Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 76-77

D-2-1

Defect-Controlled Selective Epitaxial Growth of GaP on Si by Migration-Enhanced Epitaxy under Atomic Hydrogen Irradiation

Takuto Tsuji, Hiroo Yonezu, Mikihiro Yokozeki, Yasufumi Takagi[1], and Naoki Ohshima

Department of Electrical and Electronic Engineering, Toyohashi University of Technology,
Hibarigaoka 1-1, Tempaku-cho, Toyohashi, Aichi 441, Japan
Phone : +81-532-44-6747, Fax : +81-532-44-6757, E-mail : tsuji@icg.eee.tut.ac.jp

1. Introduction

The selective epitaxial growth of III-V compound semiconductors on Si is necessary for optoelectronic integrated circuits (OEICs). However, a large number of threading dislocations are generated in the III-V compound layers. We have effectively suppressed the generation of threading dislocations in GaAs-on-Si and InP-on-Si by introducing strained short-period superlattices (SSPSs) and a GaP buffer layer [1], [2]. Thus, the selective epitaxial growth of GaAs/SSPSs/GaP on Si is required for fabrication of small GaAs optical devices on Si ICs. One of the key issues in the selective epitaxial growth is to grow a GaP layer without crystalline defects. The selective epitaxial growth of III-V compounds had been difficult in MBE [3]. Recently, the selective epitaxial growth was succeeded in the GaAs homo-epitaxy under irradiation of atomic hydrogen during MBE growth [4]. However, the selective epitaxial growth of III-V compounds on Si has never been investigated in MBE under atomic hydrogen irradiation. Thus, we performed the selective epitaxial growth of GaP on Si under atomic hydrogen irradiation.

2. Experimental

The surface of Si(100) substrates misoriented by 4° toward [011] azimuth was covered with a dry-SiO_2 mask.

The two-step growth and the direct growth were applied to investigate the generation mechanism of crystalline defects. In the two-step growth (Fig. 1(a)), a P-prelayer was formed on the Si surface under the irradiation of P_2beam at 450°C for 7 min prior to the growth of a GaP layer. Then, a 7 ML thick GaP layer was initially grown at 450°C by MEE. The 7 ML thick poly-GaP deposited on the mask was desorbed by increasing the substrate temperature up to 580°C under atomic hydrogen irradiation. Then, the second GaP layer was grown by about 200 nm at 550°C by MEE under atomic hydrogen irradiation.

In the direct growth (Fig. 1(b)), the P-prelayer was formed on the Si surface at 550°C for 7 min. Then, the GaP layer was grown by about 200 nm at 550°C by MEE under atomic hydrogen irradiation.

The surface was observed in-situ during the GaP selective epitaxial growth by reflection high-energy electron diffraction (RHEED). The selective epitaxial layers were evaluated by transmission electron microscopy (TEM).

3. Results and Discussion

A cross-sectional TEM (XTEM) image of the GaP layer near the edge of masked region is shown in Fig. 2. The GaP layer was grown selectively on unmasked Si area.

Fig. 3(a) shows a typical XTEM image of the GaP layer grown selectively on Si with two-step growth method. No threading dislocations and other crystalline defects were observed in the GaP layer. On the other hand, some contrasts were observed in the GaP layer with the direct growth method, as shown in Fig. 3(b).

The dark field XTEM image of the GaP layer is shown in Fig. 4. A lot of dark contrast regions were observed in the GaP layer. These dark contrast regions are attributed to anti-phase domains (APDs) generated at the GaP/Si hetero-interface [5]. The APDs were annihilated at early growth stage in the two-step growth, however, a large number of APDs propagated into the surface in the direct growth, as shown in Fig. 4. Thus, the contrasts observed in Figs. 3(b) were clarified to result from the APDs.

Figure 5 shows PV-TEM images near the GaP-Si hetero-interface grown with the 300 nm thick GaP with the two-step growth method. The density of misfit dislocations was decreased with the decrease in the growth area.

The APDs could mostly originate in the desorption of P atoms. The formation of APDs expanding into the surface was suppressed in the two-step growth, since the P desorption area would be small.

4. Conclusion

The selective epitaxial growth of GaP was achieved by MEE under atomic hydrogen irradiation. The formation of large APDs expanding into the surface was suppressed by forming a P-prelayer at low temperature. The density of misfit dislocations at the GaP-Si hetero-interface was remarkably reduced with a decrease in the growth area.

References

1) Y. Takagi, H. Yonezu, T. Kawai, K. Hayashida, K. Samonji, N. Ohshima and K. Pak: J. Cryst. Growth **150** (1995) 677.
2) K. Samonji, H. Yonezu, Y. Takagi, K. Iwaki, N. Ohshima, J. K. Shin and K. Pak: Appl. Phys. Lett. **69** (1996) 100.
3) A. Okamoto and K. Ohata: Appl. Phys. Lett. **51** (1987) 1512.
4) T. Sugaya, Y. Okada and M. Kawabe: Jpn. J. Appl. Phys. **31** (1992) L713.
5) T. Soga, H. Nshikawa, T. Jimbo and M. Umeno: Jpn. J. Appl. Phys. **32** (1993) 4912.

[1]Present affiliation : HAMAMATSU PHOTONICS Co., 1126-1, Ichino, Hamamatsu, Shizuoka 435, Japan

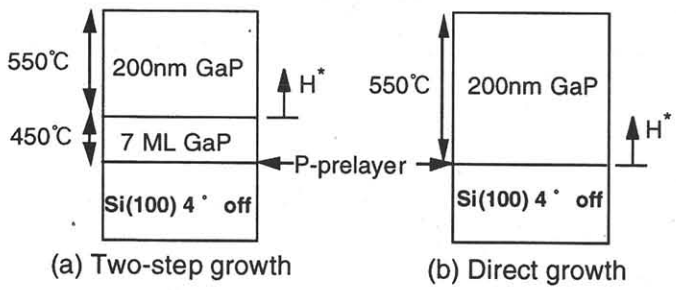


Fig. 1 Schematic drawing of the layer structures for selective epitaxial growth. (a) Two-step growth and (b) Direct growth.

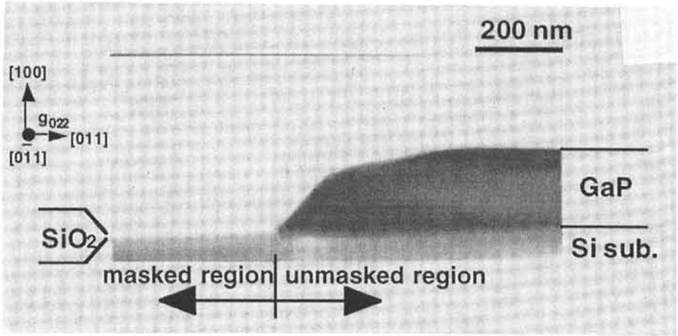
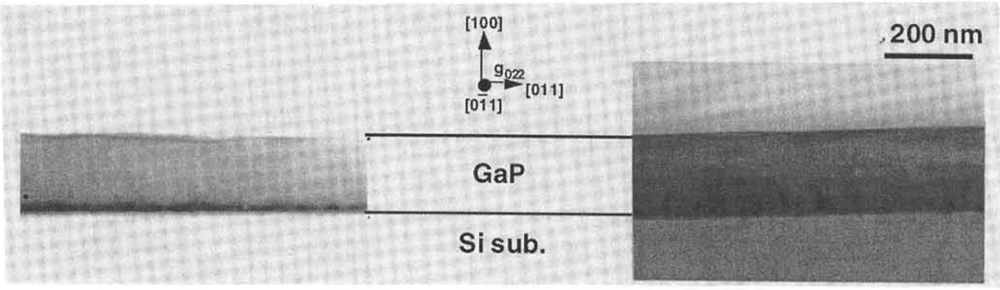
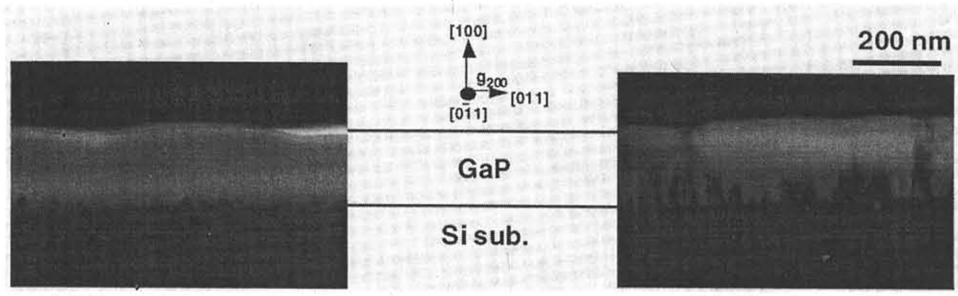


Fig. 2 An XTEM image of a selectively grown GaP layer on unmasked Si area near the edge of masked region.



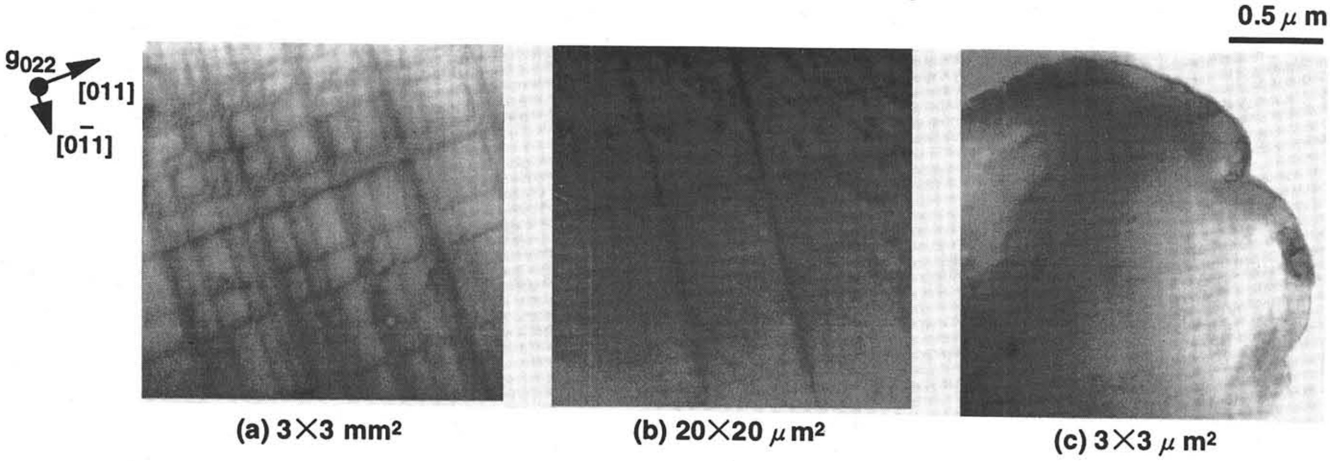
(a) Two-step growth (b) Direct growth

Fig. 3 XTEM images of the GaP layers grown selectively on Si area. (a) Two-step growth and (b) Direct growth.



(a) Two-step growth (b) Direct growth

Fig. 4 Dark field XTEM images of the GaP layers grown selectively on Si area. (a) Two-step growth and (b) Direct growth.



(a) 3×3 mm² (b) 20×20 μm² (c) 3×3 μm²

Fig. 5 Plan-view TEM images near the GaP-Si hetero-interface. The GaP layer was selectively grown with the two-step growth method on (a) 3×3 mm², (b) 20×20 μm² and (c) 3×3 μm² square Si surfaces.