Production Readiness of AlGaN/GaN HEMT on 6”/8” Si

Dong S. Lee, Jie Su, Balakrishnan Krishnan, George D. Papasouliotis and Ajit Paranjpe
Veeco MOCVD Operations
394 Elizabeth Avenue, Somerset, NJ 08873, USA.

AlGaN/GaN High Electron Mobility Transistors (HEMTs) on Si have emerged as a promising solution for high frequency power amplification and high voltage power switching applications, since they can utilize CMOS fab lines and the availability of low cost Si substrates in larger diameters ($\geq$ 6 inch) compared with SiC and GaN. Encouraged by the recent device performance results achieved for AlGaN/GaN HEMTs on Si aided by the growth of high quality crack-free GaN growth on large substrates (6-8 inch), power electronics industry is currently engaged in pilot production of devices.

We have tested GaN/Si and HEMT repeat runs on 6” and 8” Si (111) substrates to confirm the repeatability and stability in large scale production MOCVD. We have also confirmed the epitaxial process repeatability, stability and longevity. The epitaxy process is carried out in 5x6” and 3x8” multi-wafer Veeco TurboDisc K465i production MOCVD systems. AlGaN/GaN HEMT consists of AlN nucleation layer, three step-graded $Al_xGa_{1-x}N$ buffer layers of Aluminum molar fractions 0.75, 0.5, and 0.25, and 2-3 µm GaN layer with $Al_{0.25}Ga_{0.75}N$ barrier. 1 nm thick AlN spacer is optionally inserted between AlGaN barrier and GaN to improve the performance of 2DEG.

AlGaN/GaN HEMT structures exhibit good thickness uniformity (<2% in 1σ) and are free of cracks from the edge to the wafer center. The Al composition variation across the wafer is less than 1.5%. XRD FWHM (full width at half maximum) average values for (002) and (102) planes are less than 600” and 800” respectively, for GaN layers with Carbon concentration of $6.0x10^{18}cm^{-3}$. HEMT samples with 25 nm $Al_{0.25}Ga_{0.75}N$ barrier exhibit an average 2DEG mobility (μ_H) greater than $1500cm^2/V.s$, and sheet carrier concentration (n_s) higher than $6.0x10^{12}cm^{-2}$. With the insertion of AlN spacer, the average mobility μ_H is greater than 2000 $cm^2/V.s$ and n_s higher than $8.0x10^{12}cm^{-2}$. All these values are valid for 6” and 8” runs.

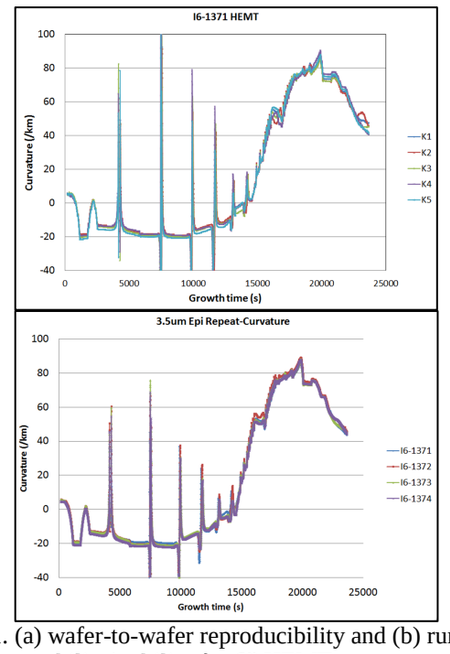
Table 1 shows the run to run (RtR) repeatability for the growth of 8” AlGaN/GaN HEMT structures. The growth rates of all the layers in the repeat runs show <0.5% in 1σ (not individual layers in the table). The average GaN XRD FWHM of (002) and (102) diffraction planes are 535 and 660 arc-second, with <2% in 1σ (within measurement limit), respectively. The post growth wafer curvatures at room temperature are consistently less than 50µm, for ~3µm stack. The repeat runs were interrupted by a system maintenance after more than 50 GaN/Si runs and LED growths to establish the system stability and flexibility.

The in-situ measurement shows reproducible wafer curvature for 6” HEMT repeat runs, as shown in Figure 1 (a) and (b). The HEMT surfaces have no micro-cracks and exhibited a step-flow feature comparable to the surface of the underlying GaN layer, indicating pseudomorphic growth of AlGaN with less strain relaxation. The root-mean-square (RMS) roughness is around 0.2-0.4 nm in a 5µmx5µm scanned area.

In summary, we report here the repeated growths of crack-free AlGaN/GaN HEMT on 6” and 8” silicon by large scale production MOCVD. The HEMT runs show good wafer-to-wafer and run-to-run repeatability, demonstrating the readiness of using Si substrates for the production of AlGaN/GaN HEMT epi.

Run #	Wafer Bow (um)	Thickness (um)	XRD 002	XRD 102
HEMT 1	-6.95	2.94	525	659
HEMT 2	-11.13	2.98	539	670
HEMT 3	-12.19	2.98	520	644
HEMT 4	-13.39	2.97	522	644
HEMT 5	-16.77	3.04	525	654
HEMT 6	2.3	3.02	536	643
HEMT 7	-13.17	3	545	669
HEMT 8	-6.53	3.07	539	649
PM				
HEMT 9	-15.79	3.03	533	666
HEMT 10	-11.22	2.96	539	666
HEMT 11	-17.01	3.02	551	655
HEMT 12	-15.08	3.04	538	646
HEMT 13	-14.57	3.06	541	667
LED run				
HEMT 14	-17.37	3.08	539	668

Table1. 8” AlGaN/GaN HEMT Repeatability Runs



(a)

(b)

Figure 1. (a) wafer-to-wafer reproducibility and (b) run-to-run repeatability/stability for 6” HEMT runs.

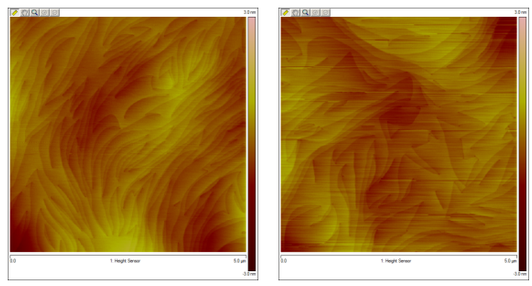


Figure 2. Identical surface morphology (RMS < 0.5nm for 5µm x 5µm scan) with pseudomorphic growth mode for run-to-run and wafer-to-wafer.