High-quality laterally overgrown GaN layers without crystallographic tilting and voids

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Abstract

We investigate the lateral epitaxial overgrowth (LEO) conditions to reduce the crystallographic tilting and the voids formed between laterally overgrown GaN subgrains by metal organic chemical vapor deposition. The high-quality laterally overgrown GaN layers with smooth surface were obtained by optimizing the reactor pressure in relation to the growth temperature.

Introduction

Lateral epitaxial overgrowth (LEO) has been proved to be one of the promising techniques for reducing the dislocation densities in nitride semiconductors. The reduction of dislocation density is essentially required to realize a long lifetime InGaN/InGaN multiple quantum well laser diodes over 10,000 h at room temperature [1]. In this paper, we report the experimental results on the dependence of the LEO GaN structure on the reactor pressure in relation to the growth temperature to reduce both tilting angle and voids between GaN subgrains.

Experiments

The LEO growth was performed on patterned 1~2 μm thick GaN template layers on (0001) sapphire substrates using a vertical reactor into which three 2" wafers can be loaded in a time. After the deposition of ~200 nm thick SiO_2 by plasma-enhanced chemical vapor deposition, a stripe pattern of 4 μm window and 10 μm mask was defined using conventional photolithography and wet chemical etching. The stripe direction was chosen to <1-100> in order to obtain high lateral growth rate. Trimethylgallium (TMGa) and NH_3 were used as the source gases and purified hydrogen was used as the carrier gas. The flow rate of TMGa and NH_3 were 150 μmol/min and 6 slm, respectively, which resulted in a planar growth rate of 2.5 μm/h. The growth temperature and the reactor pressure were varied between 1,030 and 1,075 ^oC, and between 100 and 300 Torr, respectively. We compared two types of tiltless LEO GaN layers grown under 100 Torr and 1,030 ^oC (sample A) and 300 Torr and 1,050 ^oC (sample B).

Results & Discussion

Figure 1 shows the changes in the tilting angle between laterally overgrown GaN subgrains as a function of growth temperature under different reactor pressures. In both cases the crystallographic tilting dramatically increases with growth temperature, but the tilting angle is smaller under higher reactor pressure at the same growth temperature. Crystallographic tilting should be minimized to utilize whole areas of the overgrown region.

Figure 2 shows the Normarski interference micrographs of coalesced stripes along the <1-100> direction. In case of sample A, the (0001) surface corrugates because of slow adatom migration at low growth temperature to achieve low tilting conditions. But sample B shows a smooth surface without pits and grooves. Figure 3 shows cross-sectional images of (a) sample A and (b) sample B overgrown on patterned substrate. Under sample A growth conditions, only {11-20} facets appear in the side walls, resulting in a formation of voids in the coalescence boundary. With increasing reactor pressure, {11-22} facets with {11-20} are developed, which is the favorable growth front to avoid the void formation.

Although the reason why the c-axis was tilted toward <11-20> direction is not clear at the moment, it might be closely related to the interaction between the SiO_2 mask and the overgrown GaN [2,3]. Fini et al. have suggested the two-step growth method of slow lateral growth compared to vertical growth under 76 Torr reactor pressure with {11-20} growth front to reduce the tilting angle [4]. In this paper, a new process route is proposed to reduce the crystallographic tilting without voids and surface corrugation by adjusting the reactor pressure with {11-22} growth front.

References

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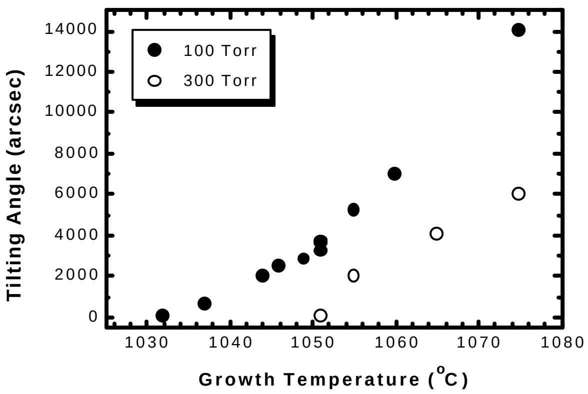
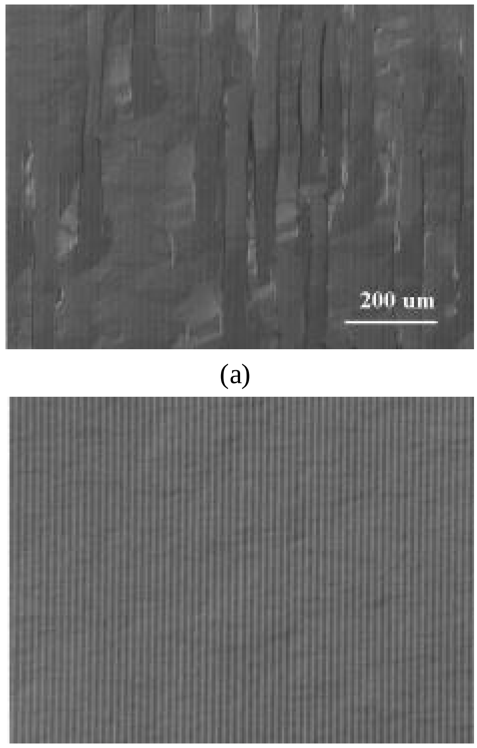


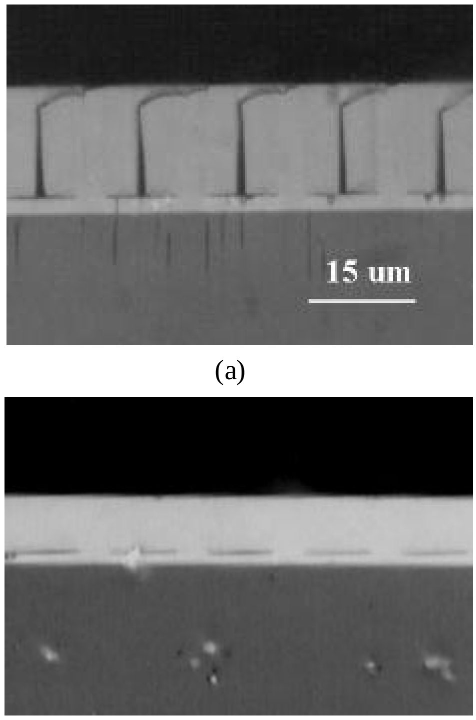
Fig. 1. Changes in the crystallographic tilting angle between laterally overgrown GaN subgrains with growth temperature.



(a)

(b)

Fig. 2. Normarski interference micrographs of (a) sample A and (b) sample B.



(a)

(b)

Fig. 3. Cross-sectional images of (a) sample A and (b) sample B laterally overgrown from 4 μm wide opening with a 0.29 fill factor. Note the different layer thickness for coalescence.