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MAGNETOOPTICAL ANALYSIS OF INTERFACE MIXING IN PULSED LASER EVAPORATION AND EPITAXY GROWN CdTe/$Cd_{0.9}Mn_{0.1}Te$ MULTIPLE QUANTUM WELL AND SUPERLATTICE

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A recently proposed magnetooptical method of determination of interface mixing was applied to CdTe/CdMnTe superstructures grown by pulsed laser evaporation and epitaxy. Diffusion length were found ≈ 5 Å for a multiple quantum well and > 15 Å for a superlattice. Ranges of Mn mole fractions and well width values enabling efficient application of the method were determined.

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It has been reported [1] that magnetoreflectivity can provide valuable information on interface quality in the CdTe/CdMnTe system. The Zeeman splitting of ground states of quantum wells with $Cd_{0.7}Mn_{0.3}Te$ barriers has been shown to be extremely sensitive to interface mixing between the nonmagnetic well and the barrier containing Mn^{++} ions, allowing to estimate the interface mixing range.

In this work we test for the first time a superstructure grown using pulsed laser evaporation and epitaxy (PLEE) technique [2]. Besides testing the quality of the interface in the PLEE method, we shall try to estimate the useful range of the superstructure parameters, allowing efficient application of the magnetooptical method of interface characterization.

In our experiment we analyzed two samples: a multiple quantum well (CCM108) with relatively large well thickness and a superlattice (CCM206). Samples were grown by PLEE method on (001) $Cd_{0.95}Zn_{0.05}Te$ substrates. The multiple quantum well (MQW) contained 30 pairs of CdTe wells of nominal thickness 120 Å with 170 Å thick CdMnTe barriers. The superlattice (SL) contained 40 pairs of wells and barriers with thickness 20 Å and 95 Å, respectively. Both samples were grown on a CdMnTe buffer and covered by a CdTe capping layer.

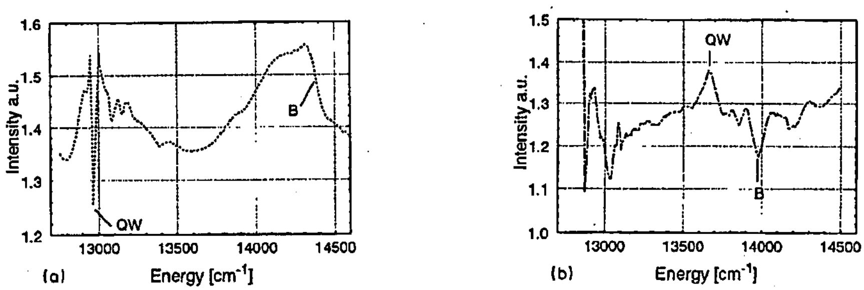

Fig. 1. Reflectivity spectra of samples (a) MQW CCM108 and (b) SL CCM206, taken at 1.9 K. Structures associated with ground states of excitons localized in quantum wells and in barriers indicated by QW and B, respectively.

Magnetoreflectivity measurements were performed in the Faraday configuration with samples mounted strain-free in a superconducting magnet. The samples were immersed in superfluid helium at 1.9 K. The zero-field reflectivity spectra are shown in Fig. 1. We identify structures marked by arrows, as related to heavy hole ground state excitons in wells and excitons located in barriers. The absolute value of energy E_{ex} of the exciton in the barrier was used to determine Mn concentration x in $\mathrm{Cd}_{1-x}\mathrm{Mn}_x\mathrm{Te}$ layers. We used the formula for bulk $\mathrm{Cd}_{1-x}\mathrm{Mn}_x\mathrm{Te}$ [1]: $E_{\mathrm{ex}} = 1.596\,\mathrm{eV} + 1.563x\,\mathrm{eV}$.

The Zeeman splitting of structures connected with excitons in barriers was equal to the splitting in bulk material with the same Mn concentration as in the barriers. The Zeeman splitting of exciton localized in wells is presented in Fig. 2. To

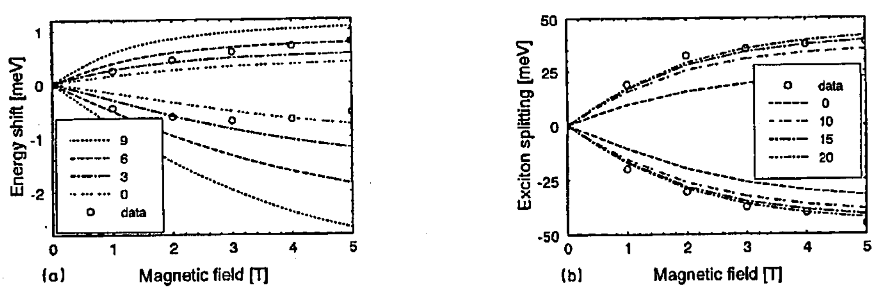

Fig. 2. The Zeeman splitting for several values of diffusion length (in angströms) plotted versus magnetic field for (a) MQW CCM108 and (b) SL CCM206. The points represent experimental results.

explain the observed dependence we used the model introduced in [1]. We assumed a diffusion profile between CdTe and CdMnTe represented by the error function, scaled by the diffusion length l_{dif}. Any variation of the potential in the plane of layer was neglected. The potential shapes across interfaces were calculated using bulk dependence for local Mn mole fraction [1]. The ground states of electrons and heavy holes were found by numerical integration of the Schrödinger equation as a function of magnetic field. For SL the mean energy of the lowest band was calculated. Transition energies were obtained for the two circular polarizations. The splitting obtained for different diffusion length values were compared with experiment in Fig. 2. We shall discuss first the two cases separately:

1. Superlattice CCM206

We can determine only the lower limit of about 15 Å for the interface diffusion length. With increasing interface mixing the Zeeman splitting tends to saturate at a value increased only by about 50% compared to that of the perfect interface. The observed smaller sensitivity of the Zeeman effect on interface mixing than observed in Ref. [1] can be understood having in mind that the enhancement of the Zeeman splitting comes from the increase in magnetization of the ions in the interface regions due to dilution which decreases influence of the ion–ion interaction. In a barrier containing 10% Mn this interaction is much smaller than in the barriers of the sample studied in Ref. [1] (containing 30% Mn).

2. MQW CCM108

The splitting is very weak because of the large well width. Therefore, three effects, neglected in our calculation, must be discussed: exciton diamagnetic shift, electron and hole gyromagnetic factors (without exchange) and variation of the exciton binding energy with magnetic field. The latter is important primarily for the low-energy component, for which the heavy hole potential well becomes very shallow, approaching a type I–type II transition [3]. The two first effects have the same order of magnitude (a fraction of meV) and signs opposite for the upper component and equal for the lower one. For all these reasons we should take the upper component for comparison with the calculations. Even then the estimate of the diffusion length (about 5 Å) is rather qualitative.

The difference between the absolute values of the calculated and the measured transition energies at zero field must be attributed to the binding energy of the confined exciton. In order to obtain reasonable agreement with theoretical estimate done according to Ref. [1] we had to modify the nominal well widths of samples using 140 Å instead of 120 Å for MQW CCM108 and 19 Å instead of 20 Å for SL CCM206.

We obtained drastically different results for the two superstructures studied. For the MQW diffusion length was about 5 Å and for the SL it was above 15 Å. We believe that a part of that difference is real, however we must note that in the MQW the CdTe layers are too wide for the method to be efficient.

On the basis of the results obtained so far we can outline the limits for the superstructure parameters enabling a determination of the interface mixing by the magnetooptical method: Mn mole fraction in the barriers equals at least to 10% and nonmagnetic well width not exceeding a few tens of angströms.

The interface mixing values typical of molecular beam epitaxy (MBE) (a few angströms) seem to be available also in the PLEE grown superstructures. However, more samples of suitable parameters must be examined to reach a more precise conclusion.

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