Homoepitaxy of GaN on Free-Standing GaN substrates by Metalorganic Chemical Vapor Deposition

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Abstract

Homoepitaxy of GaN layers was performed by metalorganic vapor phase epitaxy (MOCVD) on free-standing GaN substrates which were fabricated by hydride vapor phase epitaxy (HVPE) and UV laser lift-off method. Polishing damage layers of free-standing GaN was investigated by TEM and PL. High quality homoepitaxy layers were obtained after removing of damaged layer by ion beam etching. Preliminary results on the laser diodes grown on free-standing GaN showed superior performance than on sapphire substrates.

Introduction

Although Nichia Chemical Co. succeeded in the first commercialization of violet laser diodes (LDs) based on the nitride semiconductors [1], GaN single crystal substrate is still required to the performance improvement of GaN optoelectronic and electronic devices. Homoepitaxy on GaN substrate will resolve many problems due to the different substrate use such as high dislocation density, thermal mismatch, cleaving for facet formation of laser diode, electrically vertical device fabrication, and heat extraction from the devices. This paper reports on the MOCVD homoepitaxy of GaN on the free-standing GaN substrates grown by HVPE, and the results on the laser diodes fabricated on the free-standing substrates.

Experiments

In order to fabricate free-standing GaN substrate, thick GaN epilayers (~300μm) were grown on the sapphire substrates by HVPE. After that GaN layers were separated from the sapphire substrate using UV laser induced lift-off method. Mechano-chemical polishing was used to obtain the surface roughness less than 10 angstrom, and mechanical damaged layers were removed by chemically assisted ion beam etching (CAIBE) technique. Regrowth of GaN was conducted by low pressure MOCVD. Finally LD structures were grown on the free-standing GaN substrates from which surface damaged layer was removed. The growth conditions have been described elsewhere [2].

Results

Figure 1 shows transmission electron micrograph of polished free-standing GaN substrate. TEM indicated that the surface layer on the substrate is damaged due to the mechano-chemical polishing. Figure 2 shows normarski optical micrographs of GaN regrown on the free-standing GaN substrates. The surface of homoepitaxy GaN on polished substrate is very rough. However, GaN regrown on ion beam etched substrate has smooth surface. This results shows that surface damaged layer on free-standing GaN should be removed to obtain high quality homoepitaxy layers. Cross-section TEM, as shown in Figure 3 (a), also showed considerable defect generation from the interface between homoepitaxy layer and mechanical damaged layer. By contrast, No defect was observed at the interface in homoepitaxy layer on ion beam etched substrate (Figure 3 (b)).

InGaN multiple quantum well LDs were fabricated on the free-standing GaN substrates by homoepitaxy. Preliminary results showed that the lasing was observed up to a pulsed current duty ratio of 40 % at room temperature. Improvement of the performance of LDs grown by homoepitaxy is expected, and additional results will be reported later.

Conclusion

Regrowth of GaN layers were performed by MOCVD on free-standing GaN substrates. To obtain high quality homoepitaxy layers, surface damaged layers were removed by CAIBE. Preliminary results obtained from the LDs showed that homoepitaxy on free-standing GaN substrate will make it possible to fabricate high performance GaN devices.

References

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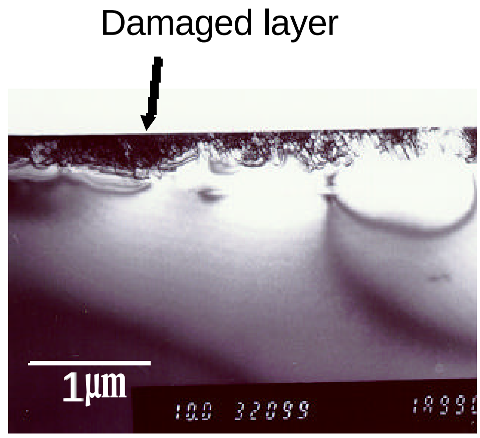
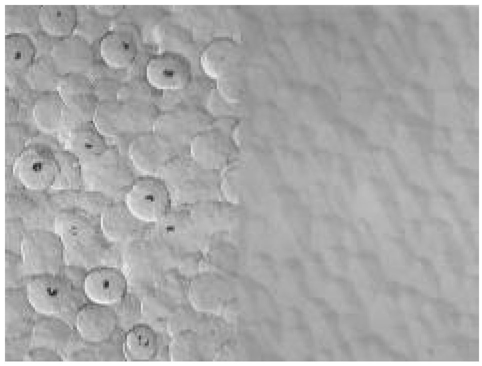
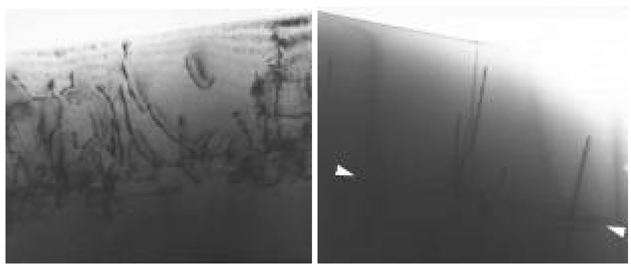


Figure 1. Cross-section TEM of free-standing GaN after polishing.



(a) (b)

Figure 2. Normarski optical micrographs of homoepitaxy GaN layers grown on free-standing substrates as polished (a) and after ion beam etching (b).



(a) (b)

Figure 3. Cross-section TEM of homoepitaxy GaN layers on free-standing substrates as polished (a) and after ion beam etching (b).