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APPLICATION NOTE

Process improvements in the growth of AlGaN / GaN heterostructure on Silicon by Ammonia MBE

Introduction

On the basis of the previous work⁽¹⁾, the first purpose of this application note is to show the high stability of the Aluminium flux necessary to achieve reproducible growth. Further more this note describes a method to minimize the formation of silicon nitride on the Si substrate surface during oxide removal procedure at elevated temperature, in order to achieve high quality AlGaN/GaN heterostructures.

Work was carried out at RIBER GaN Process Technology Center (PTC) in Valbonne, France, in collaboration with the CRHEA- CNRS team, in the Compact 21 research system specifically dedicated to GaN growth.

Ammonia was chosen as group V element source because of its better capability in achieving high uniformity and excellent growth quality.

(1) Ask for the application notes:
608 26 N 02 “State of the art quality of GaN/AlGaN quantum wells grown on GaN template.”
608 27 M 62 “ Outstanding uniformities of GaN quantum wells”

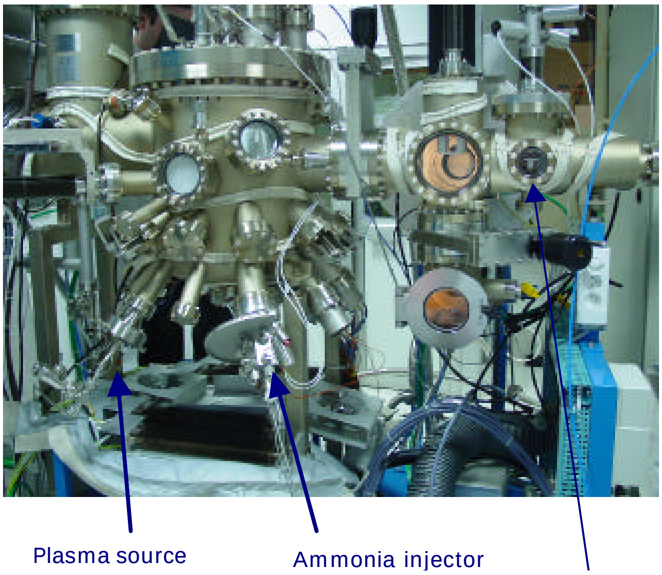


Figure 1: Compact 21 GaN dedicated MBE system

Experimental

Epilayers were grown in the RIBER Compact 21 GaN dedicated MBE system, as shown in figure 1. Growth chamber is equipped with a 4” substrate holder (up to 3” substrate) receiving a high temperature, high uniformity substrate heater⁽²⁾ (up to 1100°C pyrometer measurement).

Gallium source material is loaded in the standard ABN 80 (80 cc) double filament effusion cell. Silicon dopant is loaded in the ABN 135 DC (21 cc) single filament doping cell. A cold neck single filament effusion cell, model ABN 80 CN has been specifically designed for the use of Aluminium.

The necessary high vacuum conditions, in the growth chamber, are obtained via a liquid nitrogen cryo-panel surrounding the epitaxy volume, in addition to a turbopump.

The system is equipped with two nitrogen sources: an NH_3 injector, model HTI 163 and an Addon N_2 RF Plasma source. In this case, work is achieved using the ammonia source.

(2) ask for the Product news:
608 27 N 52 “New high temperature substrate heater”

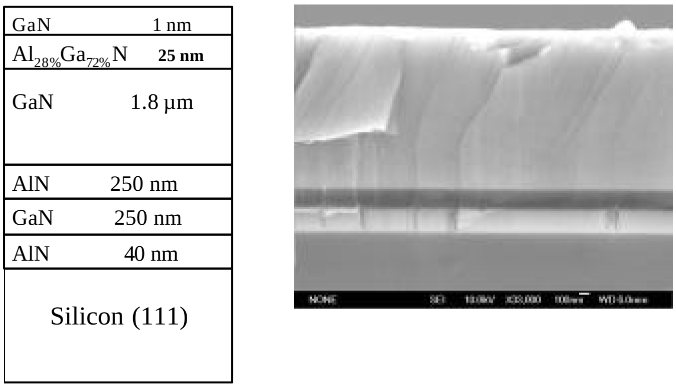


Figure 2: Sketch of the AlGaN / GaN heterostructure

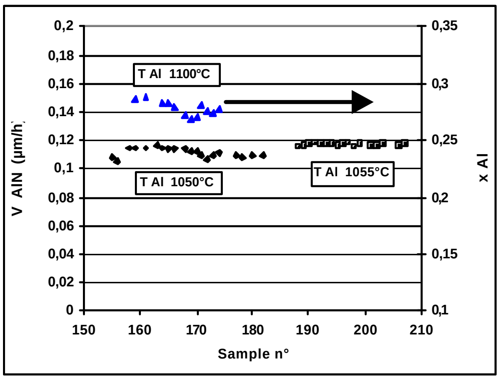
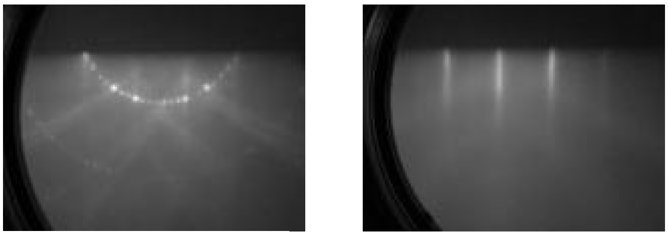


Figure 3: Stability of AlN growth rate measured by in-situ reflectivity



a-(7x7) Si (111) at 600°C

b-(1x1) GaN at 800°C

figure 4 : Si(111) prepared in the growth chamber under high vacuum - reference

Structure

Figure 2 shows a sketch of the AlGaN/GaN heterostructure. Growth performed on 2” Si(111) wafer consisted in a 40nm AlN nucleation layer followed by 0.25µm GaN / 0.25µm AlN layers and a 1.8µm thick GaN buffer layer. The active layers are a 25 nm AlGaN barrier capped with 1nm GaN.

Results

Excellent Al flux stability over growths

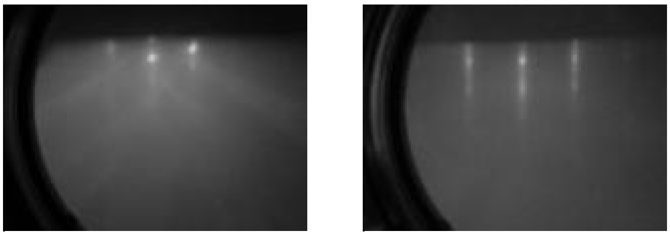
Aluminium flux stability presents a great interest as it is an important parameter for reproducible experiments and layers. To determine the stability of the Al flux, the AlN growth rate of the 250nm AlN buffer layer was measured by in-situ reflectivity.

A first set of data has been recorded at an Aluminium cell temperature of 1050°C. A second set of data has been recorded at 1055°C, both sets reported on figure 3. Results exhibit a very slow growth rate variation between both temperatures over 40 samples, leading to the conclusion that a temperature correction of less than 5°C should maintain stable the Aluminium composition of the alloy.

Upstream process development to obtain high quality AlGaN / GaN heterostructures

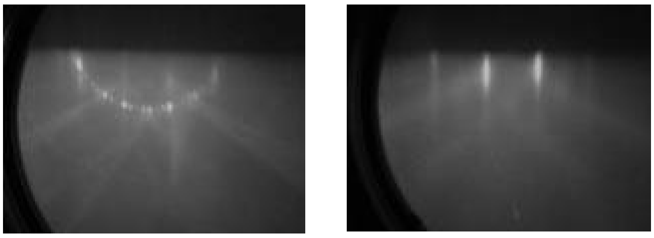
To obtain high quality III-N layers on silicon substrate, it is first necessary to remove the silicon oxide from the surface before starting the structure growth.

Figure 4-a shows the (7x7) RHEED pattern of the silicon substrate surface prepared under high vacuum conditions (low 10^{-9} Torr), meaning that there is no ammonia background in the growth chamber. This pattern is used as our reference.



a- Si (111) at 600°C b-(1x1) GaN at 800°C

Figure 5 : Si(111) prepared in the growth chamber with ammonia background pressure



a- (7x7) Si (111) at 600°C b-(1x1) GaN at 800°C

Figure 6 : Si(111) prepared in the preparation chamber

To eliminate this silicon nitridation, ammonia trapped on the cryopanel during previous GaN growth needs to be eliminated before deoxidation. Consequently a daily cryopanel recovery procedure has been set up and optimized in the first months of the PTC, but obviously too much time consuming.

To avoid this time costly procedure, not applicable in production, it was tested to thermally remove the substrate oxide in the preparation chamber (see picture 1). The latter, has been equipped with a high temperature oven and a water cooled panel. The silicon substrate is thus deoxided at 930°C in the preparation chamber, cooled down at 200°C and quickly transferred into the growth chamber (which has not been submitted to any maintenance procedure).

As RHEED patterns, figure 6 show it, silicon substrate surface is really improved (6-a) and permits the growth of good quality GaN layers (6-b) nearly like in ultra high vacuum conditions (4-b).

Next step, is to set a valve between the transfer and the preparation chambers to reduce traces of ammonia coming from the transfer part and therefore increasing even more the GaN layer quality.

Conclusion

This work has obviously shown a good control of the Al content in the AlGaN layers leading to high quality, uniform and reproducible heterostructures.

Furthermore PTC fulfilled one of its main target by improving processes of III-N structure growths on silicon substrates, resulting in very promising results in term of layer quality.

About PTC

PTC allows customers and prospective users to test growth structures or target specific device properties to enhance and accelerate their process knowledge. Training courses may be tailored to meet individual requirements. Experience accumulated in advance of system delivery saves months of post-installation process development.