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CHANGES OF FIR REFLECTIVITY OF HgSe:Cr IN A MAGNETIC FIELD

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The results of FIR magnetoreflectivity of HgSe:Cr are presented. They are interpreted using a classical dynamic dielectric function.

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Diluted magnetic semiconductors are crystals in which one of the non-magnetic components is substituted in a controlled way by magnetic ions [1]. Currently, the main interest has shifted from manganese based compounds to crystals in which the cations are substituted by other transition metal ions, see for example, see for example [2]. In HgSe:Cr the Cr^{2+} ion substitute Hg atoms in the zinc blende type host lattice.

HgSe, having an inverted band structure is always n-type. The only possible way of investigating low-energy excitations in such a material is through reflectivity measurements. The considerable number of competing processes such as plasma-, phonon- and electron-related excitations can make it difficult to identify the origin of observed structures. However, for energy levels which can be tuned by an applied magnetic field, magnetospectroscopy can help to clarify the nature of the observed spectral features.

The investigated samples had low concentrations of Cr, not exceeding several times 10^{18} cm^{-3}. Therefore for these crystals we do not expect to observe effects due to local vibrations and exchange interaction. The magnetoreflectivity measurements were performed in the spectral range 50–700 cm^{-1} in magnetic fields up to 20 T using a Fourier Transform Spectrometer which was connected via an outcoupling optic to either a superconducting coil or a Bitter magnet [3]. All measurements were done in the Faraday geometry with nonpolarized light at 2 K.

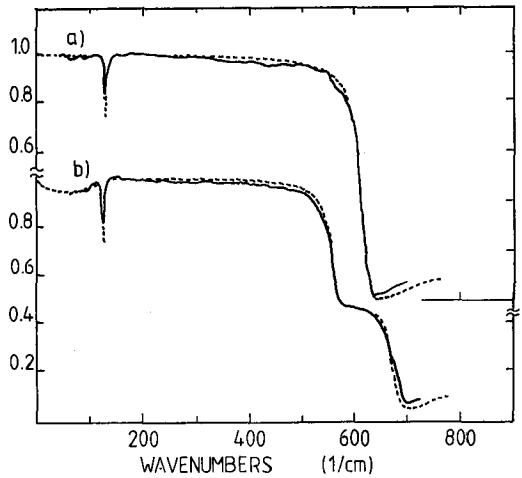

Fig. 1. The reflectivity of HgSe:Cr measured at 2 K at 0 T (a) and 8 T (b). The solid line represents experimental data and the broken line shows the calculated reflectivity spectrum with the following parameters: TO phonon oscillator strength 4.5, TO phonon energy 132.4 cm^{-1}, TO phonon damping 1 cm^{-1}, plasma energy 610 cm^{-1}, plasma damping 20 cm^{-1}, and $\varepsilon_{inf} = 15$. (See text for details).

Typical reflectivity data taken at zero magnetic field are shown in Fig. 1a. At about 620 cm^{-1} the plasma edge is well pronounced. The structure at about 130 cm^{-1} is due to the TO phonon. The presented behavior is well known from previous measurements in HgSe [4, 5] and has been explained using the dynamic dielectric function (DDF). In our case with the free electron concentration of the order of 10^{18} cm^{-3}, the Fermi energy is so large that in the investigated energy range at 2 K the dielectric function due to the $\Gamma_8^v - \Gamma_8^c$ transitions can be taken as real constant [4–6]. We therefore used the DDF in the following form:

$$\varepsilon(\omega) = \varepsilon_{inf} + \varepsilon_{fc}(\omega) + \varepsilon_{ph}(\omega), \tag{1}$$

where ε_{inf} is the so-called high frequency dielectric constant, $\varepsilon_{fc}(\omega)$ is the free-carrier term taken from the Drude model and is magnetic field dependent, (see for example [6]), and $\varepsilon_{ph}(\omega)$ is the phonon contribution. Because the Cr concentration in the investigated crystals is small, as in typical mixed crystals, we take only HgSe phonon modes into account in $\varepsilon_{ph}(\omega)$. The theoretical curve calculated with parameters listed in the caption of Fig. 1 well describes the experimental data.

The measured magnetoreflectivity at 8 T is shown in Fig. 1b. Because the light was unpolarized, the experimental data are a superposition of reflectivities for Cyclotron Resonance Active (CRA) (−) and Cyclotron Resonance Inactive (CRI) (+) circular polarization. As one can see, all typical features of classical magnetoplasma, are visible, (see for example [6]). The plasma edge is split into two components normally observed only for one circular polarization. At low energy the opening of a helicon wave "window" is also clearly visible. We would like to attract the reader's attention to the "unusual" behavior of the phonon structure.

It shifts with magnetic field and becomes dispersive (Fig. 2) when entering the helicon wave region. To explain the described behavior of reflectivity we used the dielectric function given by Eq. (1) with the free-carrier part dependent on magnetic field in the following way [6]:

$$\varepsilon_{fc\pm}(\omega) = \frac{\omega p^2}{\omega(\omega \pm \omega_c \pm i\gamma)}, \tag{2}$$

where ω_c is the cyclotron frequency. We also assume that $R = (R_+ + R_-)/2$, which means totally unpolarized light. The reflectivity calculated using the DDF function (1) with ε_{fc} in the form (2) is plotted in Figs. 1b and 2.

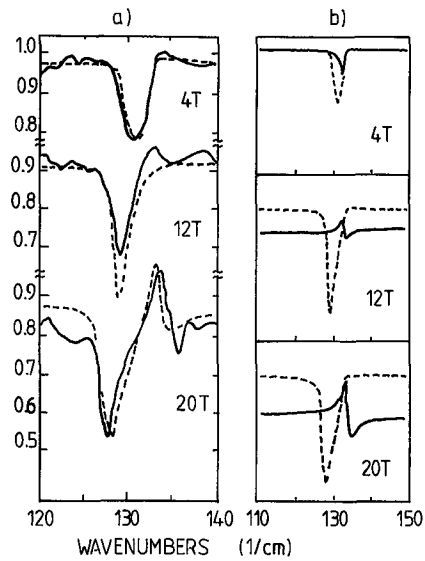

Fig. 2. a) The phonon part of the reflectivity for selected magnetic fields. The solid line represents experimental data and the broken line shows the calculated reflectivity spectrum (see text for details). b) Reflectivity curves calculated for CRA (solid line) and CRI (broken line) polarizations in the phonon region.

We would like to point out that the dispersive behavior of the phonon structure comes from CRI polarized light in the region of helicon waves only. Roughly speaking it is due to the existence of a positive real part of the electronic dielectric function in this energy range. For CRA polarization the real part of this function is always negative and the phonon structure behaves "normally". These effects, and the changes of position of the phonon structure, are shown in Fig. 2. The shift of the structure is due only to the different contribution of the free carrier dielectric function to the total DDF at different fields. Of course, the phonon energy is not dependent on magnetic field.

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