FIR optical investigations of Fe-based semimagnetic semiconductors

FIR OPTICAL INVESTIGATIONS OF Fe-BASED SEMIMAGNETIC SEMICONDUCTORS*,**

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The results of transmission, magnetotransmission and reflectivity in the far infrared spectral region for ZnFeSe, CdFeTe and CdFeSe are reported.

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The Far Infrared (FIR) investigations of the manganese-based semimagnetic semiconductors (SMSC) have shown the host crystal reststrahlen band and additional structures due to the manganese impurity modes [1, 2] (local and "acoustic"). In the iron-based SMSC one could expect the observation of similar phonon modes as well as transitions between crystal field and spin-orbit split ^5E electronic levels (as observed for Fe-doped II–VI compounds [3]). In order to study these effects, we measured the transmission, magnetotransmission and reflectivity of $Zn_{1-x}Fe_xSe$ ($x < 0.06$), $Cd_{1-x}Fe_xTe$ ($x < 0.04$) and $Cd_{1-x}Fe_xSe$ ($x < 0.03$) in the spectral range 10 cm^{-1} — 380 cm^{-1} and at temperatures from 1.3 K to *RT*.

For ZnFeSe in the energy range 10 cm^{-1} — 60 cm^{-1} two absorption lines are observed as shown in Fig. 1. The position and shape of these lines are magnetic field dependent. This pronounced field dependence proves that they are due to the transitions between

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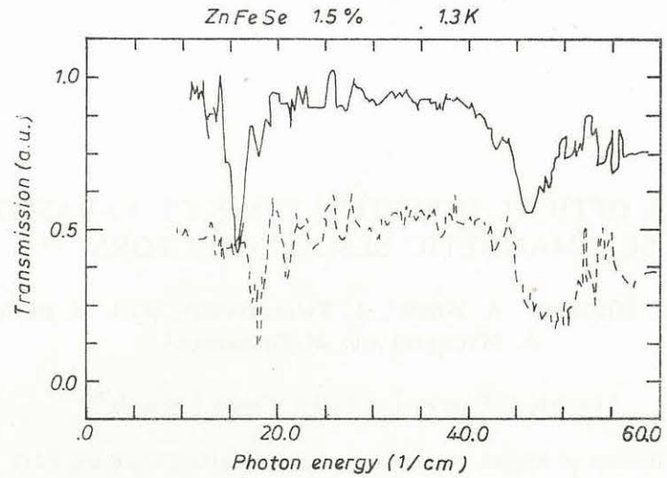

Fig. 1. The magnetotransmission data taken for $Zn_{1-x}Fe_xSe$ with $x = 0.015$ at 1.3 K in the energy range from 10 cm^{-1} to 60 cm^{-1}. The upper curve is taken without magnetic field. The lower one at field of 3 Tesla. The changes of line position and shape are clearly seen

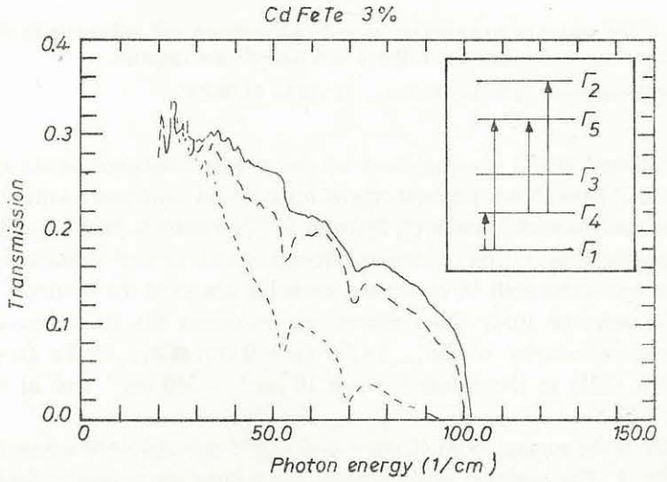

Fig. 2. The transmission of $Cd_{1-x}Fe_xTe$ with $x = 0.03$ versus photon energy between 20 cm^{-1} and 100 cm^{-1} at three temperatures. The solid line is for data taken at about 15 K, the dotted line represents data for about 80 K and dashed line data for RT. In the inset, the energy levels of ^5E iron term are presented (based on paper [3]). The discussed in the text allowed electric dipole and magnetic dipole transitions are marked by the solid arrows and by the dashed arrow, respectively

electronic states. Since the experiment was performed at 1.3 K, only the ground state (Γ_1) of Fe term ^5E is populated. Therefore, we ascribe these transitions to the $\Gamma_1 \rightarrow \Gamma_4$ and $\Gamma_1 \rightarrow \Gamma_5$ transitions (see inset in Fig. 2) as in Ref. [3]. Magnetic field lifts the threefold degeneracy of Γ_4 and Γ_5 levels, what results in splitting of absorption lines [3]. In our case this splitting is unresolved being observed as a change of the line shape only. The blue shift of the lines with magnetic field is in accordance with theoretical predictions.

The transmission data for CdFeTe in the energy range 20 cm^{-1} — 100 cm^{-1} are presented in Fig. 2. The temperature dependence of absorption lines suggests that they could be due to the transitions from Γ_4 to Γ_5 and Γ_2 levels (inset in Fig. 2). However, the reflectivity measurements have shown that the Fe local mode appears at about 183 cm^{-1} e.g. at the same energy as Mn local mode [1, 2]. This means that the force constants for Mn and Fe in CdTe are almost the same because there is practically no atomic mass difference between these atoms. Consequently, one should expect that the other impurity modes observed for manganese exist also for iron at the same energy (e.g. about 55 cm^{-1}) and the lower absorption line (Fig. 2) could be due to such a mode. Both explanations are not consistent with that given in [3]. It should be pointed out that the low-energy $\Gamma_1 \rightarrow \Gamma_4$ and $\Gamma_4 \rightarrow \Gamma_3$ transitions are below our energy range (about 18 cm^{-1} [3]). Further experiments (with magnetic field) should be made to find the proper explanations of the origin of the absorption lines observed for CdFeTe.

In the case of CdFeSe no pronounced absorption structures are visible below 100 cm^{-1}. If there occurs absorption due to the transitions between iron ^5E levels or due to the Fe impurity modes it is masked by the absorption due to the existence of impurities at the level of 10^{15} cm^{-3} (hopping and free-carrier absorption like in the CdMnSe). At higher energies the absorption due to the iron local mode is observed but due to the thickness of sample its energy could not be established.

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