Magnetic field induced polarized optical absorption in europium chalcogenides

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Abstract. The optical absorption spectrum of EuTe epitaxial layers grown by molecular beam epitaxy was studied at low temperatures and high magnetic fields, using circularly polarized light. At high magnetic fields a narrow line (width 41 meV) emerges at the low energy side of the absorption threshold. The line shows a huge displacement with magnetic field and is attributed to a magnetic exciton. The emergence of this line has a strong effect on the Faraday rotation, which becomes strongly non-linear.

Europium chalcogenides have interesting optical properties due to the *d-f* exchange interaction between band-edge electrons and localized Eu^{2+} spins [1,2]. Early investigations showed that the band-edge absorption spectrum in EuTe is associated with a $4f^7 \rightarrow 4f^6 5d$ electronic transition, characterized by a very broad band seen at ~2.3 eV (full width at half maximum (FWHM) of almost 1 eV). It also presented a broad photoluminescence (PL) (FWHM 150 meV) with a large Stokes shift (>0.6 eV). Recently, molecular beam epitaxy (MBE) was used to produce EuTe, which has lead to the observation of a much narrower photoluminescence line (FWHM 10 meV), and at a much photon higher energy (1.92 eV) than in previous investigations [3].

In this work we studied the $4f^7 \rightarrow 4f^6 5d$ absorption of epitaxial layers of EuTe. The layers (thickness in the range 0.18 – 2μm) were grown by molecular beam epitaxy on (111) BaF2 substrates. The x-ray rocking curve of the (222) Bragg reflection of the thicker layers showed a peak corresponding to a bulk lattice parameter of 0.6600 nm, with a full width at half maximum of only 400 arcsec. PL measurements at T=2K showed a sharp luminescence (FWHM 10 meV) at 1.922~eV. The optical absorption spectra were measured at 1.8K, using left and right circularly polarized light, in magnetic fields of intensity up to 17 Tesla. Measurements were done in the Faraday configuration, using optical fibers coupled to *in situ* focusing optics and circular polarizers. At zero magnetic field, the optical absorption spectrum is described by a threshold around 2.3~eV (Fig. 1). When the intensity of the applied magnetic field is increased above 6 T, a very sharp absorption line (full width at half maximum of 41 meV) appears at the low energy side of the absorption onset. With increasing field this line shows a huge red shift (~36 meV/T).

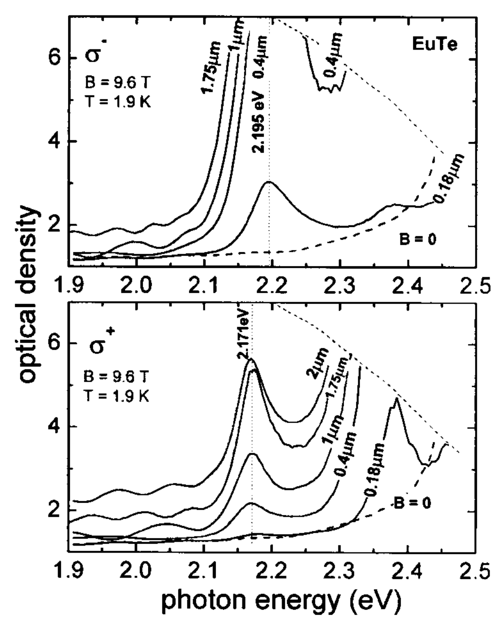

FIGURE 1. Optical absorption in EuTe layers.

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At high fields the absorption intensity is much greater in the σ^- polarization than in the σ^+ one. The optical density shows a linear dependence on the thickness of the layers, demonstrating that it is a bulk effect (Fig. 2).

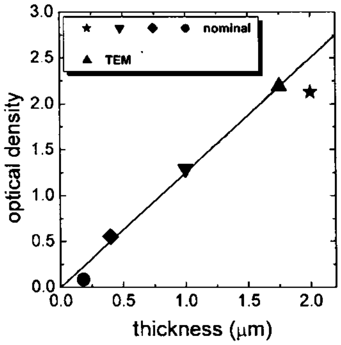

FIGURE 2. Thickness dependence of the σ^+ absorption.

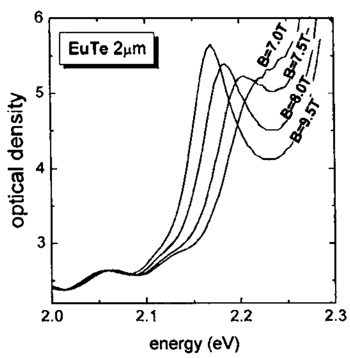

FIGURE 3. σ^+ absorption as a function of magnetic field.

The position of the σ^+ absorption line was studied as a function of the magnetic field intensity (Fig. 3, 4). Solid line in figure 4 is the theoretical result, assuming the formation of a magnetic exciton whose exchange energy is 0.15 eV and a bandgap of 2.321 eV [4].

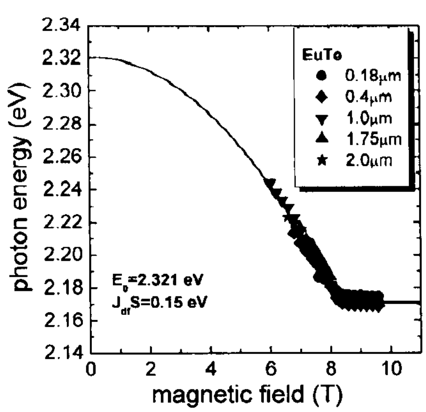

FIGURE 4. Position of the σ^+ absorption peak.

The Faraday rotation (FR) in the transparency gap was also studied at T=2K (Fig. 5). FR is linear at low fields. However, at fields when the new absorption line emerges, Faraday rotation becomes strongly non-linear. This strong FR non-linearity is in sharp contrast to earlier EuTe investigations [5]. The non-linear FR can be qualitatively explained by the emergence of the optical absorption line at high fields. The theoretical line shown in Fig. 5 is given by [6]

$$\Theta_F = \left[\frac{A}{E_0^2 - (h\nu)^2} + B \frac{f_X}{E_X^2 - (h\nu)^2} \right] M(B) \qquad (1)$$

where E_0=2.321 eV is energy gap, E_X is the position of the magnetic exciton line, f_X is the oscillator strength (taken to be proportional to the E_X absorption intensity), M(B) is the magnetization, and A and B are adjustable constants.

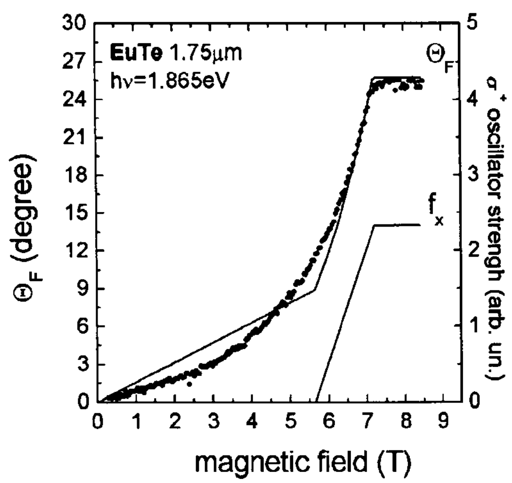

FIGURE 5. Faraday rotation for $h\nu$=1.865 eV.

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