THERMAL CONDUCTIVITY OF $LaSn_3$*

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Thermal conductivity λ and electrical resistivity ρ of monocrystalline $LaSn_3$ were measured in temperature range 6–300 K. A high and sharp maximum was observed for $\lambda(T)$ dependence at temperature $T_m = 14$ K. The dependence has revealed the linear behavior of λ with temperature below T_m and the exponential one for temperatures higher than T_m. The electronic component to the thermal conductivity was estimated assuming validity of the Wiedeman–Franz law. It was found that the electrons play an essential role in the heat transport of $LaSn_3$. Temperature dependence of the Lorenz function for $LaSn_3$ is given as well.

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1. Introduction

The $LaSn_3$ belongs to the $RESn_3$ family of intermetallic compounds crystallizing with the $AuCu_3$ type of structure, where the RE ions form a simple cubic lattice. Compounds of this family are studied from a view point of Kondo lattice, heavy fermion, crystal field effect and superconducting properties. Among the $RESn_3$ compounds $LaSn_3$ is the only one, which does not exhibit the f–electron magnetism, therefore it is often used as a nonmagnetic reference standard for different electron transport investigations. Information on scattering mechanisms taking place in the $LaSn_3$ is very helpful for a later interpretation of more complicated transport phenomena in the case of other $RESn_3$ intermetallics, where the f–electrons scattering mechanisms play a major role. This motivated us to examine thermal conductivity of $LaSn_3$. The results obtained by us are the first experimental data on thermal conductivity for the $LaSn_3$, although its electron transport properties are well known [1–3].

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2. Experimental

Single crystals of the $LaSn_3$ have been grown using self–flux method [4]. The size of the sample was $0.6\times0.6\times3.0$ mm^3. The residual resistivity ratio (RRR) $\equiv \rho_0/\rho_{300}$ for our samples was close to 41. The both, high value of the RRR factor as well as a very sharp maximum observed on the temperature dependence of the thermal conductivity indicate the high quality of the sample. The thermal conductivity was measured using the stationary heat flux method within the temperature range between 6 K and 300 K. The experimental set–up and the measurement procedure have been described in detail in [5]. The temperature gradient applied along the sample ranged between 0.1 K and 0.5 K for the lower and higher temperatures, respectively. A particular care was taken to avoid a parasitic heat transfer between the sample and its environment. The measurement error was below 5%.

3. Results and discussion

It is generally assumed that the total thermal conductivity λ is the sum of two contributions:

$$\lambda = \lambda_{\mathrm{e}} + \lambda_{\mathrm{ph}} ,$$

where λ_{e} and λ_{ph} are the electronic and the phonon thermal conductivities, respectively. Assuming that all the mechanisms responsible for the thermal resistivity of a metal are additive (the Matthiessen rule), the electronic contribution to the thermal conductivity can be expressed as follows:

$$1/\lambda_{\mathrm{e}} = W_{\mathrm{e}} = W_{\mathrm{e,i}} + W_{\mathrm{e,ph}} ,$$

where the particular terms occurring in the above equation denote the thermal resistivities due to collisions of conduction electrons with the lattice imperfections and phonons respectively. The scattering of electrons on the lattice imperfections is elastic and it is most important in low temperatures, while the electron–phonon one may have elastic or inelastic character. The latter scattering is described by process of the normal type or the Umklapp one. Fig. 1 shows the temperature dependence of the thermal conductivity over the whole temperature range investigated. The dependence displays a sharp maximum in low temperatures, which is characteristic for pure metals. Maximum of $\lambda(T)$ takes place at 14 K. Below this temperature $\lambda(T)$ is proportional to $T^{0.75}$. Since the linear $\lambda(T)$ dependence is typical for the scattering of electrons on lattice imperfections, we suggest that this mechanism plays essential role below 14 K. In the medium temperature range $14\ \mathrm{K} < T < 100$ K, the $\lambda(T)$ is proportional to $\exp(5.2/T)$. The exponential dependence is characteristic, in turn, for the inelastic scattering of electrons on lattice vibrations (Umklapp process). For the highest temperature range

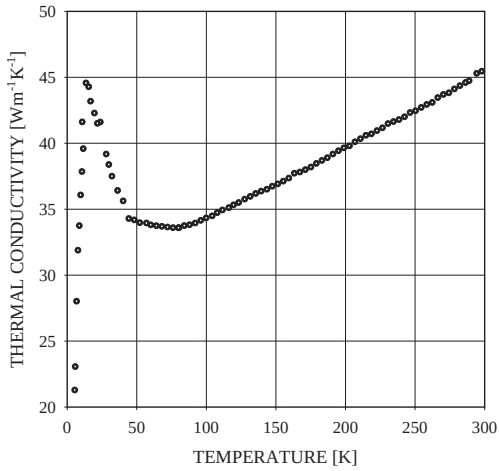

Fig. 1. Temperature dependence of the thermal conductivity for $LaSn_3$.

investigated $T > 100$ K, $\lambda(T)$ changes linearly with temperature. The linear dependence is not predicted theoretically, but it had been observed previously in many RE intermetallics [6]. We do not know what kind of mechanism is responsible for the linear $\lambda(T)$ dependence in high temperatures. The temperature dependence of the Lorenz function $L(T) = \lambda(T)\rho(T)/T$ is shown on Fig. 2. $L(T)$ is lower than $L_0 = 2.45{\times}10^{-8}$ [WΩK^{-2}] in temperatures below 50 K. It means, that for $T < 50$ K the low-angle electron–phonon inelastic scattering is the dominating one, while the high–angle electron–phonon inelastic scattering plays an essential role above 50 K, where $L > L_0$.

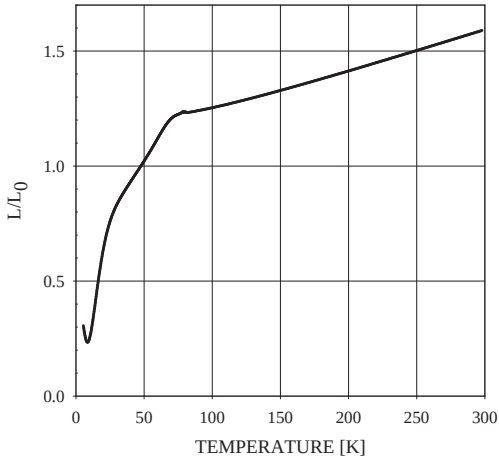

Fig. 2. Temperature dependence of the reduced Lorenz function for $LaSn_3$.

It is characteristic for $LaSn_3$ that its $L(T)$ is higher than L_0 in a wide temperature range 70–300 K and that it increases up to 1.6 L_0 at 300 K. Such behavior of the $L(T)$ together with the observed exponential $\lambda(T)$ dependence led us to the conclusion that the Umklapp process plays an important role in the heat transport of $LaSn_3$ at temperatures $T > 50$ K.

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REFERENCES

[1] W.D. Grobman, *Phys. Rev.* **B5**, 2924 (1972).

[2] B. Staliński, Z. Kletowski, Z. Henkie, *Phys. Status Solidi* **A19**, K165 (1973).

[3] A. Hasegawa, *J. Phys. Soc. Jpn.* **50**, 3313 (1981).

[4] Z. Kletowski, N. Iliew, Z. Henkie, B. Staliński, *J. Less–Common Met.* **110**, 235 (1985).

[5] A. Jeżowski, J. Mucha, G. Pompe, *J. Phys.* **D20**, 1500 (1987).

[6] J. Mucha, A. Jeżowski, A. Czopnik, H. Misiorek, Z. Kletowski, *J. Alloy. Compd.* **199**, 145 (1993).