The Growth of AlGaN/GaN Structure on 200mm Si(111) with Low Wafer Bow

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Abstract

GaN-on-Silicon growth by MOCVD is wildly discussed in the context of stress and strain management. The low bow AlGaN/GaN structure grew on 200mm Si(111) wafer was demonstrated in this study. After using the sapphire pits on the normal flat susceptor, the wafer bow and residual stress decrease to 21.27um and 0.28GPa tensile stress. The GaN quality and the Rs in HEMT also got huge improvement.

Introduction

In recent years, the GaN electronics catch more and more attention. According to the different application, the user can choose different substrate to achieve the target [1]. Especially, the GaN on the silicon substrate get more attentions. The silicon substrate has lower cost, better thermal conductivity, and easy to integrated with Si device…etc advantages. Therefore, there were many company and research group more focus on the GaN on Si devices. But, there were also some drawbacks for the GaN on Si substrate. For example, the huge thermal extension mismatch will induce larger wafer bow and residual stress, and the larger lattice mismatch will induce poor GaN quality. There were many researchers try to develop a good buffer layers design, that will release the stress in the epitaxy structure [2].

Experiments

In this study, the wafers were grown by the CCS (Close Couple Showerhead) reactor, which was manufactured by AIXTRON. All the AlGaN/GaN structures were performed on 1mm thick, 200mm Si(111) wafers. The full structure was show as the Fig .1. The buffer layer was consisted with three different composition AlGaN layers. Then, the GaN #1 was grown under lower pressure. And, the GaN #2 was grown under higher pressure. After that, the 20nm $Al_{0.24}Ga_{0.76}N$ was stack on the GaN layers. Finally, the 2nm GaN was grown on the top for capping.

Fig.1. The epitaxial structure for all samples.

In this study, there are two samples. One is grow the HEMT structure on Si(111) with the original flat susceptor. Before the second sample growth, the 12 pcs sapphire pits were located on the original flat susceptor. The sapphire pits distribution show as the Fig.2. The Fig.2b show the sapphire pits on the susceptor.

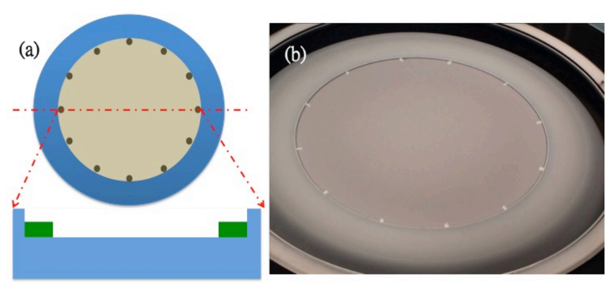

Fig. 2. (a) Illustration of the sapphire pits on susceptor; (b) The picture for the sapphire pits distribution on the susceptor.

Results

The Fig. 3 show the curvature curve, which was take by the Laytec in-situ curvature measurement systm. The sample, with the sapphire pits on the susceptor, shows the more convex strain from the AlN nucleation layer. The higher convex stain was exhibit during the GaN growth. In the final curvature, the "w sapphire pits" sample exhibited the curvature value almost close to 0.

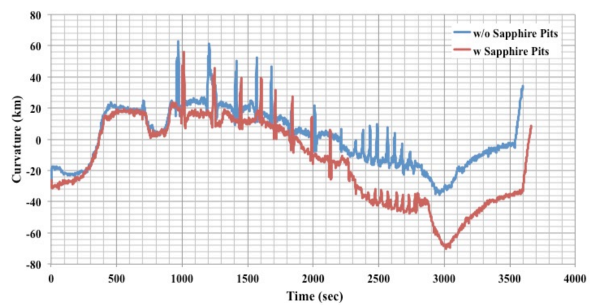

Fig.3. The in-situ curvature measurement for the samples growth with sapphire pits and without sapphire pits".

The final bow measurement after growth was done by TOHO stress measurement system. The 3D bow measurement and the calculating result were show as the Fig.4. The final bow of the two samples shows the concave strain. The sample, with sapphire pits, shows lower final bow 21.27um and lower residual stress 0.28GPa. The bow value was the 77% off from the sample without sapphire pits. From the figure, it also exhibits the sample with sapphire pits can get lower variation in multiple bow measurement.

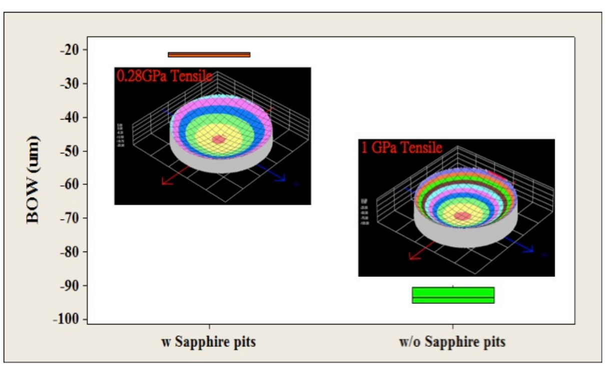

Fig. 4. The stress measurement result exhibited for the sample with and without using sapphire pits.

The GaN quality characterization was done by HR-XRD. The GaN(002) OMEGA scan results were show as the Fig.5. That is the calculation results from the FWHM of the GaN (002) OMEGA scan. The FWHM of the GaN(002) show lower value (599arcsec) and better uniformity(0.22%) in the sample with sapphire pits. The sample, with sapphire pits, will get better GaN quality for better device performance.

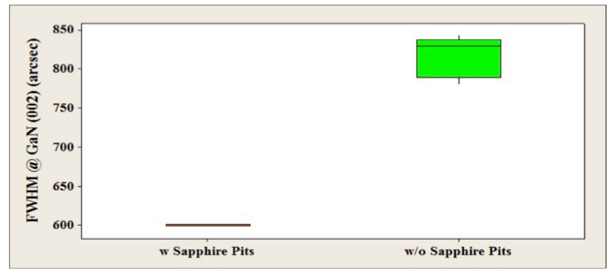

Fig. 5. The FWHM @ GaN(002) for the sample with and without sapphire pits.

The HEMT structure performance was performed with the sheet resistance. Those were extracted by the Lehighton system. The sheet resistance result was show as the Fig.6. The sample, with sapphire pits, shows lower sheet resistance 370 ohm-mm. That also gets more uniform sheet resistance performance in the whole wafer. The better GaN quality is the root cause to improve the sheet resistance in the HEMT structure. Lower sheet resistance will induce higher drain current in the HEMT device.

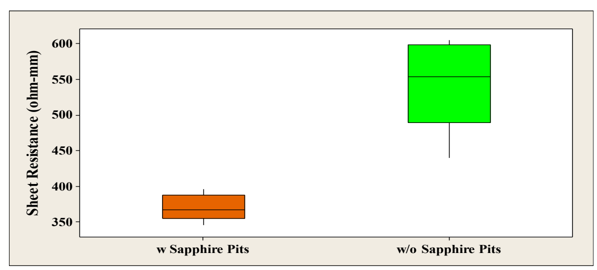

Fig.6. The sheet resistance for the samples with and without sapphire pits.

Summary

According to the above results, the sample with sapphire pits can release the residual stress effectively. The final wafer bow also can reach 21.27um. The GaN quality and the sheer resistance in 2DEG are also be improved. And, an easy modify that can get a huge improvement.

Reference

[1] Y. Cao, O. Laboutin, C. F. Lo, K. O'Connor, D. Hill, and W. Johnson, "GaN-on-Silicon Growth by MOCVD: A Mechanistic Approach to Wafer Scaling", 2014 CS MANTECH, Denver, CO.

[2] K. Cheng, M. Leys, S. Degroote, B. Van Daele, S. Boeykens, J. Derluyn, M. Germain, G. Van Tendeloo, J. Engelen, G. Borghs "Flat GaN epitaxial layers grown on Si(111) by metalorganic vapor phase epitaxy using step-graded AlGaN intermediate layers", J. Elec. Mater., 35, 592 (2006).