MAGNETO-OPTICAL EFFECTS OF THE ANTIFERROMAGNETIC SEMICONDUCTOR EuTe

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The Faraday rotation and the absorption of EuTe have been measured on thin films in the fundamental absorption region from 2.0 to 4.3 eV. Above the Néel temperature, $T_N = 9.6 \, ^\circ$K, we observe in the energy range of the $4f^7 - 4f^6 5d_{5/2}$ transition, one minimum and two main maxima of rotation. The temperature dependence of the maxima is found to be different: for one extremum the rotation resembles the magnetization curve of an antiferromagnet with a maximum at the Néel temperature; for the second, however, the rotation shows a ferromagnetic dependence on temperature with a point of inflexion at the Néel temperature and saturation for lower temperatures.

This ferromagnetic behaviour within the antiferromagnetic structure of EuTe can be explained by assuming a ferromagnetic superlattice which gives rise to a magnetic Brillouin zone. Thus the “ferromagnetic peak” is attributed to transitions from the localized $4f$ ground state to the new zone boundaries.

The europium chalcogenides EuO, EuS, EuSe and EuTe are magnetic semiconductors which all crystallize in the NaCl structure. The first two members of the series are ferromagnetic, while EuSe is metamagnetic and EuTe antiferromagnetic with a Néel temperature of 9.6 $^\circ$K. The optical absorption spectrum is similar for all four substances and is shown for a thin film of EuTe in fig. 1. Two regions of intrinsic absorption can be distinguished and mainly be attributed to transitions from the localized $4f^7(8S_{7/2})$ ground state into the crystal field split $5d_{5/2}$ and $5d_{3/2}$ states, respectively.

Optical transitions from spin polarized $4f^7$-states are of great interest for the investigation of magneto-optical effects. Thus Busch and Wachter [1] found a large red shift of the absorption edge for the ferromagnetic Eu-chalcogenides in the vicinity and below the Curie temperature. This effect, and likewise a splitting of absorption peaks can be explained by an exchange splitting and spin orbit coupling of the $4f^6(7F_J) 5d$ excited states [2, 3].

The purpose of this paper is to examine the change of the energy band structure of EuTe when the substance orders antiferromagnetically. Since any effect is expected to be much smaller than in the ferromagnetic Eu-chalcogenides, it is necessary to employ a differential method like the Faraday rotation (F.R.) besides the absorption measurements. We were able to show a doubling of the maxima in the F.R. in the energy range of the $4f^7 - 5d_{5/2}$ transition upon cooling below the Néel temperature in very weak magnetic fields. This and other arguments discussed below, are taken as direct evidence of the existence of a magnetic Brillouin zone, theoretically predicted by Slater [4] and also taken into consideration by Feinleib and Pidgeon [5].

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To measure the F.R. up to 4.3 eV (i.e., for absorption coefficients between $0.6 \times 10^5$ and $6 \times 10^5 \, \text{cm}^{-1}$) we must use thin films, ranging in thickness from 300 to 2200 Å. Absorption measurements at room temperature show no variation of the absorption coefficient with film thickness and were in good agreement with those obtained from an analysis of reflectivity measurements on single crystals [6]. The cubic NaCl-structure and the lattice constant of the films were controlled by X-ray diffraction. A mass spectroscopic analysis did not reveal any change in the chemical composition of the films compared with the original charge. The F.R. measurements up to 3.2 eV were performed with an automatic registration system (similar to [7]) and in the high energy range point by point.

![Graph](image)

Fig. 1. Absorption coefficient of EuTe at 7 K and zero magnetic field (without correction for reflection losses), and Faraday rotation at 7 K and fields of 6.7 kOe and 2.2 kOe.

Besides the absorption at 7 K, fig. 1 shows the F.R. between 2.2 and 4.3 eV at 7 K with fields of 6.7 and 2.2 kOe. The F.R. is defined as one half the rotation observed when the field is reversed. For the higher field one discerns 6 distinct peaks denoted by A to F. For 5 of these (A, B, C, E, F) we find correlated absorption peaks or shoulders at nearly the same energies. The very complex structure between the maxima A and B, and the maximum D, however, cannot be resolved in the absorption, clearly indicating the higher resolution of the F.R. Faraday measurements at low fields which less disturb the antiferromagnetic spin structure, show two smaller humps at 2.77 and 2.92 eV.

Comparing these features with the F.R. or the circular dichroism [8] at room temperature, where only two maxima appear in the spectral range between 2.2 and 3.2 eV, we observe a doubling of the maxima going from the paramagnetic to the antiferromagnetic state.