The photoluminescence investigation of $Zn_xMn_{1-x}Te$ films

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Abstract

We have measured photoluminescence spectra of $Zn_{1-x}Mn_xTe$ films placed on a GaAs substrate with ZnSe buffer layer at the low temperature (10 K). These spectra were taken with the use of an Ar ion laser excitation (=488.8nm). The value x equals 0, 0.045, 0.117, 0.152, 0.1811 and 0.268. For the pure ZnTe, we observed the well-resolved five exciton lines that can be attributed to free and bound excitons. The integral (total) intensity of photoluminescence lines for the sample with x=0.045 approximately in five time higher than for the sample ZnTe. The photoluminescence for the samples is caused by excitons bounded on Mn. With the increasing of the Mn, the line width of the main peak increases essentially. For the ZnTe film the FWHL is 3 meV about, for the $Zn_{0.74}Mn_{0.26}Te$ film the one is 35 meV. The essential increase of the line width indicates an increase of an inhomogeneous structure.

Key words: ZnMnTe; photoluminescence; exciton

1. Introduction

$Zn_{1-x}Mn_xTe$ mixed crystals are diluted semimagnetic semiconductors in which Mn atoms replace Zn atoms in zinc-blende structure ZnTe. The ternary alloy offers possibilities of lattice matching and band-gap tunability. Wide band-gap ZnTe and related mixed crystals are promising materials for use in optoelectronics, since they have a high emission efficiency. Optical properties of ZnTe are well known [1]. It should be expected that the substitution solid solution with Mn will influent on photoluminescence spectra and intensity of the mixed crystals.

In this study, we report and discuss the low temperature photoluminescence spectra of $Zn_{1-x}Mn_xTe$ mixed crystals. The $Zn_{1-x}Mn_xTe$ films were grown by MBE growth on GaAs substrate with ZnSe buffer layer. There were 6 samples with x=0; 0.045; 0.117; 0.152; 0.181; 0.268. The thickness of the film is over 3 μ, of the buffer layer is 0.2 μ about. The excitation source for the PL measurement was Ar-ion laser and the close-cycle refrigerator was used to get the measurement temperature 10 K. The excitation wave length was 488.8 nm that corresponds to the energy 2.5407 eV. The spectra were measured by triple monochromator with the resolution 0.1 meV.

2. Results and discussion

The photoluminescence spectra (they involve excitons and Raman scattering) of ZnMnTe films are presented in Fig. 1. Multyphonon resonant Raman scattering gives a contribution to the photoluminescence spectra. The Raman scattering lines on LO (mainly) and TO phonons are narrow ones. In particular, the sharp lines at the energies 2.5150 eV, 2.4873 eV, 2.4604 eV, 2.3858 eV, 2.3583 eV, 2.3322 eV are caused by scattering on ZnTe-like one, two three, six, seven, and eight LO phonons, respectively [2]. The well-resolved free- and bound-exciton lines for the pure ZnTe indicate good crystallinity of the film. For the ternary alloys the well-resolved lines are not observed. To find out the reason of this we have analyzed a dependence of the integral intensity on x. This dependence is pre-

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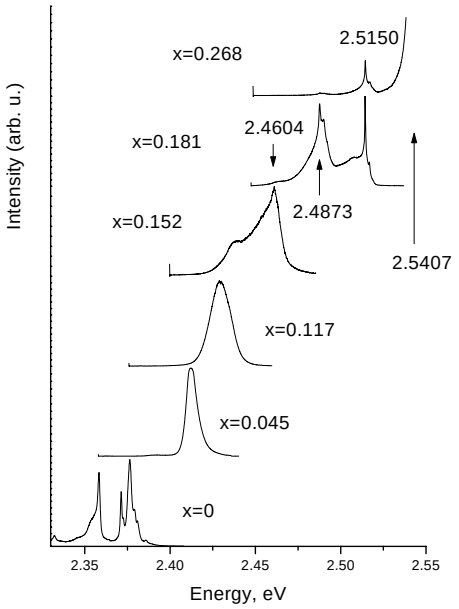

Fig. 1. The low temperature (10 K) photoluminescence spectra of $Zn_{1-x}Mn_xTe$ films.

sented in Fig. 2. One can see that the total photoluminescence intensity for the ternary sample with 4.5 % Mn-content is higher approximately in five time than the one for the pure ZnTe film. It means that excitons bounded on Mn give the main contribution in photoluminescence spectra of the mixed crystals. One type of the excitons (bounded on Mn) for the ternary alloys is surpassed. Therefore, another exciton types are not observed for the ternary alloys. At the same time one can see that the total intensity of the mixed crystals at x¿0.12 decreases essentially. It means that a probability of nonradiation recombination processes increases with Mn content. It is clear that this probability depends on the Mn concentration nonlinearly. It increases very strong at the Mn content 14 - 15 %. Probably, at such concentrations the exciton radius is approximately equal to the average distance between Mn atoms. In our case the radii equals approximately two lattice constant (about 10 - 12 Å). Such radius assumes an enough high an exciton binding energy. Indeed, it is known that II-VI compounds exhibit significantly larger exciton binding energies. For example, the exciton binding energy is 21 meV in ZnSe [3] and 60 meV in ZnO [4] comparing to 4.2 meV in GaAs. The binding energy for free light hole excitons in pure ZnTe is 12.7 meV [1]. The excitons bounded on impurities have higher value of the binding energy. One can estimate the binding energy from classical hydrogen model. If suppose the dielectric function to be 10, and comparing the exciton radius and classical Bohr radii, one finds the effective mass of the carriers to be

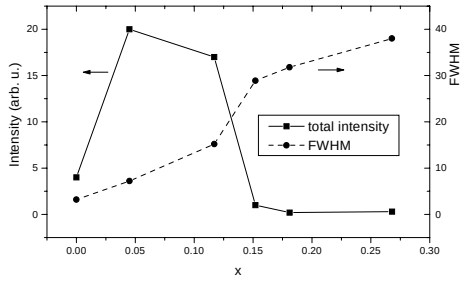

Fig. 2. The dependence of the total photoluminescence intensity and the line width (FWHM) on Mn contents

$0.5m_0$ (m_0 the free electron mass). Therefore, the exciton binding energy is 50 - 60 meV about. These data correlate with photoluminescence line width ones.

The photoluminescence line width contain of inhomogeneous and homogeneous broadening. The homogeneous broadening arises from a neighbour nonuniformity and cannot be diminished by a temperature decrease. Another part of the line broadening is caused by lattice vibrations and depends on the temperature. This exciton scattering is caused by acoustic and optical phonons. For our investigation it is necessary to note that the scattering on the phonons at 10 K does not influent by the Mn content change. Therefore, a line width behavior on the Mn content reflects mainly an inhomogeneous distribution of the Mn impurities. The depending of the photoluminescence line width on the Mn content is presented in Fig.2. One can see that the line width increases from 3 meV (ZnTe) to about 35 meV ($Zn_{0.74}Mn_{0.26}Te$). As for the total intensity one can see the increase of the line width at the Mn content 14 15 %. It should be noted that big structural fluctuations can take a place nearly percolation threshold. For the 3-D case the percolation threshold takes a place at 19 % that is nearly 15 %.

In conclusion, we have supposed that the essential decrease of the total intensity at the 14 15 % Mn content is caused by the scattering of the excitons on Mn (it means that exciton radius equals the distance between Mn atoms). On the basis of the hydrogen model the exciton binding energy was estimated. It is 50 60 meV. The inhomogeneous line broadening was explained by the exciton scattering on the Mn atoms.

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