SCATTERING OF CONDUCTION ELECTRONS ON THE MAGNETIC SPIN SYSTEM IN THIN DYSPROSIUM FILMS[1])

J. DUDÁŠ[2]), A. FEHER[3]), J. DANIEL-SZABÓ[3]), Košice

The influence of the spin system on the conduction electron scattering in thin dysprosium films has been studied. The increase of spin disorder resistivity with decreasing thickness of these films has been observed especially below ~120 nm. Spin resistivity depends on the square of the temperature below 60 K with the transition to the $T^{3/2}$ dependence for $T>60$ K.

I. INTRODUCTION

The magnetic structure of dysprosium influences the transport properties due to the direct exchange interaction occurring between the conduction electrons and the $4f$ electrons [1]. We have studied the scattering of the conduction electrons on the magnetic spin structure and also in the paramagnetic region, for thin dysprosium films in the temperature range from 4.2 K to 300 K for the interval of thicknesses from 26.3 nm to 350 nm.

II. EXPERIMENTAL METHOD

The preparation of thin dysprosium films and their electrical contacts is described elsewhere [2, 3]. The thickness of the films was measured by the absolute optical Tolansky method with the accuracy of ± 2 nm. Electrical resistance was measured by using conventional dc method described elsewhere [2] with the accuracy of ± 0.05 %. The temperature was measured with germanium and platinum thermometers from Lake Shore Cryotronics, Inc. by means of an ac resistance bridge with the accuracy of ± 0.05 K. The samples were mounted in the helium cryostat [2]; the temperature drift was controlled by the Joule heating and did not exceed 5 K per hour in the vicinity of the magnetic phase transitions.

[1]) Contribution presented at the 7th Conference on Magnetism, Košice, June 5—8, 1984.
[2]) Dept. of Theoretical Electrotechnics and Circuit Techniques, Technical University, Komenského park 3, 043 82 KOŠICE, Czechoslovakia.
[3]) Dept. of Experimental Physics, Faculty of Science, Šafárik University, nám. Febr. víťazstva 9, 041 54 KOŠICE, Czechoslovakia.

III. RESULTS AND DISCUSSION

Spin disorder resistivity caused by conduction electron scattering on disordered magnetic spin, in the paramagnetic region was estimated as follows [1]

$$\varrho_{spin} = \varrho - \varrho_0 - \varrho_{ph}$$

where ϱ is the measured value, ϱ_0 is the residual value and ϱ_{ph} arises from conduction electron scattering by phonons. The values of ϱ_{spin} estimated from this expression for all the studied films are shown in Fig. 1 as a function of thickness. The increase of the values of ϱ_{spin} is clearly seen in this figure, especially for thicknesses lower than ~120 nm. The values of ϱ_{spin} for thicker films are closer to

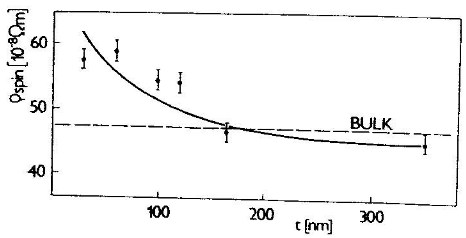

Fig. 1. Thickness dependence of the spin disorder resistivity of thin dysprosium films.

the $\varrho_{spin} = 47.4 \times 10^{-8}$ Ωm for the c-axis of single crystal dysprosium and for lower thicknesses closer to the value $\varrho_{spin} = 61.9 \times 10^{-8}$ Ωm for the basal plane of Dy [1]. Therefore we assume the thin dysprosium films to exhibit the preferential orientation in the c-axis in the substrate plane with increasing thickness. This assumption could be supported by the anomalies of the temperature dependences of electrical resistance for our films in the vicinity of the Néel point [3].

Assuming the linear temperature dependence of ϱ_{ph} down to 0.2 T_D (Debye temperature) we estimated the conduction electron scattering on the magnetic spin structure ϱ_m. The temperature dependences of ϱ_m are illustrated in Fig. 2 in the log-log scale for all the studied films as well as for the bulk sample. Analysing these dependences we found $\varrho_m \sim T^2$ in the temperature range from ~45 K to ~60 K and the $T^{3/2}$ type of the dependence of ϱ_m for temperatures from ~60 K to ~80 K for all the studied films. The observed ϱ_m vs. T dependences of our films are in agreement with our results in the bulk sample. We conclude that in contrast to [4] we have observed the increase of the ϱ_{spin} with decreasing thickness. Moreover, we did not find any apparent influence of the thickness on the ϱ_m vs. T dependence of our dysprosium thin films.

ACKNOWLEDGEMENTS

We express our appreciation to Dr. Š. Jánoš for his continual interest in this work and to M. Bobalská and A. Pavlendová for their help in some measurements.

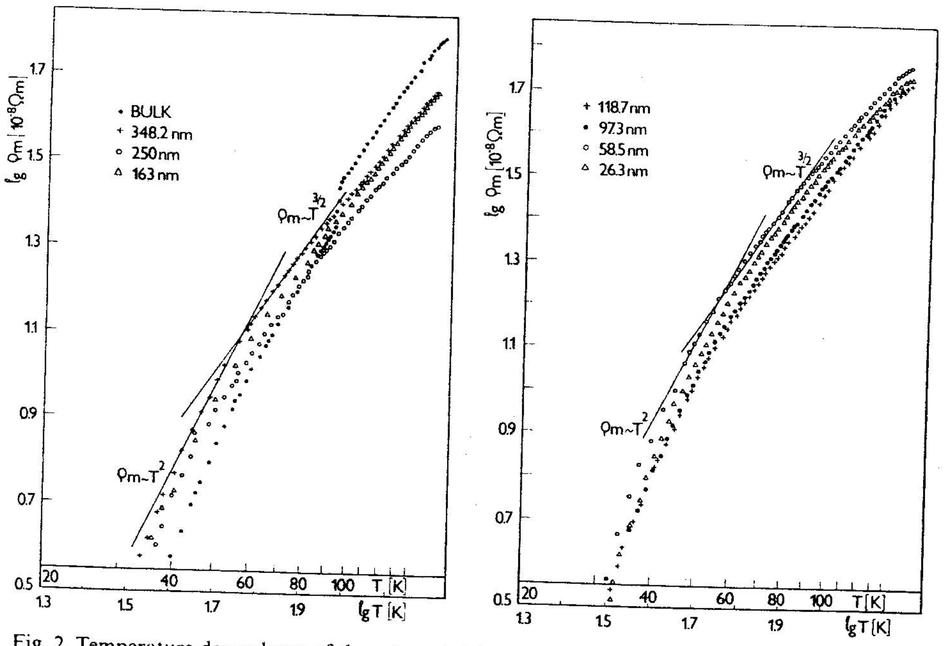

Fig. 2. Temperature dependence of the spin resistivity of thin dysprosium films in the log-log scale: a) for thicknesses of 1 — bulk, 2 — 348.2 nm, 3 — 250 nm, 4 — 163 nm; b) 5 — 118.7 nm, 6 — 97.3 nm, 7 — 58.5 nm, 8 — 26.3 nm.

REFERENCES

[1] Taylor, K. N. R., Darby, M. F.: *Physics of Rare Earth Solids*, Chapmann and Hall, London 1972.

[2] Dudáš, J., Feher, A.: Elektrotechn. čas. 35 (1984), 688.

[3] Dudáš, J., Feher, A., Konč, M.: 7th Conf. on Magnetism, Košice, June 5—8, 1984. It will be published in Ac. Phys. Slovaca.

[4] Lodge, F. M. K.: *Thesis.* University of Durham, 1969.

Received January 4th, 1985

РАССЕЯНИЕ ЭЛЕКТРОНОВ ПРОВОДИМОСТИ НА СПИНОВОЙ СИСТЕМЕ В ТОНКИХ ПЛЕНКАХ ДИСПРОЗИЯ

В работе приведены результаты исследований влияния спиновой системы на рассеяние электронов проводимости в образцах тонких пленок из диспозия. Обнаружено, что составляющая удельного сопротивления, обусловленная спиновой неупорядоченностью, увеличивается с уменьшением толщины пленок особенно в области толщин ниже 120 нм. Удельное электрическое сопротивление, обусловленное рассеянием электронов проводимости на спиновой структуре, при температурах ниже 60 К имеет температурную зависимость типа T^2, Которая для температур выше 60 К постепенно переходит в зависимость типа $T^{3/2}$.