes. Points are experimental $\chi_{общ}$ values, dotted curves are χ_p^0

The anisotropy of the thermal conductivity of the bismuth telluride crystal lattice is characterized by the ratio $\frac{\chi_{p\parallel}}{\chi_{p\perp}} \approx 2-3$. ($\chi_{p\parallel}$) and $\chi_{p\perp}$) are, respectively, thermal conductivity measured along the cleavage planes). $\chi_{p\parallel}$ of single-crystal samples and those obtained by directional crystallization are in good agreement and are 14.5•10-3 W/cm•degree at room temperature. It was estimated that the thermal conductivity of the crystal lattice of samples with a concentration of charge carriers ~10^{19} cm^{-3} begins to increase sharply at temperatures above 300 K (Fig. 2). The value of "additional" thermal conductivity is calculated as follows

$$\chi_{доб} = \chi_{общ} - \chi_e - \chi_p^0$$

(χ_p^0- - is the thermal conductivity of the grid extrapolated to the temperature range T > 200 K according to the law χ_p^0~ 1/T described by formula (1) for bipolar diffusion of current carriers.

Conclusion

I learned that if the electronic component of thermal conductivity is determined accurately enough, then it is possible to estimate the mechanism of diffusion of current carriers in matter.

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