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Epitaxial lateral overgrowth of InP/GaAs (1 0 0) heterostructures by metalorganic chemical vapor deposition

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Abstract

Epitaxial lateral overgrowth (ELOG) was used to grow InP on GaAs(1 0 0) substrates by metalorganic chemical vapor deposition (MOCVD). The selectivity of InP by ELOG is excellent and the regrowth InP epilayers have good morphology without polycrystalline on SiO_2 mask. The $[0\,\bar{1}\,1]$ directional mask stripes and high V/III ratio are benefit to InP lateral growth. Compared to conventional direct growth, ELOG is effective in reducing the dislocation density, relaxing compressing strain in epilayers. In addition, the full width at half maximum (FWHM) of X-ray diffraction (XRD) ω scans and room temperature (RT) photoluminescence (PL) for a 3 μm thick epilayer by ELOG are 198 arcsec and 44 meV, respectively.

Keywords: Epitaxial lateral overgrowth; MOCVD; X-ray diffraction; Scanning electronic microscopy

1. Introduction

The InP-based optoelectronic devices are essential for optical communication, while InP-based integrated circuit (IC) technology is still immature compared to that of GaAs IC. If the InP-related optical devices and GaAs electronic devices are combined on GaAs substrates, optoelectronic integrated circuits (OEIC) could be obtained [1]. Therefore, InP layers grown on GaAs substrates have attracted considerable attention [2–5]. In addition, large-area and low-cost GaAs substrates are available compared to InP substrates.

To overcome the 4% lattice mismatch of InP/GaAs heterostructure, two-step method [2], sawtooth-patterned substrates [3], strained-layer superlattice [6,7] and composition-graded [8,9] buffer layers were commonly adopted. Epitaxial lateral overgrowth (ELOG), a method to solve heteroepitaxial growth with large lattice mismatch, was widely used in GaN/sapphire [10–13], GaAs/Si [14,15], but it was seldom reported to be used in InP/GaAs heterostructures. ELOG is a kind of epitaxial growth on a partially masked substrate [16], the main advantage of this method is that the dislocations can be blocked by the mask, thus it is a promising tool to grow high-quality epilayers on lattice-mismatched substrates.

In this work, we attempted to use ELOG to grow InP/GaAs heterostructures by metalorganic chemical vapor deposition (MOCVD), the ways to improve the ratio of lateral to vertical growth rate were investigated, the epilayer quality was characterized by scanning electron microscopy (SEM), double crystal X-ray diffraction (XRD) and room temperature (RT) photoluminescence (PL).

2. Experimental procedure

Firstly 0.4 μm thick InP epilayers were grown on GaAs substrate by two-step method in a low-pressure MOCVD system [17]. Then the InP epilayers were coated with 200 nm SiO_2 using plasma-enhanced chemical vapor deposition (PECVD). Openings were defined using standard lithographic

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procedures and SiO_2 was etched with hydrofluoric acid (HF). The pattern consisted of 5 μm SiO_2 mask and 5 μm InP window stripes alternately, which oriented along the $[0\bar{1}1]$ direction or the $[0\bar{1}\bar{1}]$ direction, as shown in Fig. 1.

Lastly, the patterned substrates were cleaned in acetone and ethanol before loading to reactor chamber again. Subsequent regrowth was carried out at 685 °C and the nominal thickness was 3 μm, trimethyl-indium (TMIn) and phosphine (PH_3) were used as source materials and the V/III ratio was 200.

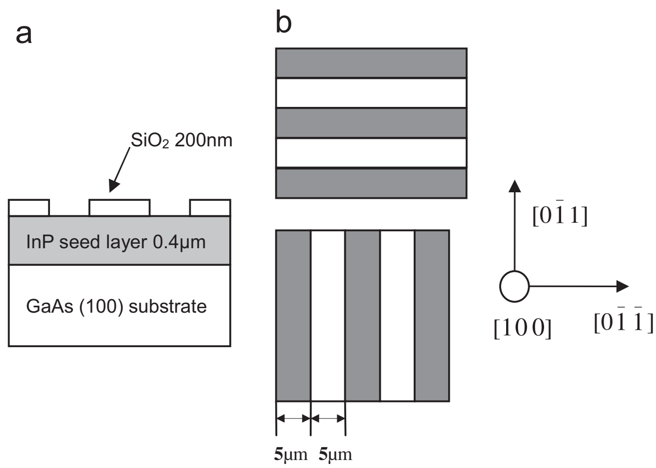

Fig. 1. (a) Cross-sectional and (b) surface schematic diagrams of InP/GaAs(1 0 0) substrate with SiO_2 mask stripes along the $[0\bar{1}1]$ direction or the $[0\bar{1}\bar{1}]$ direction.

3. Result and discussion

Fig. 2 shows the SEM images of ELOG InP on GaAs substrates with the mask pattern shown in Fig. 1, among them, Fig. 2a is the surface image of Fig. 2b, it can be seen that the surface morphology is good and no cracks occur [10], in addition, there is no polycrystalline on the SiO_2 mask [10,18,19], which shows that the selectivity of InP grown by ELOG is excellent.

Fig. 2b–d shows the SEM cross section images of three samples with different growth conditions. The samples shown in Fig. 2b and c have the same SiO_2 mask stripe direction, i.e., along the $[0\bar{1}1]$ direction, they are taken from $(0\bar{1}1)$ cross section, but the sample shown in Fig. 2c has higher V/III ratio (250) than that in Fig. 2b (180) when the regrowth was carried out; both the two samples show a trapezoid shape in cross section, a higher V/III ratio would be benefit to lateral growth, since the largest width in Fig. 2b is 7.62 μm compared to 7.84 μm in Fig. 2c while they all have the same 5 μm InP window width and total 3 μm thickness, though the improvement is not obvious

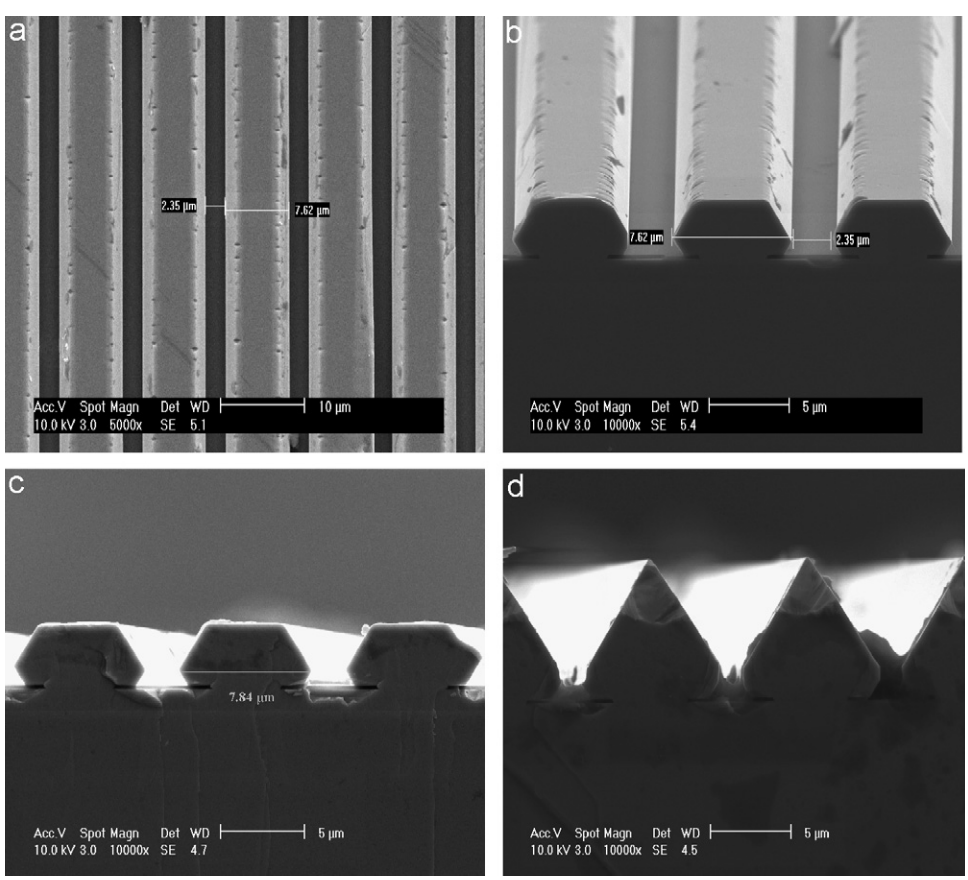

Fig. 2. SEM images of ELOG InP on GaAs(1 0 0) substrates: (a) surface; (b) cross-sectional images with the SiO_2 mask stripes along the $[0\bar{1}1]$ direction, the V/III ratio is 180; and (c, d) cross-sectional images with the SiO_2 mask along the $[0\bar{1}1]$ and $[0\bar{1}\bar{1}]$ direction, the V/III ratio is 250 and 180, respectively.