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PHOTOLUMINESCENCE OF EXCITONIC REGIONS OF GAAS/ALGAAS QUANTUM STRUCTURES

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Abstract
The excitonic spectra of photoluminescence, photoluminescence excitation, and magnetophotoluminescence of single (GaAs/AlGaAs/ZnMnSe) and double (GaAs/AlGaAs/ZnSe/ZnCdMnSe) heterovalent quantum wells fabricated by molecular beam epitaxy have been studied. It is shown that the spectrum exciton absorption of such quantum wells basically reproduces the resonance spectrum of excitons expected for ordinary isovalent quantum wells with similar parameters, while the process radiative recombination of excitons shows significant differences: there is an additional a localization mechanism determined by defects generated by the heterovalent interface

Keywords: Photoluminescence, molar mass, quantum well recombination, relaxation.

Introduction

Heterovalent semiconductor structures are heterostructures containing compounds of various chemical groups. Currently The most studied structures of this type include heterovalent interfaces A3B5/A2B6, For example GaAs/Ge or GaAs/Si. Initial interest in it was determined by the search for new semiconductor systems that allow flexible control of the size of zone gaps at the heterointerface. Initial interest init was determined by the search for new semiconductor systems that allow flexible control of the size of zone gaps at the heterointerface. For example, it was shown that the valence band discontinuity at the GaAs/ZnSe boundary can vary directionally between 0.58 and 1.2 eV by changing the intensity ratio of Zn/Se molecular flows at the initial stage of ZnSe growth on the GaAs surface using the molecular beam method epitaxy (MPE) [5]. The disadvantage of heterovalent structures is the obligatory presence of charged (donor and acceptor) bonds at the hetero-interface, which leads to the formation of point defects, and also to the appearance of areas of local doping and strong electric fields [4]. Probably exactly these factors are responsible for the observation of expanded photoluminescence (PL) spectrum (up to 50 meV) in

heterovalent quantum wells AlAs/GaAs/ZnSe [6] and smoothed absorption edge without excitonic features in multiple quantum wells and superlattices GaAs/ZnSe [7]. Significant progress in understanding the properties of heterovalent nanostructures has been the development and fabrication of double heterovalent quantum wells GaAs/AlGaAs/ZnSe/ZnCdMnSe [8,9]. In these structures electrons in a non-magnetic GaAs/AlGaAs quantum well and the quantum well of dilute magnetic semiconductors (DMS) ZnCdMnSe/ZnSe are resonantly coupled through a thin tunnel barrier containing a heterovalent AlGaAs/ZnSe interface. In this work, optical exciton spectroscopy methods are used to assess the influence of the heterovalent interface on the electronic properties of both single and double heterovalent quantum wells GaAs/AlGaAs/ZnSe/Zn(Cd)MnSe. In particular, for the first time in heterovalent quantum wells, a distinct resonant spectrum of exciton absorption.

Samples and experimental techniques

We studied two samples of heterovalent quantum wells (with a single quantum well and with a double quantum well), grown on GaAs substrates in a two chamber MBE setup (see [8]). The layers of the lower part of the structure (GaAs and AlGaAs) were deposited in a chamber specialized for the growth of group A IIIBV compounds. Then the sample was moved through a high-vacuum pipeline into the second chamber, intended for the growth of compounds of the AII-VI group, where the growth of Zn(Mn)Se and ZnCdMnSe layers was carried out. The key factors determining the overall quality of a sample are

1) final reconstruction of the layer surface A_3B_5

2) sequence of operations at the initial stage A_2B_6, height A -parts of the structure, i.e. during the formation heterovalent interface.

Options double quantum wells were chosen based on the intention to realize the resonance of the lower levels of the dimensional quantization of electrons in two quantum wells. Gap valence band at the AlGaAs/ZnSe heterointerface is about 1 eV. Low-temperature PL and PL excitation spectra were measured in the temperature range 1.9–10 K in an optical helium cryostat. During the measurements, the sample was in liquid helium under pumping conditions or in helium vapor. PL spectra were detected at excitation by linearly polarized light of a laser line of 532 nm (continuous laser Verdi10 from Coherent) or 404 nm (continuous laser Cube from Coherent). PL excitation spectra were recorded by scanning the lasing wavelength laser pumped pyridine-2 dye Verdi10. To measure the PL spectra when an external magnetic field was applied, the sample was placed in Magneto-optical helium cryostat from Oxford with split superconducting solenoid. Faraday geometry was used, in which the

magnetic field parallel to the direction of propagation detected radiation and the structure growth axis (z axis).

The degree of circular polarization of the PL was analyzed using a (1/4)-wave plate and film linear polarizer. Numerical calculation of resonant energies and relative oscillator strengths of exciton states in quantum pits was carried out within the framework of the envelope function method variational method using the factorized test function of a quasi-two-dimensional exciton [11,12].

Experimental result

The parameters of semiconductor connections necessary for calculations are taken from [13]. In Fig. Figure 2 shows the PL and excitation spectra PL of a sample with a single quantum well. Structure shows a single bright PL line with energy quantum near 1.643 eV. Line width at half maximum is 14 meV, which is comparable to the energy variation lower exciton level as the width changes 35 angstrom quantum well per monolayer. In other words, the observed width of the PL peak is quite described as standard for a single quantum well the mechanism of inhomogeneous broadening associated with monolayer fluctuations of its thickness. PL excitation spectrum shown. The PL excitation spectrum shown in Fig. 1, was detected at a wavelength near the peak maximum PL when scanning the exciting wavelength Sveta. The spectrum consists of two distinct lines with maxima near quantum energies of 1.657 and 1.688 eV.

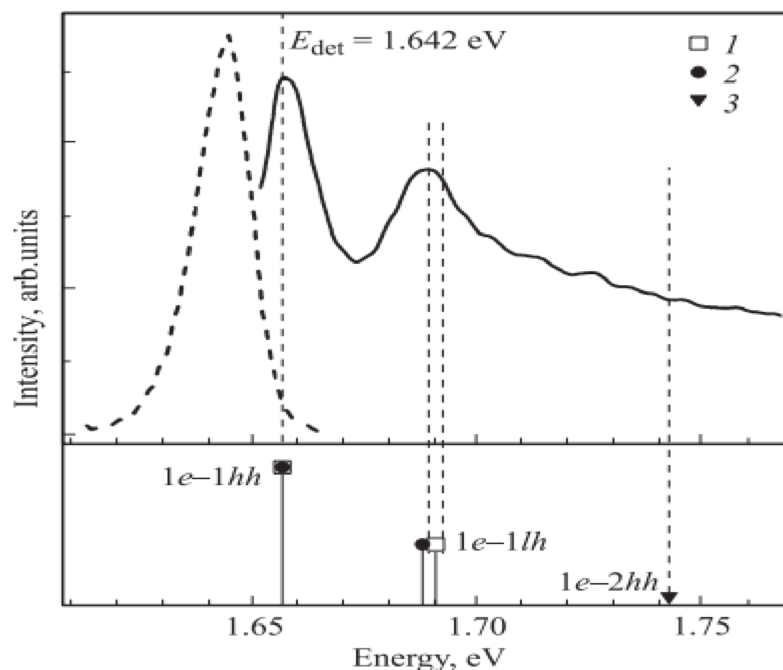

Fig.1. Spectra of photoluminescence (dashed line) and photoluminescence excitation (solid line) structures with a single heterovalent quantum well

GaAs/AlGaAs/ZnSe/ZnMnSe at 10 K. In the lower part of the figure, vertical segments conventionally show the calculated energies and oscillator strengths of exciton transitions. Symbols 1 correspond to the ratio of conduction band and valence band discontinuities at the GaAs/AlGaAs interface, equal to 65/35, and symbols 2 and 3 - 69/31. It is natural to attribute the lower peak to resonant absorption of light with the participation of the ground exciton state in the quantum well, corresponding to transitions between the first electronic level and the first level heavy hole (1e−1hh). Theoretical adjustment of the energy of such a state to the experimentally measured one value gives the quantum well width 37˚A. Stokesov shift of the PL line maximum relative to the lower peak exciton absorption is 14 meV. This value is 40% higher than the shift value determined according to the phenomenological relationship 1Est = 0.61PL , where 1PL is the width of the PL peak at half maximum [14], which may indicate the presence additional mechanism for exciton localization in heterovalent quantum well.

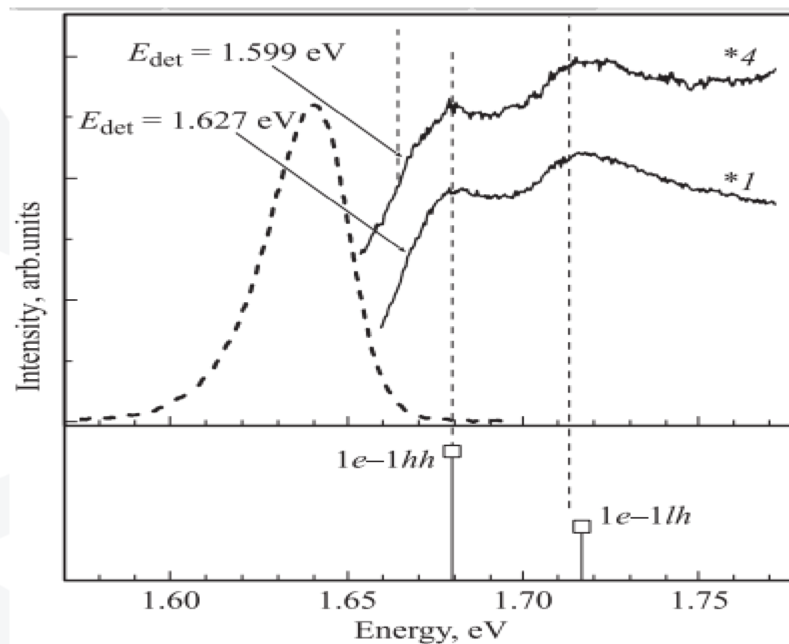

Fig 2. Spectra of photoluminescence (dashed line) and photoluminescence excitation (solid lines) of a structure with a double heterovalent quantum well

GaAs/AlGaAs/ZnSe/ZnCdMnSe at 10 K. In the lower part of the figure, vertical segments conventionally show the calculated energies and oscillator strengths of exciton transitions. (Qc = 65%)

The second peak in the PL excitation spectrum is well described by resonant absorption at the excitonic transition, including the first electron level and the first light hole level (1e−1lh). At the bottom of Fig. 2 vertical segments show the parameters of the calculated exciton states: the position of the segment marks the resonant

excitation energy of the exciton, and its length is the relative strength of the oscillator. Different icons at the tops of segments correspond to different values of the parameter Qc, which determines the proportion contribution of the conductivity band discontinuity at the GaAs/AlGaAs heterointerface to the total difference in band gap widths GaAs and AlGaAs zones. Symbols 1 correspond to the most generally accepted value of Qc = 65% [13], while symbols 2 correspond to Qc = 69%. In this calculation, the presence of a heterovalent interface at a distance of 30˚A from the quantum well was not taken into account; both barriers of the quantum well were modeled as infinite layers of AlGaAs. It can be seen that the second value is slightly better describes the position of the exciton peak with a light hole. However, the difference between the two calculated values (~ 3 meV) is small and comparable to the expected the error of the energy calculation method used exciton resonances, which allows us to draw a conclusion about the actual identity of the experimental spectrum of excitons in the heterovalent quantum well under study and the expected spectrum for a model GaAs/AlGaAs quantum well with similar parameters. An important test for the presence within a quantum well
noticeable electric field having a non-zero projection onto the direction of growth is a manifestation in the exciton spectrum of “cross” transitions between levels of electrons and holes with different parities. For In a symmetric quantum well, such transitions are completely prohibited, while the application of an electric fields reduces symmetry and makes them resolved. Symbol 3 at the bottom of the figure. 2 corresponds to the calculated energy of one of these transitions (1e–2hh). There are no features in the experimental spectrum near this quantum energy, which indicates insignificance of the influence of the heterovalent interface on the symmetry of electronic states in a quantum well.In Fig. Figure 2 shows the PL and excitation spectra PL measured in a sample with a GaAs/AlGaAs/ZnSe/ZnCdMnSe double heterovalent quantum well. Peak PL in this structure is observed at almost the same the same quantum energy as in the sample with a single I my. Despite the close width of the quantum well
GaAs/AlGaAs, spectral width of the PL peak in this the structure turns out to be 2 times larger, which indicates the presence of additional expansion mechanisms. As in the sample with a single quantum well, the PL excitation spectrum includes 2 peaks, energies which correspond to the calculated energies of the lower levels of excitons with heavy holes e 1–1hh and e 1–1lh in a GaAs/AlGaAs model quantum well width 32˚A. However, the peak intensities are inverted - the exciton with a light hole dominates, which characteristic of resonantly coupled quantum wells [15]. Moreover, the shape of the heavy exciton absorption peak hole depends on the detection

wavelength: when recording within the long-wavelength tail of the PL line the lower peak in the PL excitation spectrum has a complex shape with a characteristic shoulder at the long-wave decay. Such features of the spectrum indicate the implementation of resonant interaction of electronic levels in GaAs/AlGaAs and ZnCdMnSe/ZnSe quantum wells

Conclusion

The presented results allow us to evaluate the prospects for the design and manufacture of structures with heterovalent quantum wells in the (Al,Ga)As/(Zn,Cd,Mn)Se system. It is shown that the technology MBE makes it possible to produce quantum wells of optical quality in close proximity (2–3 nm) from the heterovalent interface. Exciton spectrum absorption of such quantum wells (both single and and double) basically reproduces the spectrum excitons, expected for conventional isovalent quantum wells with similar parameters. Nevertheless the process of radiative recombination of excitons in such structures demonstrates significant differences. If in undoped isovalent narrow quantum wells, the main recombination channel is associated with the emission of excitons localized by fluctuations in the thickness of the quantum well, then in heterovalent structures there is an additional localization mechanism determined by defects generated by heterovalent interface.

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