Simulation and characterization of AlGaInAs layers selectively grown by LP-MOVPE.

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The quaternary AlGaInAs is considered as an alternative of considerable interest to the most commonly used GaInAsP system for InP-based optoelectronic devices. Indeed a larger conduction band gap offset ΔE_c, leads to improved electron confinement and hole density uniformity in quantum wells. However, work on integrated optical devices using Selective Area Growth (SAG) technique [1–4] has been much more reported for the GaInAsP system than for the AlGaInAs one. In this work we have investigated the AlGaInAs active material system in SAG by low pressure Metal Organic Vapor Phase Epitaxy (LP-MOVPE).

In SAG the growth appears on substrate with a dielectric mask patterned on it. As growth precursors cannot react on the mask, they diffuse close to it which leads to thickness and compositional variations. To model those effects we used a simple three dimensional vapor-phase diffusion model. This computational model based on the diffusion equation ($\nabla^2 N = 0$) simulates the concentration profile $N(x, y, z)$ close to the dielectric mask taking into account both species diffusion length (D/k) and mask pattern.

The MOVPE-SAG technique was performed on different (1 0 0) InAs, GaAs and InP substrates partially covered by mask stripes parallel to the [0 1 1] direction. Stripe width varied from 20 to 230 μm and opened gap between two stripes varied from 20 to 60 μm. This mask pattern allowed us to get a strong SAG effect: a high thickness enhancement ratio and a high compositional shift. The layer composition was evaluated with X-Ray diffraction and Micro Photoluminescence (μPL) with spot size ≈ 3 μm. Thickness was measured by an interferometric technique with high vertical resolution (± 10 Å).

We first studied the three binary alloys InAs, GaAs and AlAs which were grown with a high selectivity, that is without any polycrystal deposition on the mask surface. Using our vapor-phase diffusion model we fit experimental thickness measurements to get the diffusion length of In, Ga and Al species. As usually reported we found that Indium has a really short diffusion length compared to Gallium. The diffusion length of Aluminum which, to our knowledge, had never been reported before, was found in between Indium's and Gallium's ones.

Those three coefficients were then used without any further adjustment to calculate the ternary and quaternary thickness and compositional variations. Figure 1 shows good agreement between experimental and calculated thickness profiles for the AlInAs ternary alloy. On Figure 2 the simulated variation of In, Ga and Al ratio in the stripe direction of AlGaInAs quaternary alloy are reported on left axis. Those variations were then correlated with theoretical photoluminescence variation which appears on the right axis of the graph. The photoluminescence measurements (squares) are in good agreement with those calculations (line). These results valid our model.

The simple vapor-phase diffusion model was shown to be quite accurate for the geometry studied in this work. Moreover, the high selectivity of the growth and the excellent control of the grown material indicate that AlGaInAs SAG technique is suitable for integrated optical devices.
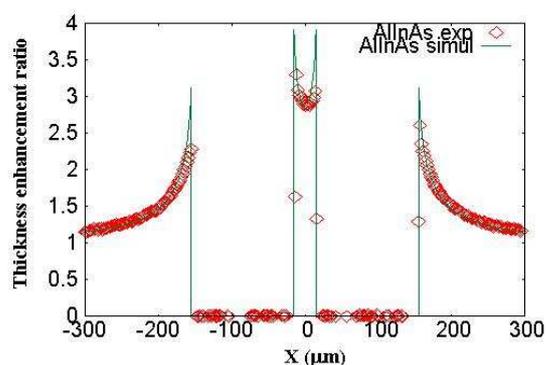

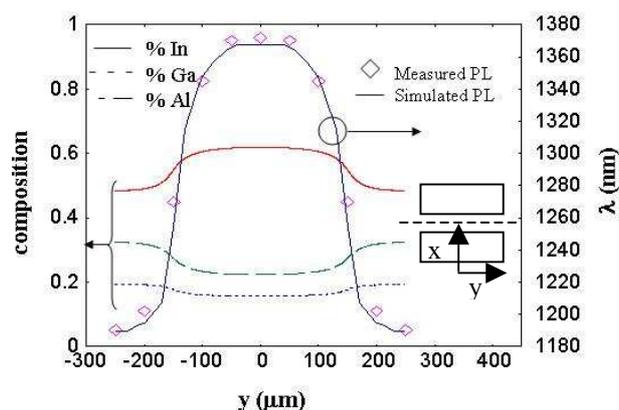FIG. 1. Measured (line) and simulated (squares) thickness variation of a AlInAs layer.

FIG.2. AlGaInAs composition variation (left axis) in the stripe direction together with the corresponding simulated and measured μPL (right axis).

References

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