Chemical Sensing and Advanced Process Control for AlGaN/GaN HEMT Manufacturing

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High Performance Applications

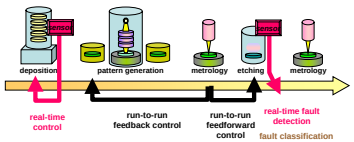
GaN-based electronic devices for high frequency, high power applications, such as radar electronics


Challenges

Growth of GaN epi films and GaN-based alloys with reproducibility and quality constraints that are much higher relative to optoelectronic applications

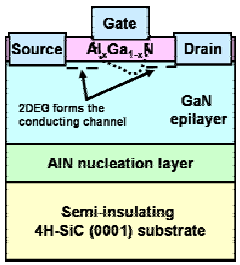
Approach

Advanced Process Control (APC) already pervasive in the Si ULSI industry is applied to the GaN-based processes to bring reproducibility and process optimization

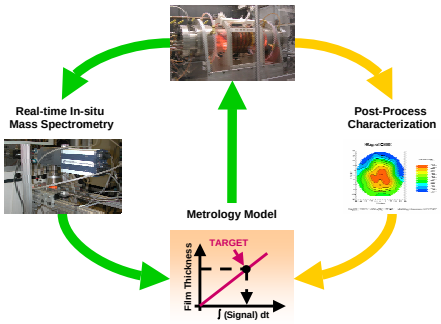


GaN-based Heterostructure Design

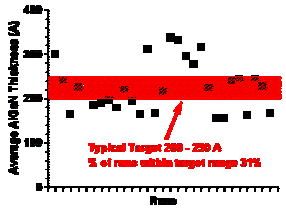
Multiple material parameters across the multi-layer structure must be co-optimized ➔ Direct consequences in terms of device performance



Sensor-based REAL-TIME Advanced Process Control

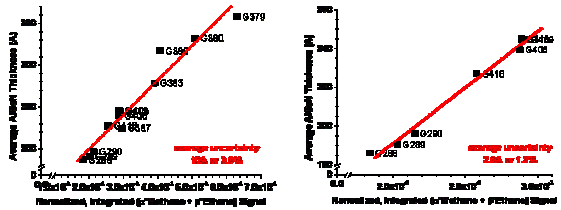


Process Variability is a Concern...



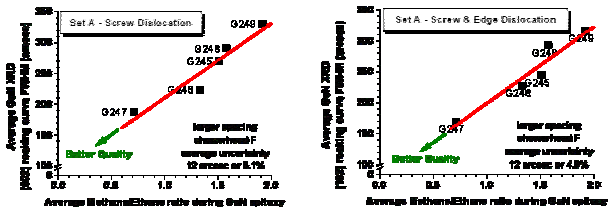
AlGaN Cap Layer Thickness Metrology

Sensor-based metrology can predict/control AlGaN thickness to within 3A or 1%



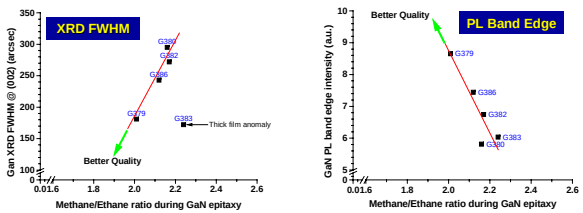
GaN Epilayer Crystal Quality Prediction

- Based on intrinsic process chemistry – two major byproducts Methane & Ethane representing different reaction pathways
- *Monitoring the Me/Et ratio predicts product crystal quality to ~ 5% precision*



GaN Epilayer Photoluminescence Quality Prediction …

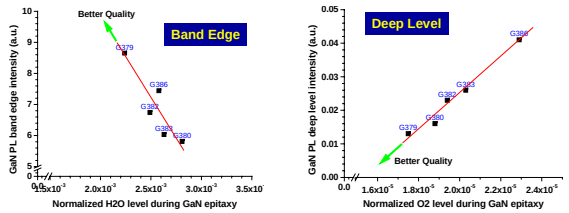
Same Me/Et ratio predicts PL band edge intensity to ~ 5% precision



Lower Me/Et ratio produces better quality (XRD, PL band edge)
➔ Surface reaction (Ethane) pathway desired

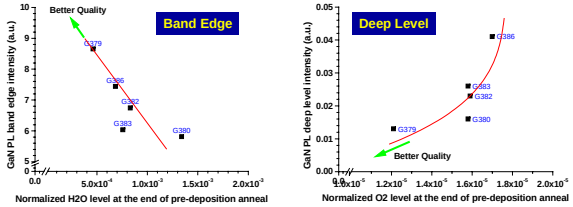
… GaN Epilayer Photoluminescence Quality Prediction

Band edge and deep level must be optimized concurrently



Low impurity condition must be established prior to GaN growth step
➔ Can predict, but little room for course correction during GaN step itself

Pre-process Contamination Control is a key



- *Reduce impurity levels in reactor through pre-process purge, anneal, and R2R bake-out*
- *Watch for impurity levels to drop below critical limit to guarantee acceptable PL quality*

CONCLUSIONS

- In-situ metrology is key to achieving real-time APC
- GaN for advanced electronic application faced with serious manufacturing hurdles

- Chemical sensing in GaN MOCVD for Advanced Process Control
  - *Accelerated learning at R&D stage*
  - *Manufacturing reproducibility*
  - *Insight into intrinsic chemistry & process*

- Extensive fault detection & management in use already
- Precision metrology for critical AlGaN layer thickness (20-25nm) to ~1% in real-time demonstrated
- Accurate prediction of product quality (crystal quality, PL) in real-time demonstrated

- APC benefits exploited by Northrop Grumman development
  - *AlGaN thickness control*
  - *Pre-process contamination control*