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OPTICALLY DETECTED MAGNETIC RESONANCE STUDIES OF $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.095, 0.007$)*

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The dominant mechanism responsible for the optical detection of the Mn^{2+} magnetic resonance in $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.095, 0.007$) is explained. By either change of the external magnetic field or by setting the conditions for the Mn^{2+} magnetic resonance, we could change the relative efficiencies of the two competing excitonic recombination processes. By lowering magnetization at the magnetic resonance, recombination via the acceptor bound exciton channel, which is mainly nonradiative, is enhanced. Then, a large up to 50% decrease in the total photoluminescence efficiency was observed in the optically detected magnetic resonance experiment. Such observation allows for verification of the large efficiency of the Auger-type transition responsible for the nonradiative decay of the acceptor bound exciton.

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1. Introduction

The mechanism of optical detection of magnetic resonances (ODMR) was discussed by several authors [1]. For Mn-based semimagnetic semiconductors Malyavkin and Komarov et al. [2,3] proposed that Mn^{2+} resonance is detected optically due to photoluminescence (PL) changes caused by a decrease in sample magnetization occurring at magnetic resonance transition. Our recent ODMR and magneto-optical investigations [4] confirmed an important role of the above mechanism. The decrease in the magnetization decreases the Zeeman splitting of exciton and impurity states. As a result the "edge" emission spectra, due to the free exciton (FE) and the acceptor bound exciton (ABE), shift toward higher energies at the magnetic resonance transition. The shift alone does not explain the shape

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of the response of PL to the magnetic resonance [4]. Large changes of PL intensity accompanied the shift induced by the magnetic resonance. This point is explained by the present ODMR and magneto-optical study of bulk $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.095, 0.007$) samples. Some test measurements were performed for the $x = 0.28$ sample.

2. Magneto-optical experiments

The “edge” part of the PL spectrum and its magnetic field dependence is shown in Fig. 1. The PL spectrum consists of free exciton line at 1.738 meV, acceptor bound exciton line at 1.718 meV and a broad PL band at 1.667 meV, which is due to free electron–acceptor (FA) and/or donor–acceptor pair (DAP) transitions. Magnetic field applied strongly modifies the emission observed, as was

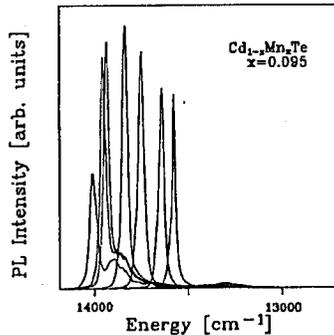


Fig. 1. “Edge” part of the photoluminescence spectrum of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$ ($x = 0.095$) sample for (from left to right) 0, 1, 1.25, 3, 5, 10, and 18 T external magnetic field.

observed previously [5]. All PL spectra shift toward lower energy. This effect is the largest for FE emission. Electron and hole in FE can freely adjust the direction of their spins to magnetic field direction. This is not possible for two holes in ABE [5, 6]. Due to this fact ABE emission is destabilized for higher magnetic field, when FE recombination energy becomes lower than that of ABE. The intensity ratio between FE and ABE is rapidly changed with increasing external magnetic field, as Fig. 1 shows. The intensity of the ABE line is reduced, as was observed previously [5, 6].

3. The Auger mechanism of ODMR detection

An Auger process is cooperative interaction of three particles. The process becomes very efficient for all three particles localized at one center. The first reports on very high efficiency of the Auger effect for neutral donor BE [7] and ABE [8] confirmed this expectation. It was shown that the decay time of P bound DBE is 500 times shorter than expected for radiative recombination only [7]. The effect was related to Auger-type nonradiative recombination, based rather on indirect arguments.

In this work we utilize the ODMR experiment to verify directly the efficiency of Auger-type nonradiative recombination at ABE. The idea of the ODMR study was very simple. Applying an external field and magnetic resonance, we could change sample magnetization and in this way regulate the relative efficiency of FE and ABE recombination channels. FE recombination is mostly radiative one, whereas ABE was expected to be mostly nonradiative. Due to this fact we should change the PL efficiency of total emission at Mn^{2+} magnetic resonance. The information on nonradiative recombination rate could be obtained in this way.

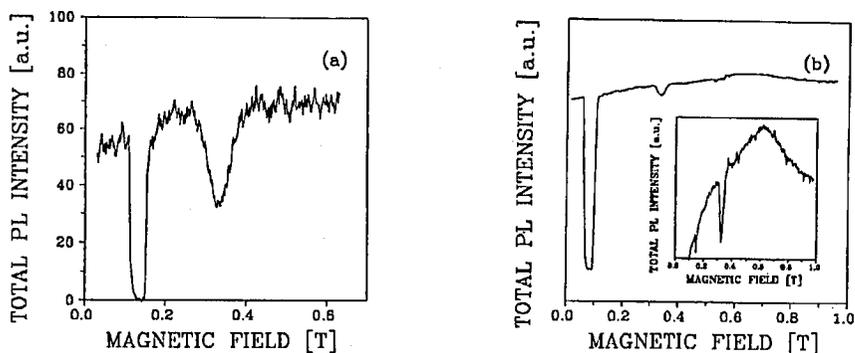


Fig. 2. Mn^{2+} magnetic resonances of $\text{Cd}_{1-x}\text{Mn}_x\text{Te}$, samples with $x = 0.095$ (a) and $x = 0.007$ (b) detected via the change of intensity of total emission measured with the germanium detector. The relative size of PL changes is shown by turning off the excitation at the beginning of the magnetic field scan. The spectra were measured for 2 K sample temperature and 200 mW microwave power.

Figure 2 shows that for the $x = 0.095$ sample total PL intensity decreases by 50% at magnetic resonance when we increase ABE recombination rate. This is a direct visualization of extremely efficient nonradiative recombination at ABE and explains the shape of the ODMR-PL reported previously. We indicate also that the low intensity of ABE in PL spectrum is entirely due to competition of the Auger nonradiative decay and that carrier recombination via ABE must be efficient.

The above effect is much smaller for the $x = 0.007$ sample due to much smaller effect of magnetic resonance on FE versus ABE recombination rate. Here only about 7% change of the total PL efficiency was observed. We have also performed control measurements of PL changes induced by a sample or spin heating by the applied microwave power and for the $x = 0.28$ sample. Basing on these investigations, we can definitely exclude that the observed PL changes may be related to other effects than the discussed here Auger nonradiative recombination. Concluding, the observed response of the edge PL to magnetic resonance cannot be explained without including the large change of the relative intensities of free and bound excitonic emissions.

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