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Enhanced Magneto-Optical Interaction in CdTe/CdMnTe Quantum Wires

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1. Introduction

Low-dimensional heterostructures of semiconductors induce spatial confinement effects on photo-excited carriers, which lead to pronounce excitonic effects due to an enhanced spatial overlap of the electron and hole wavefunctions. This property becomes remarkable as the dimension falls down. On the other hand, diluted magnetic semiconductors (DMSs) show increased magneto-optical properties, which are caused by the exchange effect of electrons and holes interacting with the magnetic ions. We can separate the active region interacting with light from the magnetic region, which enables us to develop new-type magneto-optical devices. The low-dimensional DMSs are also expected to enhance the magneto-optical effects, and, which can be controlled by the quantum structures. [1, 2] Recently, the magneto-optical properties of DMS quantum well (QW), of which the barrier is the DMS, have been investigated by Takeyama. [2] They demonstrated interactions between photoexcited carriers and magnetic ions doped in the barrier layer. This interaction is expected to be enhanced by decreasing the dimension of quantum structure. In this work, we designed CdTe/$Cd_{0.75}Mn_{0.25}Te$ quantum wires (QWRs) and studied the magneto-optical properties.

2. Experiments

Organized growth of semiconductors on vicinal substrate was used to realize QWRs; the repeated deposition of a fractional monolayer (ML) m of material **A** followed by n ML of **B** results in a high-density array of QWRs, or a $\mathbf{A}_m\mathbf{B}_n$ tilted superlattice. In this experiment, CdTe/$Cd_{0.74}Mg_{0.26}Te$ QWRs and CdTe/$Cd_{0.75}Mn_{0.25}Te$ QWRs, with m and $n\approx0.5$, was grown on the $Cd_{0.96}Zn_{0.04}Te$ (001) substrates misoriented 1° toward the [100] direction by molecular beam epitaxy (Fig. 1). The cross-section of the QWRs was a square of 9.3×9.7 nm^2. [3]

PL excitation (PLE) measurement was performed under the excitation by the monochromatic light of a tungsten lamp. PL measurement was performed at 1.9 K in an optical cryostat with a superconducting split-coil magnet up to 7 T. The excitation laser wavelength is 387 nm.

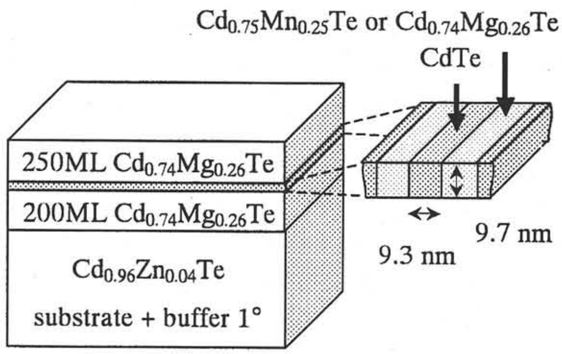

Fig. 1 Schematic illustration of QWRs .

3. Results and discussion

Figures 2 show PL and PLE spectra of CdTe/$Cd_{0.75}Mn_{0.25}Te$ QWRs. Solid and dashed lines show the PLE and PL spectra, respectively. The sample temperature was 3.8 K. The strong excitonic absorptions are observed at 1.832 eV. These correspond to the exciton transition between the ground electron and heavy-hole states. The absorption edge due to the continuum state of the barriers appears above 2.0 eV in the PLE spectrum.

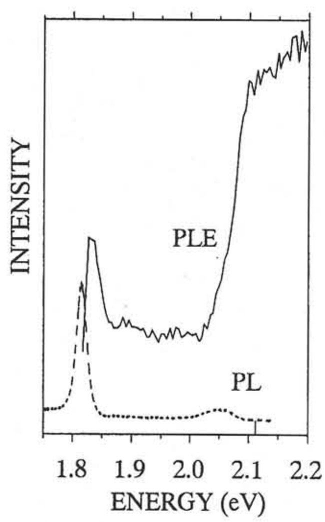

Fig. 2 PL and PLE spectra of CdTe/$Cd_{0.75}Mn_{0.25}Te$ QWRs. Solid and dashed lines show the PLE and PL spectra, respectively.

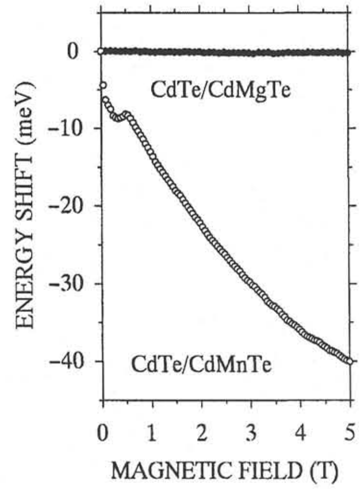

Fig. 3 PL peak energy shift of $CdTe/Cd_{0.74}Mg_{0.26}Te$ QWRs and $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs for magnetic field perpendicular to the wire.

Figure 3 plot PL peak energies as a function of magnetic field perpendicular to the wire. Solid and open circles plot the results for $CdTe/Cd_{0.74}Mg_{0.26}Te$ QWRs and $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs, respectively. The magnetic field dependence can be well described by a sum of the diamagnetic shift and the Zeeman splitting. In $CdTe/Cd_{0.74}Mg_{0.26}Te$ QWRs, the effective g factor obtained from the Zeeman splitting and the exciton-reduced masses obtained from the diamagnetic shift are -2.1 and $0.095m_0$, respectively. In contrast to the non-magnetic QWRs, an extremely large Zeeman shift was found in $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs. The effective g factor is -200. Since the wavefunctions in the QWRs penetrate into the DMS barriers, the strong s-d and p-d

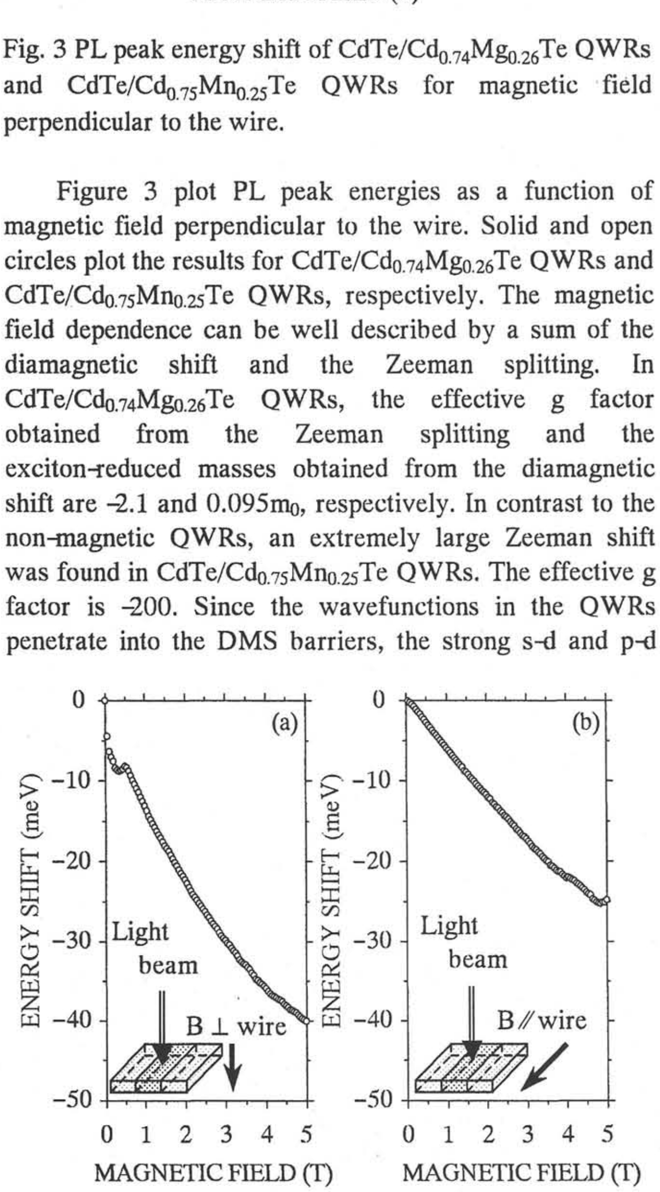

Fig. 4 PL peak energy shift of $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs for magnetic field (a) perpendicular and (b) parallel to the wires.

Table I Effective g factor

sample	magnetic field	effective g factor
CdTe/CdMgTe	B ⊥ wire	-2.1
CdTe/CdMnTe	B ⊥ wire	-200
CdTe/CdMnTe	B // wire	-120

exchange interaction take place. In the case of the QWRs, furthermore, the lateral confinement of the wavefunction enhances it all the more. [4] In asymmetric $Cd_{0.86}Mn_{0.14}Te$-CdTe-$Cd_{0.78}Mg_{0.22}Te$ QWs, of which the well width is 4.9 nm, the Zeeman shift of 3 meV under 3T was reported. [2] Thus, the Zeeman shift of our QWRs is almost ten times larger than their value.

Figures 4 (a) and (b) show PL-peak-energy shift of $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs under magnetic field perpendicular and parallel to the wires, respectively. The effective g factor for magnetic field parallel to the wires is -120, which is smaller than the value for magnetic field perpendicular to the wire. Table I summarizes the effective g factors obtained for our QWRs. Under the parallel magnetic field, the exciton-spin polarization is perpendicular to the magnetic polarization. This explains the reduction of the effective g factor.

4. Conclusions

Magneto-optical properties of $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs were investigated. The magnetic field dependence of the PL peak energy was compared with that for non-magnetic $CdTe/Cd_{0.74}Mg_{0.26}Te$ QWRs under magnetic field perpendicular to the wire. The effective g factor for the $CdTe/Cd_{0.74}Mg_{0.26}Te$ and $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs are 2.1 and 200, respectively. The Zeeman effect is enhanced greatly in the $CdTe/Cd_{0.75}Mn_{0.25}Te$ QWRs, because the wavefunctions in the QWRs penetrate into the DMS barriers, and strong s-d and p-d exchange interaction take place. Furthermore, anisotropy of the effective g factor was observed under magnetic field parallel and perpendicular to the wire.

References

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