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SELF-INDUCED PERSISTENT PHOTOCONDUCTIVITY IN ZnTe-$Cd_{1-x}Mn_xTe_{1-y}Se_y$ HETEROJUNCTIONS*

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At temperatures lower than 200 K the photomemory effect has been observed in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions. The persistent photoconductivity can be achieved either by *illumination* from an external light source or by a *self-absorption* of the electroluminescence radiation when a voltage of about 10 V for a few seconds is applied to the diode. Current–voltage characteristics are of the form $I \sim V^m$. The capacitance and electroluminescence measurements show that the photomemory effect in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions can be caused by the bistable nature of the In dopant in the $Cd_{1-x}Mn_xTe_{1-y}Se_y$ substrate. In the high resistivity interface layer and the substrate material indium forms centers similar to DX-like centers in $Zn_xCd_{1-x}Te$ and $Cd_{1-x}Mn_xTe$.

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1. Introduction

The persistent photoconductivity (PPC) phenomenon has been observed in n-type doped II–VI semiconductors $Cd_{1-x}Zn_xTe$ [1], $Cd_{1-x}Mn_xTe$ [2], $Cd_{1-x}Mn_xTe_{1-y}Se_y$ [3]. Similarly to the case of the III–V materials PPC has been attributed to the presence of a deep energy state related to the n-type doping process. In this paper we report the observation of PPC in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions.

2. Experiment

ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunctions were prepared by the 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 in the substrate was $(1.0 \div 5.7) \times 10^{17}$ cm^{-3} and the Hall mobility equaled to approximately

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470 $cm^2/(V\ s)$ at $T = 300$ K. The fabrication of the diodes was described in detail in Ref. [4]. The current–voltage and capacitance–voltage characteristics were measured over the temperature range from 77 K to 300 K in the dark and under illumination.

3. Results and discussion

In Fig. 1 the current–voltage characteristics of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at 77 K and at the voltages smaller than 8 V are shown. The curve 1 is the I–V characteristic registered in the dark and the curve 2 under illumination with a microscope lamp. It is seen that the forward current under illumination is 10^3 times higher than the dark one. After the illumination is terminated at first the forward light current rapidly decreases by two order of magnitude and then a slow recovery process to the initial dark current is observed (see the inset in Fig. 1). The curve 3 has been obtained 1 hour after the illumination was terminated. We call this state the persistent photoconductivity state. The persistent current is by an order of magnitude higher than the dark one. The PPC state lasts as long as the sample is kept in low temperature. The set of $\log I$–$\log V$ characteristics at different temperatures in the

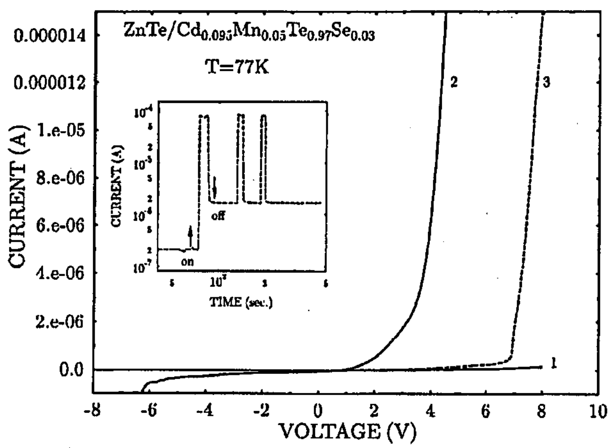

Fig. 1. Current–voltage characteristics of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at 77 K. The inset shows the relaxation curve of the forward current for triple switching light on and off.

temperature range of 77–300 K shows that the current–voltage characteristic of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction has the general form $I \sim V^m$ with m equals approximately to 4.0. The mechanism of the current flow in the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction can be described by the space-charge-limited conduction theory of Lampert [5].

Figure 2 shows the $\log I$–$\log V$ characteristic of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction at 77 K in the electroluminescence (EL) emission regime. One can

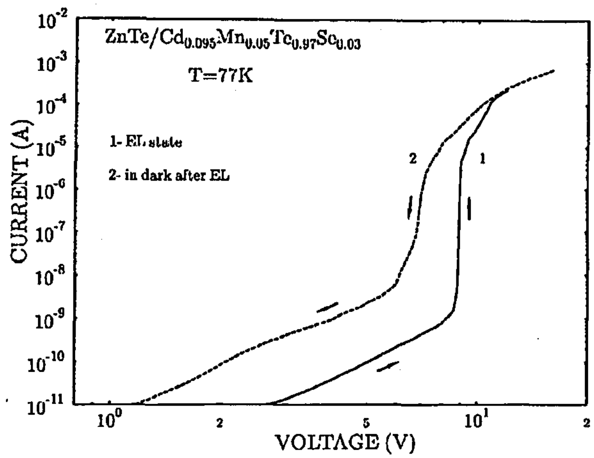

Fig. 2. I–V characteristics of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction during and after EL at 77 K.

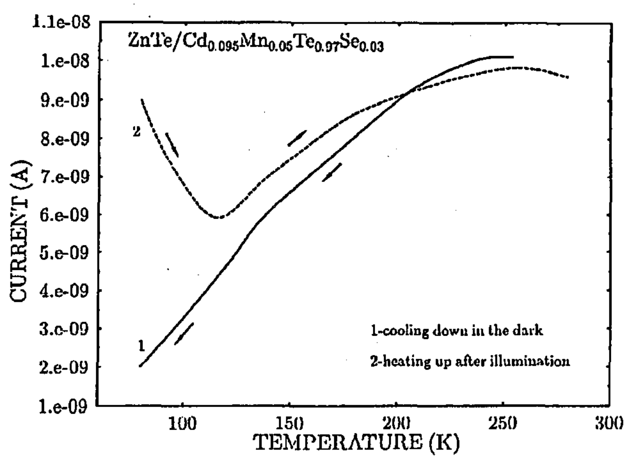

Fig. 3. Temperature dependence of the current for the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction.

see that when the voltage reaches 9 V the dark current rapidly increases (curve 1). At this or higher voltage the strong EL process occurs [4]. The subsequent decrease of the bias decreases the light intensity while the diode remains in the PPC state. The curve 2 is the $\log I$–$\log V$ characteristic of ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction measured 10 min after the electroluminescence termination. It is seen in Fig. 2 that for the voltages lower than 9 V the persistent current is also an order of magnitude higher than the dark current and for the voltages greater than 9 V the persistent and dark currents are the same. Basing on this fact we suggest that the transformation of the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ diode to PPC state is caused by the *self-absorption* of the own electroluminescence radiation in the diode.

Figure 3 shows the hysteresis behavior of the forward current as a function of temperature at the applied voltage equal to 5 V. The curve 1 is obtained by cooling down in the dark and curve 2 — by heating up after illumination at 77 K. This hysteresis behavior is characteristic for PPC for all donor doped materials quoted in the introduction. It has been noted that the heating of the sample up to 200 K leads to quenching of the PPC state.

The capacitance measurement revealed that the junction is not sharp and there exists a high resistivity interface layer. The EL spectrum measured at 77 K consists of two regions: a relatively intensive and narrow peak at about 1.45 eV and a long "tail" in the region from 1.6 to 1.9 eV. These results allow us to conclude that the emission in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ diode occurs in the $Cd_{1-x}Mn_xTe_{1-y}Se_y$ substrate and the junction region is formed by the solid solution of $Cd_{1-x}Mn_xTe_{1-y}Se_y$ with ZnTe. Hence, we suggest that the photomemory effect observed in ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ diode after either illumination from an external light source or the electroluminescence emission is due to the transition of the $Cd_{1-x}Mn_xTe_{1-y}Se_y$ substrate material from the high resistivity state in the dark to the persistent low resistivity state. This change observed in the In-doped $Cd_{1-x}Mn_xTe_{1-y}Se_y$ crystal is quite similar to the bistable behavior observed in In-doped $Cd_{1-x}Zn_xTe$ [1], $Cd_{1-x}Mn_xTe$ [2] crystals. According to Ref. [1,2], the photomemory effect observed in In-doped $Cd_{1-x}Mn_xTe$, $Cd_{1-x}Zn_xTe$ crystals is attributed to the deep-shallow bistable nature of In-dopant, which forms the centers analogous to the DX center in $Al_xGa_{1-x}As$.

In conclusion, we present the results supporting the defect-related (DX-like) interpretation of PPC in In-doped $Cd_{1-x}Mn_xTe_{1-y}Se_y$ crystal and showing that the ZnTe–$Cd_{1-x}Mn_xTe_{1-y}Se_y$ heterojunction can be used as a tool for studying the metastability effects in $Cd_{1-x}Mn_xTe_{1-y}Se_y$ crystals.

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