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FREE CARRIERS HEATING AT Mn^{2+} MAGNETIC RESONANCE IN CdMnTe

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The results of optically detected magnetic and cyclotron resonance experiments performed on $Cd_{1-x}Mn_xTe$ ($x = 0.007$) are presented. It is shown that the Mn^{2+} magnetic resonance results in heating of free holes, which can be observed via the effects of hot holes on the CdMnTe "edge" emission.

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1. Introduction

It was shown recently [1] that the dominant mechanism responsible for the optical detection of magnetic resonance (ODMR) in $Cd_{1-x}Mn_xTe$ ($x = 0.095$) is related to the decrease in the sample magnetization at the Mn^{2+} magnetic resonance. The large magnitude of the ODMR signal was related to a large efficiency of the Auger type nonradiative recombination of the acceptor bound exciton (ABE) [2], whose recombination is promoted at the magnetic resonance. In this communication we present the results of the ODMR and the optically detected cyclotron resonance (ODCR) experiments performed on 0.7% CdMnTe bulk samples. A different ODMR detection mechanism is deduced from the present results.

2. Results and discussion

In Fig. 1a we show the photoluminescence (PL) spectrum of 0.7% CdMnTe measured at 4 K under 514.5 nm excitation with Ar^+ laser. It consists of the free exciton (FE) line at 1.601 eV, the ABE PL emission at 1.556 eV, followed by its phonon replica, and the two broad donor–acceptor pair (DAP) recombination bands peaking at 1.12 and 1.04 eV. The resonance spectrum observed in the ODMR/ODCR experiment is depicted in Fig. 2. It shows a heavily damped

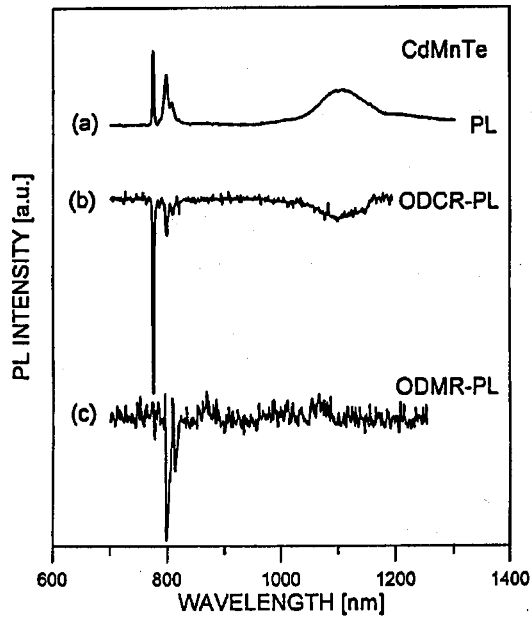

Fig. 1. Photoluminescence (a) and spectral dependence of the ODCR (b) and ODMR (c) signals. The ODCR-PL and ODMR-PL spectra were measured in phase with on-off modulated microwave power and magnetic field set at electron cyclotron resonance (b) and Mn^{2+} magnetic resonance (c).

electron CR (low field signal) followed by the sharp Mn^{2+} magnetic resonance at $g \approx 2$. The spectral dependencies of the CR and the ODMR signals are shown in Fig. 1b, c. The CR resonance was observed as a decrease in the intensity of the FE, ABE and DAP emissions, with the effect being strongest for the FE PL. A very different response was observed for the Mn^{2+} magnetic resonance. A quenching of the ABE emission was observed with only a small effect on the FE line. The off-resonance experiment suggests that the latter may partly be due to the superposition of the magnetic and broad electron cyclotron resonance signals.

As was explained recently [3], the response of a given recombination transition to carrier heating (at the CR transition) depends on a carrier binding or a center formation mechanism. For FE the exciton formation rate depends on kinetic energy (temperature) of both electron and hole. For bound excitons the formation rate is very sensitive to heating of that carrier which is localized as first by a virtue of a short range potential of either a neutral donor or acceptor, i.e., a hole for ABE. For DAP transitions the response depends on the nature of the donor and the acceptor component of the pair. For shallow donors and deep acceptors ("deep" DAP processes in CdMnTe) the DAP PL will be reduced once free electron gas is heated, which is due to a strong temperature dependence of electron trapping rates at shallow donors [4].

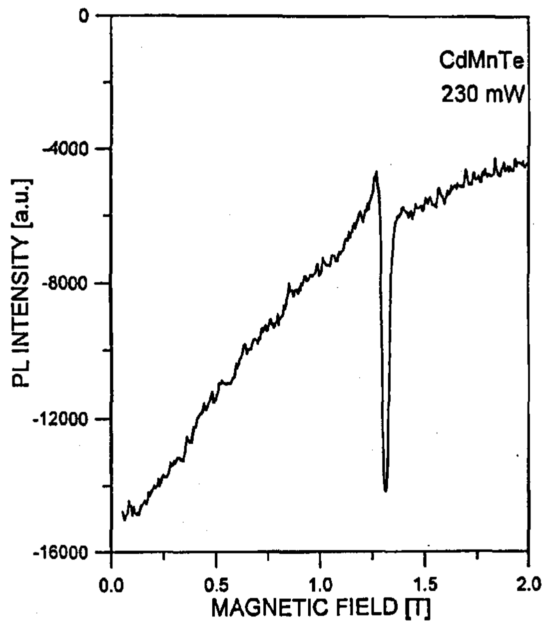

Fig. 2. Optically detected cyclotron (electron resonance) and magnetic resonance of Mn^{2+} in CdMnTe (0.7% of Mn).

The above explains the response of the PL spectra to heating of electrons at the electron CR conditions. A relatively strong quenching of the FE PL is observed with a small effect on the ABE and on the two DAP transitions. A very different response is observed at the Mn^{2+} magnetic resonance. The spectral dependence of the ODMR signal shows that the Mn resonance is detected optically via the quenching of intensity of the ABE PL emission. The response observed shows that holes are heated at the magnetic resonance. Formally, heating of holes should also affect intensity of the FE emission. However, the expected quenching can be counterbalanced by the increased rate of free carriers recombination via the FE channel once the ABE channel is deactivated.

There were several indications that the relaxation time of spin of a carrier can be affected by the presence of magnetic ions in semimagnetic semiconductors [5–8]. This is due to the strong exchange coupling between free carriers and localized magnetic moments of the Mn^{2+} ions. The present ODMR results prove that the reverse process, i.e., a fast Mn spin relaxation, caused by the exchange coupling with free carriers (spin flip-flop processes) may also be very efficient. The p–d exchange coupling in CdMnTe is about four times larger than the s–d one [9]. It is thus not surprising that the Mn^{2+} magnetic resonance increases temperature of free holes and not (or much less) of free electrons. The present results clearly indicate that the Mn^{2+} spin system relaxes via the exchange coupling with free carriers and that the spin–lattice relaxation plays a rather minor role. There are some indirect indications that the spin relaxation may be suppressed for "cold" carriers [7]. If so, the superposition of the magnetic resonance on broad CR transition could enhance the effect observed by us.

For the 9.5% CdMnTe sample we observed that the sample magnetization, decreased at the Mn^{2+} magnetic resonance, returns to its initial value in microsecond time scale. The separate PL experiments performed on the same samples showed that the spin–lattice coupling was very weak [10] and that the above result cannot be explained by the fast spin–lattice relaxation, as was proposed in case of CdMnSe [11]. Thus, these results also confirm that the Mn spin system is not in equilibrium with the lattice temperature.

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