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PHOTOVOLTAIC EFFECT OF ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ HETEROJUNCTIONS IN PRESENCE OF MAGNETIC FIELD*

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Photovoltaic effect of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions, prepared by vapor-transport epitaxy of ZnTe on $Cd_{1-x}Mn_xTe_{1-y}Se_y$ substrate was studied. The photovoltaic measurements were carried out over the temperature range from 12 K to 300 K and in the magnetic field up to 6 T. In the magnetic field, maximum of the sensitivity corresponding to the energy of the forbidden gap of $Cd_{1-x}Mn_xTe_{1-y}Se_y$ substrate splits into two components for σ^+ and σ^- circular polarizations of incident light. This phenomenon was ascribed to the exchange interaction of the magnetic moments of Mn^{++} ions with band electrons. From the value of the splitting energy the exchange integral $N_0(\alpha - \beta)$ was determined to be 1.15 ± 0.2 eV.

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1. Introduction

Heterojunction involving semimagnetic semiconductors (SMS) and ordinary semiconductors combines the properties of non-magnetic semiconductors with the magnetic-field-dependent behaviors of SMS [1]. It can provide a new tool for the optical study and the development of the magnetically tunable photoelectric conversion devices. In this paper we report the first results of the photoelectric study on ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions in the presence of a magnetic field.

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2. Experiment

ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions were prepared by vapor-transport epitaxy of ZnTe on In-doped $Cd_{1-x}Mn_xTe_{1-y}Se_y$ ($x = 0.05$, $y = 0.03$) single crystalline substrates. The electron concentration of the substrate was in the range $(1.0 \div 5.7) \times 10^{17}$ cm^{-3} and the Hall mobility was about 470 cm^2/(V s) at $T = 300$ K. The fabrication of the diodes has been described in detail in [2].

The measurements of the photoresponse of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions were performed in the Faraday configuration for both σ^+ and σ^- circular polarizations of the incident light in the magnetic field up to 6 T and temperatures as low as 12 K. The *p-n* heterojunction was illuminated from the ZnTe side.

3. Result and discussion

We show in Fig. 1 the photovoltaic spectra of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at several temperatures and in the absence of a magnetic field. The region of the spectral sensitivity ranges from 0.4 μm to 0.9 μm. The typical shape of the spectral sensitivity is characterized by two bands with peaks at 2.26 eV and 1.60 eV at 300 K, corresponding to the energies of band gap of ZnTe and $Cd_{1-x}Mn_xTe_{1-y}Se_y$, respectively. The peaks shift to larger energies with decreasing temperatures in accordance with the temperature variation of the forbidden gap of the materials forming the heterojunction. At the room temperature under the solar irradiation the investigated diodes generate an open-circuit voltage of about 0.5–1.0 V and a short circuit current density 4–8 mA/cm^2. However, the sensitivity of the measured diodes decreases with the decreasing temperature and below 10 K the diodes cease to be light sensitive. This phenomenon is not yet understood. We have tentatively ascribed this fact to recombination processes of the photogenerated carriers via the states located at the interface of the heterojunction, which are caused by the large lattice mismatch (6.1%) of the materials forming the heterojunction. This question requires further detailed investigation.

In Fig. 2 we show the photovoltaic spectra of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at 12 K in the absence of a magnetic field and in the magnetic field $H = 6$ T in the Faraday configuration. It can be seen that for the σ^+ and σ^- circular polarizations in the magnetic field, the maximum of the sensitivity corresponding to the energy of the forbidden gap of ZnTe does not shift relatively to its position in zero magnetic field. On the other hand, the maximum of sensitivity, corresponding to the energy gap of $Cd_{1-x}Mn_xTe_{1-y}Se_y$ at zero field, splits into two components. The σ^- component shifts towards higher energies and the σ^+ component — towards lower energies. Figure 3 shows the peak position in the photovoltaic spectra, observed in a magnetic field for σ^+ and σ^- circular polarizations.

The splitting of the photoresponse maximum is the result of the splitting of the conduction and valence band edges due to the exchange interaction of localized magnetic moments of Mn^{++} ions with the band carries in the $Cd_{1-x}Mn_xTe_{1-y}Se_y$ side of the junction. According to the exchange interaction model described in [3]

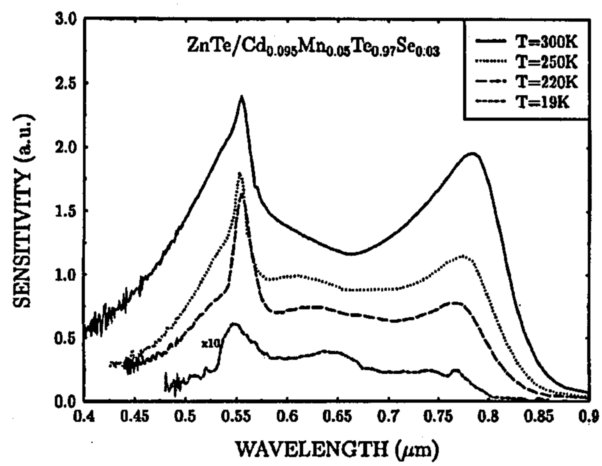

Fig. 1. Photovoltaic spectra of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at several temperatures.

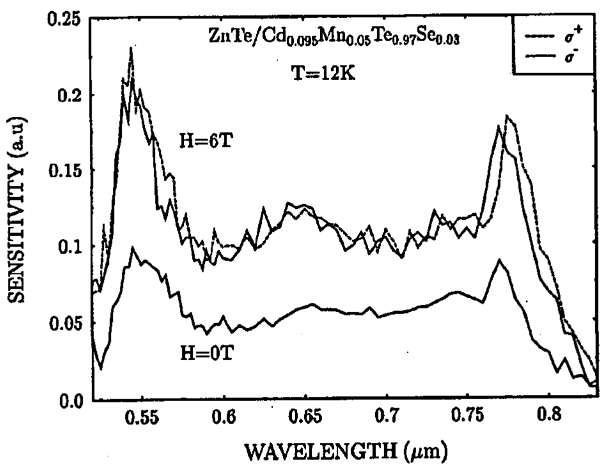

Fig. 2. Photovoltaic spectra of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at 12 K in the magnetic field $H = 6$ T in Faraday configuration.

there are two allowed interband transitions for each σ^+ and σ^- polarization in Faraday geometry. In reflectivity experiments on the $Cd_{1-x}Mn_xTe$ crystals [3], all four components in both σ^+ and σ^- circular polarizations were observed. In our case, in each polarization only one peak was observed. This can be interpreted by the fact that our measurements were carried out at relatively high temperature (12 K), where the splitting value is rather small. Also, the fact that we are dealing here with a quaternary compound, may contribute to a relatively large broadening of spectral structures and thus, failure to resolve all four components in the spectrum. It is known that the exchange splitting energy is proportional

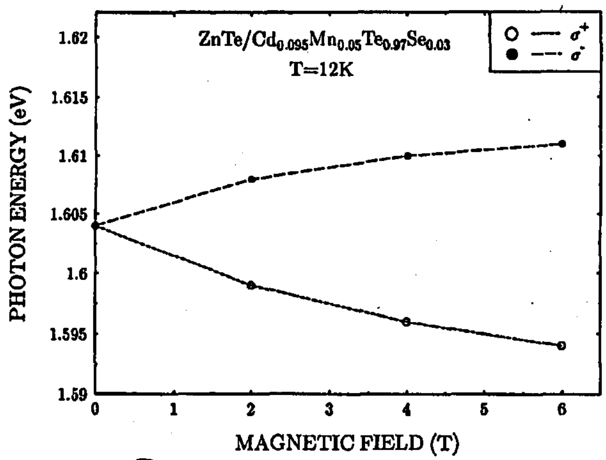

Fig. 3. Magnetic-field dependence of the energy of transitions, observed at 12 K in photovoltaic spectrum in the Faraday configuration.

to the magnetization [3] and the coefficient of proportionality allows to determine the exchange integral $N_0(\alpha - \beta)$. By using the values of susceptibility from [4], we find $N_0(\alpha - \beta) = 1.15 \pm 0.2$ eV. This value is close to that obtained in [3] for CdMnTe.

In conclusion, we have demonstrated that in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions the magnetic field affects the spectral sensitivity via the exchange interaction. We have found the value of exchange integral. Further studies are planned aiming at increasing the sensitivity of our measurements at temperatures lower than 10 K.

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