Liquid-phase epitaxial growth on nanoporous substrates

Jan Grym, Dušan Nohavica, Petar Gladkov

Institute of Photonics and Electronics AS CR, v.v.i., Chaberska 57, Praha 8, Czech Republic
grym@ufe.cz

Abstract

There is a limited number of III-V semiconductor substrates which are available at acceptable quality and cost. Restriction to lattice-matched systems would greatly limit the number of applications. Development of vapor phase growth techniques allowed to precisely control the layer thickness and uniformity on the atomic level. Still, when the critical layer thickness is exceeded, misfit dislocations are created having negative impact on the performance, reliability and lifetime of semiconductor devices [1]. A number of defect engineering approaches are available to gain control over the generation of defects during heteroepitaxial growth. One of the approaches consists in the growth on a porous substrate to accommodate elastic strains at the heteroepitaxial interface [2]. An essential step in successful application of porous substrates in epitaxial growth is to achieve control over their properties: the surface roughness, pore size, orientation, density and depth.

We report on the growth of In(x)Ga(1-x)As on porous GaAs and InP substrates by the liquid phase epitaxy technique (LPE) and compare results with those achieved by metal-organic vapor phase epitaxy. InGaAs is a material widely used in electronic and optoelectronic devices such as high electron mobility transis-tors [3], laser diodes [4], infrared detectors [5], and photovoltaic cells [6]. The InGaAs system is flexible in terms of the range of optical wavelengths that can be emitted and absorbed; by varying the indium concentration, emission or detection wavelengths ranging from 1.1 to 3 μm can be achieved.

The pore etching was carried out in an electrochemical cell containing a fluoride-iodide [7] and chloride aqueous electrolytes using a three-electrode configuration. The LPE growth took place in a standard horizontal apparatus from 690-750°C with the initial supersaturation corresponding to 1-13°C. The porous structures before and after the epitaxial growth were characterized by Nomarski differential interference contrast microscopy (NDICM), scanning electron microscopy (SEM), atomic force microscopy (AFM), low temperature photoluminescence (PL), x-ray diffraction (XRD) and transmission electron microscopy (TEM).

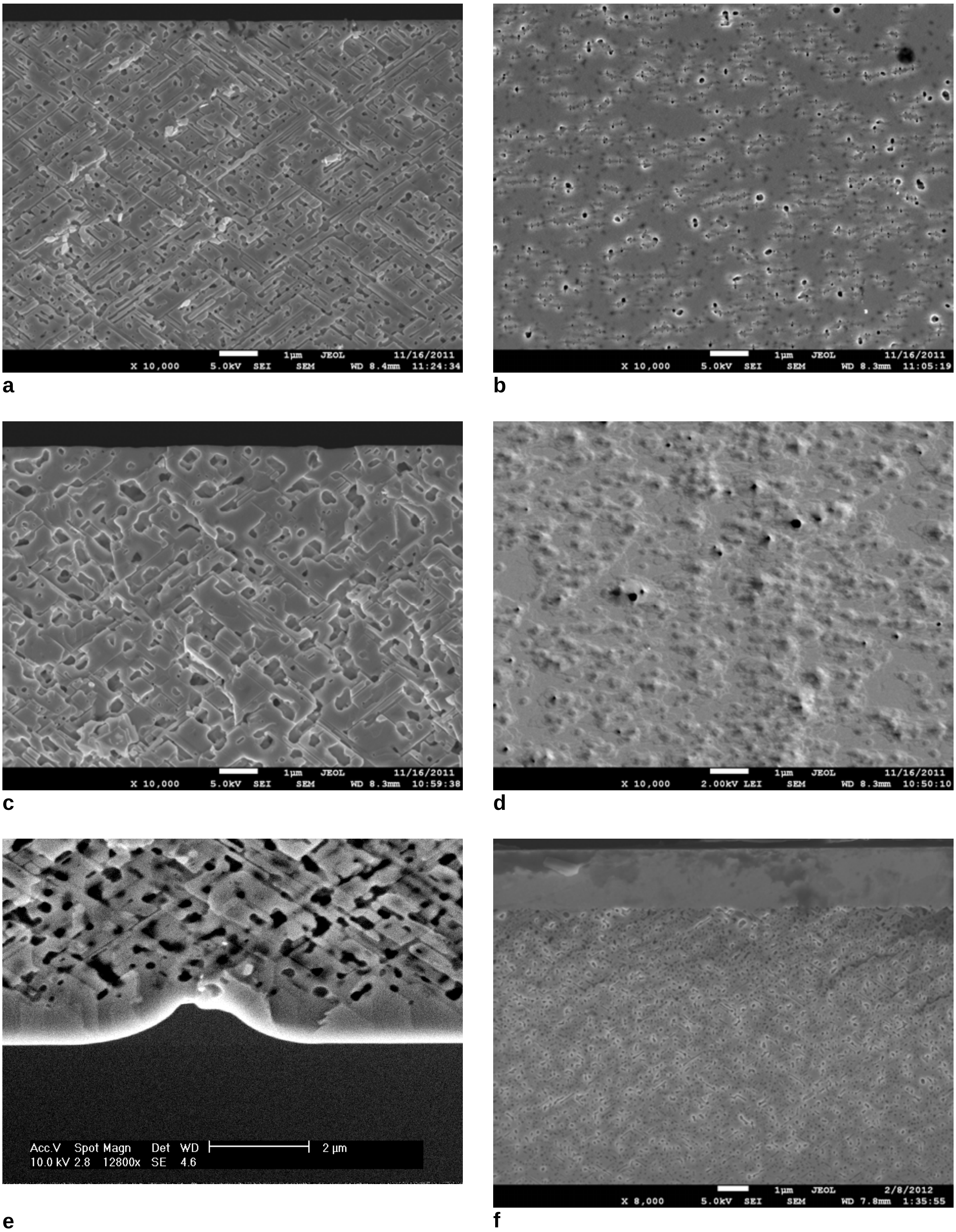
We show how the thickness of the nanoporous layer, the melt composition, the supersaturation, the growth temperature, and the heat treatment in high-purity hydrogen influence the growth mechanism, the surface morphology, and the structural and optical properties of the layers. We demonstrate that pores are capable of accommodating strain at the interface. The layers grown on porous substrates show higher thickness. Moreover, the pore annihilation under the influence of stress takes place at the boundary of InAs grains in the heterostructure InAs/InP.

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

References

[1] H. Foll, J. Carstensen, S. Frey, J. Nanomater. **2006**, 1-10 (2006).
[2] S. Mahajan, Acta Mater. **48**, 137-149 (2000)
[3] S. Ahmad, IETE Tech. Rev. 14, 397-410 (1997).
[4] F. Bugge, U. Zeimer, R. Staske, B. Sumpf, G. Erbert, M. Weyers, J. of Crystal Growth **298**, 652-657 (2007).
[5] J. B. D. Soole, H. Schumacher, IEEE J. Quantum Electron. **27**, 737-752 (1991).
[6] J. F. Geisz, S. Kurtz, M. W. Wanlass, J. S. Ward, A. Duda, D. J. Friedman, J. M. Olson, W. E. McMahon, T. E. Moriarty, J. T. Kiehl, Appl. Phys. Lett. **91**, 012108 (2007).
[7] V. Ulin, S. Konnikov, Semiconductors **41**, 832-844 (2007).

Figures



SEM micrographs of a porous GaAs substrate treated at 690°C (a) cross-section, (b) surface, 750°C (c) cross-section, (d) surface and cross-section of InGaAs layers grown at low (e) and high (f) supersaturation.