# Epitaxial growth of highly mismatched GaInAs layers on nanoporous GaAs substrates

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Pore formation in $A^{III}B^{V}$ materials was reported in a number of recent papers [1-4]. On the contrary, their technological applications in epitaxial growth have not been thoroughly investigated yet.

Epitaxial growth has always been a marriage of convenience between deposited layer and substrate. In the simplest case, both layer and substrate are of the same material, providing a homoepitaxial match. Frequently, it is impractical to use the same material for both the layer and the substrate since certain large single crystals are not available, are expensive, or their properties are inappropriate for the intended application. Different strategies were suggested to achieve high quality single-crystal thin films grown on a lattice mismatched substrate. Significant development in defect density reduction in semiconductor materials has been accomplished using epitaxial lateral overgrowth techniques [5]. Recently, semiconductor epitaxial growth has progressed to pseudomorphic, lattice mismatched systems where a small amount of strain is accommodated in very thin layers [6].

A new approach extending the critical layer thickness in highly mismatched heterostructures is nanoheteroepitaxy [7]. Nanoheteroepitaxy exploits the three-dimensional stress relief mechanisms that are available in nanoscale objects and applies this property to reduce the strain energy in lattice mismatched heterojunctions. While in conventional planar structures the epilayer can only deform vertically, in a nanopatterned substrate a selectively growing epilayer can deform vertically and laterally, and the strain energy decreases exponentially with the distance from the growth interface [8].

We take advantage of a novel concept of the epitaxial growth of largely lattice mismatched layers on nanoporous substrates [9]. It is essential that the substrate takes over most of the strain of the layer at the initial growth stage. We report on the preparation of nanoporous GaAs substrates and on the growth of GaInAs epitaxial layers by the liquid phase epitaxy and metal organic vapour phase epitaxy (MOVPE) on these nanoporous substrates.

The pore etching was carried out in an electrochemical cell containing a fluoride-iodide aqueous electrolyte ($H_2O$-HF-KI) using a configuration equivalent to four electrodes. A home-made potentiostat/galvanostat was computer-controlled and allowed to register all process variables. (100)-oriented GaAs:Si substrates with a carrier concentration of $2x10^{18}$ $cm^{-3}$ were used for the pore preparation. The layers of $Ga_{0.8}In_{0.2}As$ were grown in AIXTRON 200 MOVPE apparatus. The porous structures before and after the epitaxial overgrowth were observed by scanning electron microscopy (SEM) and atomic force microscopy (AFM). The composition of the grown layer was determined by the electron microprobe with wavelength-dispersive spectrometer and correlated with the results of low temperature photoluminescence (PL) spectroscopy. The surface morphology of the layers was observed by Nomarski differential interference contrast microscopy (NDICM).

Figure 1 shows a cross-section of a GaAs substrate with a porous layer of 5 μm in thickness, which was overgrown by 0.7 μm thick layer of $Ga_{0.8}In_{0.2}As$. A comparison of the surface morphology of the epitaxial layer grown on porous and nonporous substrates observed by NDICM is shown in figure 2. While a typical cross-hatching pattern corresponding to a large misfit between the substrate and the layer is observed on the nonporous substrate, a random pattern is observed on the porous substrate. This observation, together with the results of low temperature PL measurements indicate that the porous substrate gives rise to the decrease in the density of extended defects at the heterointerface.

*The work was supported by the project P108/10/0253 of the Czech Science Foundation.*

## References

[1] Föll, H., et al., Advanced Materials, **3** (2003) 183-198.
[2] Santinacci, L. and Djenizian, T., Comptes Rendus Chimie, **9** (2008) 964-983.
[3] Ulin, V. and Konnikov, S., Semiconductors, **7** (2007) 832-844.
[4] Ulin, V. and Konnikov, S., Semiconductors, **7** (2007) 845-854.
[5] Nishinaga, T., Journal of Crystal Growth, **237-239** (2002) 1410-1417.
[6] Atkinson, A., Jain, S.C., and Harker, A.H., Journal of Applied Physics, **5** (1995) 1907-1913.
[7] Zubia, D., et al., Journal of Vacuum Science & Technology B, **6** (2000) 3514-3520.
[8] Luryi, S. and Suhir, E., Applied Physics Letters, **3** (1986) 140-142.
[9] Sitnikova, A.A., et al., Semiconductors, **39** (2005) 523-527.

**Figures**

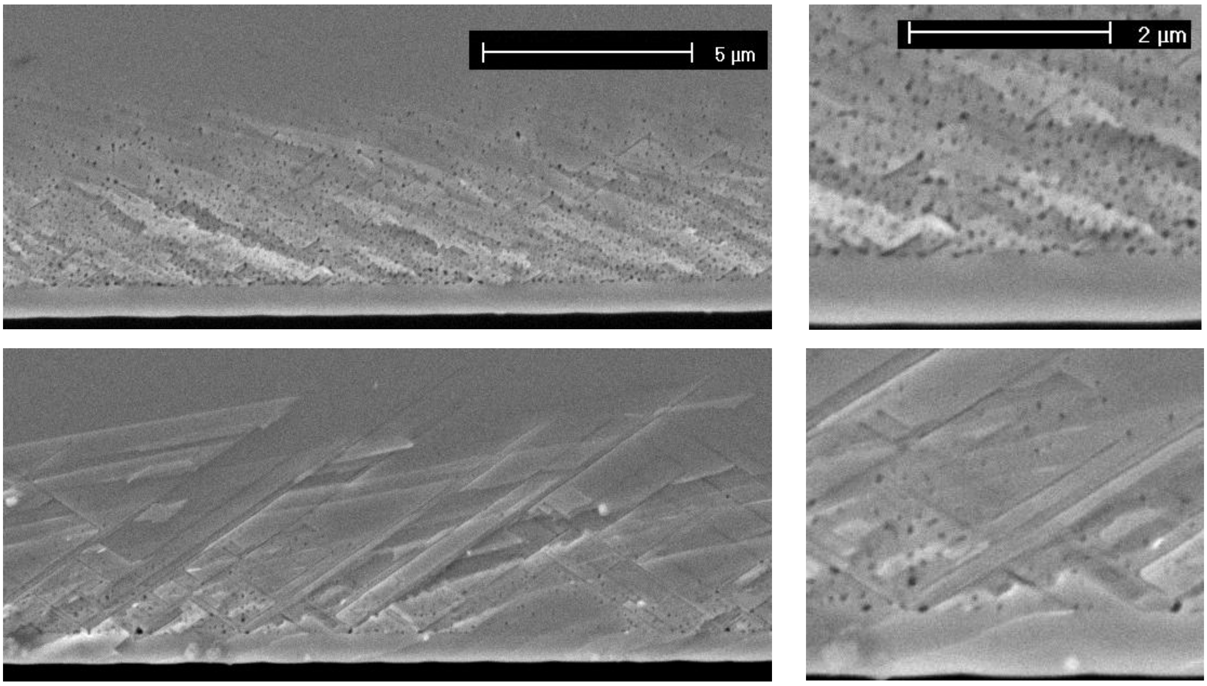


**Figure 1:** SEM micrographs of .the cross section of porous GaAs substrate overgrown by 700 nm thick layer of GaInAs. The sample was cleaved along two perpendicular directions shown on the upper and lower panel respectively. The right panel shows the same with a higher magnification.

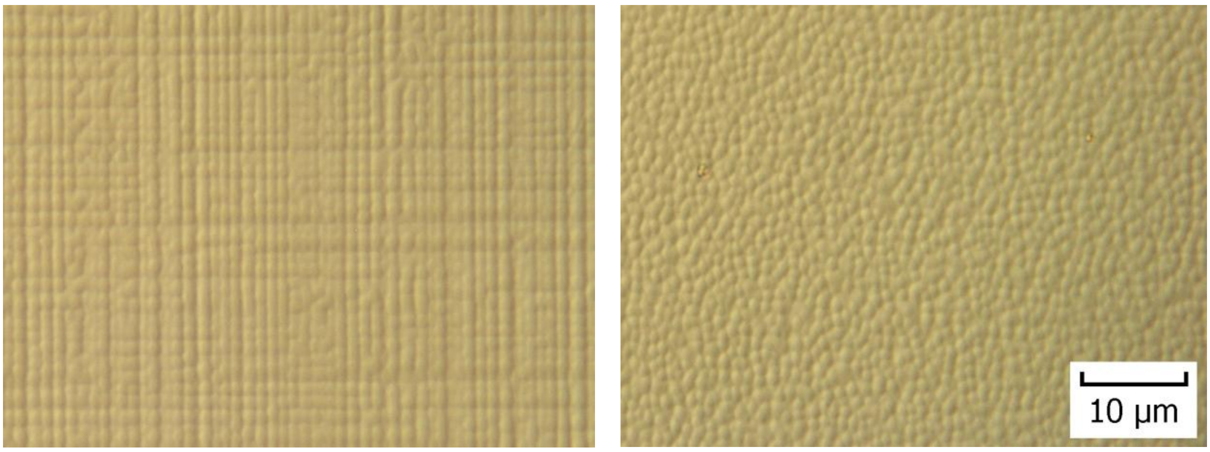


**Figure 2:** Nomarski contrast optical micrograph of the InGaAs layer grown on standard GaAs substrate (left panel) and porous GaAs substrate (right panel).