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PHOTOREFLECTANCE MEASUREMENTS OF InGaAs/GaAs QUANTUM WELLS

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Samples with InGaAs/GaAs quantum wells were grown by metallo-organic chemical vapour deposition in order to detect and analyze GaSb islands deposited on the surface. Results of photoreflectance measurements of quantum wells are reported. The correspondence between broadening of quantum well transition lines and GaSb structures has been observed.

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1. Introduction

Recently quantum dots and low dimensional structures have been of great interest due to interesting physical phenomena and possibility for useful applications. Quantum dots while observing by microscope are difficult to see in photoluminescence and photoreflectance measurements. In order to help to analyze small GaSb structures on the surface a set of samples with quantum well under the GaSb dots was prepared.

2. Experimental

Samples were prepared by metallo-organic chemical vapour deposition (MOCVD) on [100] GaAs substrate. For all samples 750 nm GaAs buffer was grown to improve a surface quality. Four samples were investigated:

1. $Ga_{0.82}In_{0.18}As$ quantum well (QW) of 50 Å covered by 200 Å GaAs barrier;
2. $Ga_{0.82}In_{0.18}As$ QW of 50 Å covered by 120 Å GaAs barrier followed by 18 Å GaSb;
3. $Ga_{0.82}In_{0.18}As$ QW of 50 Å covered by 120 Å GaAs barrier followed by 36 Å GaSb;
4. $Ga_{0.82}In_{0.18}As$ QW of 50 Å covered by 200 Å GaAs barrier followed by 36 Å GaSb.

The samples were intentionally undoped, however the electron concentration in GaAs was about 2×10^{15} cm^{-1} and the hole concentration in GaSb was about 2×10^{17} cm^{-1} as deduced from the growth parameters.

Because of the lattice mismatch between GaAs and GaSb (7.8%) a thin strained layer of GaSb is unstable and after depositing a few monolayers GaSb relaxes and forms small anisotropic islands of typical dimensions 100×200 nm in agreement with previous investigations [1]. The sample 1 with 50 Å QW but without GaSb islands was prepared for comparison.

The influence of GaSb islands on energy states in QW was investigated using photo-voltaic spectroscopy (PVS) and photoreflectance measurements (PR) at room temperature. The PR measurements were performed using a GDM-1000 monochromator, a He-Ne laser and a Si detector.

3. Experimental results

The PVS results for the sample 3 are presented in Fig. 1. Successive curves correspond to various depths of etching of the layer. The curve for $d = 0$ corresponds to an unetched layer, and the curve for $d = 2$ nm corresponds to the etching of the GaSb islands. The results of PVS show three maxima at 1.30, 1.32, 1.36 eV, corresponding to three transitions in QW.

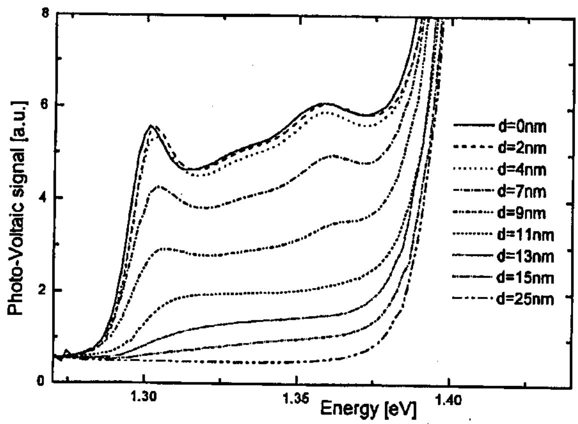

Fig. 1. Photo-voltaic spectroscopy results of the sample 3 with 120 Å barrier and 36 Å GaSb islands. Successive curves correspond to various depths of etching.

Energy positions of the first transition during etching for the sample 1 without GaSb and the sample 3 with GaSb islands are plotted in Fig. 2. It can be seen that removing GaSb islands produces a shift in a position of the first QW level by about 2 meV. This effect does not exist on the sample 1 without GaSb. Moreover the exponential dependence of energy versus barrier thickness has been observed. It is due to the exponential tail of wave functions of states in a finite quantum well: $\psi(x) = a\exp(-\kappa x)$, where $\kappa = (2\Delta E_m)^{1/2}/2\pi h$.

The photoreflectance results in the energy range 1.27–1.33 eV corresponding to the first QW state are shown for three samples in Fig. 3. Experimental results indicated as points and curves were calculated according to the following equation [2]:

$$dR/R = \mathrm{Re}[C e^{i\phi}(E - E_0 + i\Gamma)^{-n}], \quad (1)$$

where E_0 is transition energy, Γ — broadening parameter, C and ϕ — amplitude and phase. The parameter $n = 3$ for two-dimensional structures. An estimation of electric field ε in the middle of QW was performed in a simple electrostatic model,

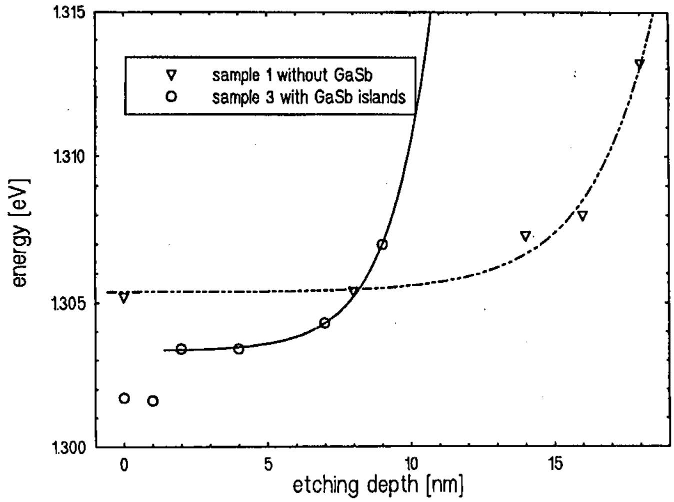

Fig. 2. Changes of the first transition energy in QW during etching. Results for the sample without GaSb and for the sample 3 (with 36 Å GaSb). Solid lines are exponential functions plotted as guides for eyes.

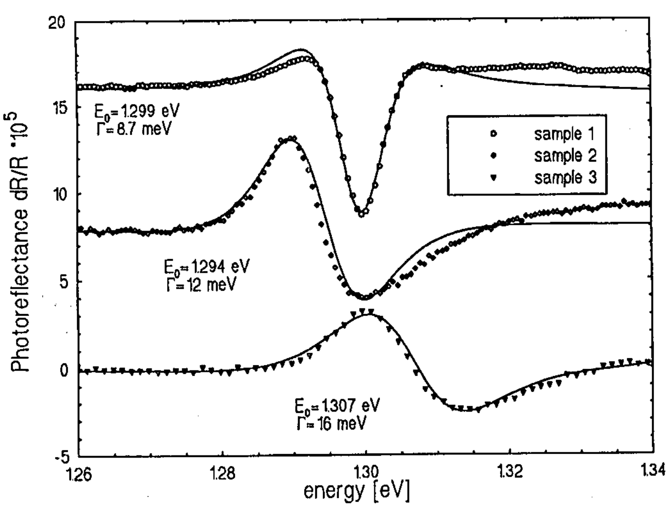

Fig. 3. Photoreflectance spectra of three investigated samples. Solid lines are fitted following Eq. (1).

taking into account that electrons from GaAs move to GaSb islands forming a depleted layer. An electric charge in the depleted layer can generate the electric field up to 10 kV/cm.

The fit of Eq. (1) to the experimental points and electric field ε calculations give the following results:
Sample 1 (barrier: 200 Å; GaSb: 0 Å): $E_0 = 1.299$ eV, $\Gamma = 8.7$ meV, $\varepsilon = 0$;
Sample 2 (barrier: 120 Å; GaSb: 18 Å): $E_0 = 1.294$ eV, $\Gamma = 12$ meV, $\varepsilon = 4.8$ kV/cm;
Sample 3 (barrier: 120 Å; GaSb: 36 Å): $E_0 = 1.307$ eV, $\Gamma = 16$ meV, $\varepsilon = 10.5$ kV/cm;
Sample 4 (barrier: 200 Å; GaSb: 36 Å): $E_0 = 1.296$ eV, $\Gamma = 12$ meV, $\varepsilon = 10.2$ kV/cm.

For the samples with GaSb small transition energy shifts (from −5 to +8 meV) in respect of E_0 for the sample 1 are observed, which can be due to uncertainty of QW width. On the other hand an increase in broadening parameter is clearly observed. A sample with 120 Å GaAs barrier has a larger broadening parameter than a sample with 200 Å GaAs barrier. An increase in GaSb thickness also leads to broadening of the line. Moreover, it is visible that the line width increases with an increase in expected electric field.

4. Discussion and conclusions

Our results clearly indicate that the presence of GaSb islands influences on the energy of the fundamental state of QW. The change of energy position and particular of the broadening of this level is observed.

In principle there can be three reasons of these effects — strain, electric field and the effect of penetration of QW wave function into GaSb islands. Taking into account the GaSb/GaAs lattice mismatch (7.8%) and GaAs pressure band gap shift (12.6×10^{-6} eV/bar) [3] we can estimate that the band gap shift induced by the strain could be at most 1 meV. From the PVS spectra we can estimate the energy shift due to the finite barrier width. For the sample 3 with 120 barrier this shift is of the order of 0.03 meV. So, the best explanation of the broadening of PR lines can be the unhomogeneities of electric field in $Ga_{0.82}In_{0.18}As$ QW generated by GaSb islands.

Acknowledgments

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