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THERMAL CONDUCTIVITY OF $PrSn_3$*

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Results of thermal conductivity measurements of $PrSn_3$ are presented. The measurements were curried out in the temperature range 4–300 K on a single crystal sample oriented along the [100] direction. It was found that the thermal conductivity λ is dominated by scattering electrons in the whole temperature range under examination. The magnetic contribution to the thermal conductivity $\lambda_{\rm e,m}$ has been separated and its temperature dependence $\lambda_{\rm e,m}(T)$ has been obtained. The thermal conductivity of $PrSn_3$ was found as a linear function of temperature at higher temperatures, whereas an anomaly was observed below T_N. In ordered state, the $\lambda_{\rm e,m}(T)$ changes in the opposite way as the total thermal conductivity does. The temperature dependence of the Lorenz number exhibits a pronounced maximum at about 20 K.

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1. Introduction

The $PrSn_3$ compound belongs to the $RESn_3$ family of intermetallics crystallising with the $AuCu_3$ type of structure where the RE^{3+} ions form a simple cubic lattice. Most compounds of this family order antiferromagnetically below 45 K. $CeSn_3$ and $YbSn_3$ which do not exhibit the magnetic order were studied from a view point of Kondo lattice, heavy fermion and superconductivity [1–3]. $PrSn_3$ orders antiferromagnetically at 8.6 K. A number of

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anomalous behaviours occurring in this compound have been interpreted in terms of the Kondo effect [4–6]. Recently the obtained data on a heavy cyclotron mass [7] have confirmed the possible appearance of the Kondo effect in this compound. This motivated us to examine thermal conductivity of $PrSn_3$.

2. Experimental

A single crystal ingot of $PrSn_3$ was grown by the Czochralski pulling method in an induction furnace under helium gas atmosphere of $3.6\,\mathrm{KG/cm^2}$. The size of the mono-crystalline sample used was $0.8 \times 0.8 \times 7.0$ cm^3. Its residual resistivity ρ_0 and the Residual Resistivity Ratio (RRR) $\equiv \rho_{300}/\rho_0$ were 0.14 $\mu\Omega$ cm and 260, respectively. This indicates the high quality of the sample. The thermal conductivity was measured using the stationary heat flux method in the temperature range 4–300 K. The experimental set-up and the measurement procedure have been described in detail in [5]. The temperature gradient along the sample was in the range 0.1–0.5 K. Particular care was taken to avoid a parasitic heat transfer between the sample and its environment. The measurement error was below 2% and the surplus error estimated from the scatter in the measurement points, did not exceed 0.3%.

3. Results and discussion

Fig. 1 shows the temperature dependence of the thermal conductivity λ of $PrSn_3$ over the whole temperature range investigated. In the paramagnetic state the thermal conductivity λ decreases strongly with decreasing temperature. Below the Néel temperature an anomaly is visible on the $\lambda(T)$ dependence (see inset in Fig. 1). The origin of this anomaly is unknown yet.

The total thermal conductivity of a solid may be regarded as a sum of electronic λ_{e}, phonon λ_{ph} and magnetic λ_{m} contributions. Assuming validity of the Mattiessen rule, the electronic contribution to the thermal conductivity is equal

$$(\lambda_{\mathrm{e}})^{-1} = W_{\mathrm{e}} = W_{\mathrm{e,i}} + W_{\mathrm{e,ph}} + W_{\mathrm{e,m}}\,, \qquad (1)$$

where the particular terms denote the thermal resistivity due to collisions of conduction electrons with the lattice imperfections, phonons and magnetic moments of the 4-f electrons, respectively. Assuming validity of the Wiedemann–Franz law, the magnetic contribution to the electronic thermal conductivity $\lambda_{\mathrm{e,m}} = \mathrm{L}_0 T/\rho_{\mathrm{m}}$ was calculated in the temperature range 5–10K.

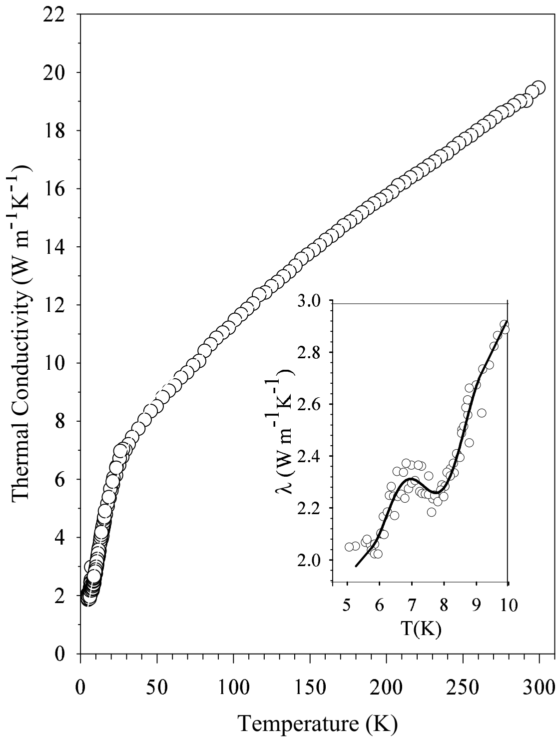

Fig. 1. Temperature dependence of the total thermal conductivity λ. The inset shows $\lambda(T)$ close to the Néel temperature T_{N}.

Here the Lorenz constant $\mathrm{L}_0 = 2.45 \times 10^{-8}\,\mathrm{W\Omega K^{-1}}$ and $\rho_{\mathrm{m}} = \{\rho(\mathrm{PrSn_3}) - \rho(\mathrm{LaSn_3})\}$ is the magnetic contribution to the electrical resistivity. Values for ρ_{m} were taken from [6]. Fig. 2 shows the temperature dependencies of both the calculated magnetic contribution to electronic thermal conductivity $\lambda_{\mathrm{e,m}}$ and the measured total thermal conductivity $\lambda(T)$. It is surprising that the behaviours of both contributions are opposite in the ordered state. The $\lambda_{\mathrm{e,m}}$ increases rapidly with decreasing temperature, whereas $\lambda(T)$ decreases, exhibiting a marked anomaly below T_{N}. Now we can not explain this phenomenon. Fig. 3 shows the temperature dependence of the Lorenz number defined as

$$L = \lambda\rho/T\,. \tag{2}$$

Where λ and ρ are total thermal conductivity and electrical resistivity, respectively. For materials where the Kondo effect plays an essential role the Lorenz number usually changes his value with temperature. For the $\mathrm{PrSn_3}$ case one observes a change of $L(T)$ from $0.8\,\mathrm{L}_0$ to $2\,\mathrm{L}_0$ in the temperature range 4–80 K. This confirms the existence of the Kondo effect in $\mathrm{PrSn_3}$.

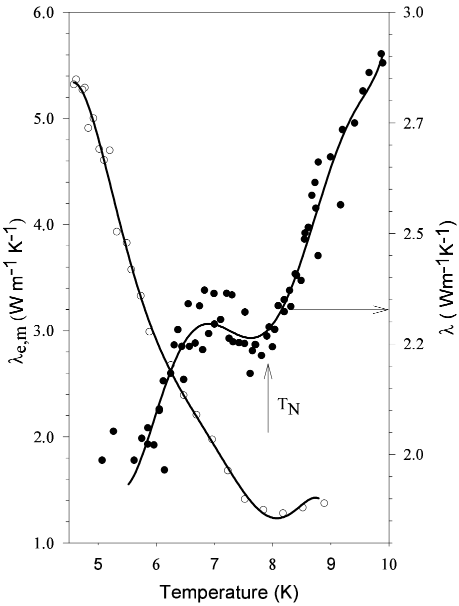

Fig. 2. Temperature dependence of both the magnetic contribution to the electronic $\lambda_{\mathrm{e,m}}$ and the total thermal conductivity λ.

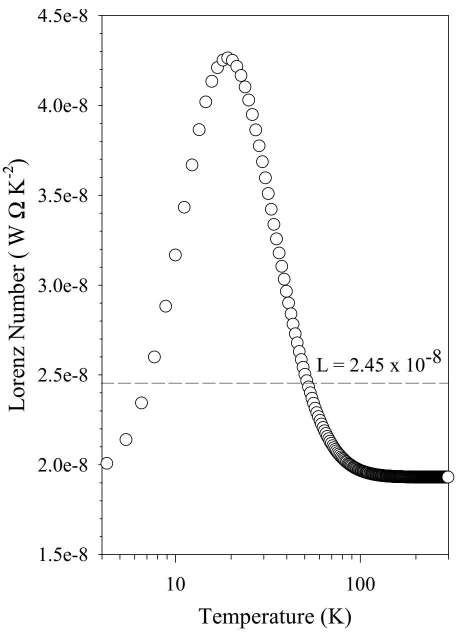

Fig. 3. Temperature dependence of the Lorenz number for $PrSn_3$. The dashed line represents theoretical value of the Lorenz number.

4. Conclusions

The thermal conductivity of a $PrSn_3$ single crystal was measured in the temperature range 4–300 K along the [100] axis. The temperature dependence of the Lorenz number confirms the earlier reports [6, 7] on a possible existence of the Kondo effect in $PrSn_3$.

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