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Characteristic comparison of GaN grown on patterned sapphire substrates following growth time

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1. Introduction

GaN, a wide energy band gap and direct transition semiconductor, is an effective material for the fabrication of blue or green LEDs, LDs, and PDs [1]. In spite of great technological successes of blue laser and LEDs, further improvement of the nitride compound devices is still required. Generally, the GaN based LEDs are grown on planar sapphire substrate [2]. But large lattice mismatch between the GaN and sapphire interface lead to relatively high density of dislocation in the order of $10^{8}\sim10^{10}$cm. therefore, In order to obtain high-quality GaN based light emitting devices, the techniques to reduce the dislocation density are of high importance.

Several epitaxial lateral overgrowth (ELOG) methods have been developed to reduce the threading dislocation density [3]. But these techniques involve the suspension of growth and contain the possibility of impurities contamination and the induced strain in the subsequent growing layer

This problem can be overcome by growing on a patterned sapphire substrate (PSS), without mask, and no suspension during the growth process. In this study, we investigated the effect of using patterned sapphire substrate. and dependence on the growing time of the GaN layer.

2. Experimental

The GaN epilayers grown on the lens-shaped patterned sapphire(0001) were performed in the MOCVD with a horizontal quartz reactor. During the MOCVD growth, trimethylgallium (TMG) and ammonia (NH_3) were used as Ga and N precursors, respectively. Prior to growth, the patterned sapphire substrates were cleaned by H_2SO_4,:H_2O_2:H_2O (3:1:1) to remove the surface native oxide layer. After preparation, the sapphire substrate was heated 1040℃ under hydrogen ambient for 5 min, to thermal etching. Low-temperature GaN buffer layer was performed at 560℃ for 2 min by feeding TMG and ammonia with hydrogen as a carrier gas. The GaN layer was deposited at 1040℃ for 10, 20, 30 and 40 min to confirm the reliance of the growing time of the GaN layer. Characterization of these layers was performed by scanning electron microscopy (SEM), double crystal X-ray diffractometer (DCXRD) and photoluminescence (PL)

3. Results and discussion

The SEM image of the patterned bare sapphire substrate (Fig. 1) shows the lens shaped pattern. The lens height and diameter of the patterned sapphire is about 1.5 μm and 5.8 μm, respectively. The distance between each lens is about 3.7μm.

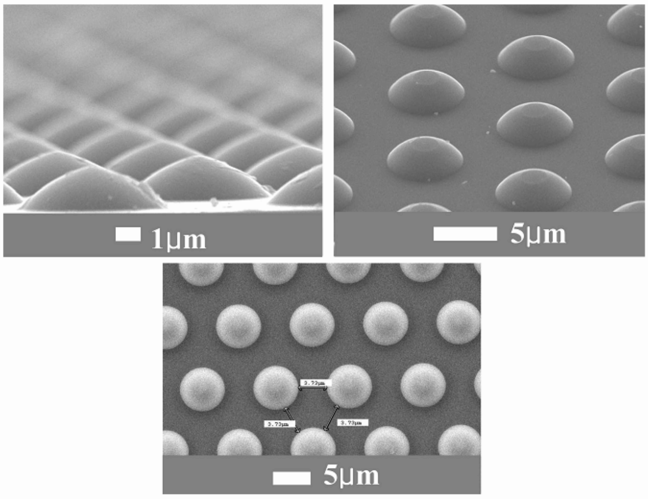

Fig. 1. SEM images of patterned sapphire substrate

The growth processes of the GaN layer on the PSS following growth time were characterized by scanning electron microscope (SEM) as shown in Fig. 2 (a), (b), (c), and (d). It can be seen that the hexagonal growth behavior of the GaN. As growth time increases, the progress of lateral growth is observed. But in this study, we can't see the fully coalesced surface. If the growth time increases, more lateral growth will be broken out, and fully coalesce will be happen [4].

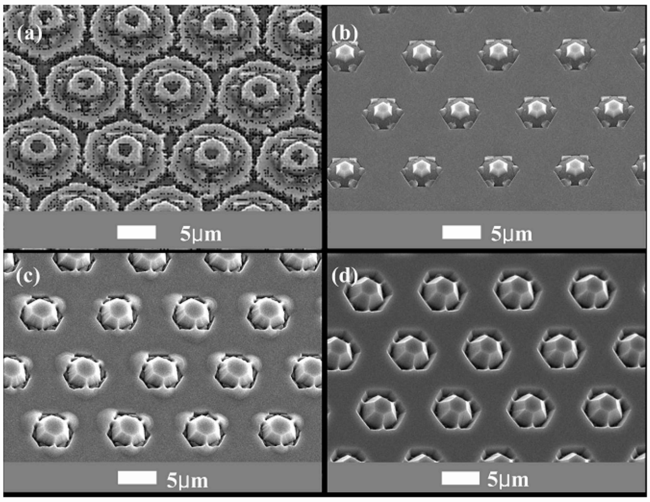

Fig. 2. SEM images of the surface of GaN layers grown on the patterned sapphire substrates for (a) 10min, (b) 20min, (c) 30min, and (d) 40min

Fig. 3 shows the FWHMs of DCXRD rocking curves for the GaN grown on PSS with different growth time. As shown in fig. 4, FWHM value increased along with growth time approximately. However the difference of the FWHM of (b) and (c) is small. It is considered that imperfect coalesce during the lateral growth affects crystalline.

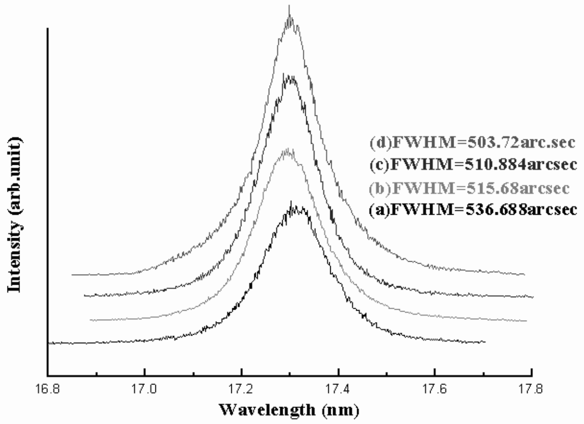

Fig. 3. DCXRD spectra of GaN layer grown on the PSS : (b) 20min, (c) 30min, and (d) 40min

Fig. 4 shows a comparison of room temperature PL spectrum, from a GaN layer on the PSS following growth time. Defect related luminescence was observed from all samples. Intensity of the defect related peak decreased with increasing growth time. This result has good agreement with that of shown in fig. 3.

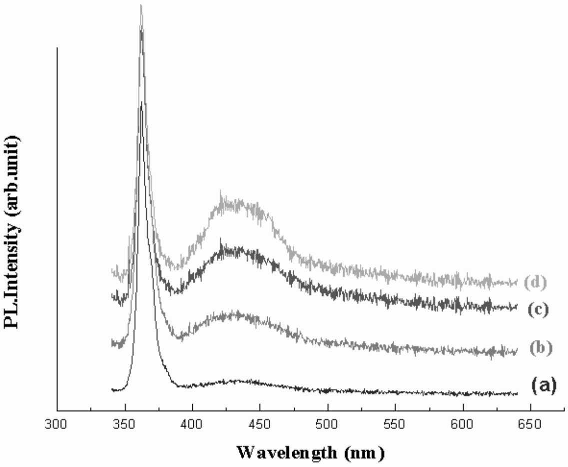

Fig. 4. Photoluminescence spectra which taken RT from a GaN layer on PSS : (a) 10 min, (b) 20 min, (c) 30 min, and (d) 40 min.

4. Conclusions

We compared the GaN layers grown on PSS as growth time increases. Consequently, it is considered that as growth time increase, the lateral growth is break out. We can confirm that GaN grown on the PSS brings good results to reduce the dislocation density.

References

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