Determining Cause

GaN HEMT Reliability: An Evaluation of Degradation Analysis

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Review of Publications

• In the study of the underlying Chemistry and Physics that play a role in device lifetimes, how well is the electrical behaviors linked to the physical locations analyzed?

• In review of several published articles, papers and presentations the systematic methods are often not disclosed or appear to be post stress only. And some blindly select where to analyze.

“If you don’t know, you don’t know!” – Ball Park Frank Commercial
GaN Device trends

Large area devices with shrinking geometries.

Hall electron mobility of AlGaN/GaN samples as a function of edge TD density. Note defect densities are measured between $5 \times 10^9$ and $1.5 \times 10^{10}$ TD/cm$^2$. This equates to observing between 60 to 180 threading dislocations in a TEM slice of a 8 um wide channel region.

This also equates to one TD every 2 TEM slices up to 3 TD under the gate area in a 100nm gate in a TEM slice.

New materials are not defect free leaving high density of background to confuse or hide the mechanism. And not likely to improve.

How do you know if there is a potential Failure Mechanism?
Metrology Trends

• Analysis capabilities are able to resolve atomic distances of atoms but are limited in the volumes to be analyzed.

• Below is a stressed 2 X 150um device. Do you know where the potential failure mechanism is?

Considerations on metrology typically used and limitations

TEM – Slice 10 um by 150nm thick wedge typical 70 pm res
App 75 samples or 0.0000375% of total volume

AFM – Scan 5 to 30nm res for current sensing

RAMAN – Scan 1um res

PE – Scan 1 um res

IR – Scan greater than 100um devices 5um res

EBIC – Scan ~20 nm res– dependent on electron beam control

CL – Scan ~ 20 nm res – dependent on electron beam control

Bare substrate
Do you know what came first?

• Non destructive isolation techniques - EBIC

What points were there prior to stressing?
Photo Emissions and Infrared

Non destructive isolation techniques – Photo Emission (PE)

Were these localized points there prior to stress?

Do you know?

Infrared (IR)
Background Changes

• Do you know if there are changes in background between pre and post stressing?

Example of EBIC mapping pre and post stress without isolated points.
Background Changes

Have the background levels changed from pre stress conditions?

PE Images of a device pre and post stress.
Proposed Methodology

Closing the loop between pre stress measurements and post stress analysis.

Utilize non destructive metrology to characterize pre and post.

Align metrology with expected changes.
Closed Loop Information

- EBIC Mapping
- Active marking of EBIC points with Pt
- Active EBIC image of cross section
- SEM image of failed area
Closed Loop Information

Common Failure Mechanisms reported and observed
Crack formation under edge of Gate


Time lapse EL image with Hot Electrons resulting in defect peculations was reported

Utthiya Chowdhury et al. IEEE ELECTRON DEVICE LETTERS, VOL. 29, NO. 10, OCTOBER 2008
Methodology Pros and Cons

Drawbacks:

• Time to take the measurements.
• Technique availability / collaboration / service.
• Device architecture conflicts - field plated and Air Bridge devices.

Benefits:

• Gain a filtering method.
• Lessen missed observations.
• Define areas of interest.
• Determine wear out or pointed events.
• Know the electrical observations are tied to the chemistry and physics changes observed in the analysis.
Questions?