acta phys. slov. 35 (1985), No. 4—5

THERMAL CONDUCTIVITY OF DYSPROSIUM AND SAMARIUM AT LOW TEMPERATURES1)

A. FEHER2), P. PETROVIČ2), Š. MOLOKÁČ3), Š. JÁNOŠ3), Košice

The paper reports the results of the investigation into the thermal conductivity of polycrystalline dysprosium and samarium in the helium temperature range. Experimental results show that in this temperature range only electrons scattered on impurity atoms and on lattice defects participate in the heat transfer.

УДЕЛЬНАЯ ТЕПЛОПРОВОДНОСТЬ ДИСПРОЗИЯ И САМАРИЯ ПРИ НИЗКИХ ТЕМПЕРАТУРАХ

В работе приводятся результаты исследований теплопроводности поликристаллических образцов диспрозия и самария в области гелиевых температур. Обнаружено, что перенос тепла в образцах в основном определяется рассеянием электронов проводимости на атомах примесей и дефектах решетки.

I. INTRODUCTION

The study of the thermal conductivity of lanthanides at low temperatures provides information on the influence of the particular scattering mechanisms of the conduction electrons and phonons on the heat transfer. So far the experimental evidence of the thermal conductivity of the lanthanides is very limited, especially in the temperature range below 4 K [1]. The external magnetic field influences the magnetic structure of the lanthanides as evidenced by the results of the electrical magnetoresistance measurements [2]. It is therefore reasonable to expect that the thermal conductivity of the lanthanides will be influenced in a similar way by an external magnetic field. In the region of the residual electrical resistance (usually below 4 K), where the scattering of conduction electrons on impurities and lattice defects plays the most important role, a linear dependence of the thermal conductivity on the temperature is expected. In this case the thermal conductivity is determined by the Wiedemann-Franz law (W-F) as $K = L_0 T/\varrho_0$, where $L_0 = 2.445 \times 10^8$ WΩK^{-2}, ϱ_0 is the residual electrical resistance and T is temperature. The participation of phonos in the heat transfer is manifested by a quadratic term in the temperature dependence of the thermal conductivity. The magnetic contribution to the thermal conductivity is manifested probably by a similar dependence whose coefficient depends on the applied magnetic field. Generally, the applied magnetic field decreases — in a rough agreement with Kohler's rule — the electronic part of the thermal conductivity in pure paramagnetic and diamagnetic metals. In metals with a magnetic ordering (both crystalline and non-crystalline) the influence of the magnetic field on the thermal conductivity may be more complex. The magnetic field may lead either to an increase of the thermal conductivity due to the lower scattering of the conduction electrons on the magnetic structure, or to a decrease of it due to the suppression of magnons participating in the heat transfer.

The thermal conductivity of dysprosium in the helium temperature range was studied only in [1] and the data for the thermal conductivity of samarium are only given in [3] for temperature above 4 K. However, in neither case [1, 3] the influence of the magnetic field on the thermal conductivity was reported.

II. EXPERIMENTAL METHOD

A two-chamber cryostat [4] was used to measure the thermal conductivity of Dy from 2 K to 7 K and Sm from 2 K to 4.8 K. The thermal conductivity was measured by a steady-state method. The temperature gradient along the sample was measured by germanium calibrated thermometers, whose electrical resistance was measured by an AC bridge Cryo-4A. The samples had the form of cylinders with a diameter of 3 mm, the distance between the thermometers was 39.7 mm for Dy and 36.9 mm for Sm. The samples were supplied by Gyredment, USSR and were not heat treated prior to the measurements. The ratio $R_{300}/R_{4.2}$ was 52 for the Dy sample and 20 for the Sm sample.

III. RESULTS AND DISCUSSION

The results of the thermal conductivity measurements for Sm are given in Fig. 1. In the temperature range from 2 K to 5 K the linear dependence of the Sm thermal conductivity on the temperature was found as $K = 0.46\ T$ [W/mK]. This behaviour confirms that the conduction electrons are responsible for the heat transfer in Sm in the given temperature range and that the main scattering process in the heat transfer is realized by the conduction electron scattering on the impurities. As it is

---

1) Contribution presented at the 7th Conference on Magnetism, KOŠICE, June 5—8, 1984.

2) Dept. of Experimental Physics, Faculty of Science, Šafárik University, Februárového víťazstva 9, 041 54 KOŠICE, Czechoslovakia.

3) Institute of Experimental Physics, Slov. Acad. Sci., Solovjevova 47, 041 54 KOŠICE, Czechoslovakia.

seen, the antiferromagnetic structure which does exist in Sm at temperatures below 12 K has no apparent influence on the thermal conductivity.

Fig. 2 shows the temperature dependence of the Dy thermal conductivity from 2 K to 7 K, which is linear with K = 2.35 [W/mK]. In an applied field of 3 T no changes in the thermal conductivity are observed within the measuring error of 5 %. Using the W-F law and the values of electrical conductivity of Dy in the region of the residual electrical resistance, the electronic contribution K_e of the thermal conductivity was determined, also in Fig. 2. The absolute value of the electronic part calculated from the W-F law is lower than the measured value of the total thermal conductivity. This difference cannot be caused by the phonon part of the thermal conductivity, which has quadratic dependence on the temperature. The participation of magnons on the heat transfer in Dy need not to be considered either, because the energy gap Δ of magnons is $\Delta / k_B = 19$ K for Dy (where k_B is the Boltzmann constant), thus the excitation of the thermal magnons at temperatures below 7 K is not probable. The observed difference in the thermal conductivity of Dy may be explained by the inaccuracy of the value of the residual electrical resistance $\varrho_0 = 1.4$ μΩcm, originating in the process of preparing point electrical contacts on the rapidly oxidating Dy sample. We suppose from the obtained results that also in Dy the heat transfer is realized mainly by conduction electrons scattered on impurities. The ferromagnetic structure of Dy has no apparent influence on the thermal conductivity below 7 K.

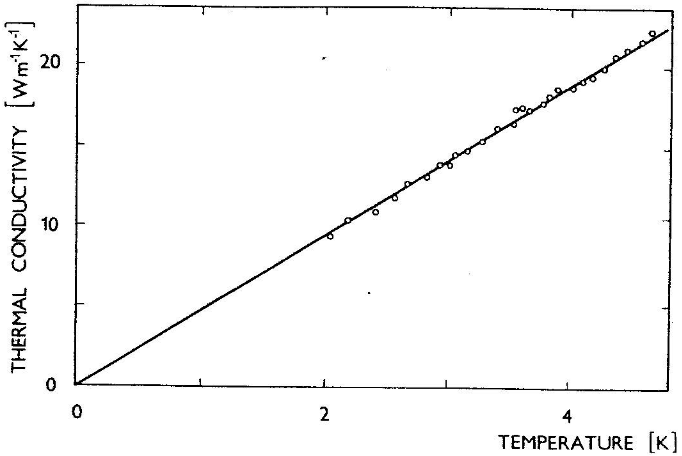

Fig. 1. Temperature dependence of the thermal conductivity of samarium.

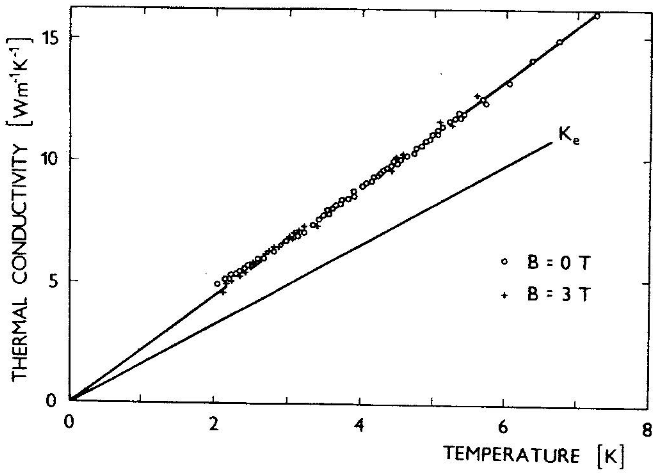

Fig. 2. Temperature dependence of the thermal conductivity of dysprosium without a magnetic field and in a magnetic field of 3T (K_e — the calculated electronic part of the thermal conductivity using the W-F law).

REFERENCES

[1] Ratnalingam, R., Sousa, J. B.: J. Low Temp. Phys. *4* (1971) 401.
[2] Singh, R. L.: Phys. Rev. B *14* (1976), 4106.
[3] Arajs, S., Dunmyre, C. R.: Z. Naturforsch. *21a* (1966), 1856.
[4] Feher, A., Jánoš, Š.: Čs. čas. fyz. A *30* (1980), 37.

Received November 13th, 1984
Revised version received February 12th. 1985