GaN/GaN-on-Si Workshop

Moderators:

Sameh Khalil, Infineon Technologies
Sandeep Bahl, Texas Instruments

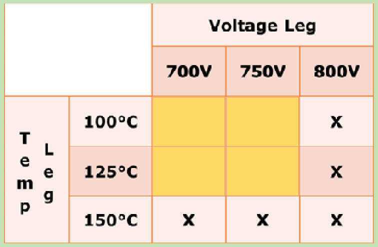
Invited Experts:

Ronald Barr: Transphorm
Charles Cheung, NIST

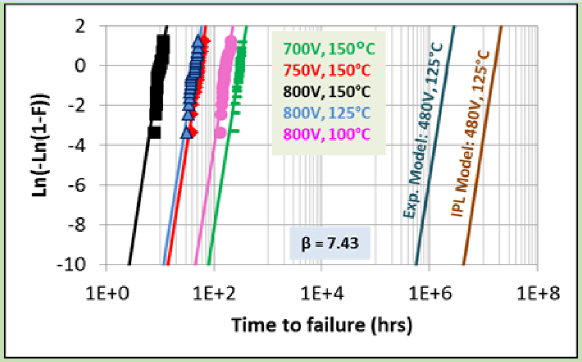
Extrinsics in GaN TDB (HTRB): Synergies between GaN and Si/SiO$_2$ Reliability

Intrinsic

- Reliability of GaN under HTRB condition follows Time-Dependent-Breakdown-Like behavior analogous to the Si/SiO$_2$ system
- GaN Lifetime prediction methodology is also derived from Silicon dielectric reliability



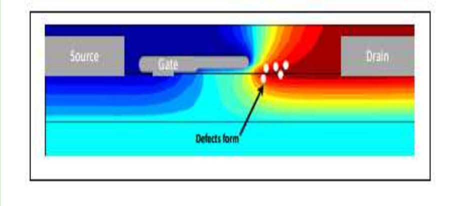
		Voltage Leg		
		700V	750V	800V
Temp Leg	100°C	🟨	🟨	x
	125°C	🟨	🟨	x
	150°C	x	x	x



H. Kannan et al. (Infineon) WiPDA 2017 & IRPS 2017

Extrinsic

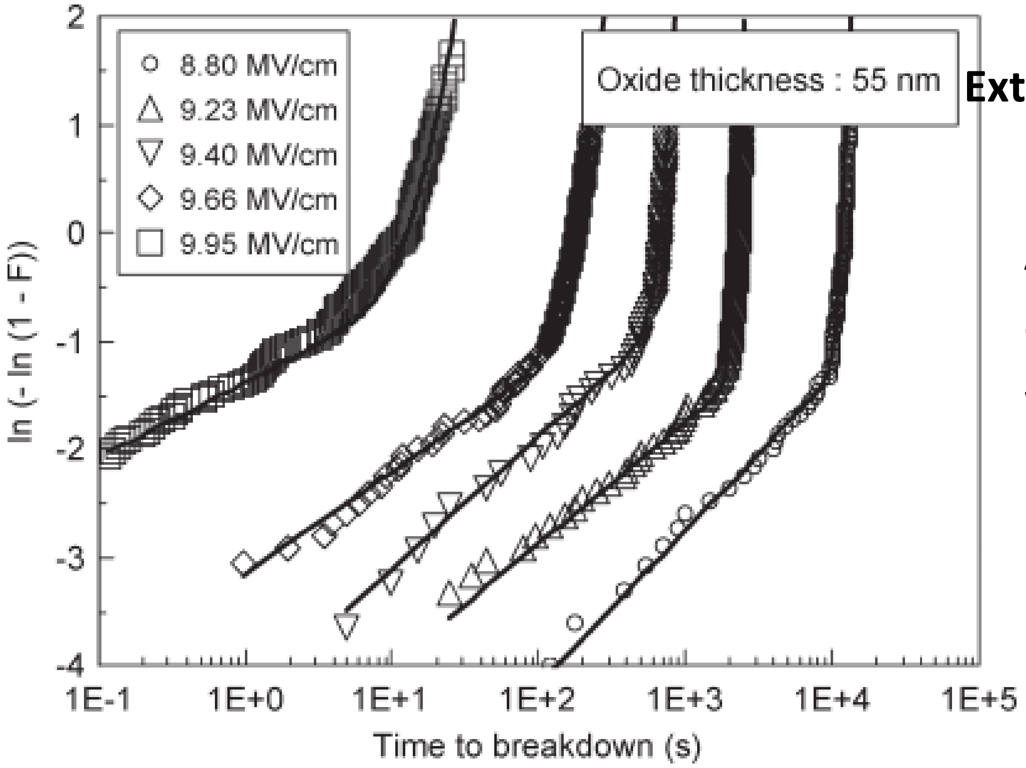
- New topic to GaN publications/literature
- Paper at WiPDA 2018 by Transphorm was first to address Extrinsic in GaN



Ronald Barr et al. (Transphorm) WiPDA 2018

Our Objectives today:

- Discuss the synergies between GaN reliability and Si/SiO2 system (or gate dielectric of Si) from **extrinsic TDB** reliability stand point
- What kind of learning and knowledge from the Silicon world need to be leveraged and applied to GaN Reliability so we do not re-invent the wheel!



S. Oussalah and B. Djezzar, TED54(7), 1713(2007)

Extrinsic gate oxide TDDB failure:

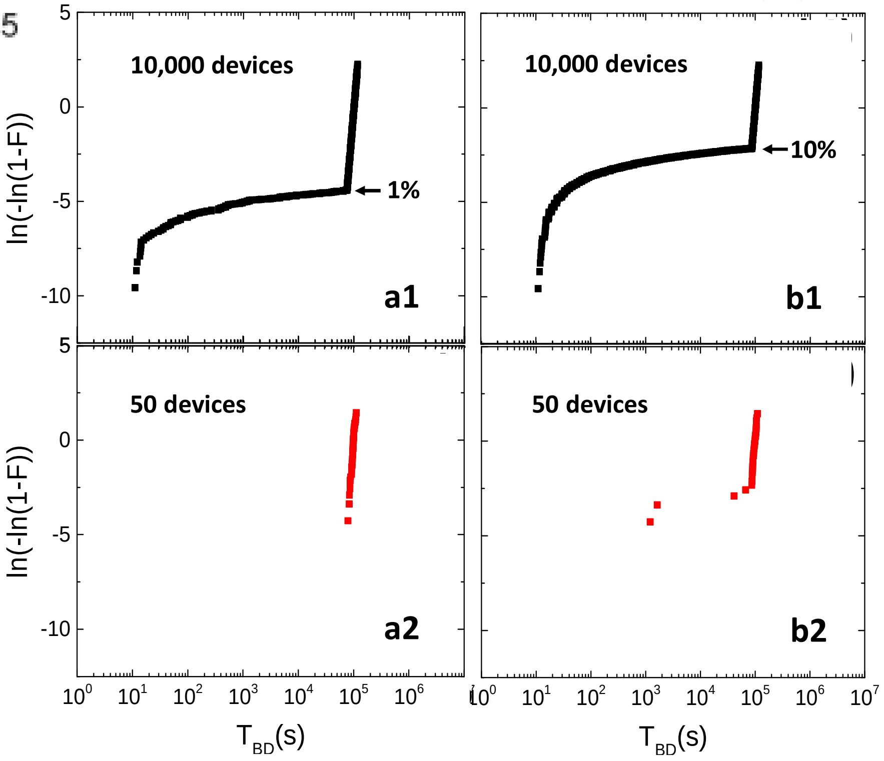
Large sample size required

Analyzed by joint distribution

Controls lifetime even after screening

Weibull factor $\beta < 1$

➔ area and probability scaling issues



Small sample size can fool you!!!

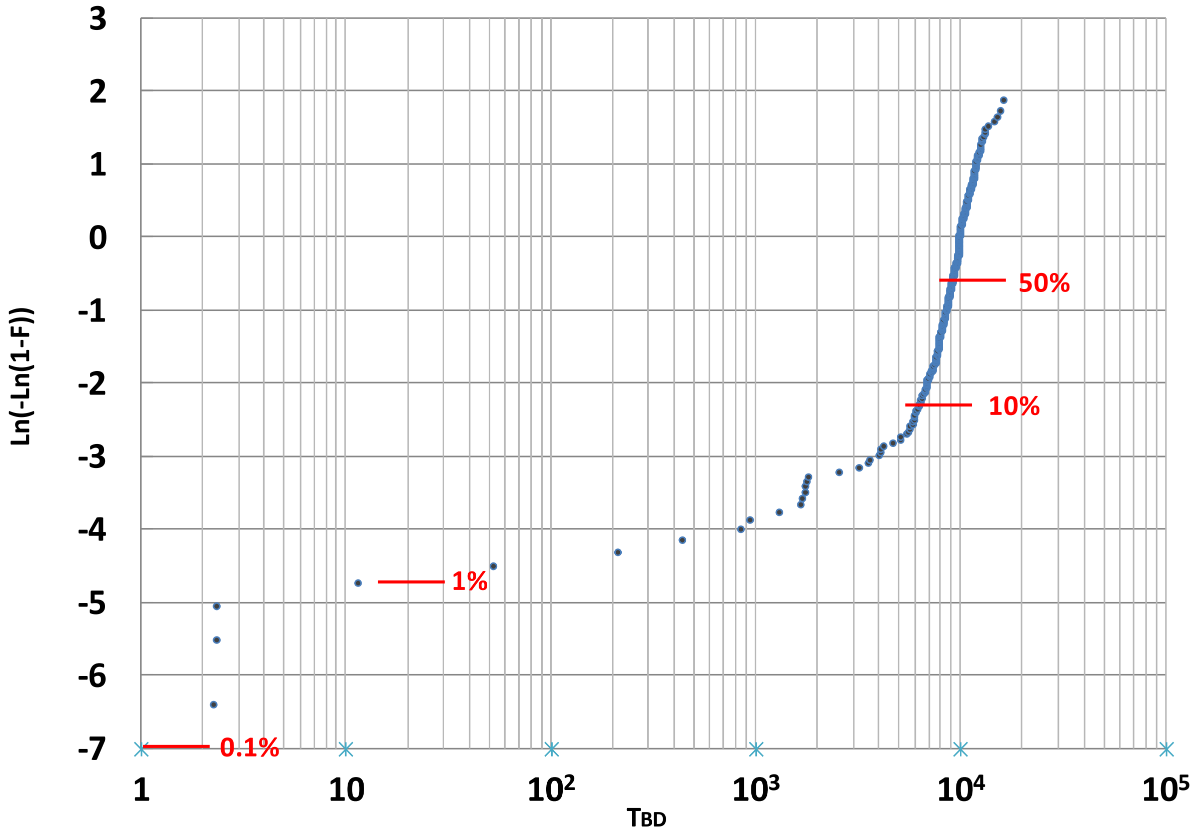
Silicon experience should be taken with care

Recent silicon gate oxide reliability literature are not applicable for thick oxide

Silicon thick oxide extrinsic failure problem were never understood.

Only model is the effective thinning model which does not explain data well

For SiC gate oxide, this was learnt the hard way.



The significance of Weibull slope β

Failure fraction scaling: $\tau_{F1} = \tau_{F2}\left(\frac{\ln(1-F_1)}{\ln(1-F_2)}\right)^{1/\beta}$ **Active area scaling:** $\tau_{63}^{P} = \tau_{63}^{T}\left(\frac{A_T}{A_P}\right)^{1/\beta}$

	β= 0.5	β= 15
From characteristic failure time (t_{63}) to 0.63% failure time:	T_{63}/10000	T_{63}/1.36
From 100µ x 100µ test structure failure time to 10 cm^2 product failure time:	10 billion times shorter	2.15 times shorter

For intrinsic lifetime of thick oxide, *t_{63}@E* of any size test device is adequate.

For extrinsic lifetime of any oxide, failure fraction and test device area must be accounted for.

Problem: Temperature Acceleration Alone to demonstrate ELF FIT<1 requires large number of parts/resources
define FIT

Sample Size Required for 1 FIT @ 85C HTRB @150C @Operating Voltage	
Eaa	**# Parts**
1.0	6,286
0.7	28,008
0.5	75,839
0.3	205,355
0.1	556,052
0.0	915,000
-0.1	1,505,659
-0.3	4,076,974
-0.5	11,039,493
-0.7	29,892,371
-0.9	80,941,563
-1.0	133,191,711

 # Parts needed based on standard HTRB testing for 1000 hrs per test

← Silicon

Power Electronics run at relatively **high temperatures,** reduces acceleration factor of standard HTRB testing

Eaa differs from silicon, and between GaN Suppliers

Solution: GaN does not avalanche enabling Voltage Accelerated Early Life Failure Test

Test Conditions
HTRB @800V @ 85C
(Transient voltage rating)
“Gentle acceleration”

~2.2K Devices
~1.1 million device test hours
Zero Failures

TP65H050WS: Generation 3

	FIT	**MTBF (hours)**	**Accelerated Hours**	
520 V	0.60	2E+09	2E+09	Max Operating Voltage
480 V	0.21	5E+09	4E+09	
400 V	0.03	4E+10	3E+10	Typical Use Case

@ 85C (Normal Use Temperature)

V model (most conservative) used for calculations
AFv = exp (Υ x ΔV) = exp(.026 x ΔV)
Based on published data

Question for IRPS panel

- The silicon industry has been using temperature acceleration to define ELF (Early Life Failure) data for years. GaN is well suited to the use of voltage acceleration either alone or in combination with temperature acceleration as it does not avalanche like a silicon MOSFET.
- **What additional data would need to be developed to demonstrate reliability and gain confidence with end users?**

Yield – Reliability Correlation

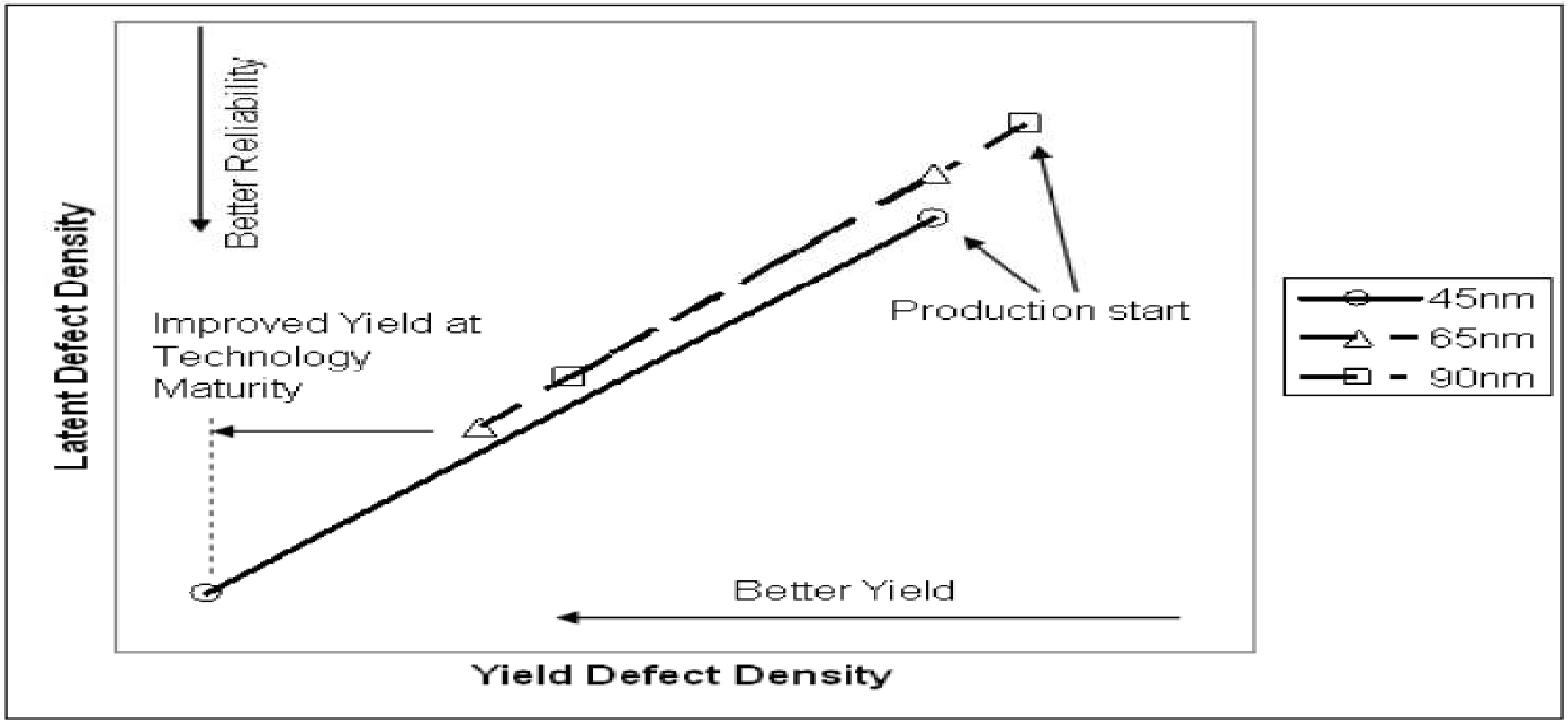


FIGURE 10. BURN-IN DEFECT DENSITY AS A FUNCTION OF PROCESS YIELD DEFECT DENSITY

R. Kasim et al., IRPS 2009 (Intel Corp.)