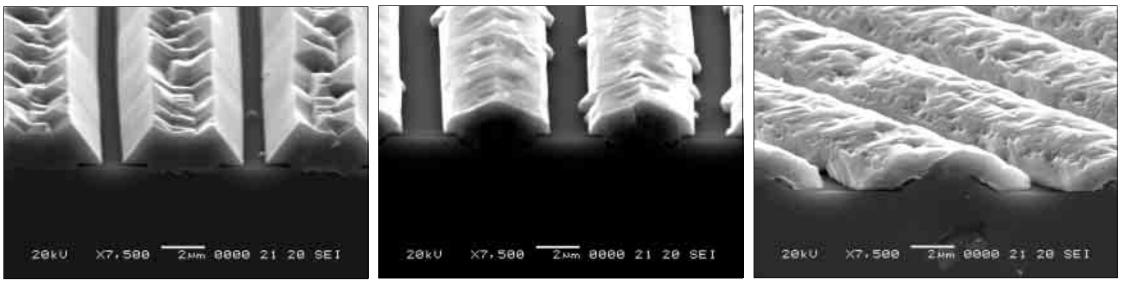
修士論文 / **Master Thesis**

Selective Growth of Cubic GaN by Metalorganic Vapor Phase Epitaxy

立方晶 **GaN** の選択成長

Sakuntam SANORPIM (サクンタム サノーピン)
February 2000 (平成 12 年 2 月 9 日)
東京大学大学院工学系研究科物理工学専攻
Dept. Applied Physics, Graduate School of Engineering, The University of Tokyo
指導教官 尾鍋 研太郎 教授
Supervisor: Prof. Kentoro Onabe

ABSTRACT: Selective Area Growth (SAG) has been widely studied for various microstructure fabrication. The potential of SAG for extended-defect reduction in the heteroepitaxial growth of III-V semiconductors has been demonstrated. The GaN film generally has high dislocation density due to the large lattice mismatch and different thermal expansion coefficient between the GaN film and substrates. The SAG is expected to substantially reduce the dislocation density in GaN film [1]. However, much research so far has been focused on hexagonal phase GaN (h-GaN) and the growth conditions of SAG of cubic GaN (SAG-c-GaN) have not been well understood. Recently, the SAG-c-GaN by MOVPE on patterned GaAs (100) substrates was first reported [2]. A better understanding of these growth mechanism and growth conditions will enhance the crystal quality as well as the reproducibility of the growth. In this paper, the issue of hexagonal phase generation in SAG-c-GaN films grown by MOVPE is addressed. We also report the effects of mask stripe orientation and fill factor on SAG-c-GaN films.



(a) (b) (c)

Fig 1. SEM images of SAG-c-GaN grown using SiO_2 mask material with fill factor of 0.500, stripe opening along (a) [001], (b) [0-11] and (c) [001] direction, respectively, after 15 min of growth.

The SAG-c-GaN films were grown by low-pressure (160 Torr) MOVPE on patterned GaAs (100) substrates. The GaAs (100) substrates were deposited with 200 nm thick SiO_2 films using RF sputtering. The standard UV photolithography and wet chemical etching were used to produce [011], [0-11] and [001] mask stripe orientation. The opening width was varied to give "fill factor, W/(W+M)" (ratio of open width to pattern period), of about 0.5-0.87 for each mask stripe orientation. Here W and M are window width and mask width, respectively. Trimethylgalium (TMG), dimethylhydrazine (DMHy) and arsine (AsH_3) were used as the precursor of Ga, N and As, respectively. A thin GaAs (~100-150 nm) and GaN (~20 nm) buffer layers were grown on the patterned GaAs (100) substrates at 700 and 600 ^oC, respectively, followed by the growth of an approximately 1.2 μm SAG-c-GaN (main layer) at 900^{o}C. Scanning electron microscope (SEM) and X-ray diffraction (XRD) were employed to study the effects on growth mask stripe orientation and fill factor on SAG-c-GaN. The hexagonal phase separation was investigated by using cathodoluminescence (CL) on SAG-c-GaN films.

Figure 1 shows surface and cross-sectional SEM images of SAG-c-GaN films grown on (a) [011], (b) [0-11] and (c) [001] stripe pattern with fill factor of 0.50. The growth feature is much dependent on mask stripe orientation and fill factor. In the case of [011] and [0-11] stripe patterns, (111)B facets and (311)A facets were clearly observed, respectively. In the case of [001] stripe pattern, rough surface and no distinct facet were formed. The CL images taken at 360 nm and 381 nm are shown in figure 2. We found that the SAG-c-GaN films

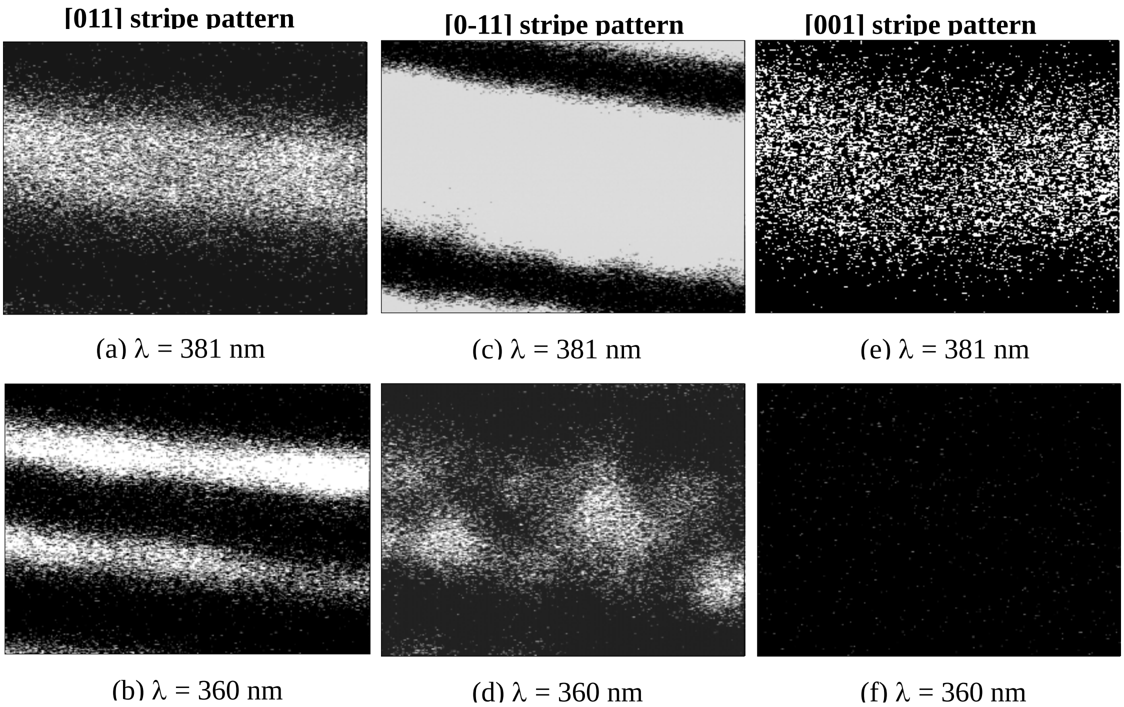


Fig 2. Plan-view images of SAG-c-GaN grown on (a,b) [001], (c,d) [0-11] and (e,f) [001]stripe pattern taken at the same location.

grown on the [011] (a, b) and the [0-11] (c, d) stripe patterns include hexagonal phase (360 nm) as well as the cubic phase (381 nm). On the other hand, the hexagonal phase generation was not observed in SAG-c-GaN grown on the [001] stripe pattern (e, f). For SAG-c-GaN on the [011] stripe pattern, the emission is dominated at 360 nm and 381 nm corresponding to lateral overgrowth region and window region, respectively. This means that the lateral overgrowth regions are condensed with hexagonal phase whereas the window regions are condensed with cubic phase. This indicates that the h-GaN is easily constructed along the (111)B facets. While the emission of hexagonal phase (360 nm) randomly contributed in SAG-c-GaN on the [0-11] stripe pattern. The h-GaN is difficult to construct along the (311)A facets, since no emission of hexagonal phase occurs at the lateral overgrowth regions.2θ X-ray diffraction demonstrated that the SAG-c-GaN condensed in cubic phase for all samples. On the other hand, the hexagonal phase inclusion was determined by ω-scan X-ray diffraction. When fill factor decreases, the amount of hexagonal phase inclusion was increased for [011] and [0-11] stripe pattern and was decreased for [001] stripe pattern. Furthermore, the hexagonal phase inclusion of SAG-c-GaN grown on [001] stripe pattern was lower than that of SAG-c-GaN grown on [011] and [0-11] stripe pattern, respectively. We also found that the c-axis of h-GaN was parallel to the [111] axis of the cubic substrate. This might be an important reasons of easy construction of h-GaN along (111)B facets. However the details of growth mechanism are not yet well understood.

In summary, we have demonstrated that the presence of hexagonal phase generation using CL and XRD characterization techniques in MOVPE grown SAG-c-GaN. The generation of hexagonal phase occurs for SAG-c-GaN on [011] and [0-11] stripe patterns indicated by the dominant emissions at 360 nm and 381 nm in CL images. While the hexagonal phase generation was not observed in SAG-c-GaN on the [001] stripe pattern. These results agree with the calculated hexagonal phase inclusion by XRD and can be useful in fabrication of single-phase SAG-c-GaN by MOVPE.

References

[1] A. Usui, H. Sunakawa, A. Sakai, and A. Yamagushi, Jpn. J. Appl. Phys. 36, L899 (1997).
[2] J. Wu, M. Kudo, A. Nagayama, H. Yagushi, K. Onabe, and Y. Shiraki, Phys. Stat. Sol. (a) 176, 557 (1999).