# MOVPE growth of AlGaAs/GaAs and InGaP/GaAs structures on patterned GaAs substrates.

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### *Introduction.*

Overgrowth of GaAs patterned substrates by MOVPE with AlGaAs or InGaP layers is an important step in fabrication of advanced semiconductor structures. This problem was studied by several authors in the past [1−5 ]. Influence of growth parameters on the layer morphology prepared on various patterns was reported in these papers. Significant dependence of the morphology on the growth temperature has been observed in general.

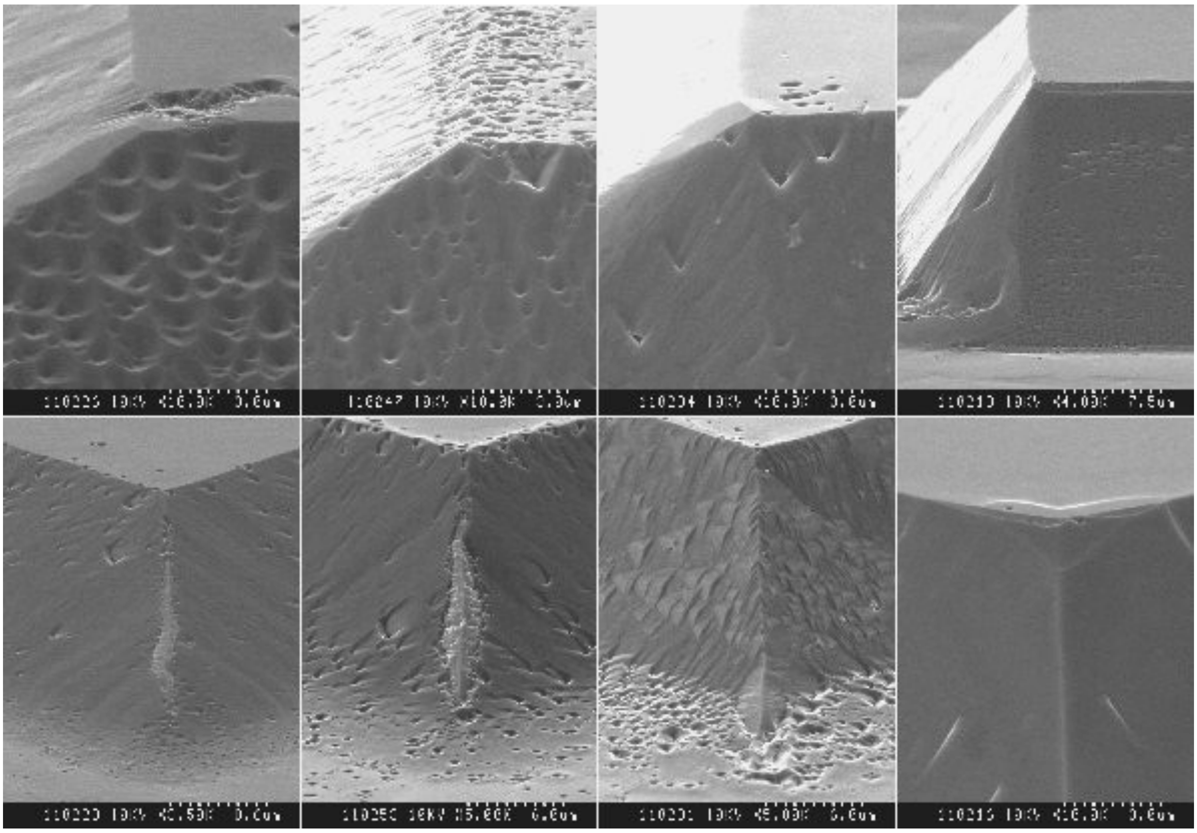
This paper also studies MOVPE growth of AlGaAs and InGaP layers on patterned GaAs substrates. The difference between this work and the data from literature lies in the shape and size of our three−dimensional patterns. A pyramid patterns with height of about 10 micrometers and various slopes of sidewalls were overgrown in our experiments. The sidewalls were prepared as non−crystallographic layers, contrary to structures published by other authors. The main goal of this work was to prepare structures with sufficiently large sidewalls. They can serve as a base for novel devices exploiting properties of two−dimensional electron gas prepared at them.

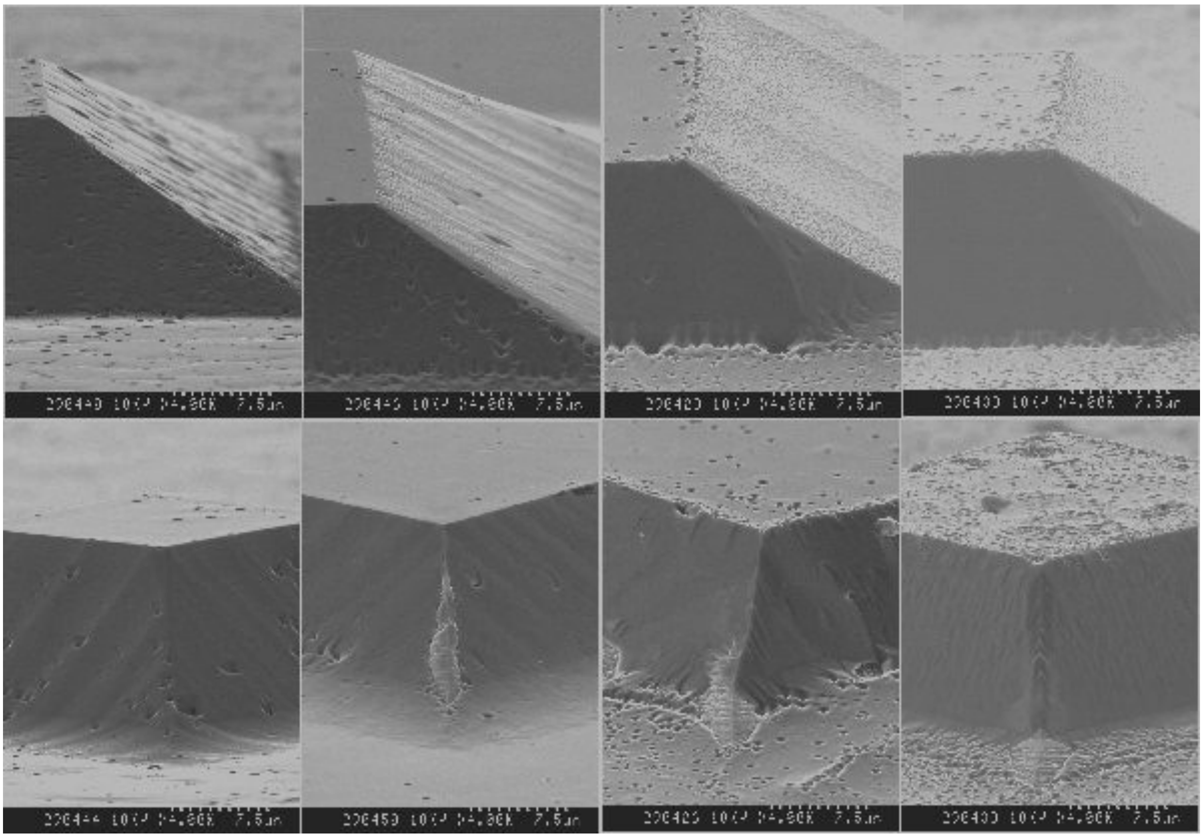
### *Experiments and results.*

Various types of patterns have been prepared on GaAs (001) substrates by unique etching method developed for this purpose [7]. Technique of sacrificial layers was used for preparation of our pyramids. The structure with thin AlAs and about 2 micrometers thick GaAs layers were grown on GaAs substrates at first. Then a titanium film was deposited and structure defined by photolithography. Pyramids were formed by etching in $H_3PO_4:H_2O_2:H_2O$ solution. The slope of the sidewalls can be adjusted by the etchant composition and the thickness of AlAs interlayer. The last step is removing the AlAs/GaAs/Ti caps from the tops of pyramids.

Pyramids with square bases oriented along [100] and [110] directions, as well as ones with circular base were prepared. They had various diameters of base from 10 to 120 micrometers, and various slopes of the sidewalls. The slopes of sidewalls on the [100]−oriented pyramids were 28, 34, 43, and 52 degrees. Different values of the slopes were measured on the [110]−oriented pyramids. While the slopes of sidewalls oriented along [1−10]direction were comparable with [100]−oriented sidewalls, the slopes of [110]−oriented sidewalls were lower due to crystallographic anisotropy. The sidewalls of etched pyramids were smooth, typical value of RMS was about 1−3 nm.

Patterned substrates were overgrown by AlGaAs and InGaP layers in Aixtron AIX 200 apparatus with horizontal reactor in hydrogen atmosphere. Trimethylindium, trimethylgallium, trimethyaluminium, arsine, and phosphine were used as precursors. AlGaAs layers were grown at 640 and 700 $^{o}$C, total pressure in the reactor was 20 mbar, V/III ratio was 330 or 550. Growth rates were 0.87 and 0.52 micrometers/hour. Bad morphology of overgrown sidewalls was typical for the temperature 640 $^{o}$C. Better morphology was observed on the samples grown at 700 $^{o}$C. Pyramids with sidewall slopes of 28, 34, 43, and 52 degrees can be seen in Fig. 1. Pyramids oriented along [1−10]−direction can be seen in upper row, [100]−oriented ones are in bottom row. Sidewall angles are increasing from left to right.





Figs. 1. and 2. SEMs of the AlGaAs pyramids grown at 700 $^{o}$C,growth rate was 0.87 and 0.52 micrometers/hour.

We can see that the quality of [1−10]−oriented sidewalls increases with the slope and the quality of [110]−oriented ones is constant. The worst quality from [100]−oriented sidewalls exhibited pyramids with slopes of 43 degrees. Sidewalls with other slopes were smooth. We repeated the epitaxial growth of AlGaAs layer at 700 $^{o}$C with lower growth rate of 0,52 micrometers/hour. This was motivated by our previous experience with the growth of GaAs, where the growth rate was the most important parameter for preparation of smooth GaAs layers on the sidewalls of pyramids [6]. We can see the results in Fig. 2. We can see worse morphology of [110]−oriented sidewalls and morphology of [100]−oriented pyramid with slope of 43 degrees is better than in previous case. On the other hand, the morphology of [100]−oriented pyramid with slope of 52 degrees is worse in this case.

InGaP layers were grown at pyramids at 600 $^{o}$C, the pressure in the reactor was 50 mbar. The growth parameters were optimized in our previous experiments with respect to the morphology and GaAs/InGaP interface quality. We can see the results in Fig. 3. Strong difference between the morphology of [1−10]−oriented sidewalls and [110]−oriented ones has been observed, especially for low slopes. Difference between various slopes of [100]−oriented sidewalls is also significant.

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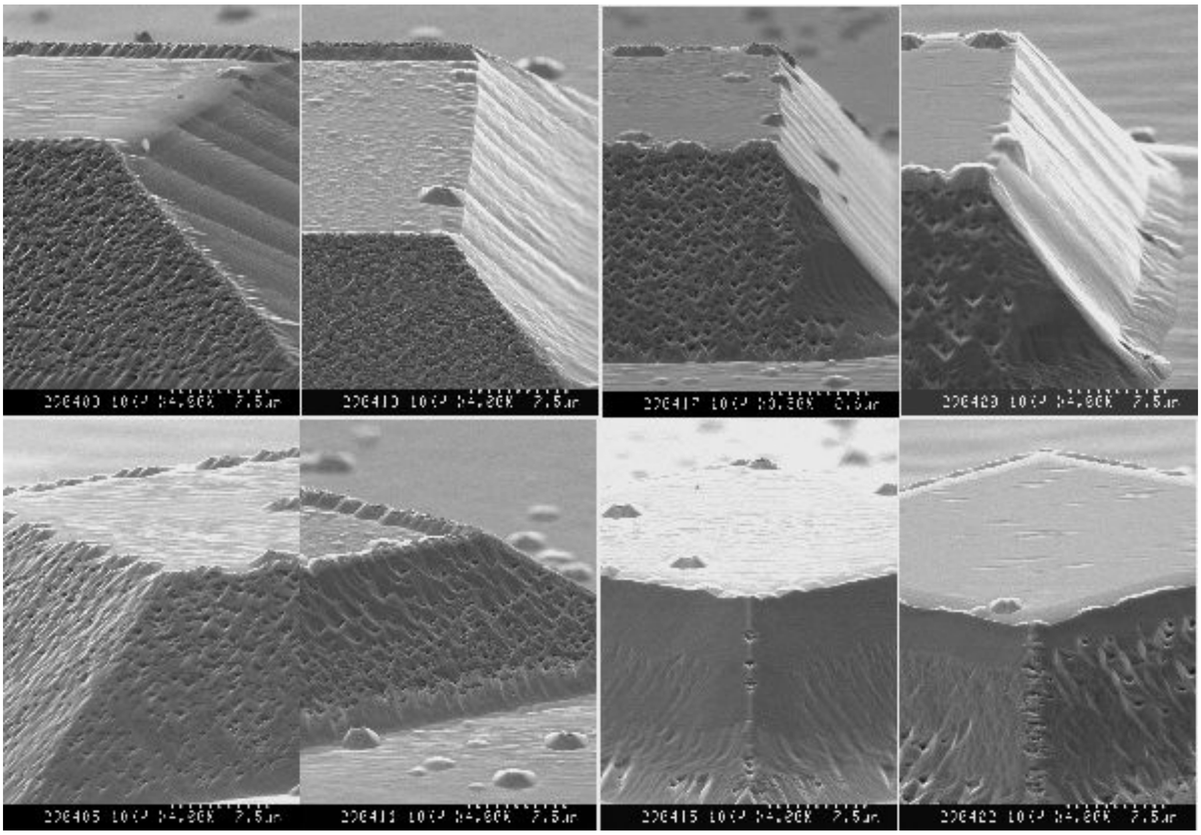

Fig. 3. SEM of the pyramids overgrovn by InGaP at 600 $^{o}$C, growth rate was 1.1 micrometers/hour.

We ca see differences between surface structures of AlGaAs and InGaP sidewalls along [1−10] and [110] directions. That is why they were studied in detail by AFM. While [100] oriented sidewalls are similar and smooth, rough surfaces were observed on [1−10]−oriented sidewalls. We have observed also different structures of the surfaces. Differences between the layer morphology for the slopes 28 and 43 degrees was clear, more significant for InGaP.

***Conclusions.***

Growth temperature is important parameter for preparation of the smooth layers on the sidewalls of the pyramids. Temperature of 640 $^{o}$C was not sufficient for preparation AlGaAs layers, while for GaAs growth it was optimal value [6]. Temperature of 600 $^{o}$C seems to be sufficient for InGaP growth. No dependence on the flow direction has been observed during our experiments. Surface kinetic processes and surface diffusion of adatoms play probably a key role in surface morphology. While better morphology of AlGaAs can be attributed to a slow growth rate, and higher surface diffusion lengths and/or better kinetics consequently, it can be also disadvantage in some cases (Figs.1, 2., [110]−orientation).

The layer thickness on the sidewalls were uniform, small inhomogenities were observed only near edges of pyramids. This fact supports the conclusion, that surface kinetics is the most important factor which has influence on the morphology.

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