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THE EFFECT OF MOLAR MASSES ON THE OPTICAL PROPERTIES OF QUANTUM WELLS I $N_XGA_{1-X}AS/GAAS$

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Abstract
The heterogeneity of the composition of quantum wells over their thickness has been established. The energy position of exciton recombination lines in quantum wells with a stepwise indium distribution profile has been calculated, the results of which are in good agreement with experiment.

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

Introduction

Basic Scope of Work for Creation and Investigation structures with single or multiple hetero-transitions, such as heterostructures with selective alloying, quantum pits and superlattices, you are full on the basis of gallium and aluminum arsenides [1]. The crystal lattice parameters of these two materials represent an almost perfect heteropara, that enables to obtain high quality structures. One-to-one use of other materials can be significant improve the performance of existing instruments and expand their functionality. Recently, structures with stressed $InxGa_{1-x}As$ layers limited by barriers from GaAs or AlGaAs [2,3]. So, use In_xGa_{1-x} As as high transistor channel electron mobility (NEMT) made it possible to obtain in one of the latest works [4]. maximum steepness 1510 mS/mm and a cutoff frequency of 220 GHz, which is one of the best achievements for the NEMT. Creationnear-contact varizon layers In_xGa_{1-x} As allows make non-melting ohmic contacts, which significantly simplifies the technology of manufacturing circuits with high degree of integration [5]. We have proposed an ori-ginal method for creating independent ohmic contacts to quantum pits of isotypic conductivity in a two-pit heterostructure based on the use of quantum wells of various compositions, including In_xGa_{1-x} As [6]. Such a wide application of strained InGaAs-ha-therostructures requires full-scale studies properties of the obtained samples in order to optimize technological modes of In-containing generation layers and interfaces. Another problem is to identify the zone diagram of structures with heterojunctions InGaAs-AlGaAs or quantum wells, which is a

necessary condition for creating devices with specified characteristics. In particular, in the development of the technology of obtaining quantum-dimensional layers InGaAs you need to know the basic layer settings, such as molar fraction of indium and layer thickness. To control these ex situ parameters in quantum-dimensional structures the photoluminescence (FL) method of various compositions is usually used, including In_xGa_{1-x} As. Two structures were grown with a single quantum well – A and B samples, as well as structure with three quantum wells – sample C. Based on the varying relationships of the equivalent pressures of the molecule-lar beams Ga and In with the temperature of the corresponding molecular sources and calibrations by velocities growth of GaAs and InAs layers, the molar fraction of indium (x) p-personal quantum wells was to vary from 0.08 up to 0.25, and the widths of quantum wells (d) - from 3 to 13.5 nm. The focus was on relatively wide quantum x≈0.2 pits, which can be used in field effect transistors of various types. In connection with with this to ensure high conductivity of such two-dimensional growth temperature channels In-containing layers exceeded the commonly used values on 30–40°C [7-9].

Experimental result

Photoluminescence FL measurements were performed at nitrogen fluid temperature with Ar+ excitation- laser on length 488 nm waves. Excitation radiation was formed in a spot of diametrom~50 μm. Maximum density excitation was 200 W/cm^2. The spectra were rearranged using a monochromator MDR-23 and cooled photomultiplier FEU-62 in counting mode photons. FLIPL (E) samples A, B and C, pre-core in Fig. 1, a, b show intense and however, relatively wide bands corresponding to exciton recombinations e1 – hh1quant wells. Band maximum energies E_{e1-hh1} and their width at half height are shown in Table 1 (FL column). Widening of FL bands can be a consequence of imperfections of the boundaries of the partition of the yam-barrier, leading to fluctuations in the width of the quantum well, so and heterogeneity of composition in depth of quantum wells [9-11]. The presence of such disorders is confirmed by the results of X-ray diffraction studies, on the basis of which it is more eroded (and depleted indium) is the lower hetero-boundary. Of note is the high intensity of radiator recombinationIPL from InGaAs layers exceeding by 2 orders of magnitude signal from barrier layers even for peak FL of the smallest amplitude (sample C - quantum ayama 3 nm wide).

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Samples	FL		Calculation-1		Calculation-2						
	E_{el-hhl} eV	Line width meV	d, nm	x_1	d_1 nm	x_1	d_2 nm	x_2	d_3 nm	(x)	∑d nm
A	1,4391	9	14.6	0.064	3.3	0.033	10	0.07	1.3	0.04	14.6
B	1.3306	21	13.4	0.175	3.4	0.01	10	0.17			13.4
C	1.3272 1.4459 1.2999	12 13 25	12 13 25	11 3.0 6.0	1.6 1.6 1.0	0.11 0.11 0.17	10 1.4 5.0	0.175 0.175 0.25			11.6 3.0 6.0

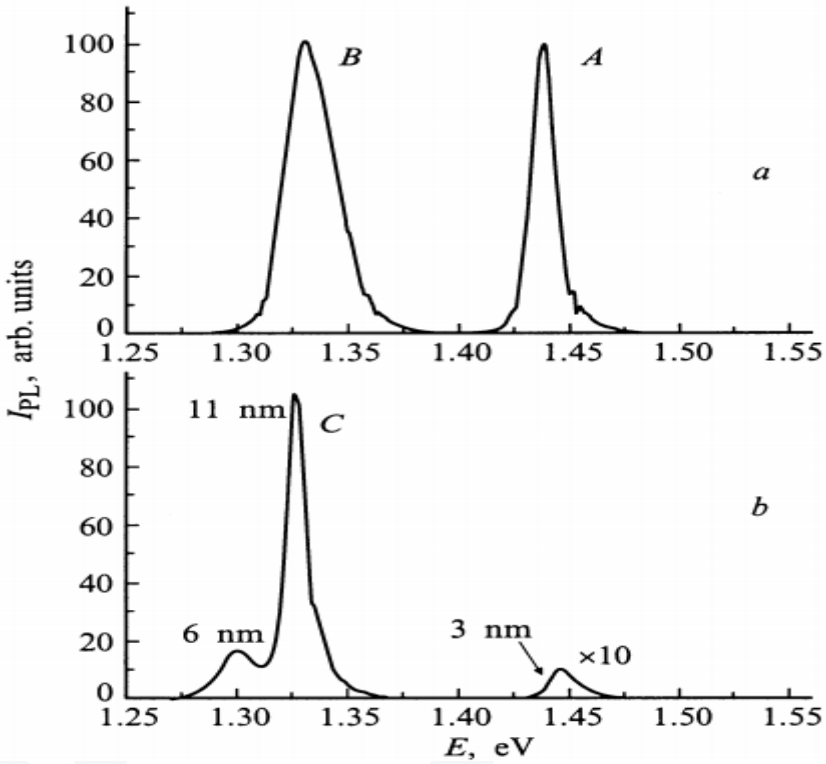

Fig. 1. Photoluminescence spectra of the samples under study: a - structures A and B with single quantum wells; b—structure C with three quantum wells. T=77 K

Calculation of the energy of the photoluminescent transition Ee1–hh1 and determination of the parameters of quantum wells Since the grown samples contained predominantly wide quantum wells, the main levels of dimensional quantization in which are located near the edges of the corresponding allowed zones, the heights of potential barriers, and therefore the choice of a specific value of ΔEc/ΔEg are not essential for the calculation the energy position of the peak of the FL. For certainty, was selected the average value of the parametraΔEc/ΔEgiz mentioned in literature equal to 0.7.

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Exciton recombination energy in a quantum well was determined by summing the width In_xGa_{1-x} As band gap at 77 K and plausions of the levels of dimensional quantization corresponding to e1and hh1 and counted from the edges of the corresponding zones, minus exciton bond energy. Dependence the band gapEg (InxGa1 – xAs) from the indium compound is mainly described by the polynomial of the 2nd order [12-14]. Polynomial coefficients for terms 1st and 2nd orders were taken from [15], and for the beginning of the countdown a band gap value has been selected for GaAs at 77 K equal to 1.508 eV:

E_g [eV] = 1.508 – 1.214x + 0.264x2. (1)

Position of the first levels of dimensional quantization for electrons and heavy holes were numerically using the Schrödinger equation, which was solved in one-electron approximation within the envelope-wave function method. Effective Carrier Weights charges (electrons and heavy holes) were considered single-cow for all layers of the structure and equal to the corresponding values in the quantum well, calculated from ratios:

m^*_e =0.0665–0.0642x,

m^*_{hh}=0.62–0.22x. (2).

Therefore, the average value exciton bond energy of 7 meV to calculate all FL peaks are a good approximation. In Figure 2, the symbols (1-3) show the experimental results, and (10–30) - calculated values E_{e1-hh1} for samplesA, Vi C. Calculation errors parameters of quantum wells for samples are returned to the errors of determination specified in Table 1 weighted average parameters of A, B, C samples. From the figure it can be seen that a satisfactory match of results calculation with energy position of FL peaks has location for a wide quantum sample A and C samples. Discrepancy with a narrow hole (3nm) is very significant. Possible the reason for this is the heterogeneity of the distribution indium in quantum pits. In Figure 5, the symbols (1-3) are shown. It should be noted that the expe-normally observed energies of the e1–hh1 transitions give underestimated values of molar fraction of indium by compared to expected. Figure 2 shows the values molar fraction of indium in right-angled quantum pits, in which the calculation results and expe-dimensional data coincide. Defined in this way image from dependencies E_{e1-hh1}= f (d, x) parameters quantum wells are given in Table 1 (calculation 1).

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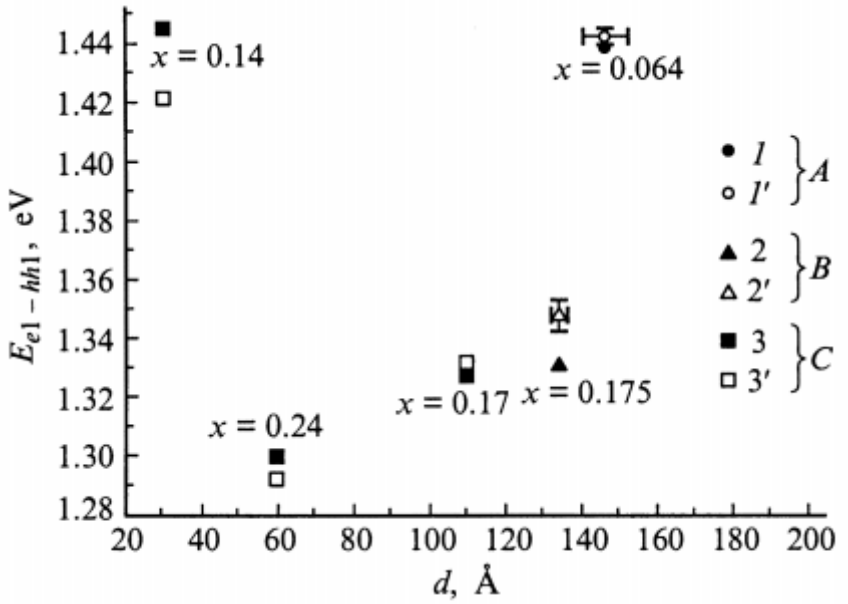

Fig. 2. Experimental exciton recombination energies e1 – hh1 in the quantum wells of the studied samples (1-3) and corresponding design values for the rectangular model pit (10–30).

It should be noted that the expe-normally observed energies of the e1–hh1 transitions give underestimated values of molar fraction of indium by compared to expected. Figure 2 shows the values molar fraction of indium in right-angled quantum pits, in which the calculation results and expe-dimensional data coincide. Defined in this way image from dependencies $E_{e1-hh1} = f(d, x)$ parameters quantum wells are given in Table 1 (calculation 1). To find the reasons for the difference between theoretical and experimental results were calculated fluorescent transition energy in quantum wells stepped shape. Formation of such an area of impoverishment due to surface segregation of indium atoms in the process of quantum well growth. Used by us the increased growth temperatures required to radiate the high conductivity of the In-containing channels; contribute to the realization of this effect. As a result, the excess indium formed in the superhostic region of the quantum well is either desorbed into the process of disrupting growth at the upper limit, or diffuses into the adjacent GaAs layer. In this case, the depleted layer is formed by diffusion of In atoms in nearby 3 mono layer GaAs barrier area designed to prevent evaporation indium when growth is interrupted. Desorption of excess indium occurs for sample B not coated with protective GaAs film when growth is interrupted on the upper geta border Taking into account the above, the energy positions of the FL peaks of quantum wells consisting of several areas with different indium content. When calculating energies fluorescent transitions of quantum wells of sample C it was assumed that InGaAs layers consist of

two obla-stey: an area depleted in indium due to surface segregation, and the core of the pit, the composition of which is close to the expected one of the epitaxy modes. It was also assumed that molar fractions of indium in these layers differ 1.5 times. Coincidence of calculated transition energies e1 – hh1 with experimental values for grown quantum wells taking into account the averaged coupling energy an exciton of 7 meV was observed at, indicated in Table 1. From the presented data should be taken into account the heterogeneous pro-fillets of the composition of quantum wells. This is especially true for narrow (less than 6 nm) quantum wells and increased epitaxy tempo-ratur, since the thickness is depleted the indium of the region is comparable to the thickness of the core of the quantum holes Fig. 4. Photoluminescence spectra of the test samples: a - structures A and B with single quantum wells; b - structures by three quantum wells. T=77 K.

Conclusion

Comprehensive photoluminescent studies carried out in this work heterostructures In_xGa_{1-x} As allowed to establish connection of energy position of photoluminance-tsence lines of quantum wells with heterogeneity of their composition. Using an empirical formula to determine band $In_xGa_{1-x}As$ in the presence of stresses involving a model of a quantum well of a pre-molar shape gives satisfactory agreement with experiment for relatively wide (more than 6nm) quantum wells with low (less than 0.17) molar share of indium. The most recent refinement of the model for calculating the FL spectra of narrow quantum wells require accurate knowledge of the jump ratio potential in the conduction zone to the forbidden width zones $In_xGa_{1-x}As$ ($\Delta E_c/\Delta E_g$).

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