Reliability Experience

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TriQuint SEMICONDUCTOR®

Purposes:

Increase Your Reliability Knowledge Base.

(Share Experience)

Answer Questions About Reliability.

Outline

Basics

- **A little about Compound Semiconductors**
- **Vocabulary**
- **A new era for reliability**
- **Arrhenius methodology review**

Beyond the Basics . . .

- **Learning from customers: it's a *Natural***
- **Breaking the cycle of learning curves**
- **Tipping your cap**
- **The Black magic of current density**
- **Amped up on defects**
- **The new PC**

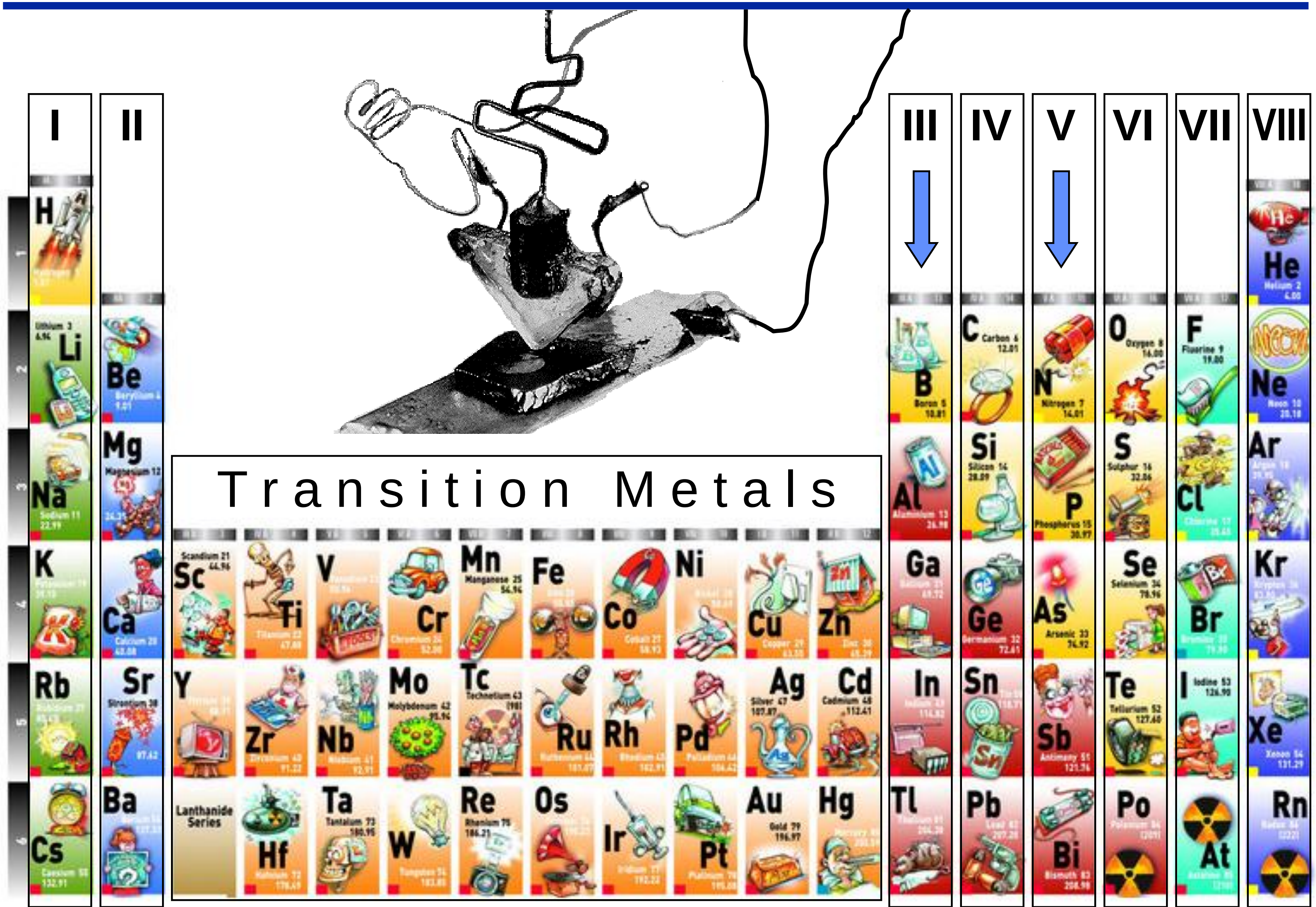
Why GaAs Reliability?

“Reliability counts.
In almost every case integrated electronics
has demonstrated high reliability.”

Gordon Moore, Electronics Magazine, 1965.
Cramming more components onto integrated circuits

- Volume drives reliability.
- GaAs is different than silicon.
- New compounds (GaN) have more to go.

Semiconductors and Compounds



I

II

III

IV

V

VI

VII

VIII

Transition Metals

Contrasting Improvement Methods

1. No significant historical improvement in lifetimes.
2. Moore's Law doesn't exactly apply to Compound Semiconductors.

	Performance	Reliability	Yield Focus
Si	Shrink Physical Size	New Materials	Defects
C.S.	New Materials	Don't Shrink (Good Enough)	Parametric

See for yourself – Check out the International Technology Roadmap for Semiconductors. There is an *RF for wireless communications* chapter!

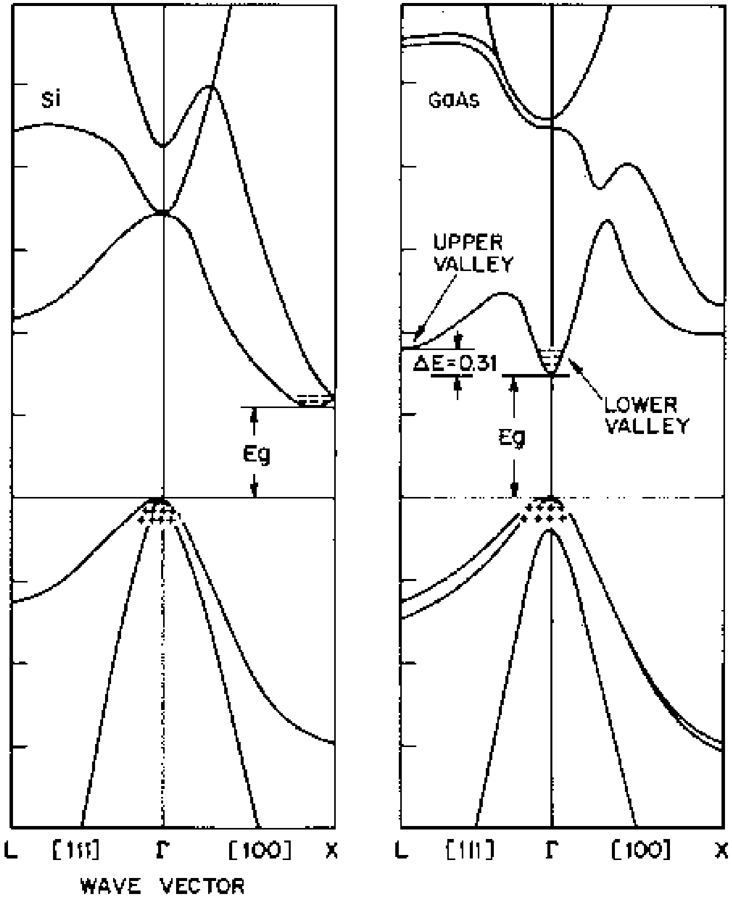
Choosing Materials

"Silicon is likely to remain the basic material, although others will be of use in specific applications. For example, gallium arsenide will be important in integrated microwave functions."

Gordon Moore, Electronics Magazine, 1965.

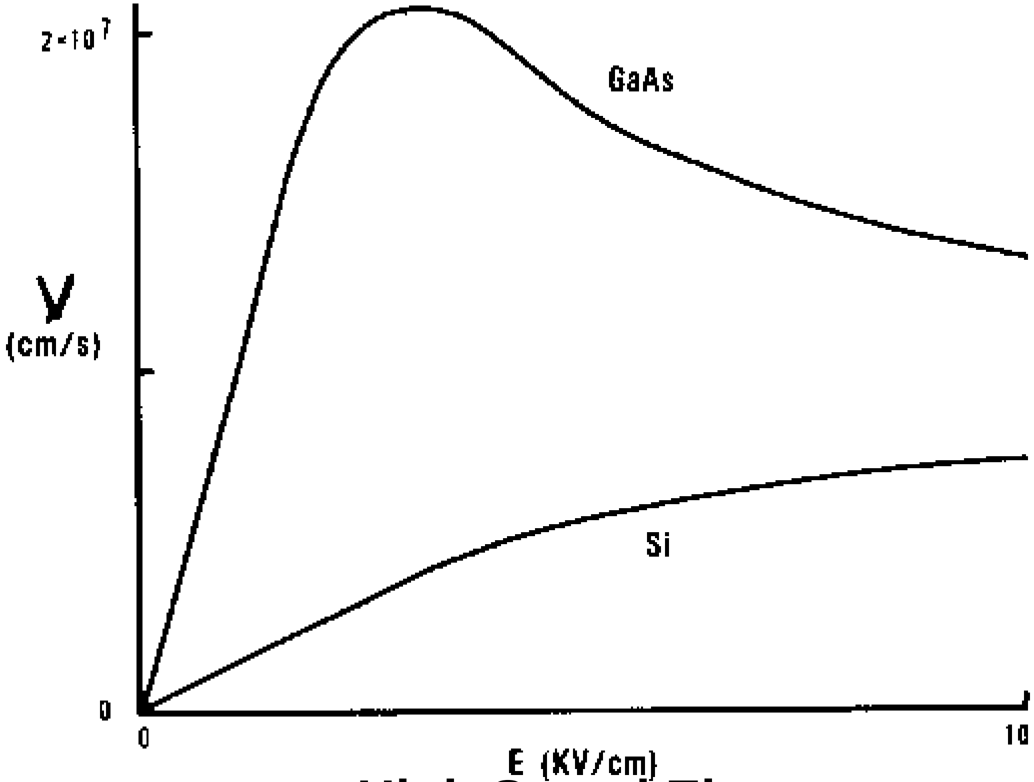
Cramming more components onto integrated circuits

What's so great about GaAs?



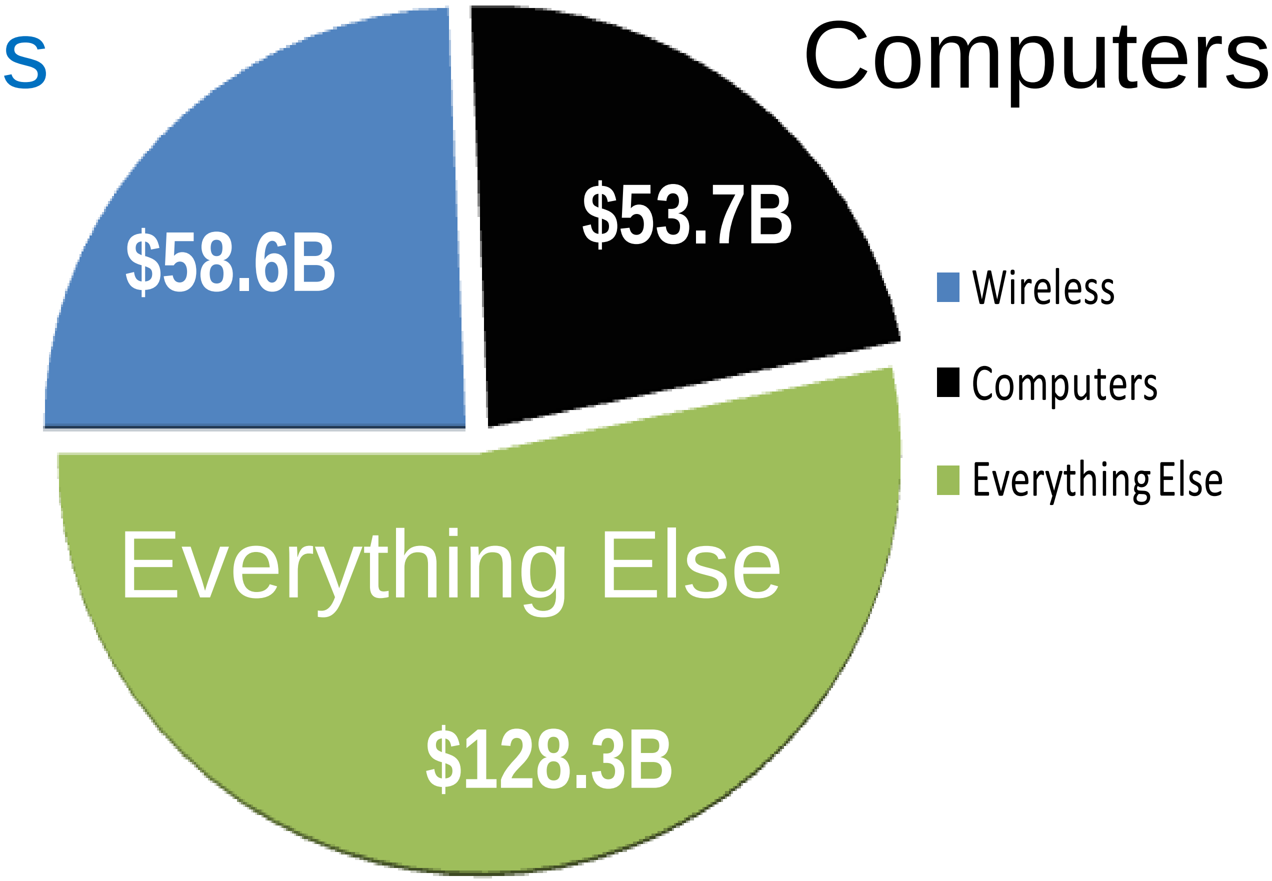
Direct Gap, Low Electron Effective Mass

Perfect for LEDs & Solar Cells



High Speed Electrons

Motivation – What indicates we've made it?



2011 Spending on Microchips

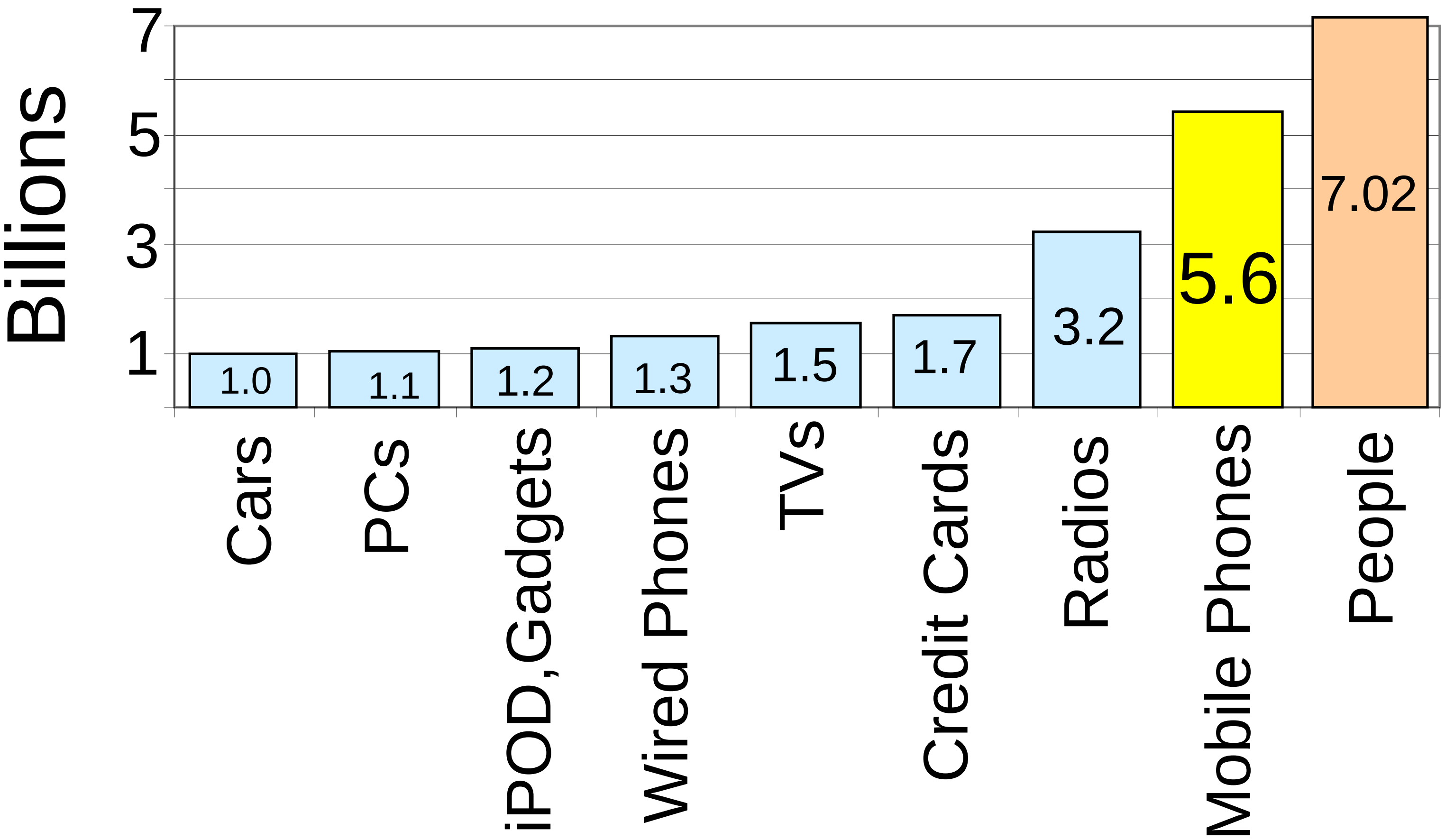
Computerworld, February 1, 2012

Vocabulary – What is an RF Product?

There's no enigma like six sigma

4 Births per second worldwide.

47 Cell phones are being produced every second.

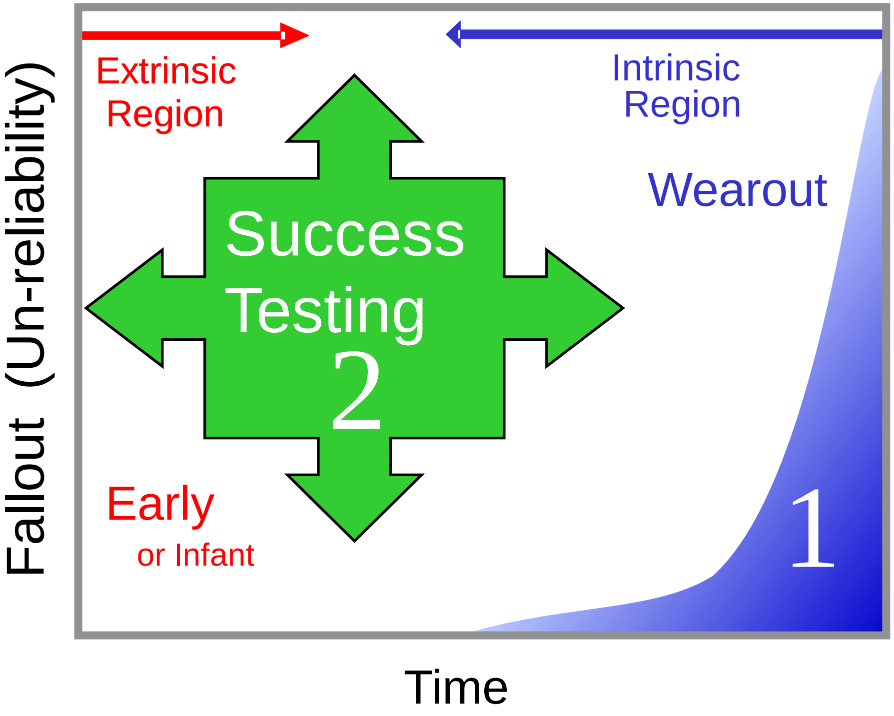


Reliability Vocabulary – Goals

- **Data: Measure degradation**
  - Wearout and Defects
  - In search of the “special lot”
  - Edges produce data
- **Finding the “Flux Capacitor”**
  - Goal 1: to predict future fallout
  - Goal 2: to improve reliability
  - Goal 3: to ensure reliability
- **Reliability Engineer: obsessed with time**
  - Measure Rates of Failure
  - Acceleration Factors: Ea, n, γ
  - Probability and Confidence Levels
  - Learning cycles and screening

Categories of Reliability Test

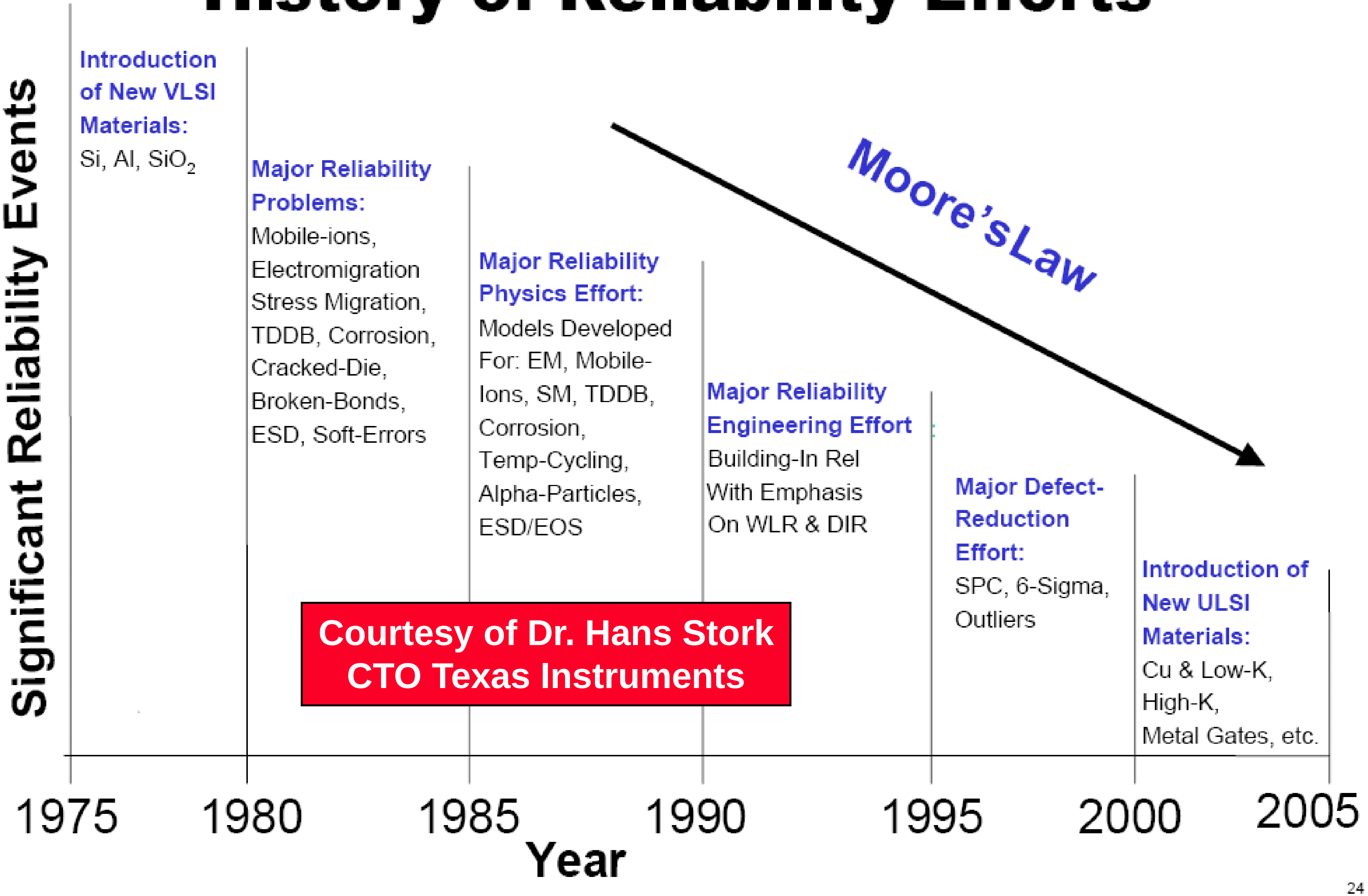
1. **Capability Testing**
   - **When does it fail?**



2. **Success Testing**
   - Is it good enough?

3. **Defect Characterization**
   - Measure & reduce the minority failure populations.

History of Reliability Efforts



Introduction of New VLSI Materials:
Si, Al, SiO_2

Major Reliability Problems:
Mobile-ions,
Electromigration
Stress Migration,
TDDB, Corrosion,
Cracked-Die,
Broken-Bonds,
ESD, Soft-Errors

Major Reliability Physics Effort:
Models Developed
For: EM, Mobile-
Ions, SM, TDDB,
Corrosion,
Temp-Cycling,
Alpha-Particles,
ESD/EOS

Major Reliability Engineering Effort
Building-In Rel
With Emphasis
On WLR & DIR

Major Defect-Reduction Effort:
SPC, 6-Sigma,
Outliers

Introduction of New ULSI Materials:
Cu & Low-K,
High-K,
Metal Gates, etc.

Courtesy of Dr. Hans Stork
CTO Texas Instruments

Historical Eras of Reliability

Era	Definition	VLSI Silicon Example	Compound Semi
1	**Materials**	**1975** Materials: Si, Al, SiO_2	**1980** GaAs, Au, Si_xN_x
2	**Mechanisms** (Major Reliability Problems)	**1980** Mobile-ions, E-M, S-M, TDDB, Corrosion, Cracked-Die, ESD, Soft-Errors	**1985** Sinking Gates, Ohmic Contacts
3	**Physics** (Major Reliability Physics Effort)	**1985 Models…** EM, Mobile-Ions, SM, TDDB, Corrosion, Temp-Cycling, Alpha Particles, EOS/ESD	**1990 Models…** Thermal Diffusion, JEP118, Hydrogen
4	**Engineering** (Major Reliability Engineering Effort)	**1990** Building-In Reliability, with Emphasis on WLR & DIR	**1995** WLR, Passives, BIR
5	**Defects** (Major Defect-Reduction Effort)	**1995** SPC & 6 Sigma Outliers	**2000** Capacitors, Interconnects

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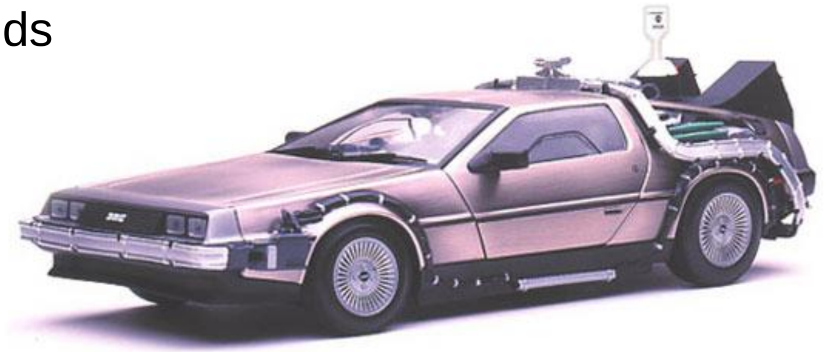
How to Accelerate?

How long does reliability qualification **really** take?

Temperature
Current
Humidity
Voltage
Mech. Stress
Contaminants
Radiation
Electric Fields
Force
Power
Pressure
Light

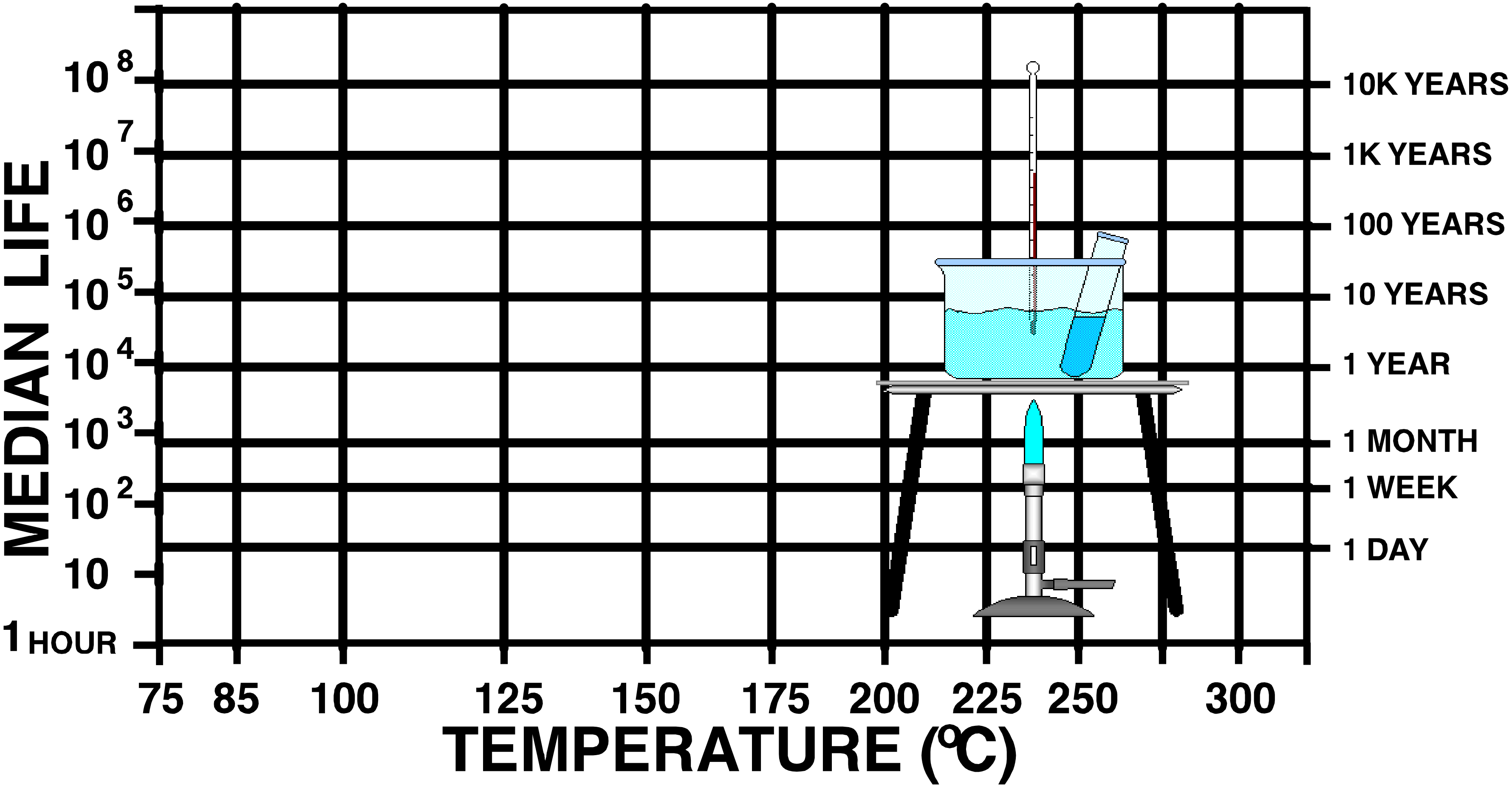
These are the reliability engineer's tools



Arrhenius: Godfather of Reliability

Time To Fail = exp[Ea/k(1/Temp)]

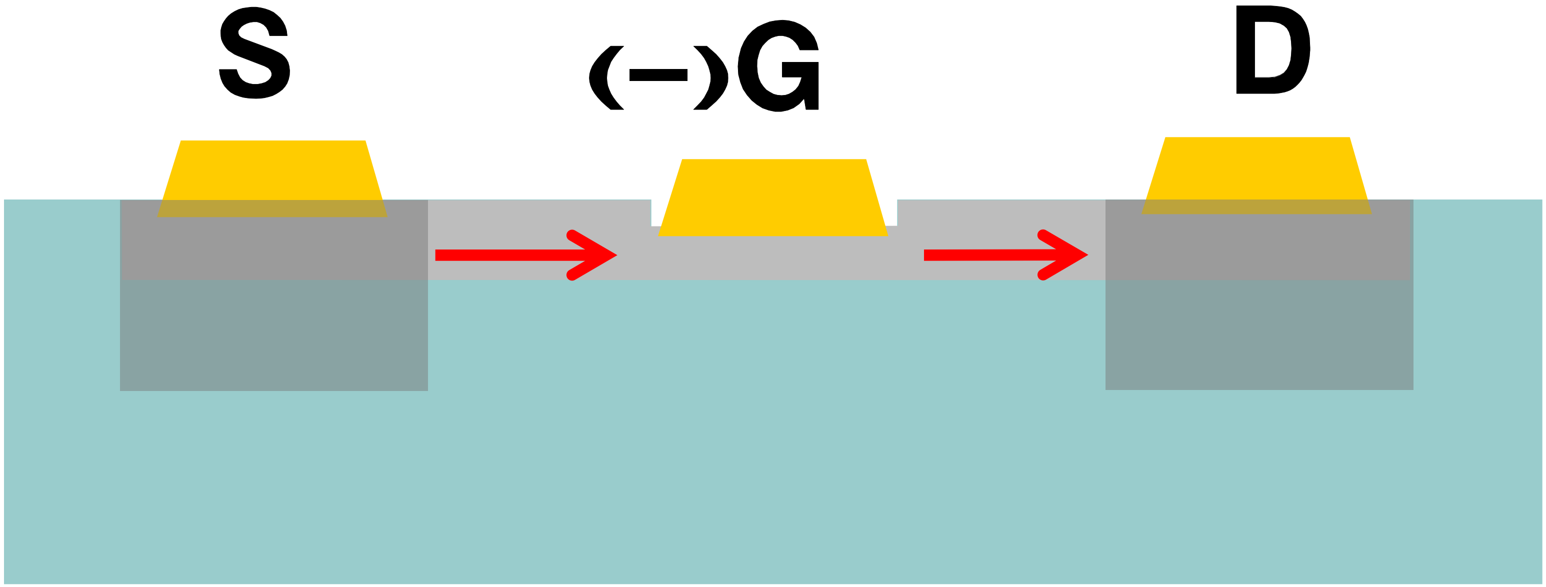
Ea = Activation Energy (in eV = "Electron Volts"), k = Boltzman's Constant



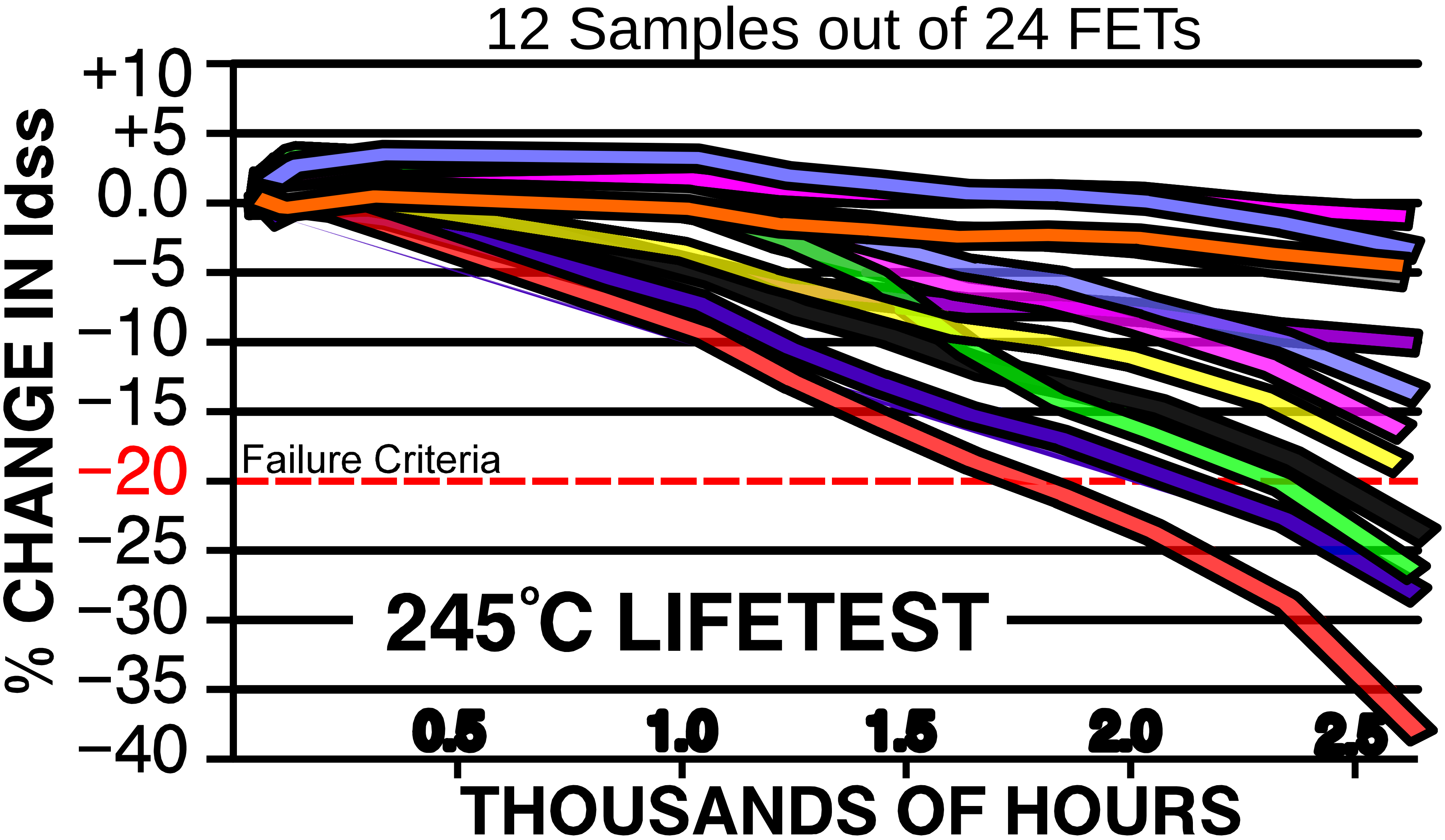
Graphical analysis using log time and 1/temperature grid to reveal thermal acceleration factor.

FET Technology Primary Wearout Mechanism

- No Gate Oxide.
- Reliable, Recessed, Schottky Gate. Not MOS!
- Less Susceptible to Surface Effects.
- No Ionic Contamination.
- Relatively Short Process Flow.

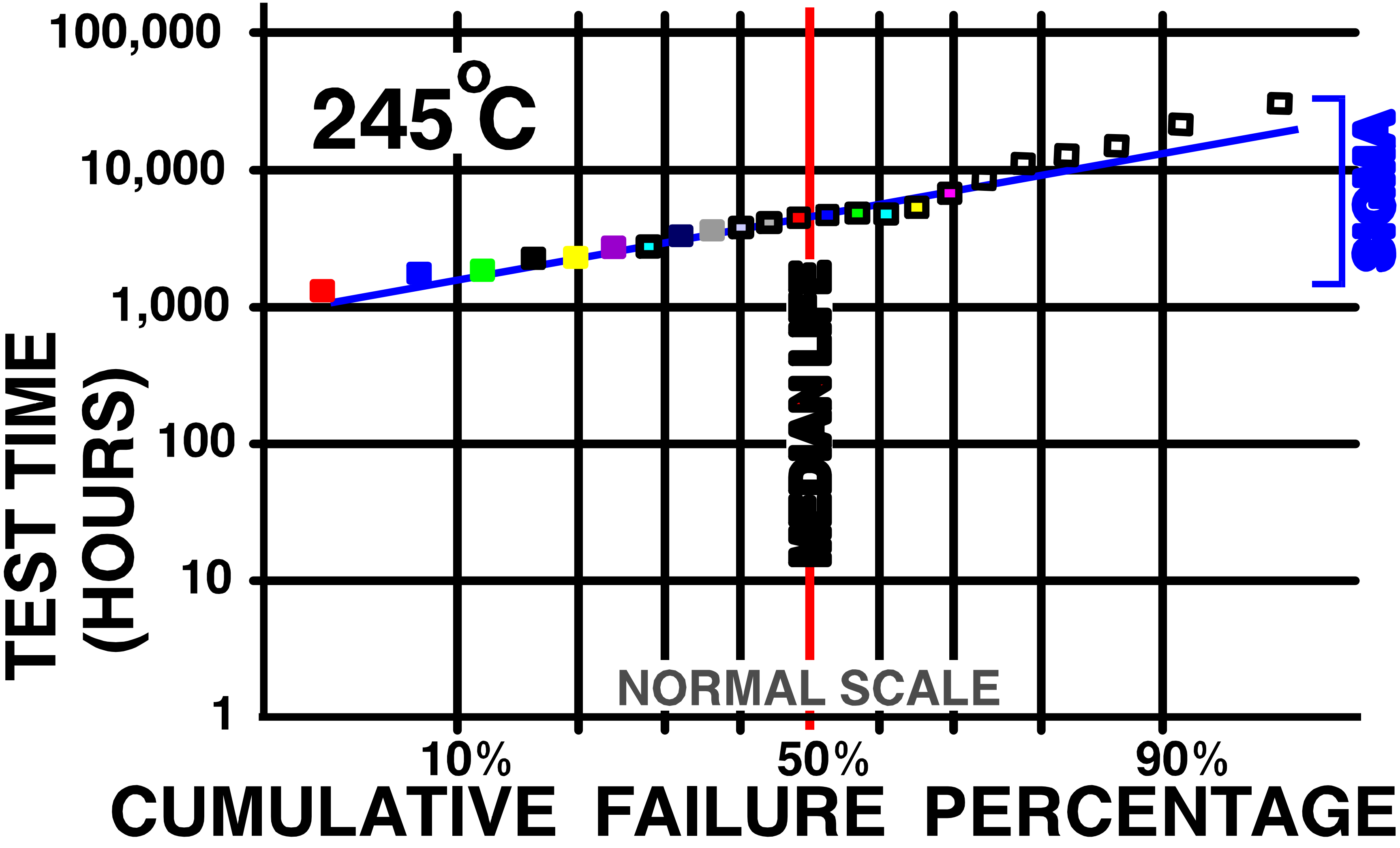


FET Degradation Distribution



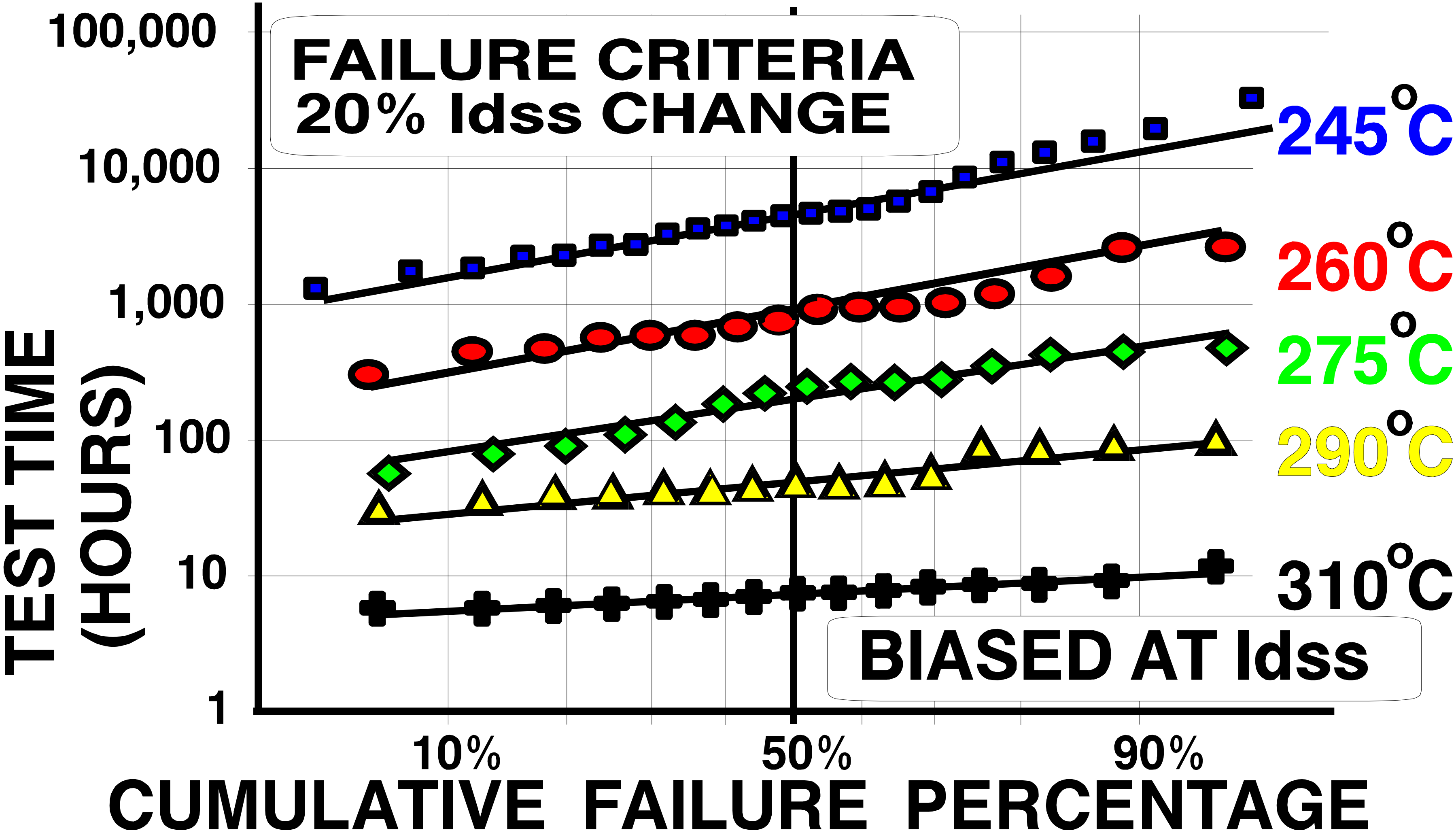
Actual Data: notice time to reach 20% reduction in channel current.

245ºC FET Distribution



These are individual FET times to failure plotted on a lognormal grid.

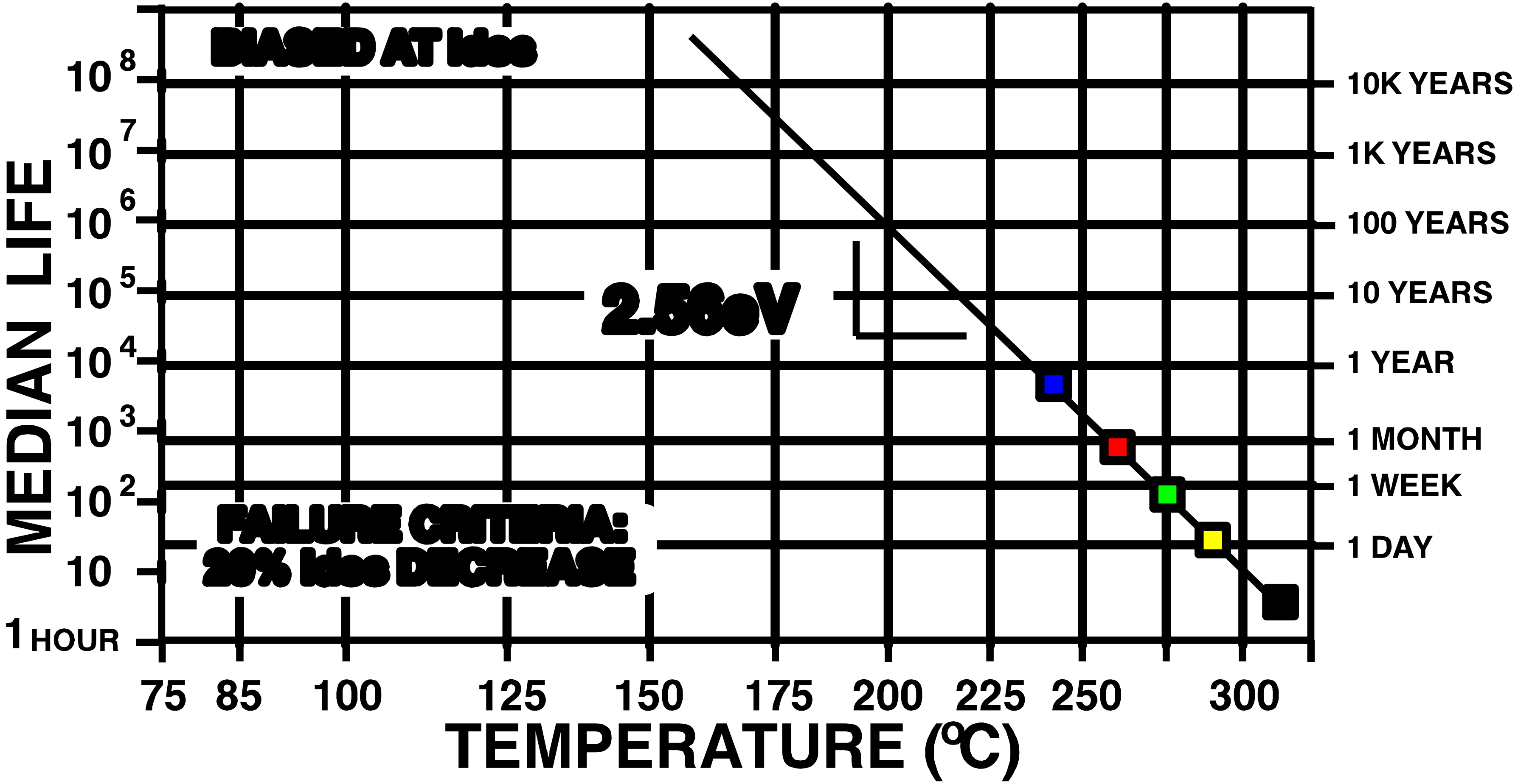
FET Distributions



Distributions for the same population aged at five different temperatures.

FET Activation Energy

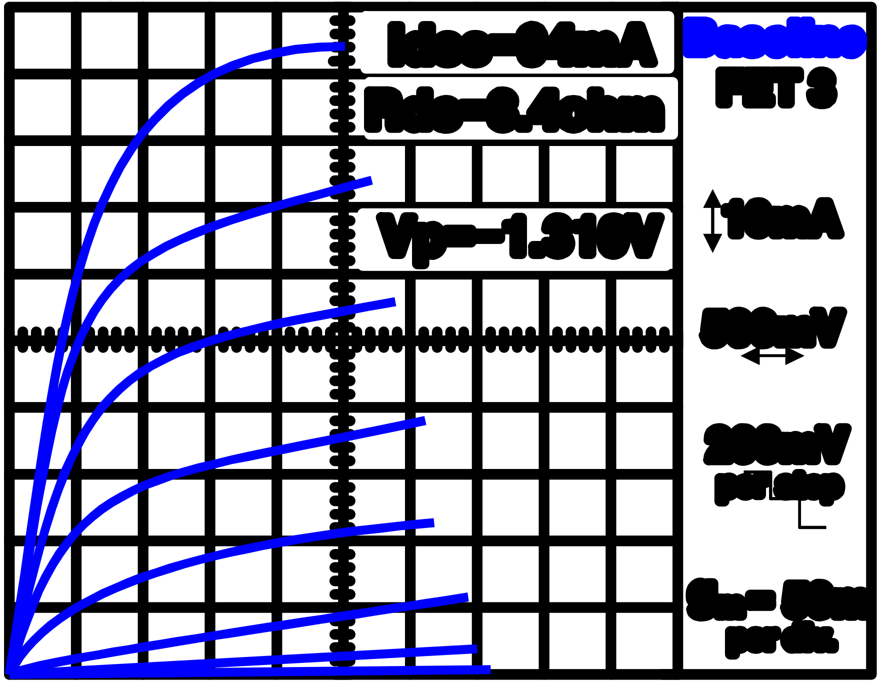
Median Lifetimes for wearout distributions measured at 245ºC, 260ºC, 275ºC, 290ºC, and 310ºC



Slope / Boltzmann's Constant = Activation Energy

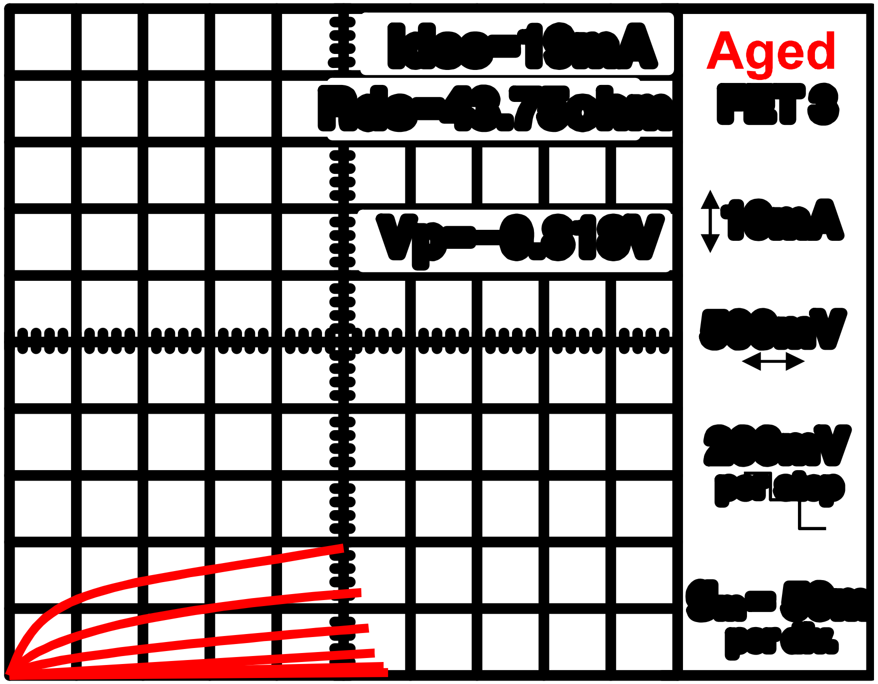
FET Degradation

Typical FET Curve



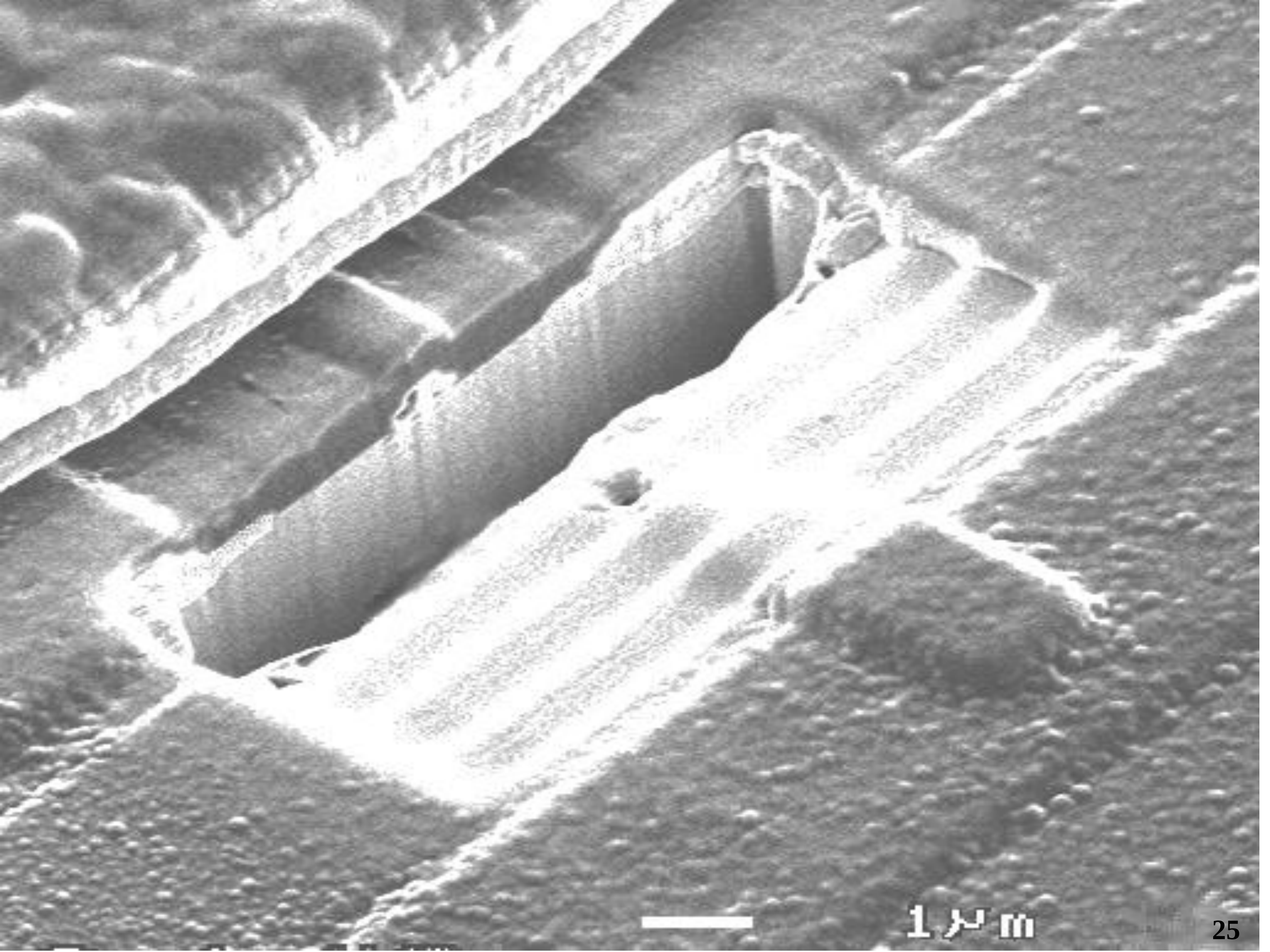
Reference Device (time = 0 hours)

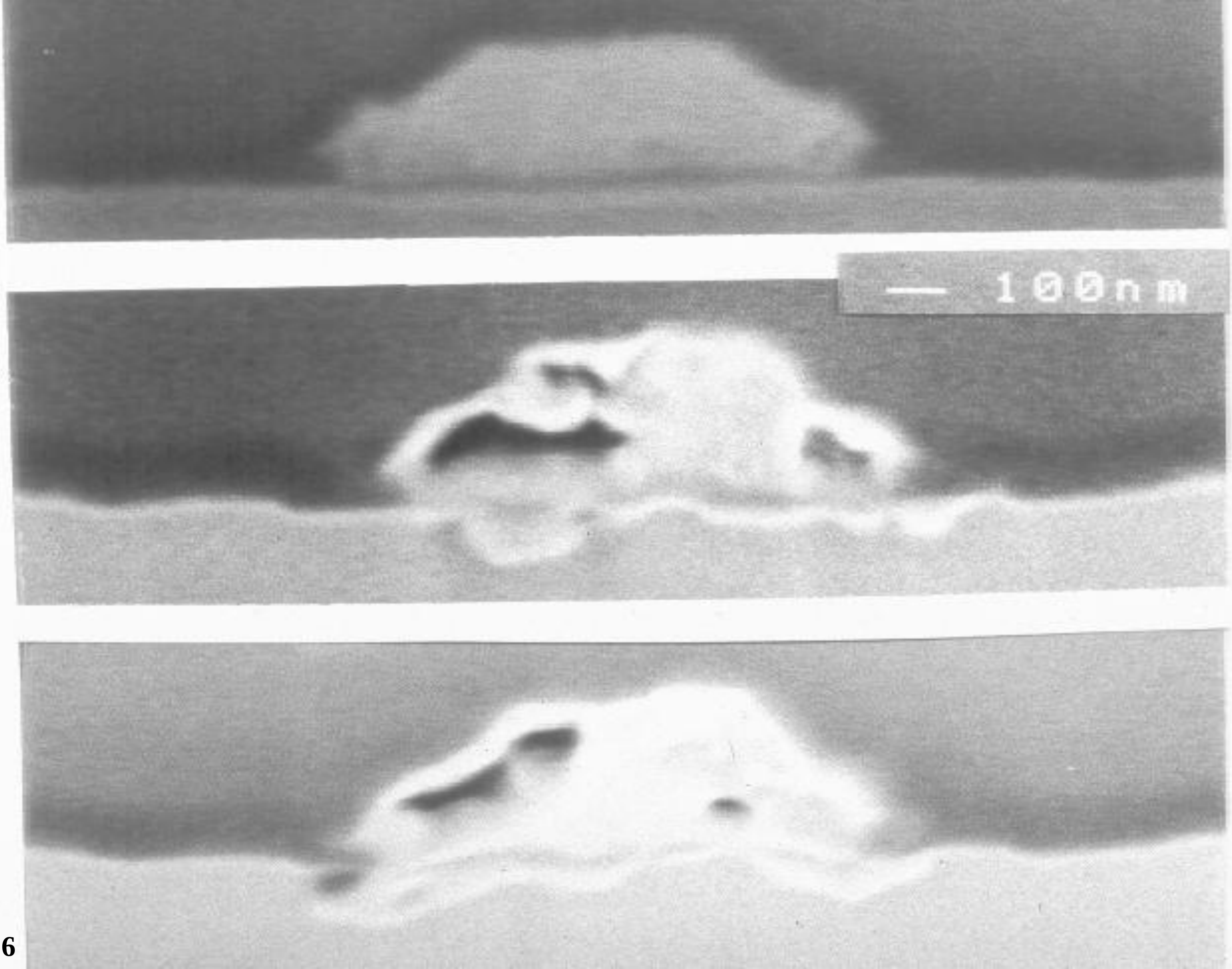
After 4380 at 260ºC



Extreme Wearout after 26 week Lifetest.

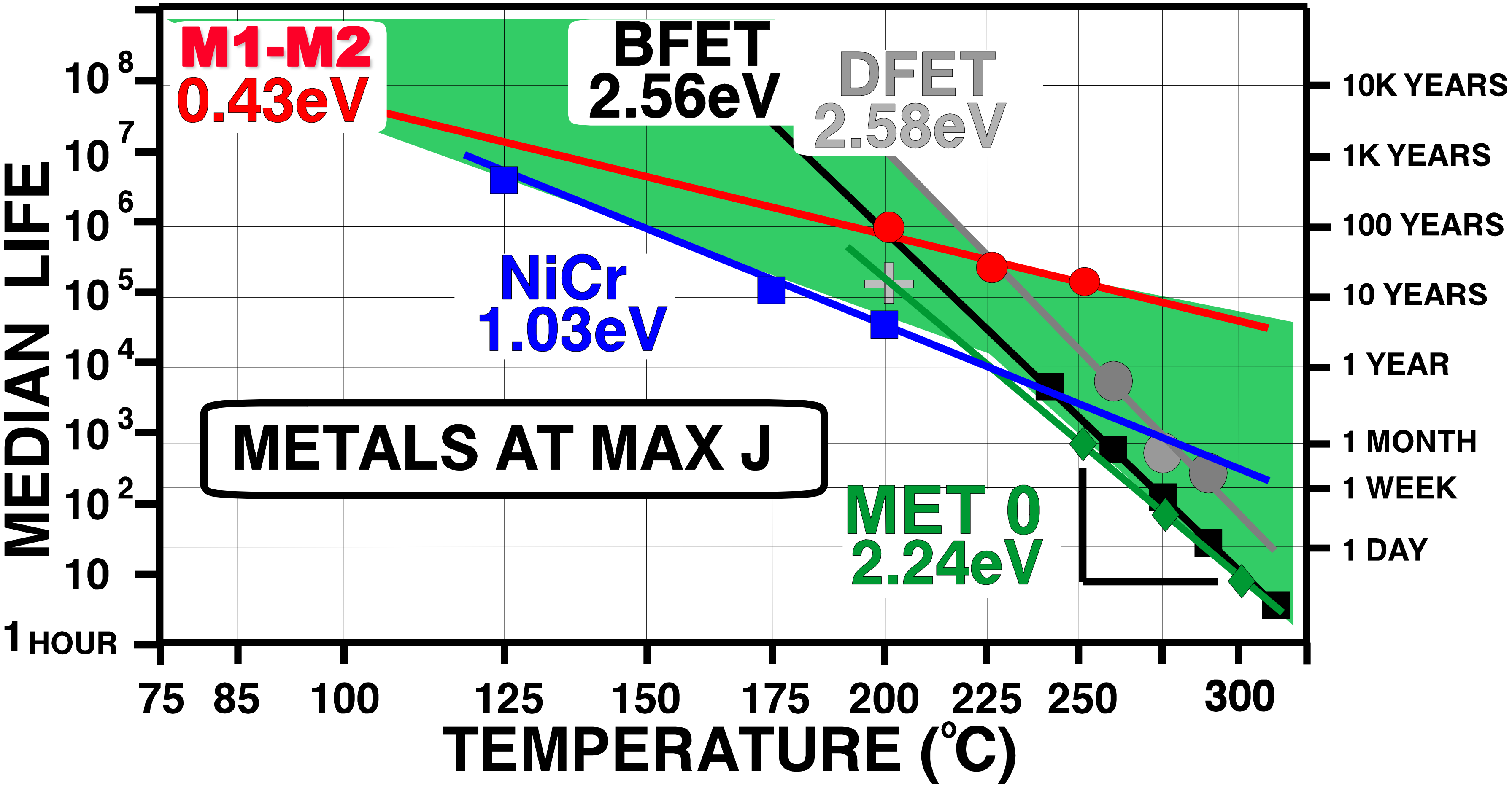
(4380 hours)


1 μm

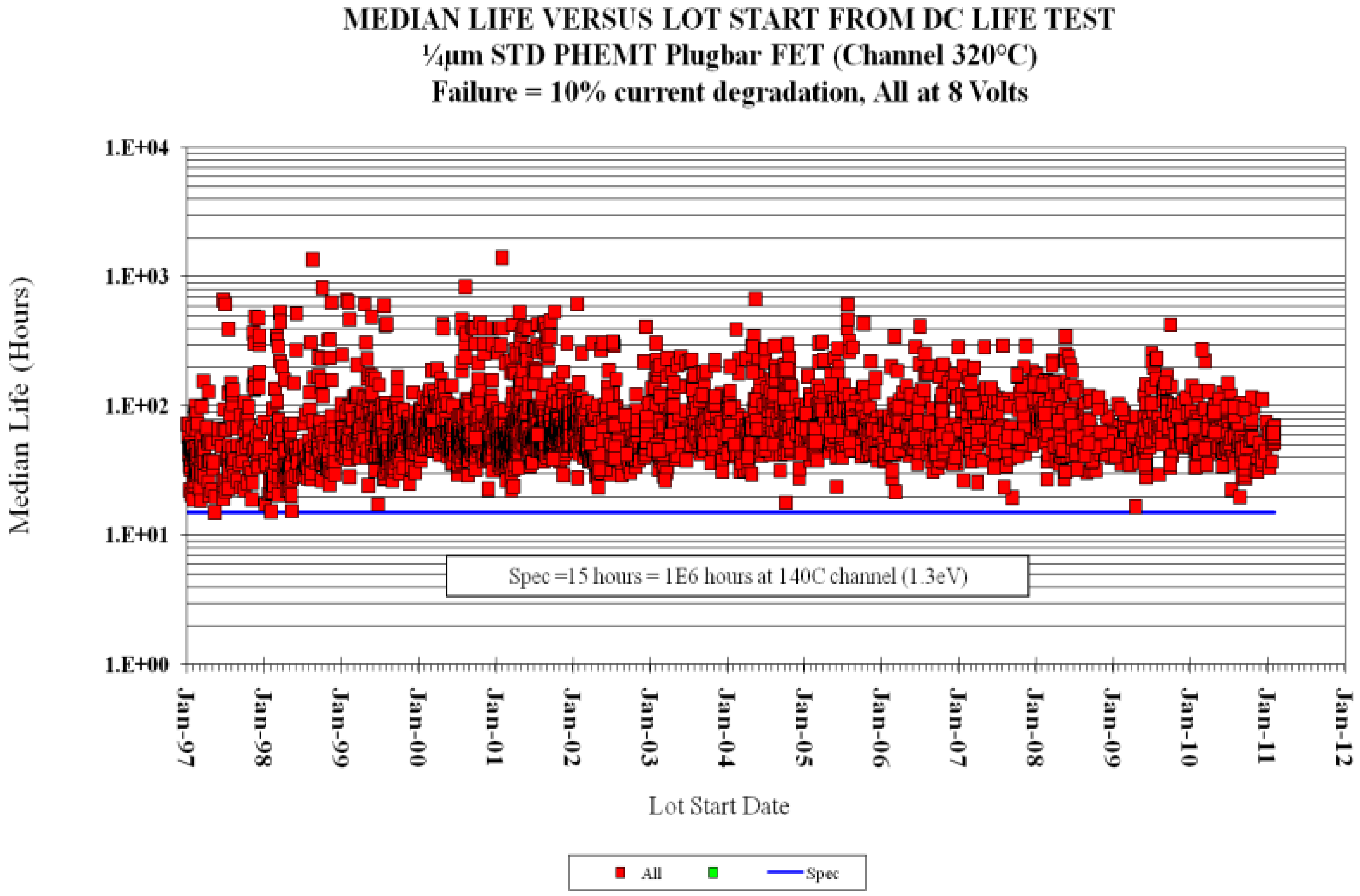

100nm

Element AE Summary

Activation Energy shown for various circuit elements used in integrated components.



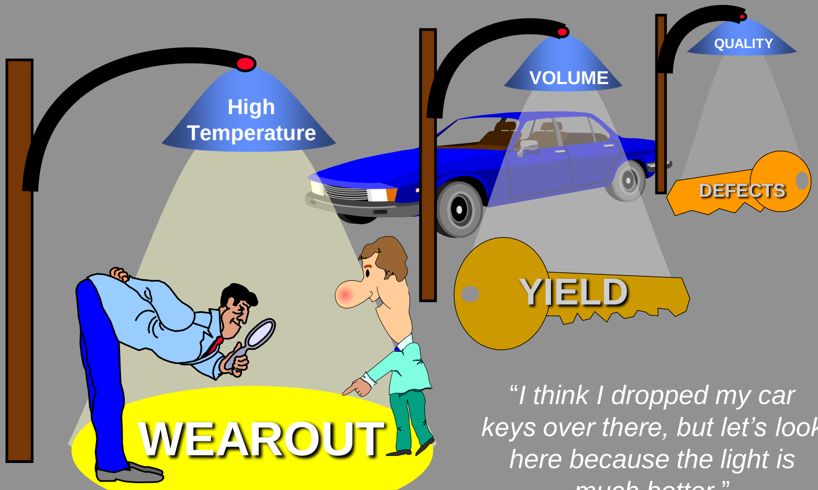
Long Term Trend for pHEMT



Basics Review

Basics

- **Vocabulary:** Reliability is the duration of quality
  - We're headed the same direction, just different words for it.
- **A new era for reliability:** Improvement follows a progression
  - The path to improvement is well travelled.
  - Compound Semiconductors don't obey Moore's law.
  - One man's trash is a reliability man's treasure.
- **Arrhenius methodology review:** Time to move beyond temperature
  - We have to stop looking where the light seems to better.
- Are we doomed to repeat history? We know where we've been.



"I think I dropped my car keys over there, but let's look here because the light is much better."

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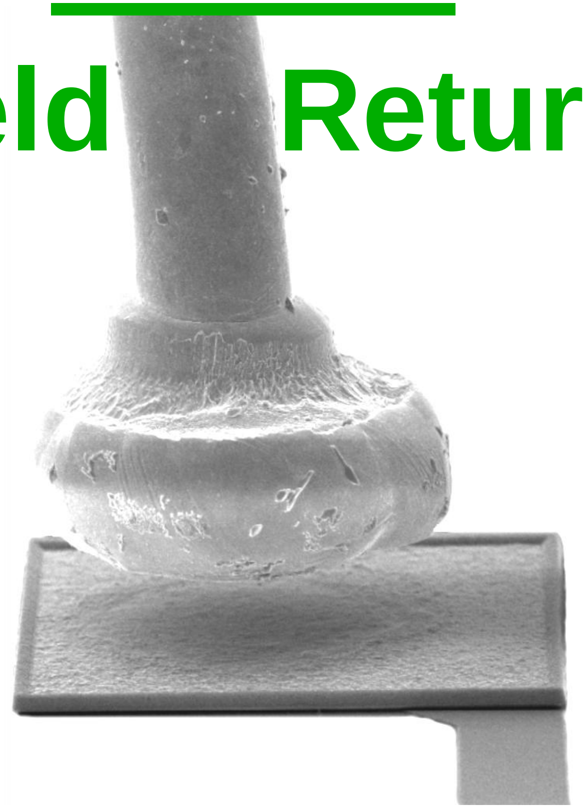
Definition of "Natural" Failure Mechanisms

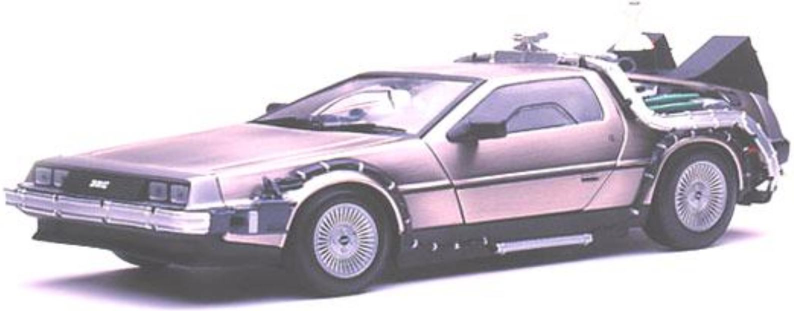
Natural

Field Returns



Artificial

Accelerated Qualification "Standard"



Motivation Behind Natural Mechanisms

Correct a previous misconception.

- –Customer Abuse
  - ✓ *Our parts would be fine if customers would just stop abusing them.*
- –Compound Semiconductors are “Special”
  - ✓ *ESD Sensitivity – High Frequency circuits are touchy*
  - ✓ *Defects don’t matter – it’s all about parametric stuff*
  - ✓ *The material is brittle and not thermally conductive*

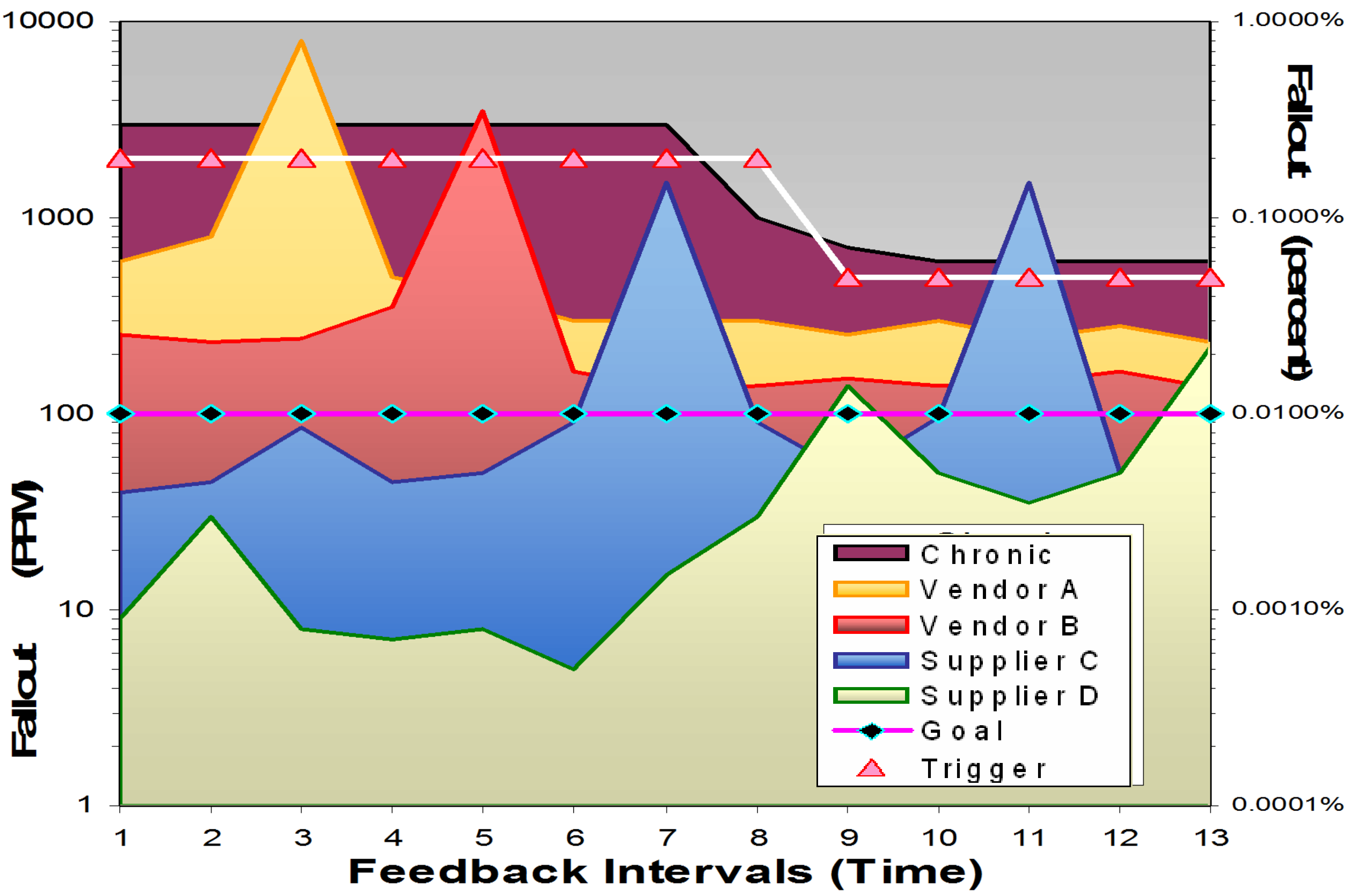
What happens
in the real world?

6σ &
1 Billion
Widgets

Delamination : 655
Cap Short : 410
Metal Shorts : 337
Die Crack : 317
ESD : 219
Design Errors : 191
Test Coverage : 156
Interconnect Open : 142
Overstress : 139
Assembly Errors : 97
Subcomponent Fails : 64

56,640

Scenarios

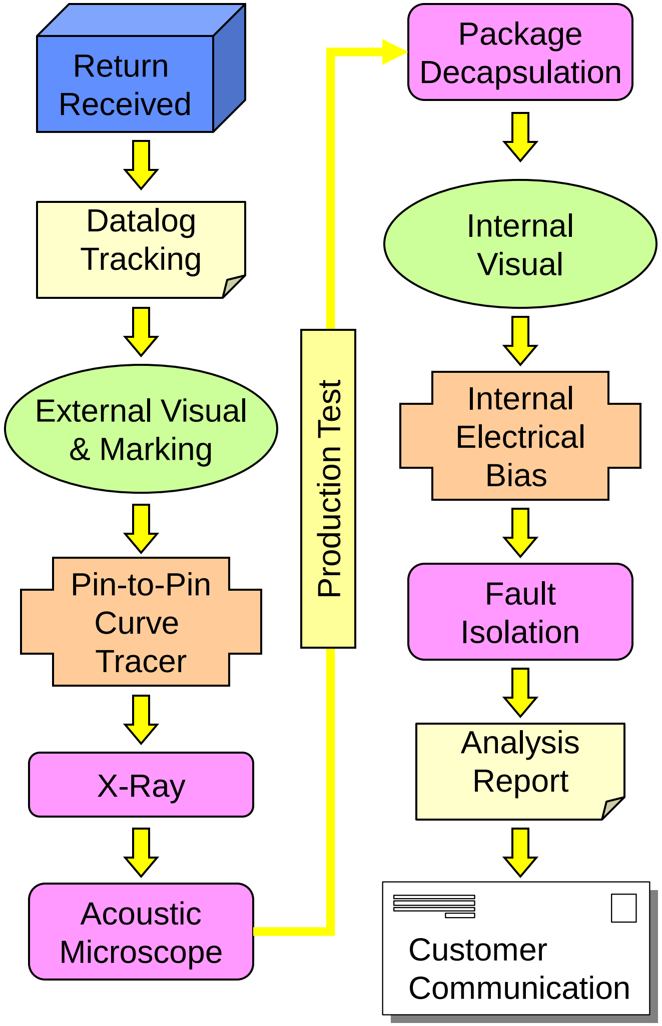


10000
1000
100
10
1
Fallout (PPM)
1.0000%
0.1000%
0.0100%
0.0010%
0.0001%
Fallout (percent)
1
2
3
4
5
6
7
8
9
10
11
12
13
Feedback Intervals (Time)
Chronic
Vendor A
Vendor B
Supplier C
Supplier D
Goal
Trigger

Levels Triggering Returns

Customer Category	RF Product Type	Volume	Claimed Trigger	Actual Trigger
Automotive	**PA**	**Low**	**> zero**	**Every Failure**
Standard Product	**Various**	**Large**	**100 DPM**	**100-2000 DPM**
Cell Phone	**PA**	**High**	**100 DPM**	**200-2000 DPM**
Cell Phone	**RF**	**High**	**100 DPM**	**20,000 DPM**
Long Haul	**Digital**	**Medium**	**100 DPM**	**20,000 DPM**
PC/LAN	**LNA**	**High**	**200 DPM**	**20,000 DPM**
Cell Phone	**PA**	**High**	**40 DPM**	**50,000 DPM**

Failure Analysis



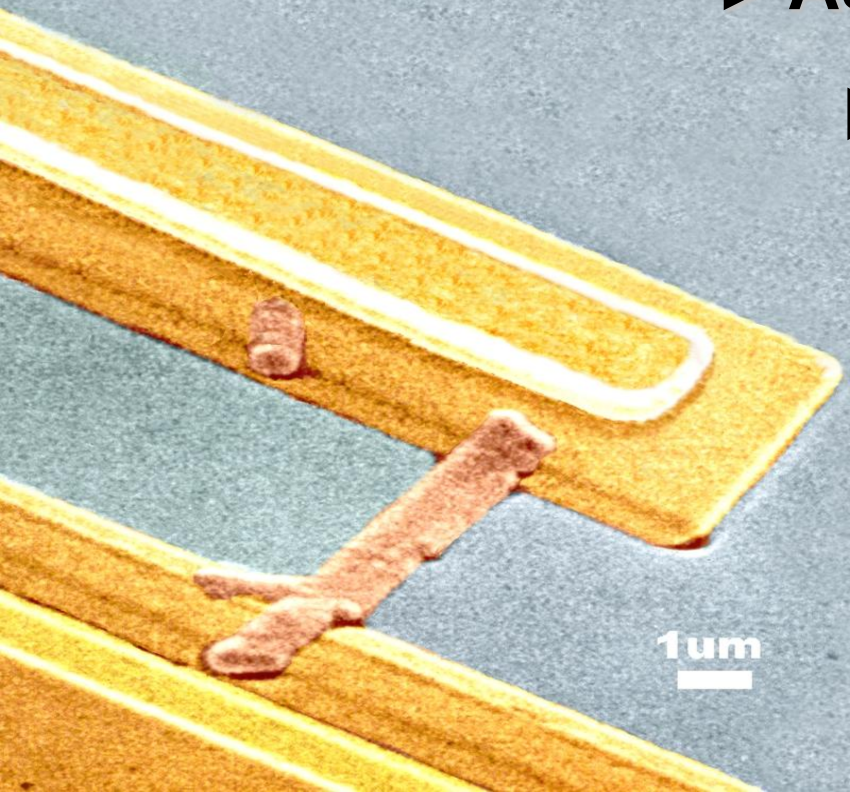
Failure Analysis Technique Frequency of Use

Analytical Method	Frequency
External Visual Inspection	**95%**
Pin-to-Pin Curve Trace	**93%**
Real-time Magnified X-Ray	**63%**
Package Decapsulation	**57%**
Internal Visual Inspection	**57%**
Production Electrical Measurement Test	**32%**
Scanning Acoustic Microscopy	**23%**
Internal Electrical Bias	**15%**
Chemical Layer-by-layer deprocessing	**5%**
Bench Test (Engineering Test)	**5%**
Light Emission Fault Detection	**4%**
Mechanical Polish Cross Section	**4%**
Liquid Crystal Hot Spot Detection	**3%**
Package Bake (Dry) & Desolder	**3%**
Scanning Electron Microscope (SEM)	**2%**
Focused Ion Beam (FIB) Cross Section	**2%**
Scanning Transmission Electron Microscopy (STEM)	**2%**
Energy Dispersive Analysis of X-Ray (EDAX)	**1%**
Backside Infrared Microscopy (through wafer)	**1%**
2 Dimensional FIB Cross-section	**1%**

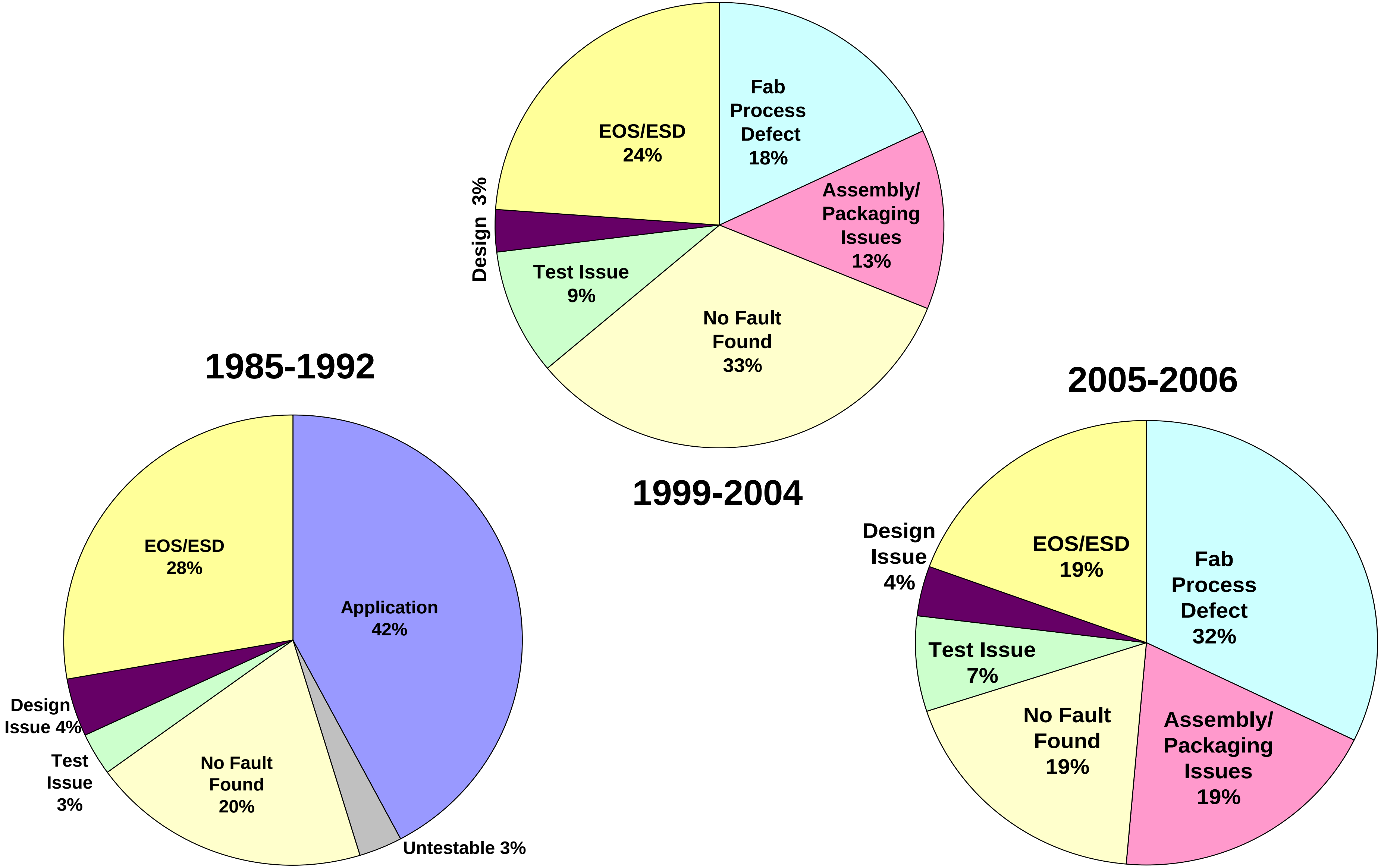
- Snapshot of 100 Analyses
- 600 individual “Failures”
- 32 Customers
- 2% were from “Field”

Natural Mechanism Examples

- ►Electrical Overstress
- ►Thermal Overstress
- ►Mechanical Overstress
- ►Assembly & Packaging
- ►No Fault Found
- ►Design
- ►Test
- ►Others
- ►Defects



Evolution of Natural Failure Mechanisms



*Raw Returns Results – History & Trend

Era	Approximate Rate of Field Returns (Raw Fallout Returned)	Total Number of Devices Analyzed
1985 - 1992	~ 0.5%	228
1999 – 2004	~ 0.15% - 0.05% (500ppm)	6,213
2005 - 2006	~ 0.05% - 0.01% (100ppm)	2,941
2007 - 2009	**5.4 ppm**	**3,535**

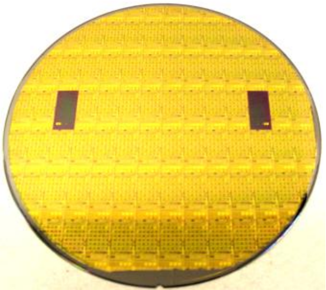
Returns are based upon chance and should be used for entertainment only.

TriQuint Qualification Requirements

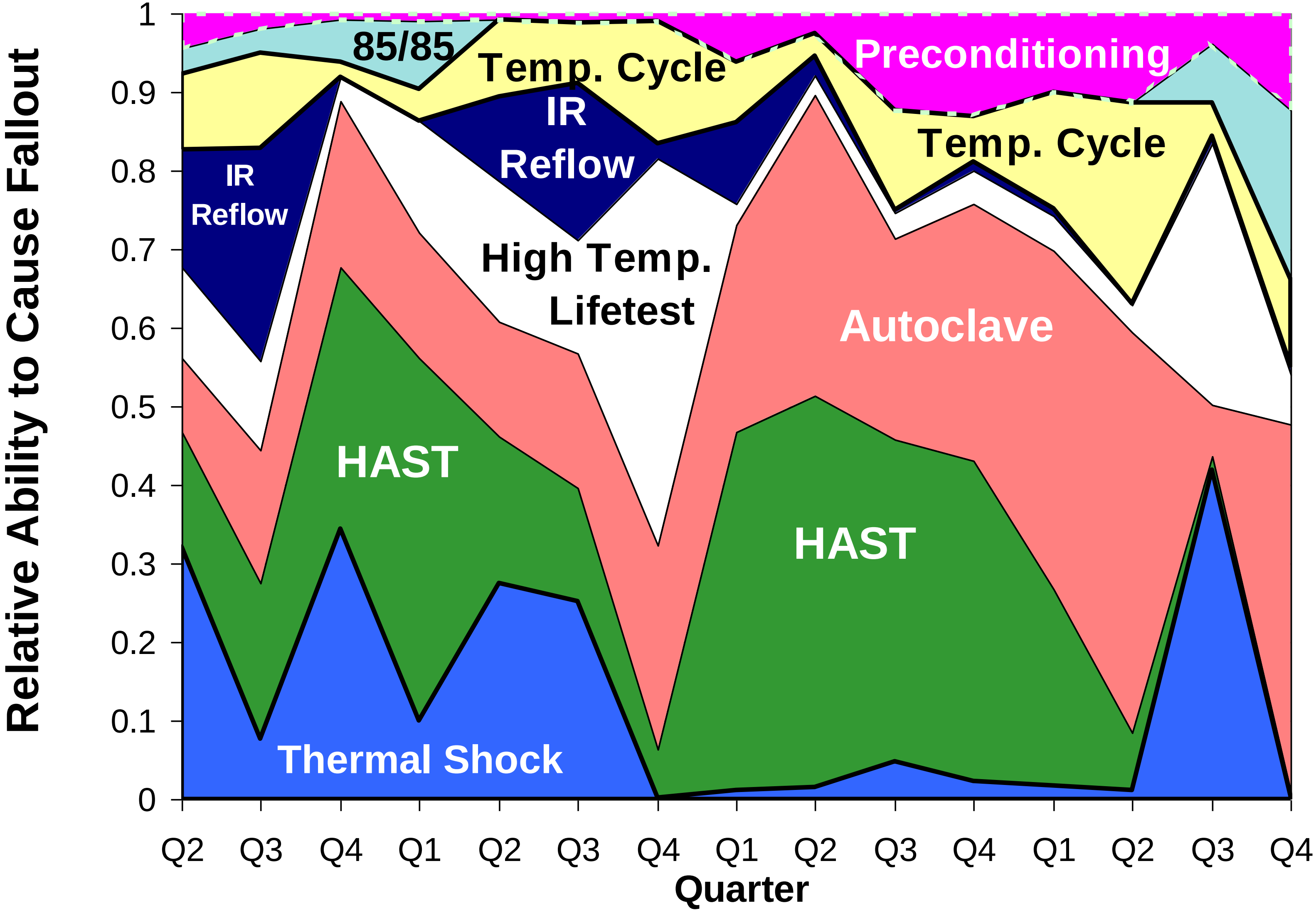
Reliability Methods: (REL.024 & REL.021)

- Element Tests, One Wafer Per Stress, 3 Lots.
  - 275ºC Bake, 168 hours.
  - 500 Temperature Cycles, -40ºC to +125ºC.
  - Autoclave, 121ºC, Saturated Steam, 96 hours.
- Lead Product Qualification, 3 Lots, 45 or 77.
  - Moisture Sensitivity Level Testing.
  - 150ºC HighTemperature Operating Life, 1000 hours.
  - Environmental: Preconditioning,
    Temp. Cycles (1K -40ºto125ºC).
    Autoclave (121ºC, 100%RH, 96 hrs).
    HAST (135ºC, 85%RH, 96 hrs).
  - Mechanical/Package: Thermal Shock,
    Physical Dimensions, Mark Permanency,
    Lead Integrity, Bond Pull, Bond Shear, Die Shear

    ESD: HBM & CDM.

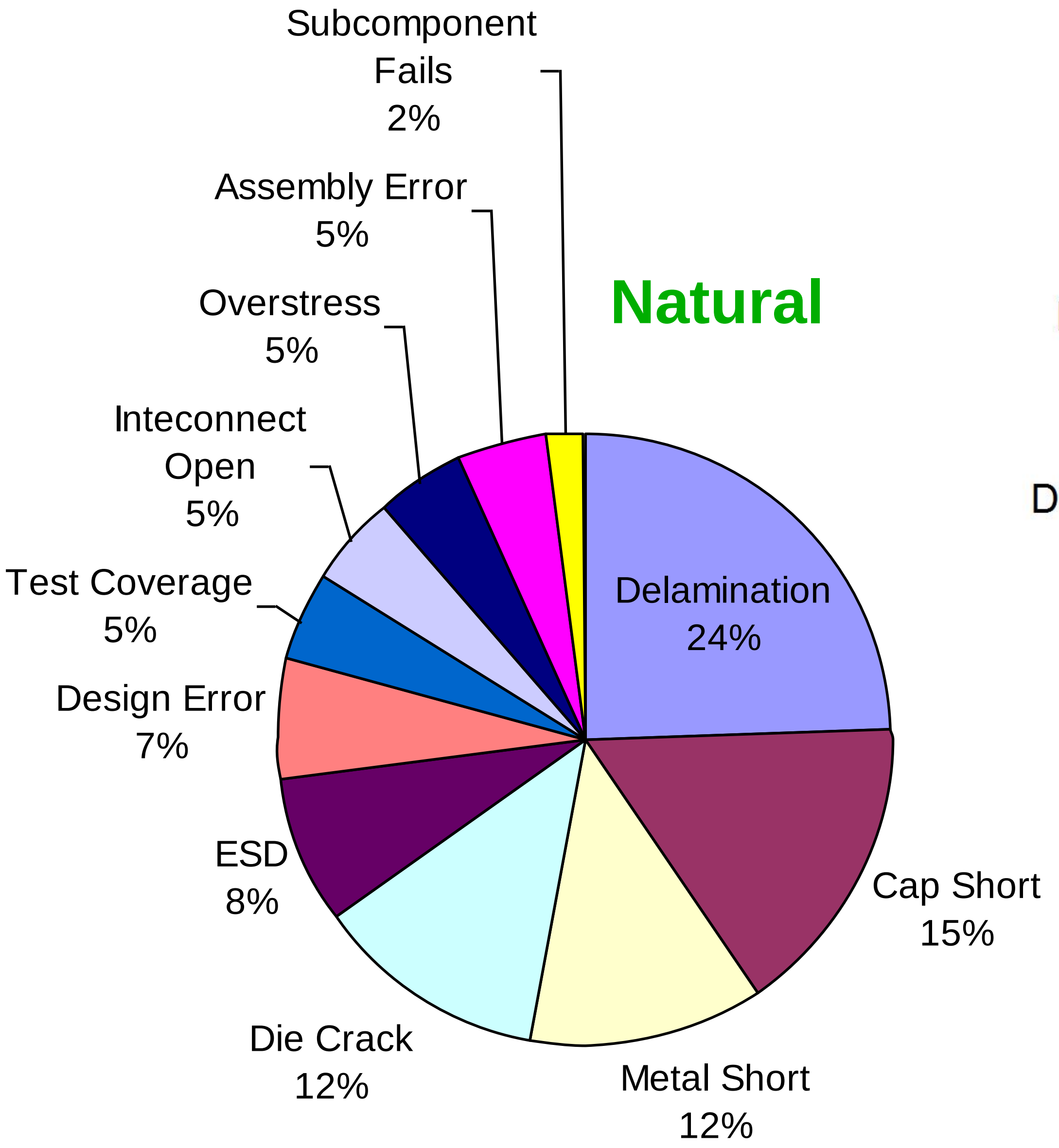


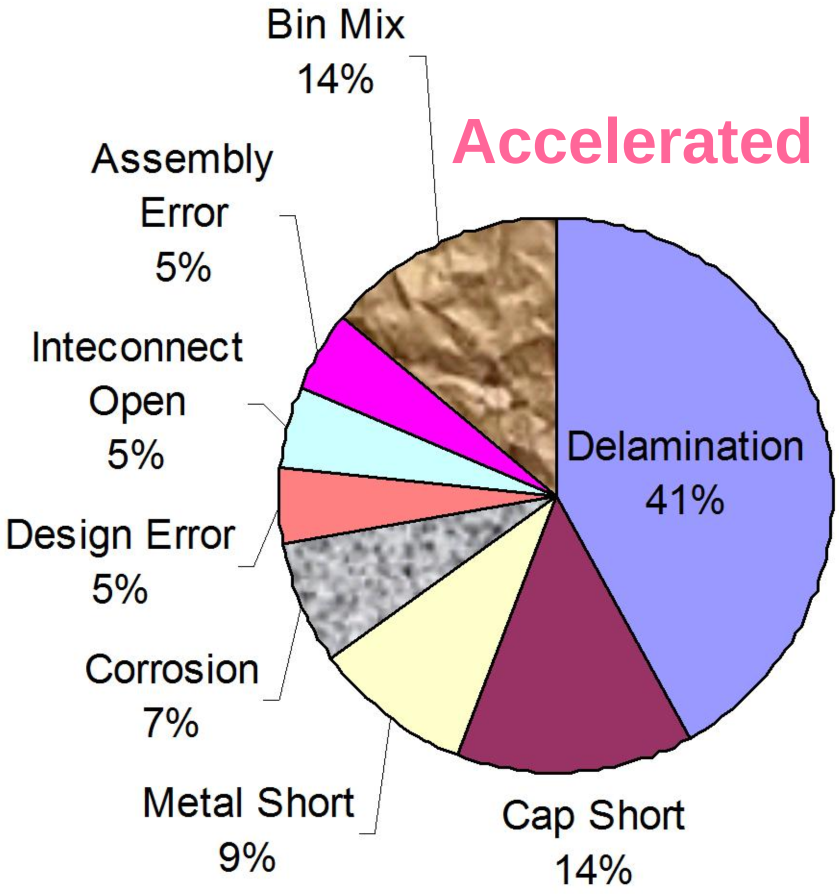
Sources of Accelerated Failures



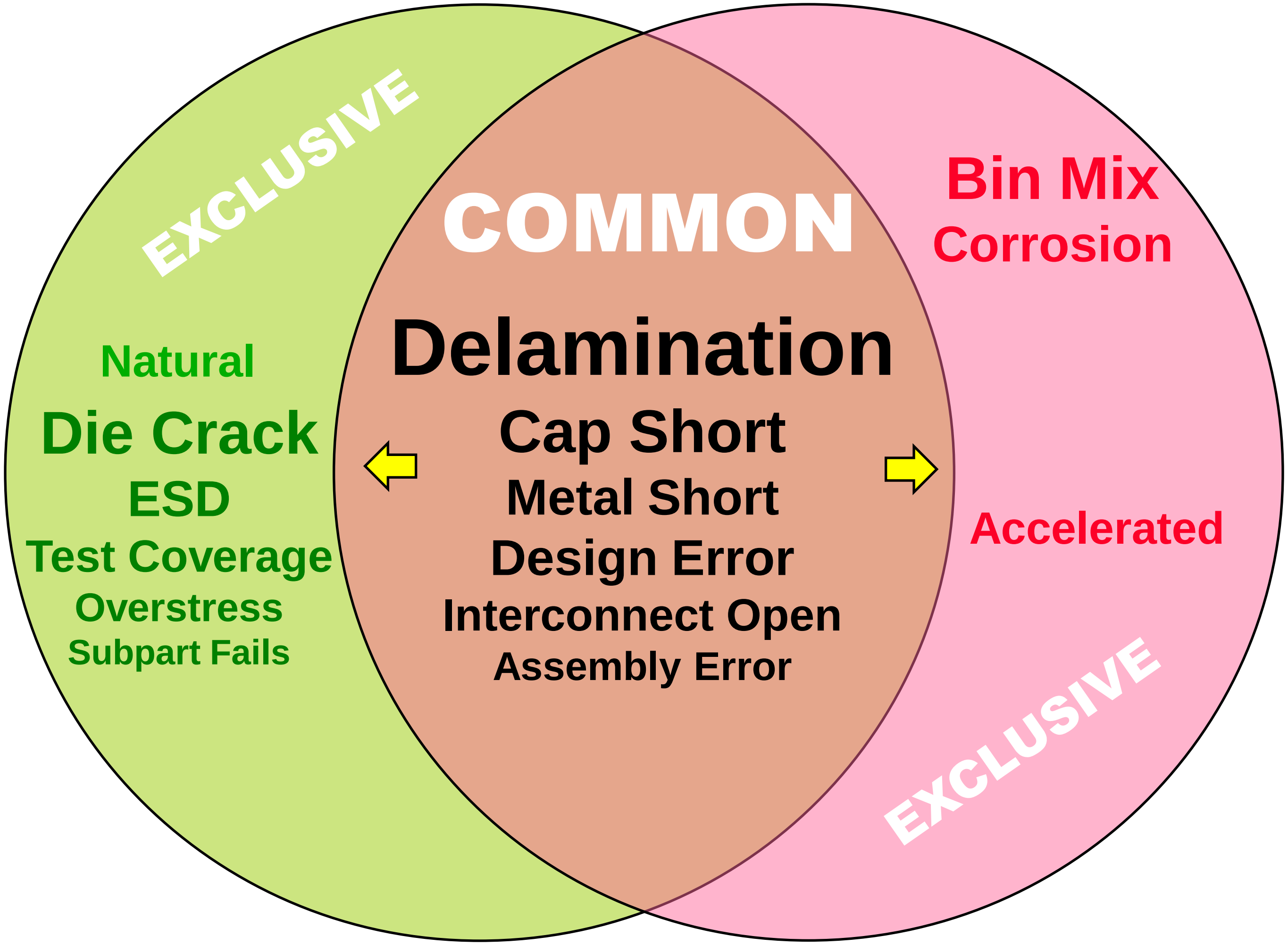
Data on 1,109,453 Samples aged.

Comparisons – A snapshot





Analyzing the Snapshot



EXCLUSIVE

Natural

Die Crack

ESD

Test Coverage

Overstress

Subpart Fails

COMMON

Delamination

Cap Short

Metal Short

Design Error

Interconnect Open

Assembly Error

Bin Mix

Corrosion

Accelerated

EXCLUSIVE

The larger the data set, the more likely common sets will dominate.
(Since the snapshot, all accelerated mechanisms have shown up naturally)

Value of Investigating Natural FMs

- **Customer data is the best we can get, but it's not perfect**
  - **Lack of returns should not be interpreted as a lack of failures**
- **Findings are not static, they change over time**
- **Focus on exclusive mechanisms (both sides)**
- ***Natural* is a sanity check on accelerated**
- ***Natural* is reactive, but only if you react**
- **Breaking through the improvement cycle**

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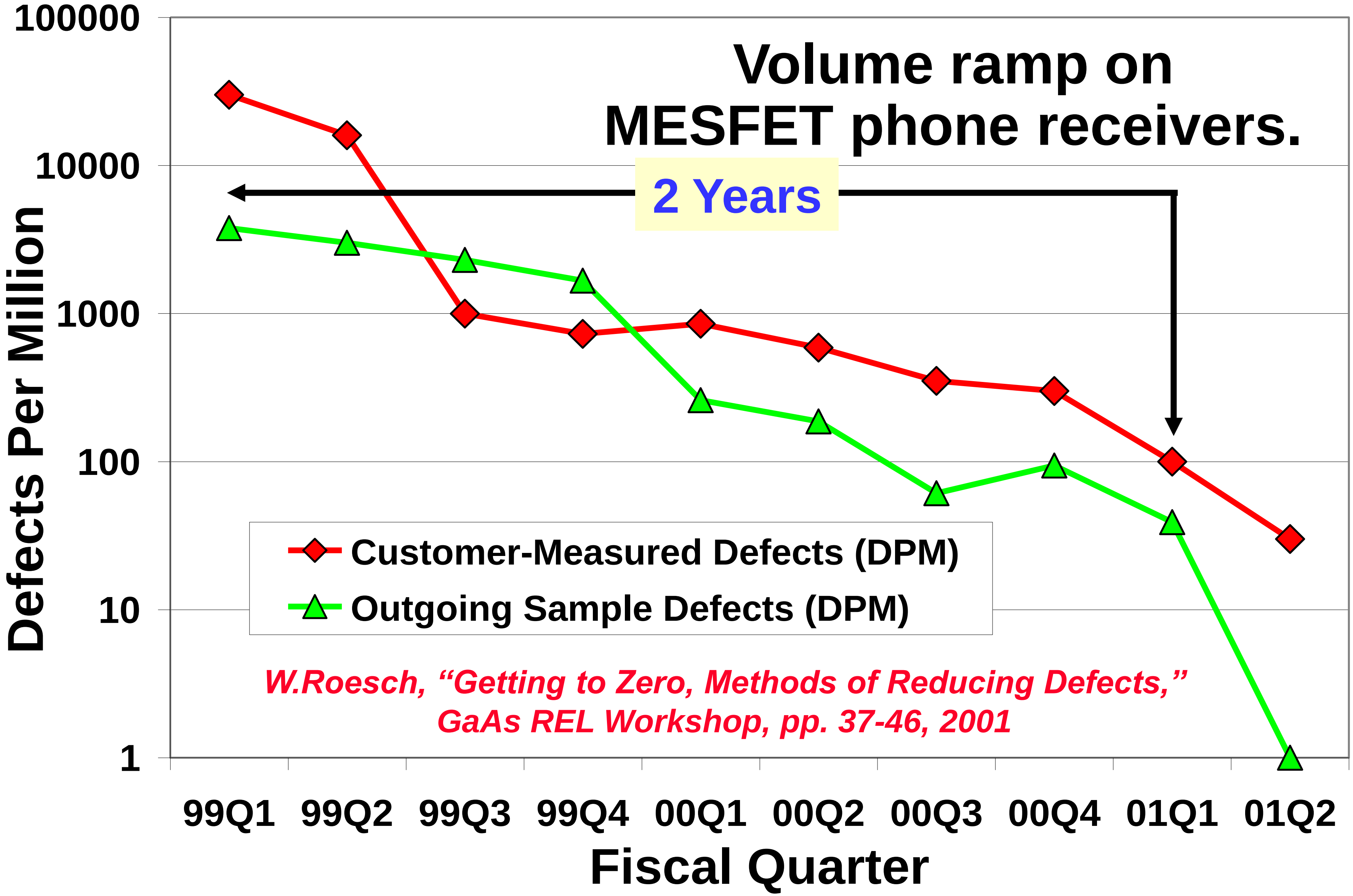
C.I. = Early RF Product Fallout Data



W.Roesch, "Getting to Zero, Methods of Reducing Defects," GaAs REL Workshop, pp. 37-46, 2001

Working With a Customer

- *We send a million parts.*
- *They return 19.*
- *We re-test, and 13 pass.*
- *We perform FA on 6.*
- *Find 3 process defects.*
- *Result ~ 3 DPM.*
- *Corrective Action.*
- *Start Over.*

Fix Process Defect.

Redesign & improve ESD Performance.

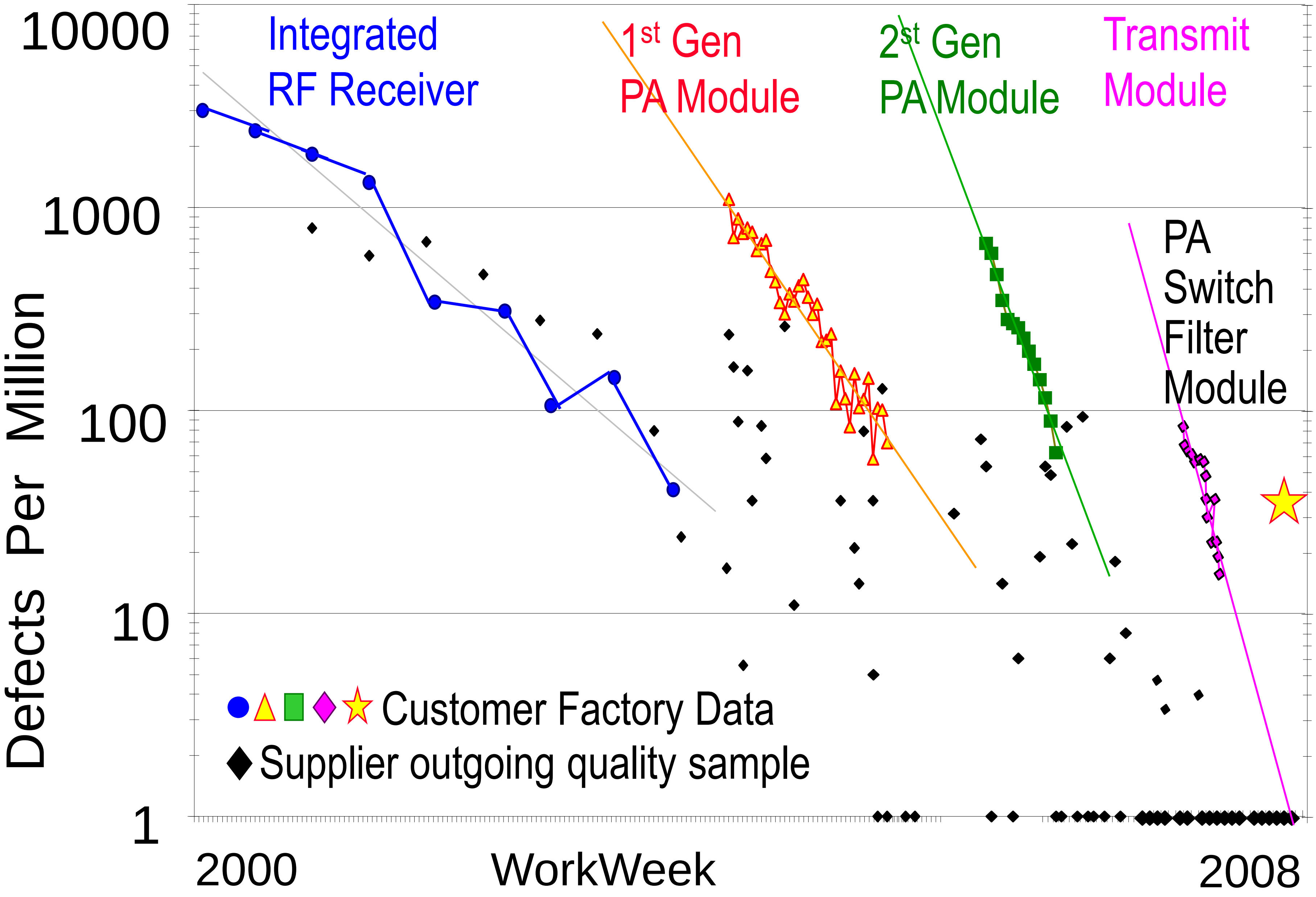
Customer finds ESD Source.

Fix Another Process Defect.

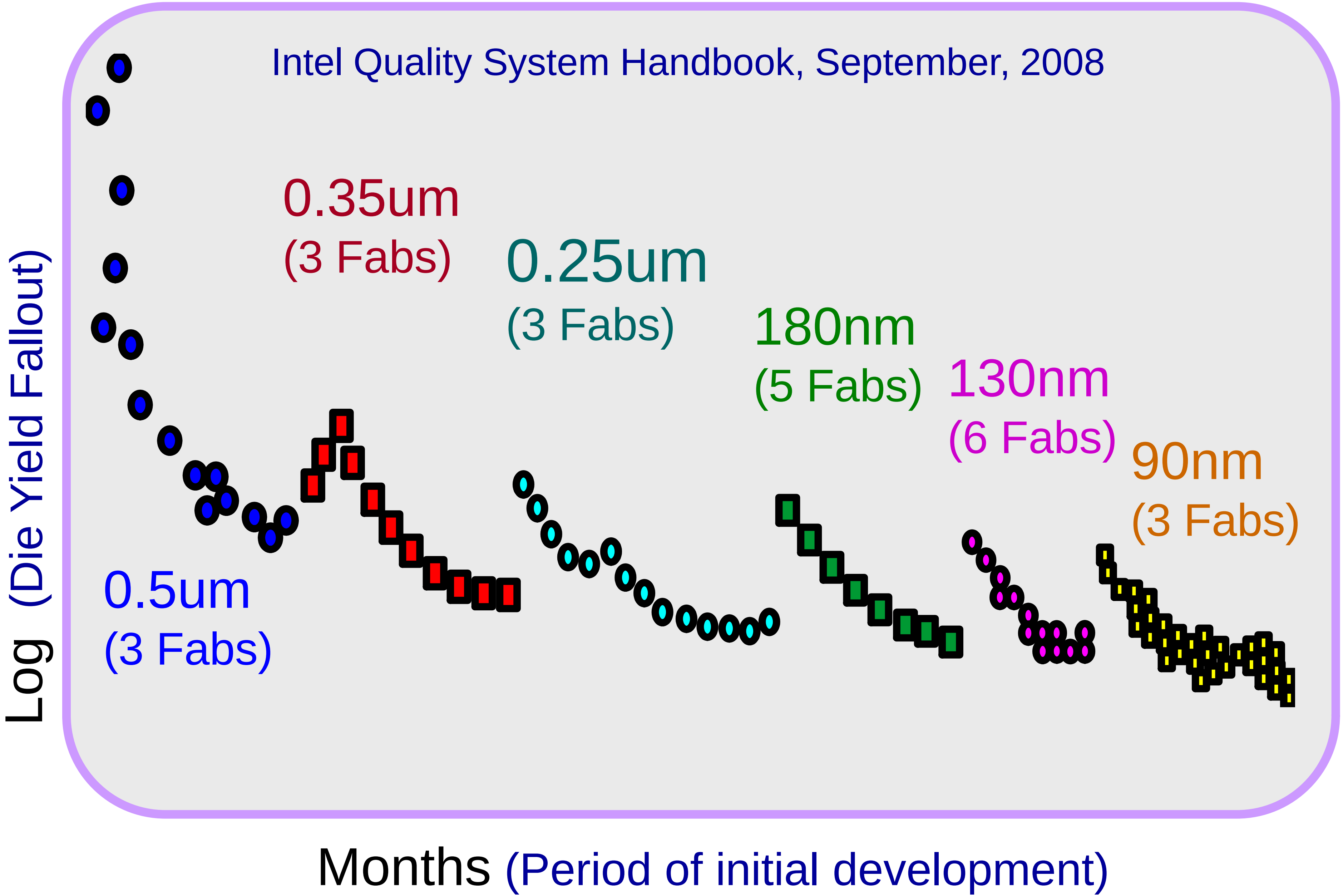
Declining Reliability Returns

Beware of the desk drawer syndrome.

Historical Product/Reliability Cycle



Improvement with shrinking node sizes



Outrunning the Bear

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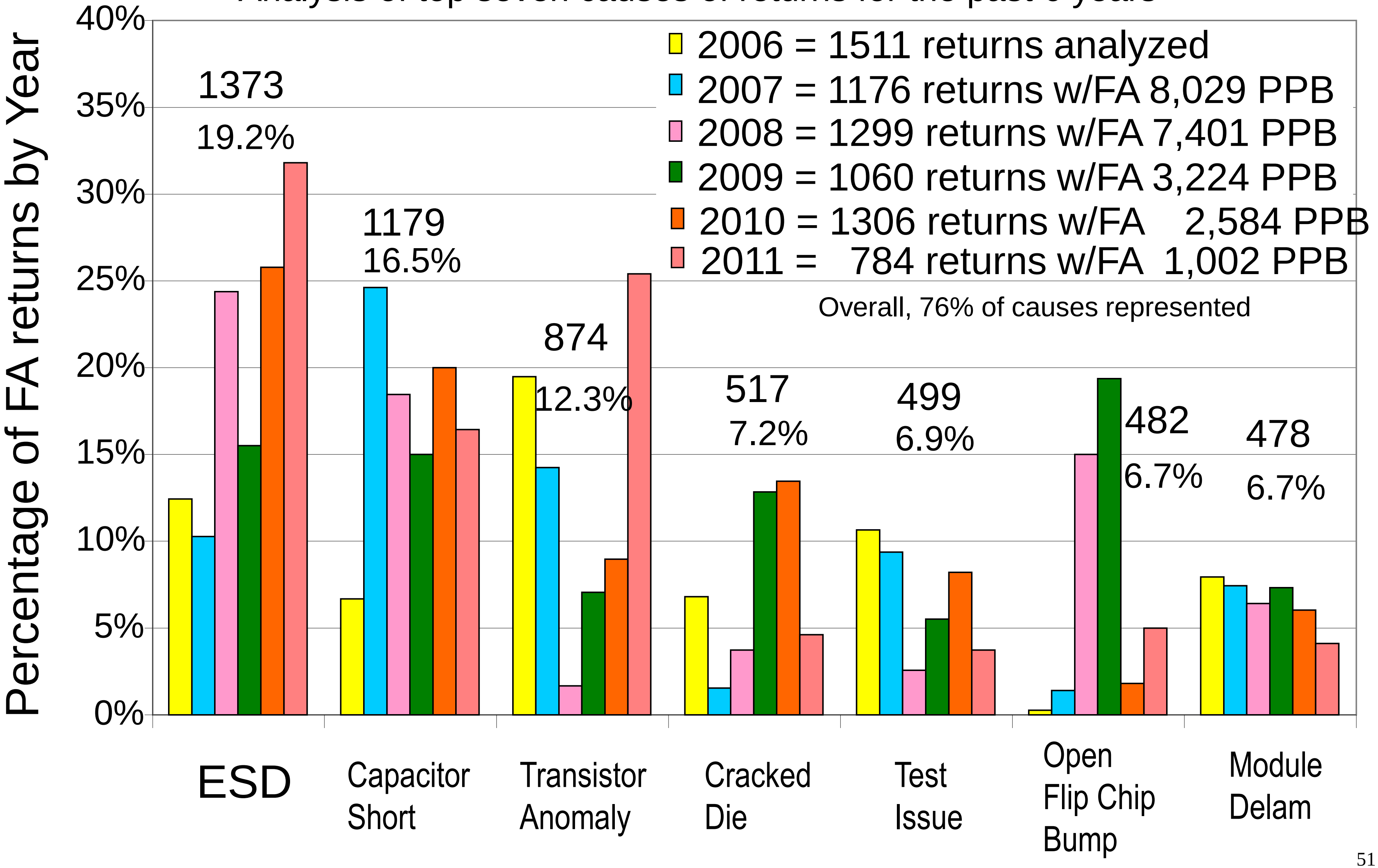
Customer Experience

Identification of Customer Returns by Individual Cause

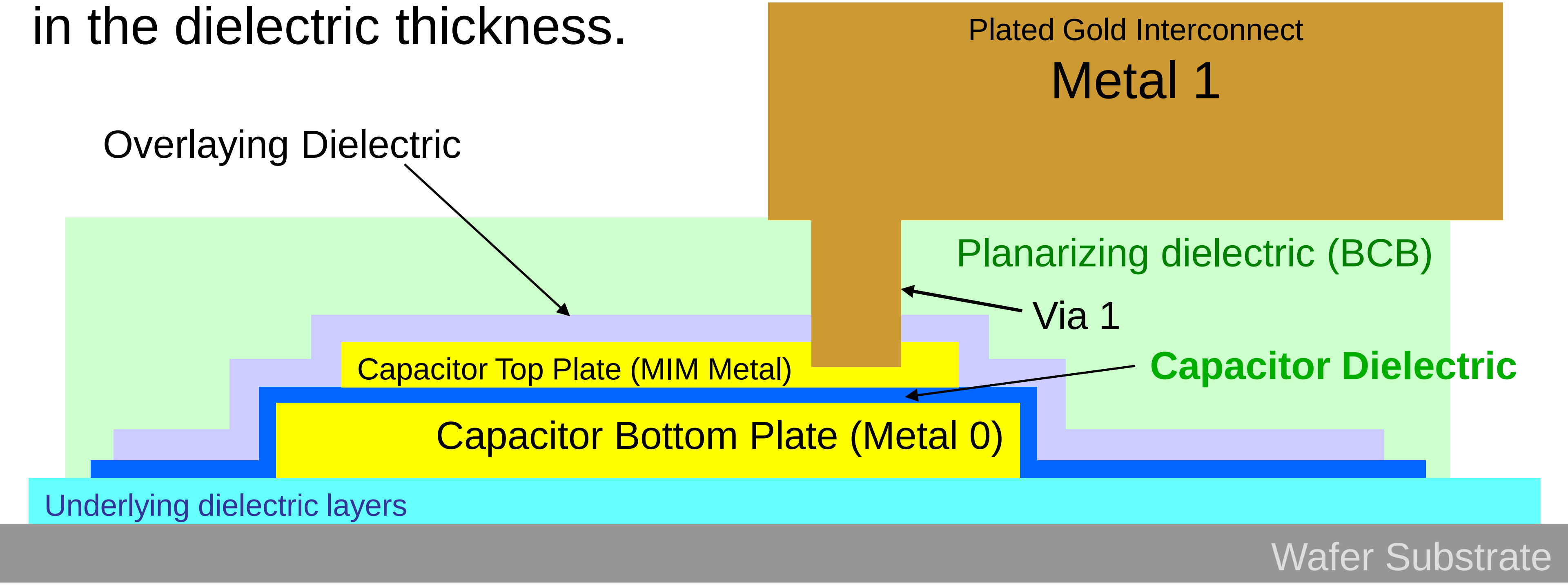
Analysis of top seven causes of returns for the past 6 years



Capacitors

Capacitor Construction – Sources of Variation

All defects underneath and coincident with the Metal Zero layer can affect the integrity of the capacitor. These “defects” and anomalies in the dielectric layer can be considered as a variation in the dielectric thickness.



Plated Gold Interconnect

Metal 1

Overlaying Dielectric

Planarizing dielectric (BCB)

Via 1

Capacitor Dielectric

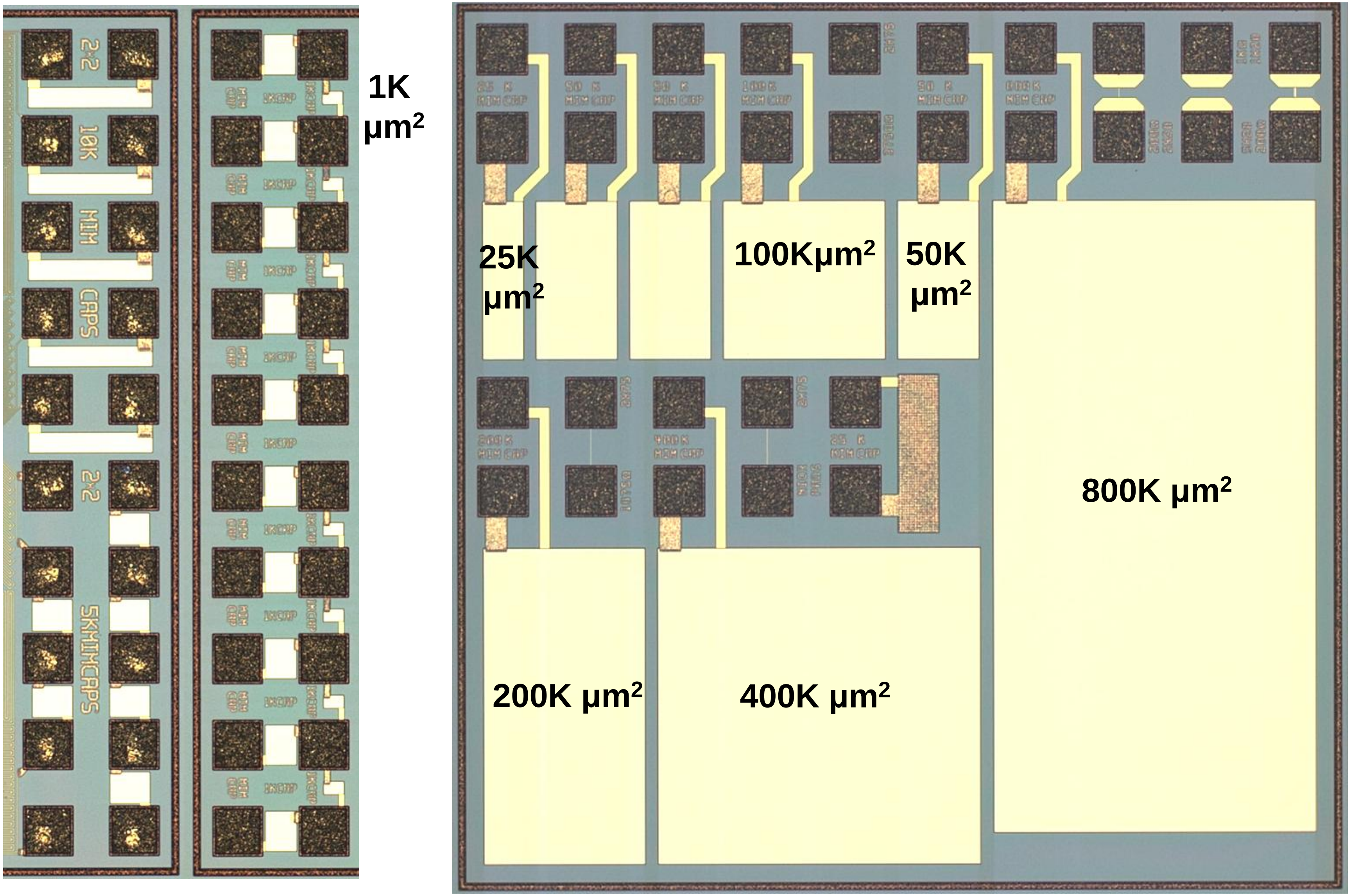
Capacitor Top Plate (MIM Metal)

Capacitor Bottom Plate (Metal 0)

Underlying dielectric layers

Wafer Substrate

Capacitor Test Structures



10K μm^2

1K μm^2

5K μm^2

25K μm^2

100Kμm^2

50K μm^2

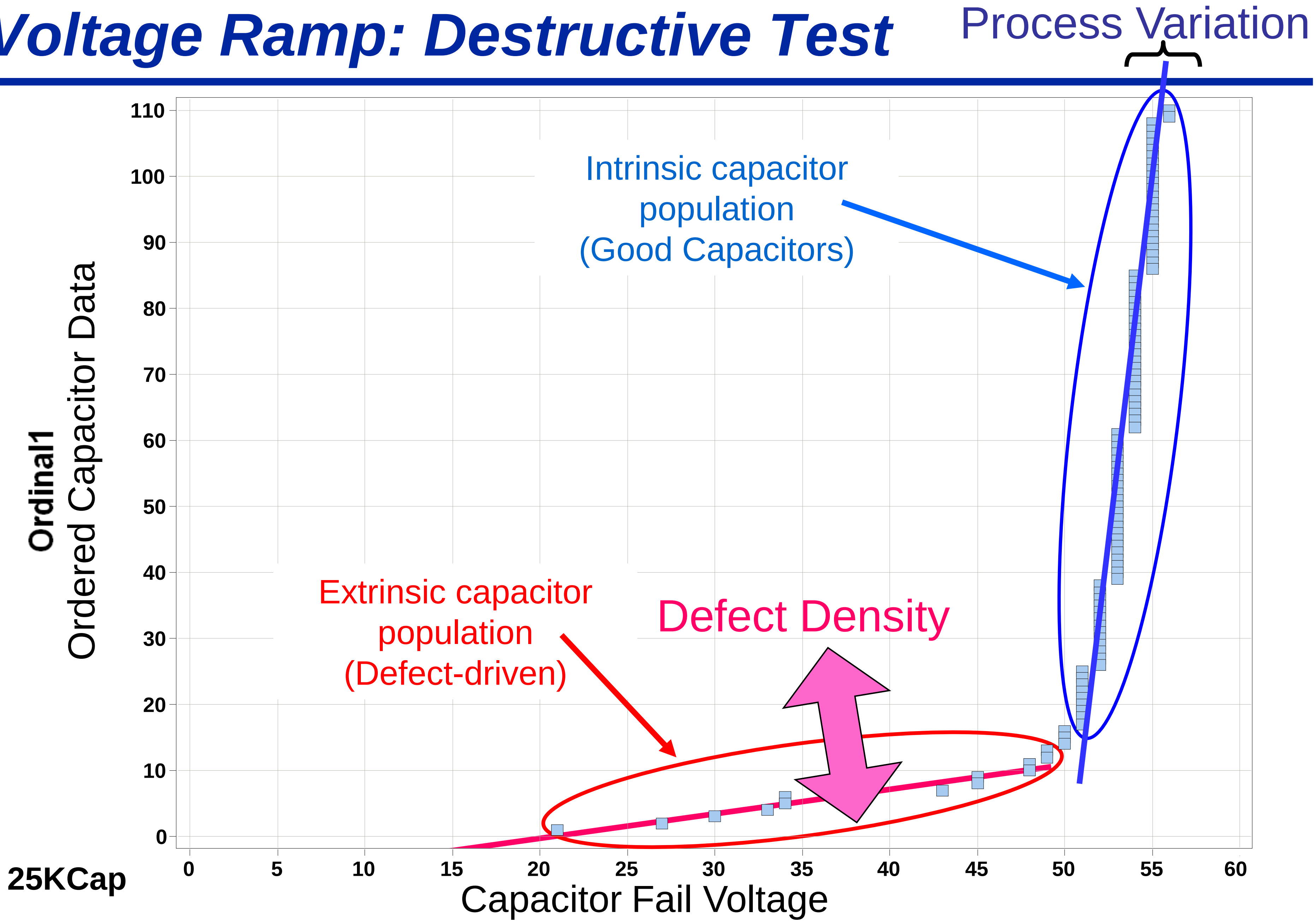
800K μm^2

200K μm^2

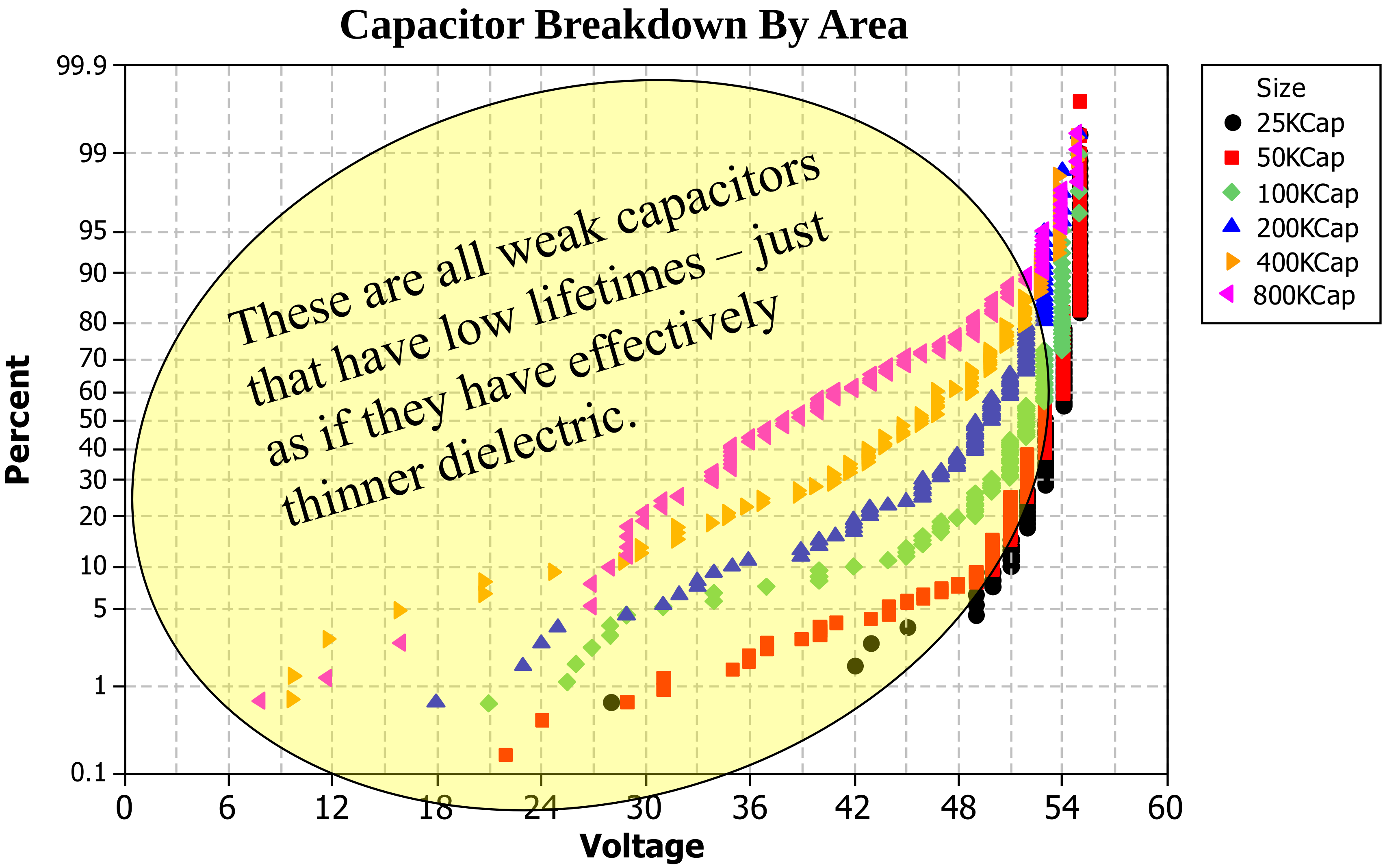
400K μm^2

1300pF/mm^2

Voltage Ramp: Destructive Test



Measuring Capacitor Defectivity

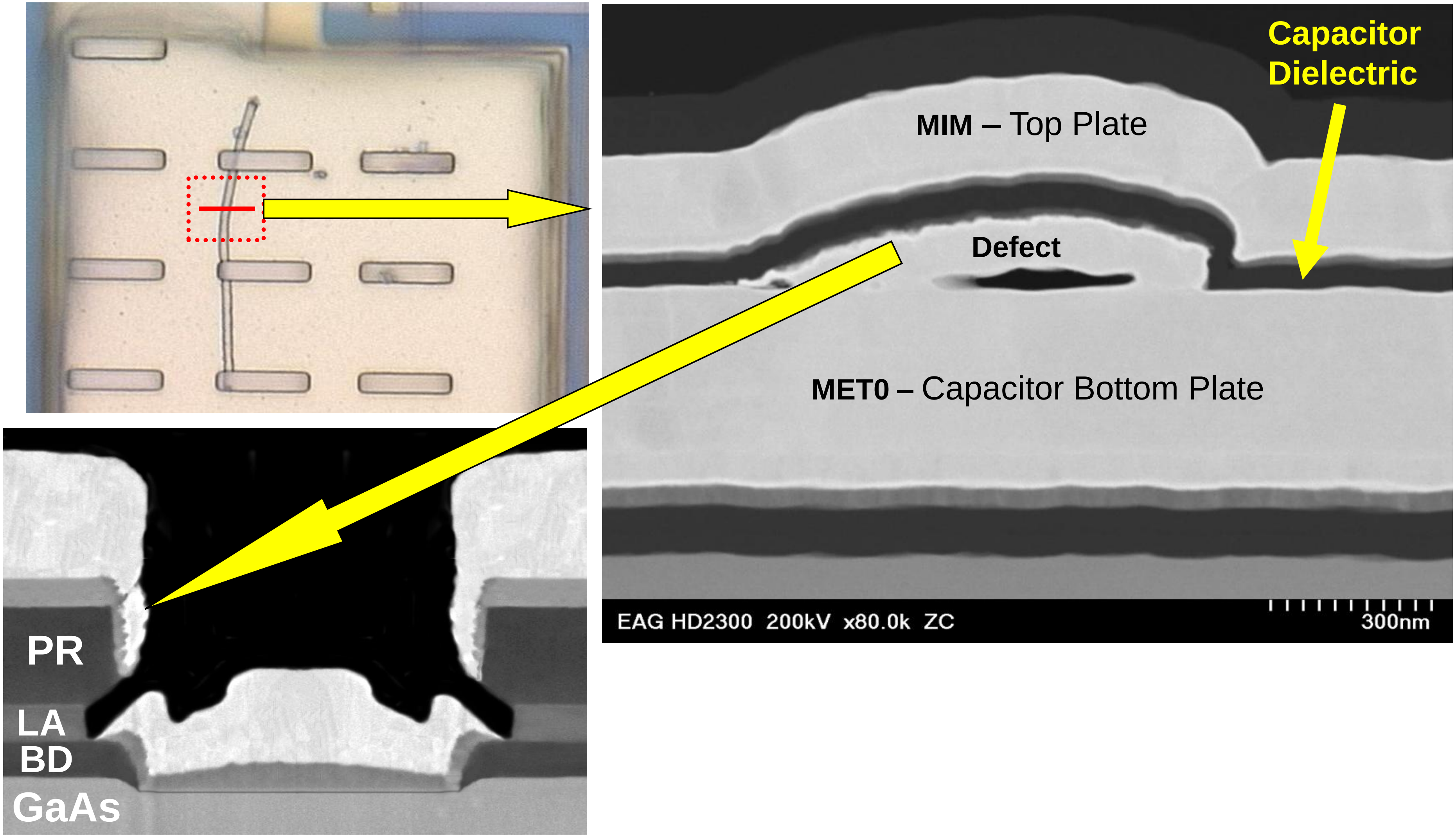


These are all weak capacitors that have low lifetimes – just as if they have effectively thinner dielectric.

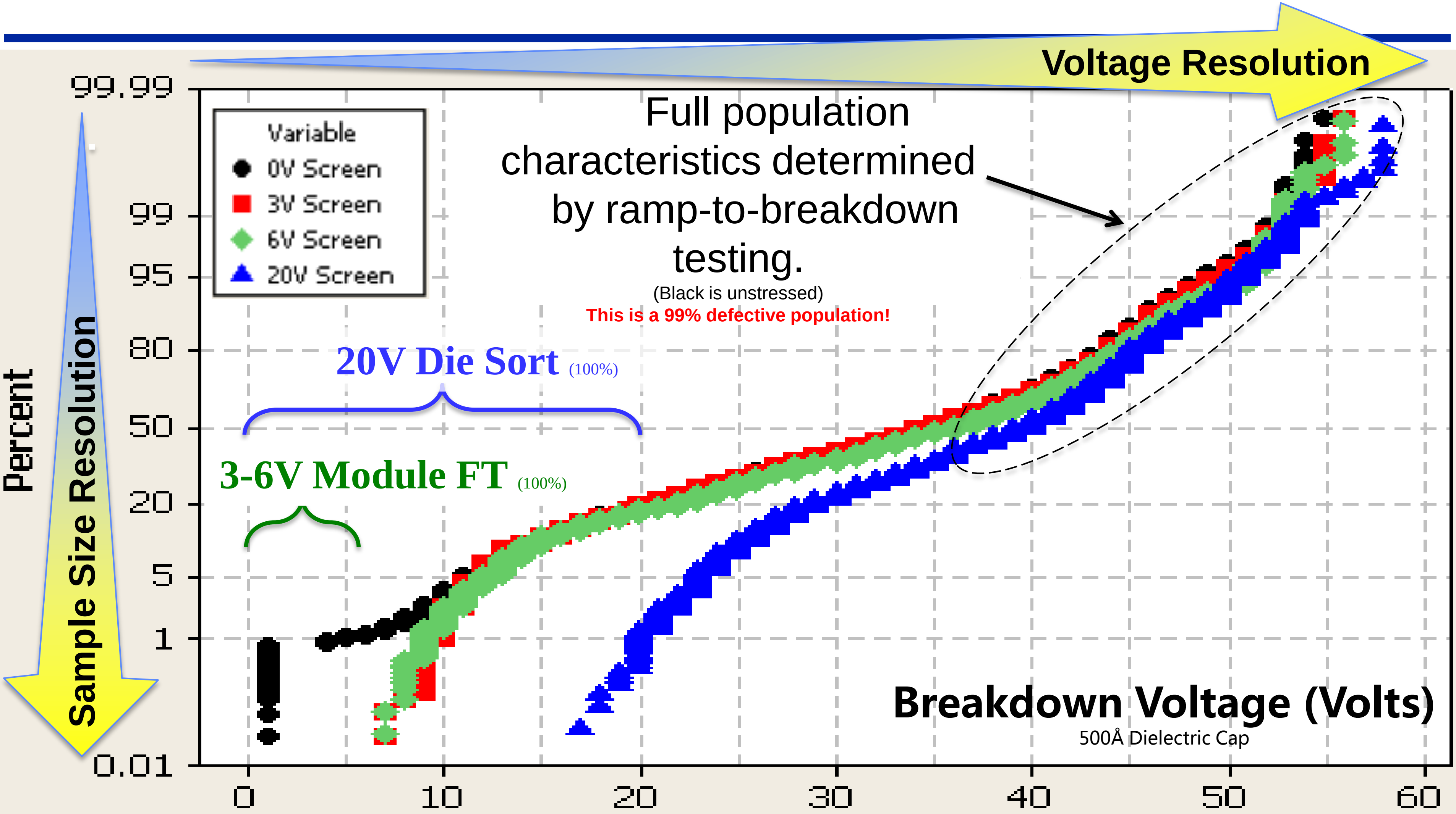
Example of a Capacitor Short due to a Defect

The capacitor is cross-sectioned at the solid red line

The defect is a metal filament lying on top of the capacitor bottom plate



Relative Resolution of Electrical Detection Methods



Full population characteristics determined by ramp-to-breakdown testing.

(Black is unstressed)

This is a 99% defective population!

20V Die Sort (100%)

3-6V Module FT (100%)

Breakdown Voltage (Volts)

500Å Dielectric Cap

Module Litmus

Sample 20- 80
10-3% LTPD

Duration

1-12hr

Not Detectible by Low Voltage Stress

Wafer Litmus

Sample 8- 22
30-10% LTPD

Duration

8.5min

Not Detectible by Moderate Voltage

Outline

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- A little about Compound Semiconductors
- Vocabulary
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- Arrhenius methodology review

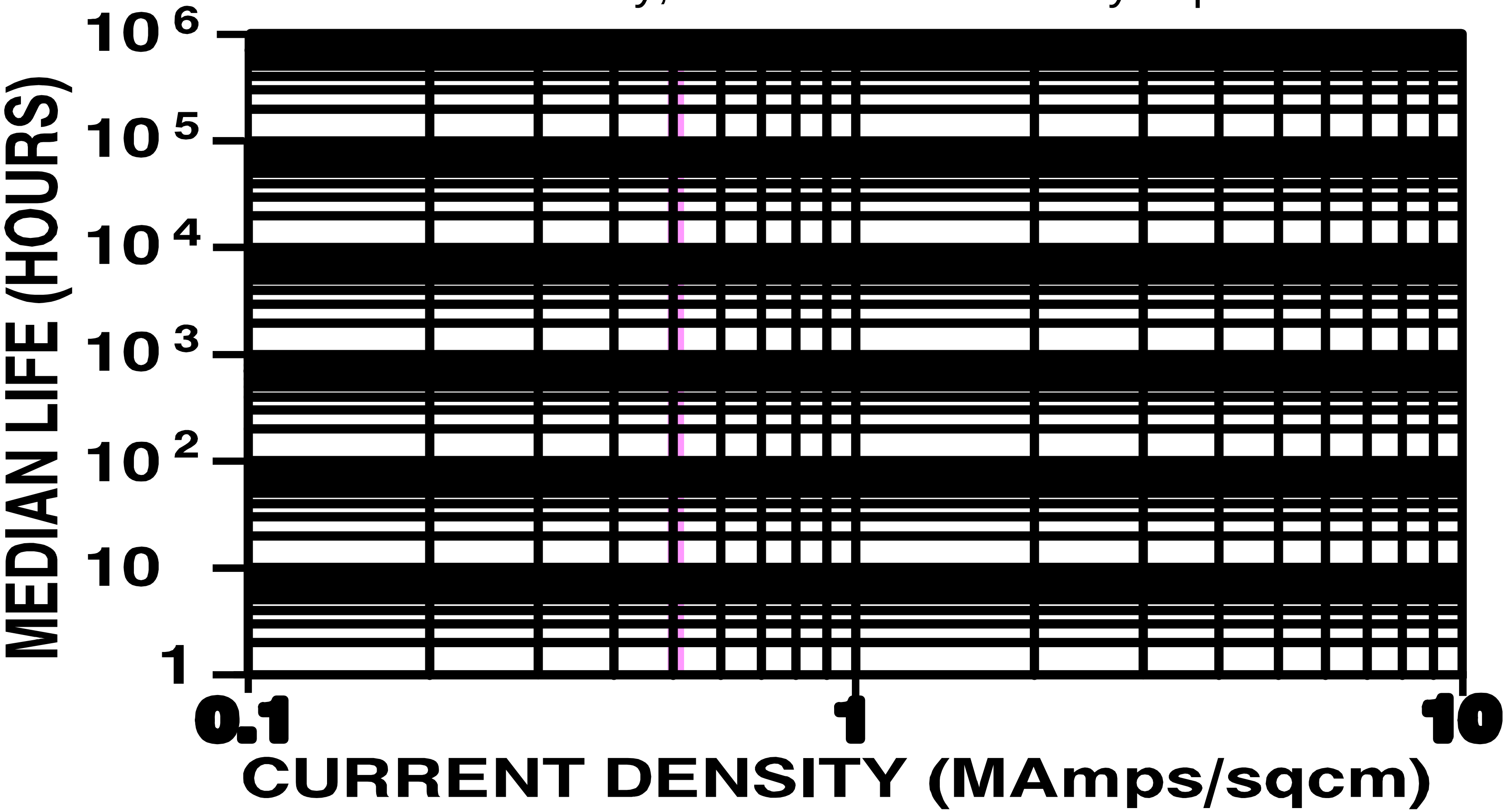
Beyond the Basics . . .

- Learning from customers: it's a *Natural*
- Breaking the cycle of learning curves
- Tipping your cap
- **The Black magic of current density**
- Amped up on defects
- The new PC

Current Induced Acceleration

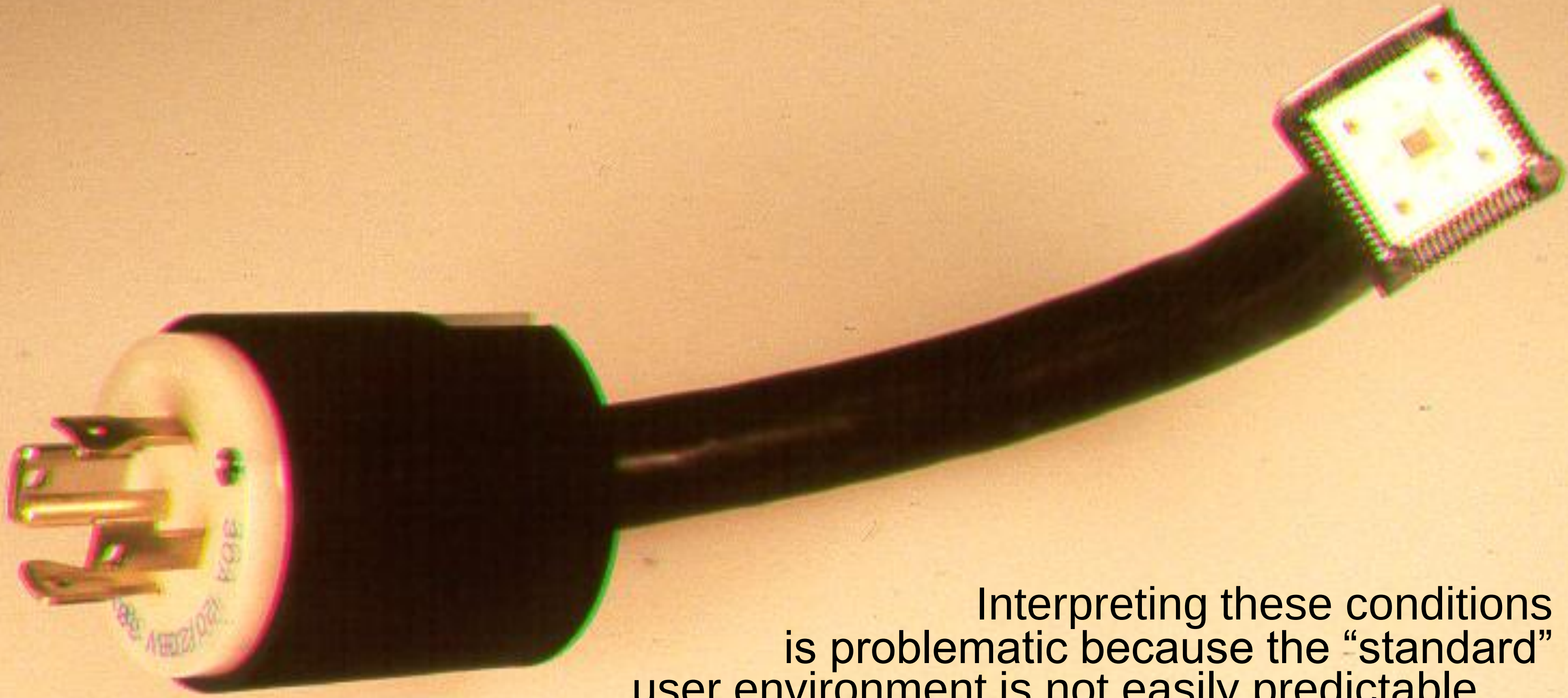
Time To Fail = $\mathbf{J}^{-n}$ exp[Ea/k(1/Temp)]

J = current density, **n** = current density exponent



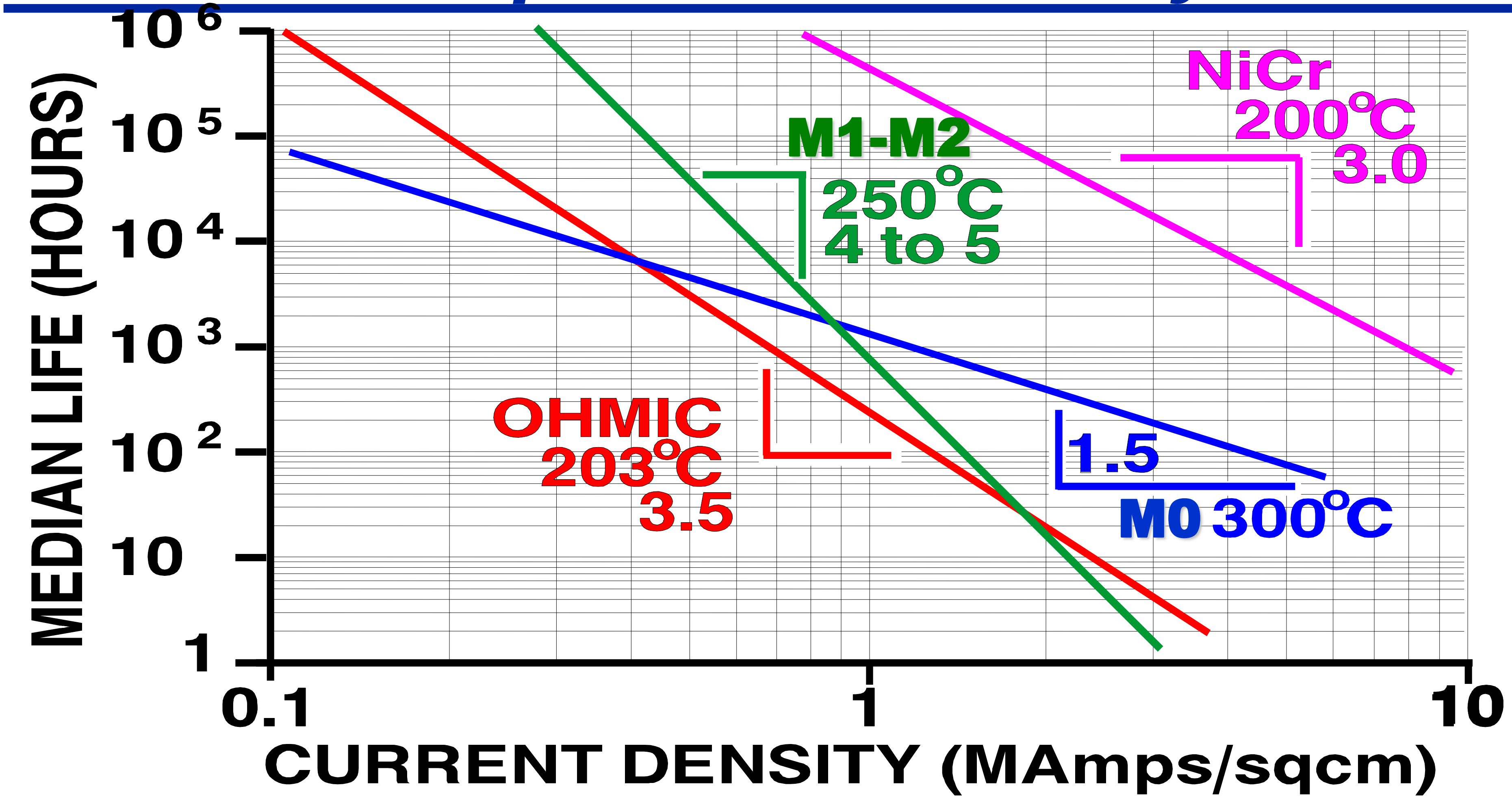
Slope = n = J exponent

How to get > 1 Million Amps?

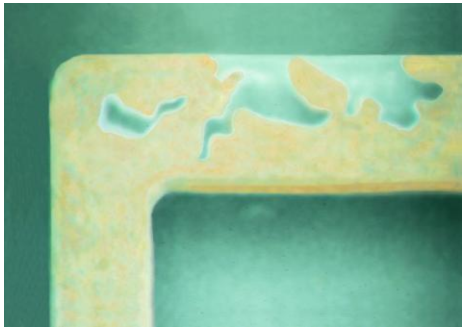


Interpreting these conditions
is problematic because the “standard”
user environment is not easily predictable . . .
and because the factors of Stress, Current, and Voltage are almost
always confounded with Temperature.

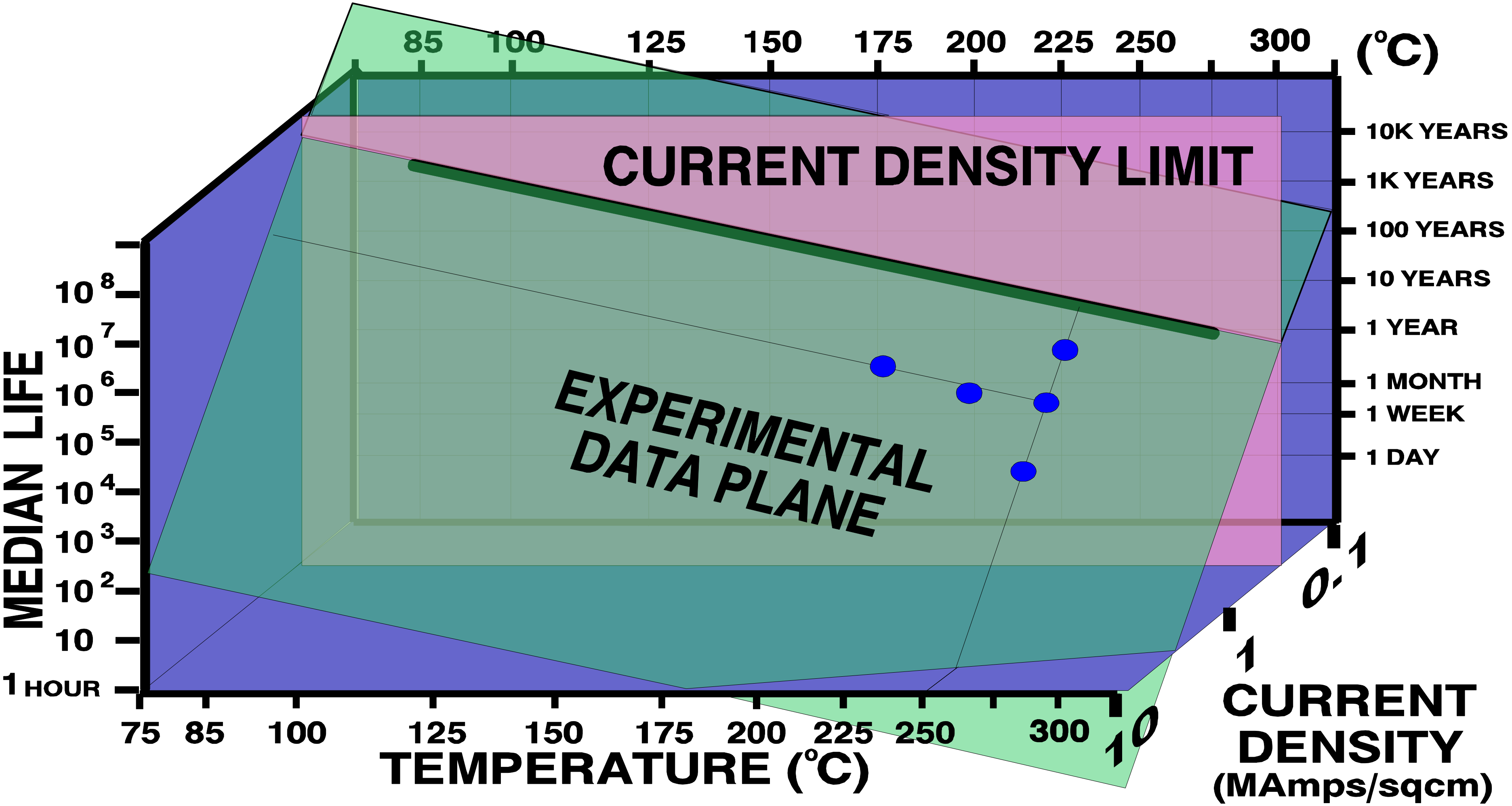
J Exponent Summary



Summary of current density acceleration factors for various circuit elements.



Plated Gold Activation Energy



Outline

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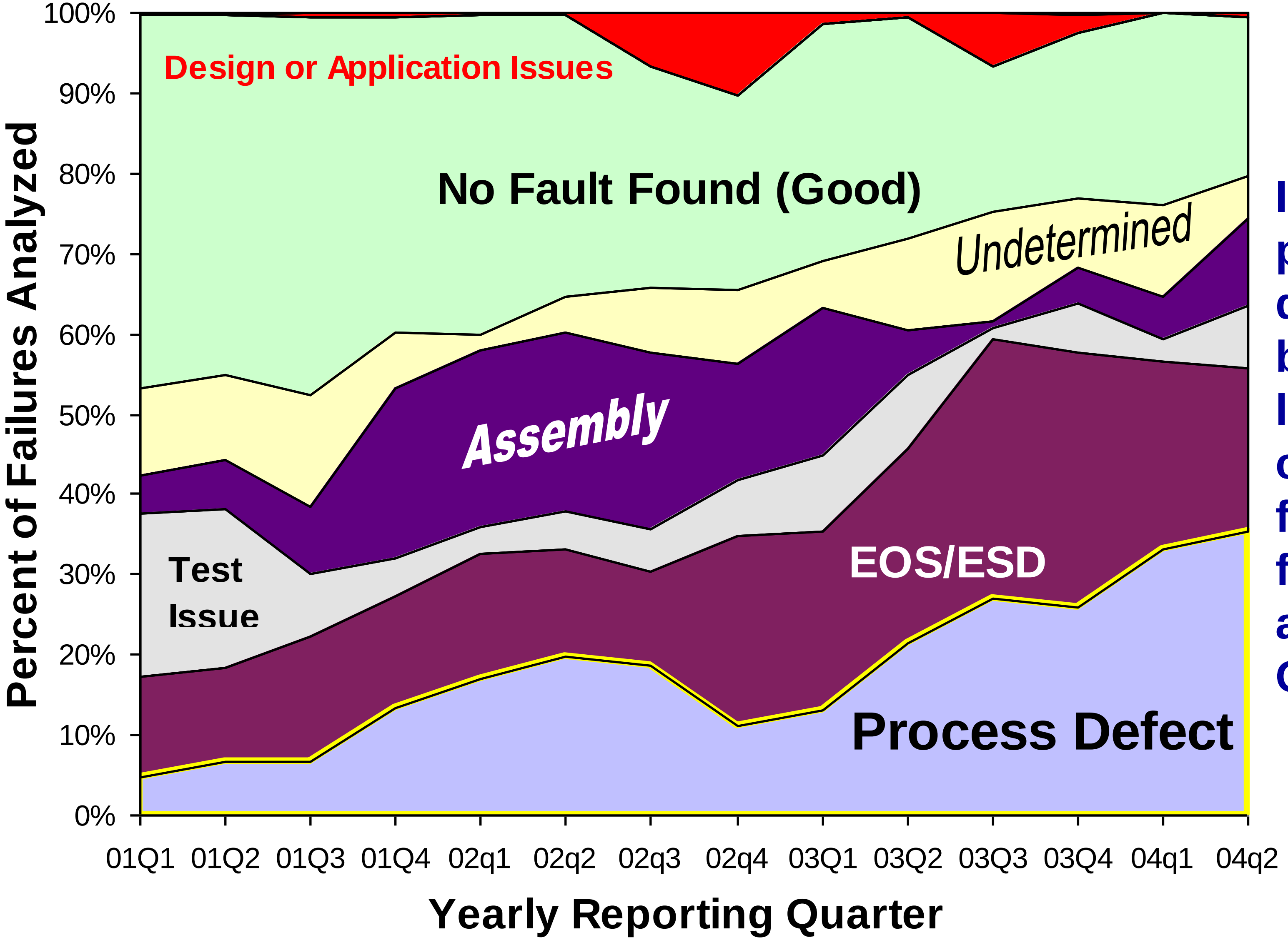
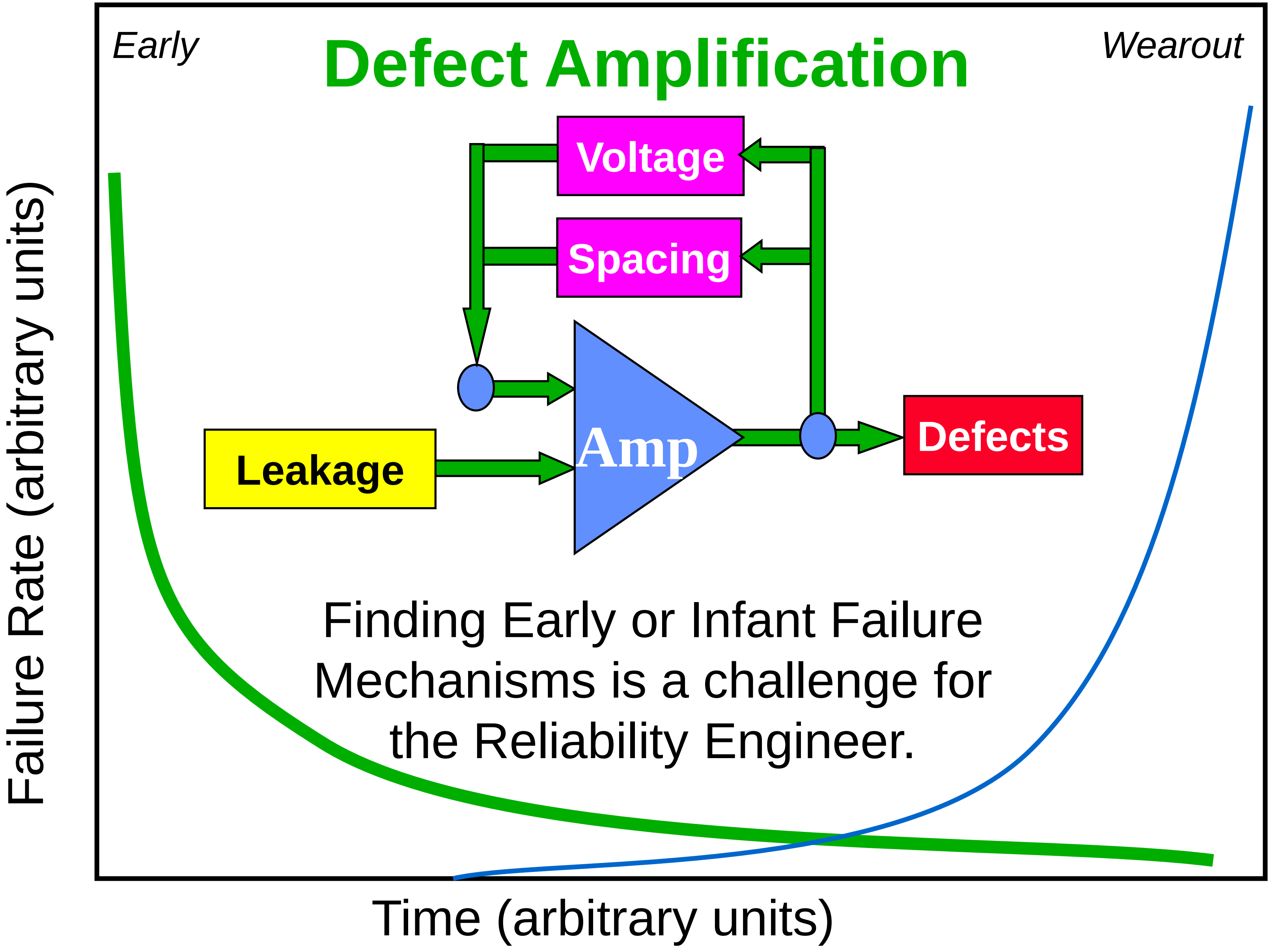
Root Causes of Field Returns



In Q1 2004, process defects became the leading cause of failure for field returns at TriQuint Oregon.

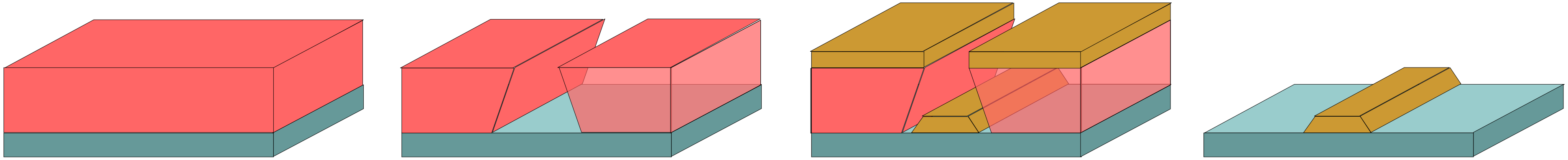
Non-thermal Acceleration Example

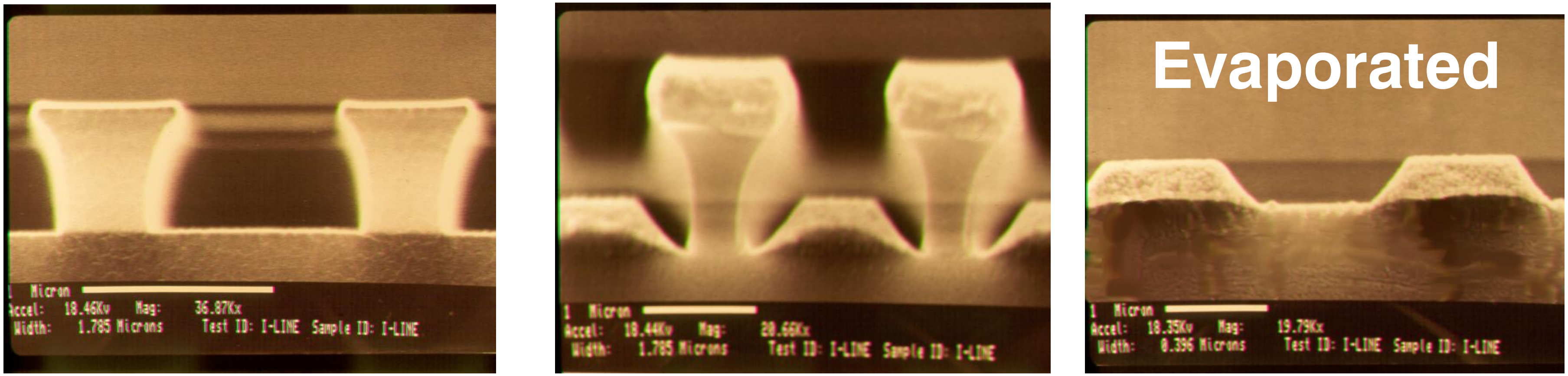


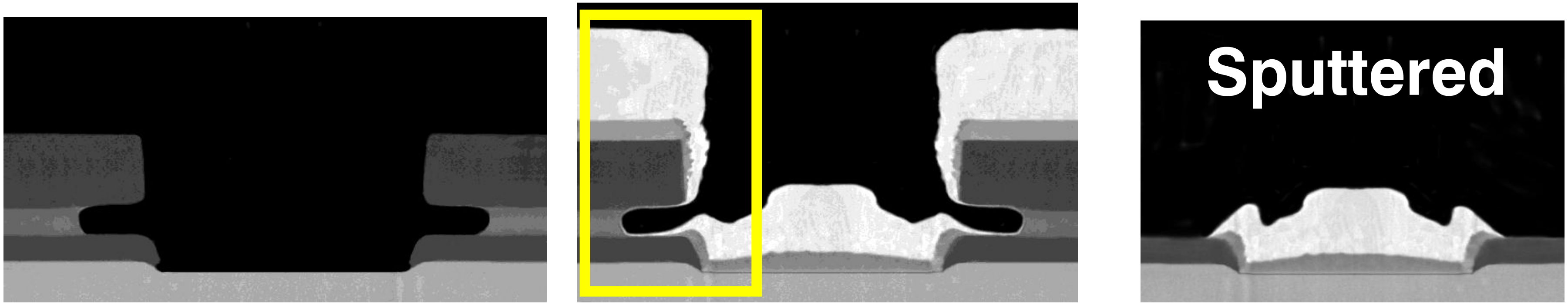
Defect Amplification

Finding Early or Infant Failure Mechanisms is a challenge for the Reliability Engineer.

Lift-Off Metallization



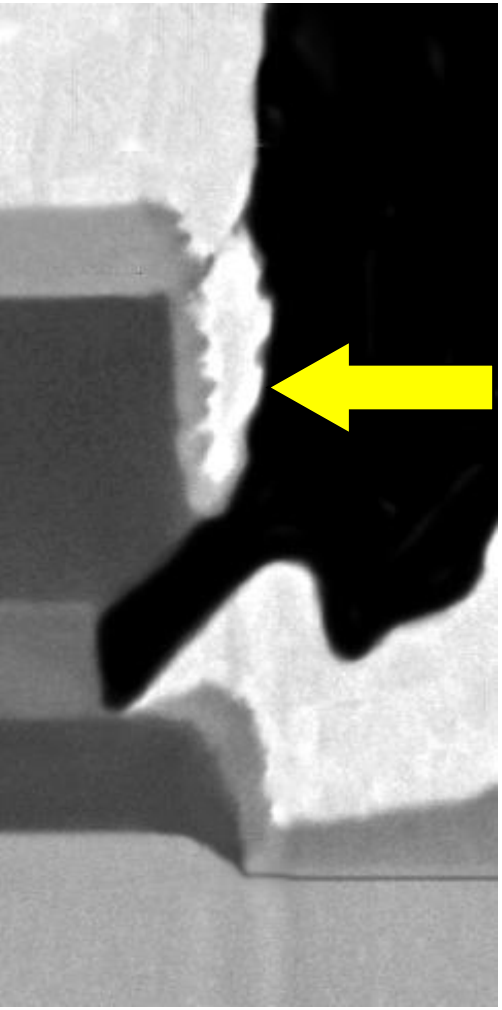




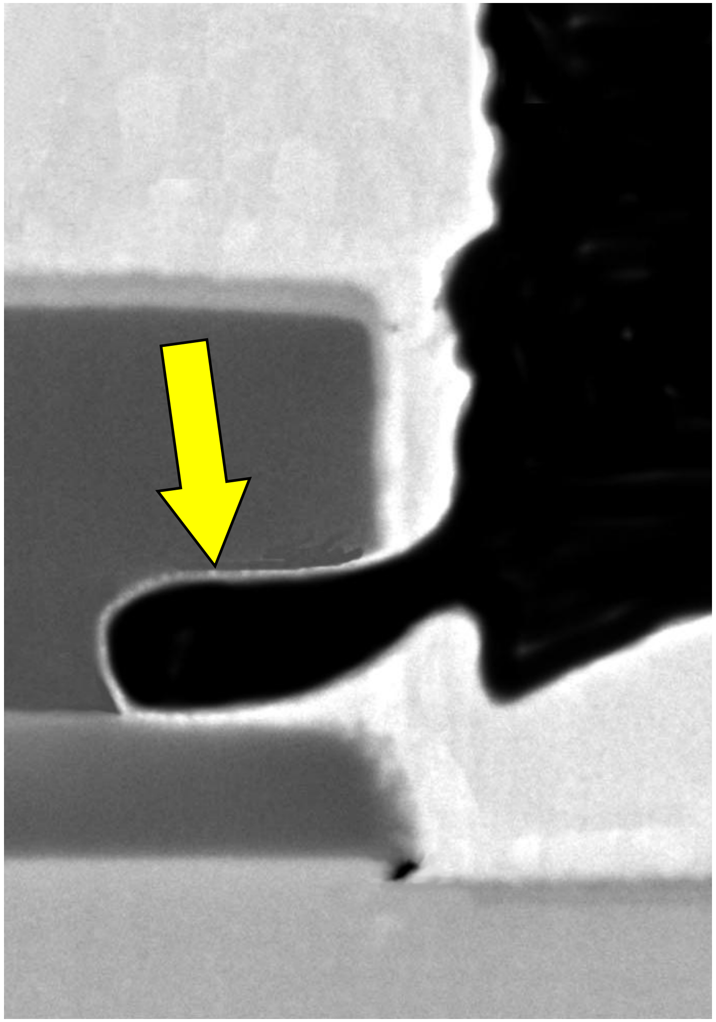
Emitter, Base, Collector, Ohmic, Gate, NiCr, Metal 0, MIM

Lift-Off Metallization Evolution

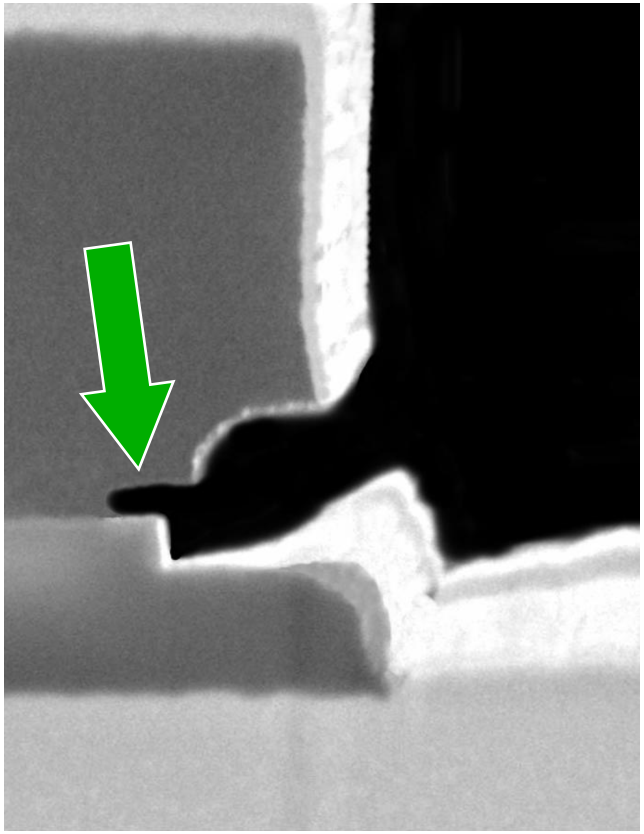
Evaporated Metal



Original Sputtered Metal



New Sputtered Metal



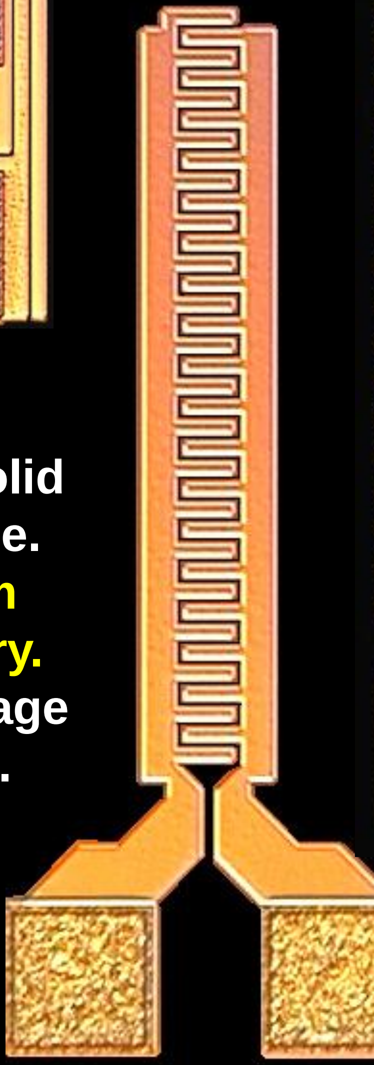
Gap

Gap in solid rectangle.

1350um Periphery.

One leakage across.

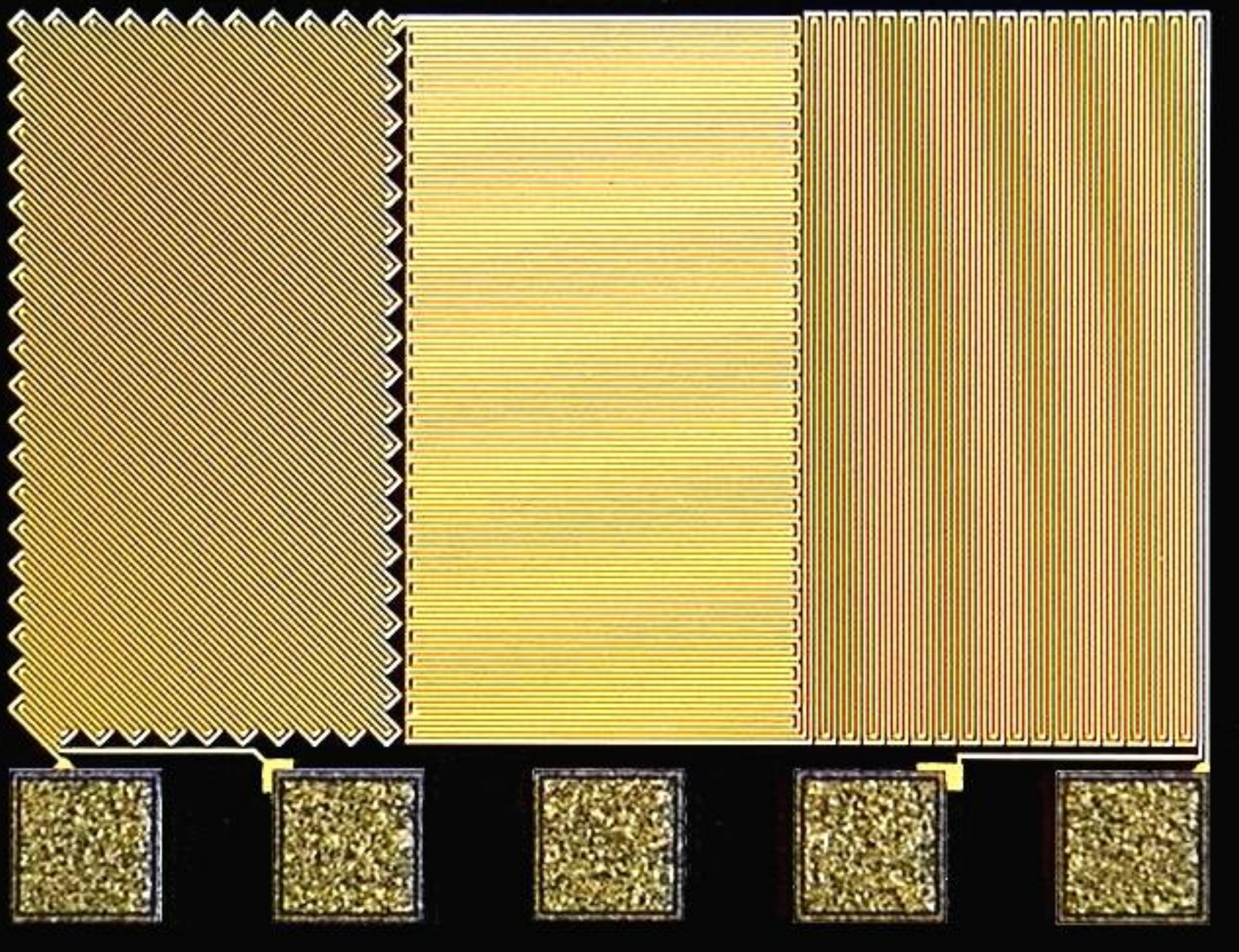
Comb



Interdigitated Fingers.

1880um Periphery.

One leakage across.



Meander

Pair of folded traces "meandering". . . diagonally, horizontally, & vertically.

30mm Periphery.

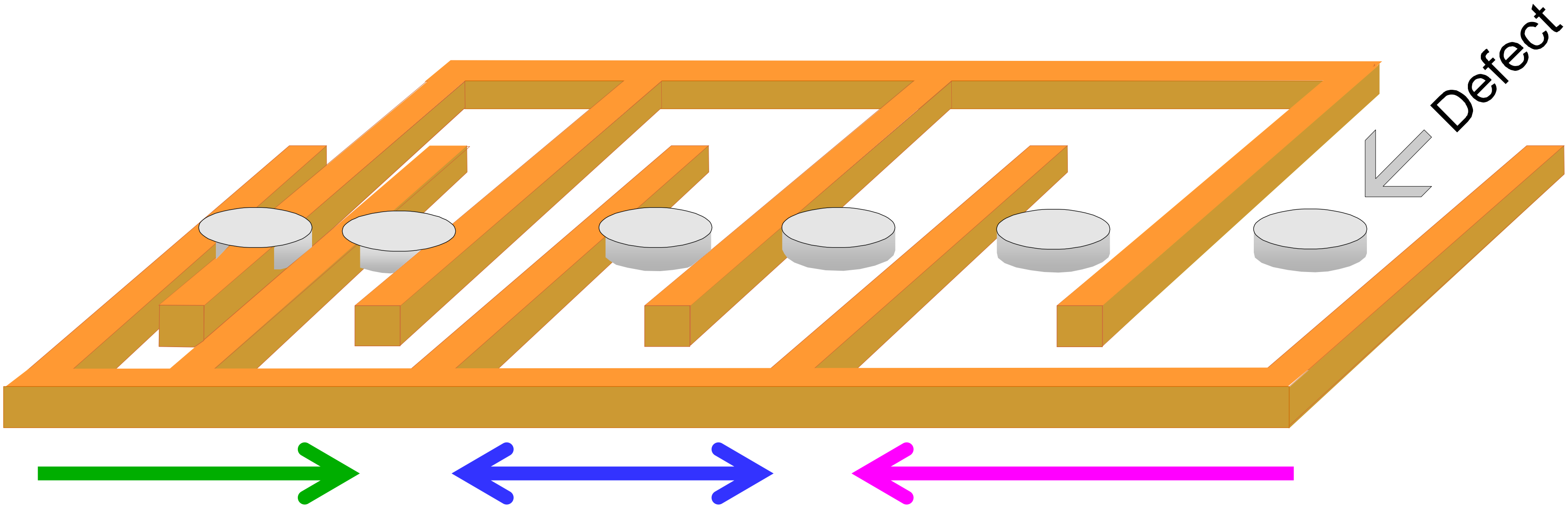
Leakage between traces.

Resistance of each trace.

How to “amplify” low level defects:

Comb Style Structure.

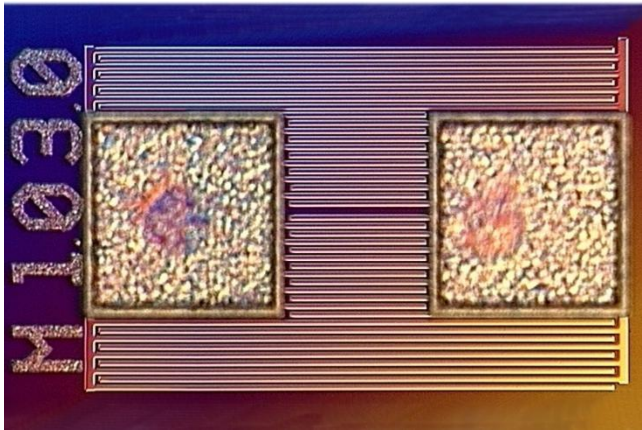
Testable Electrically: Apply Voltage, Measure Leakage



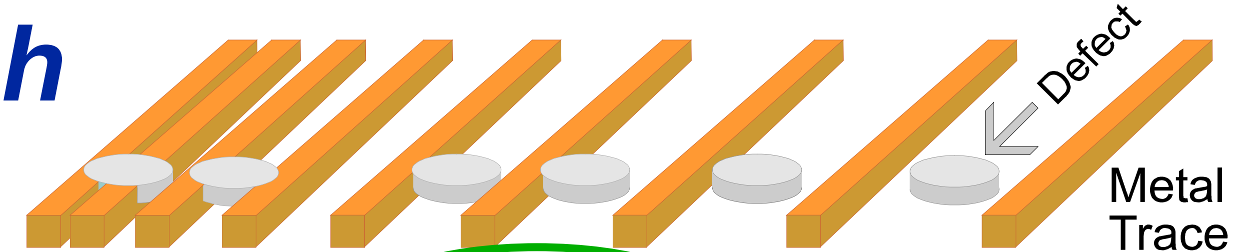
Quality Concerns (Always Shorted) Yield Loss

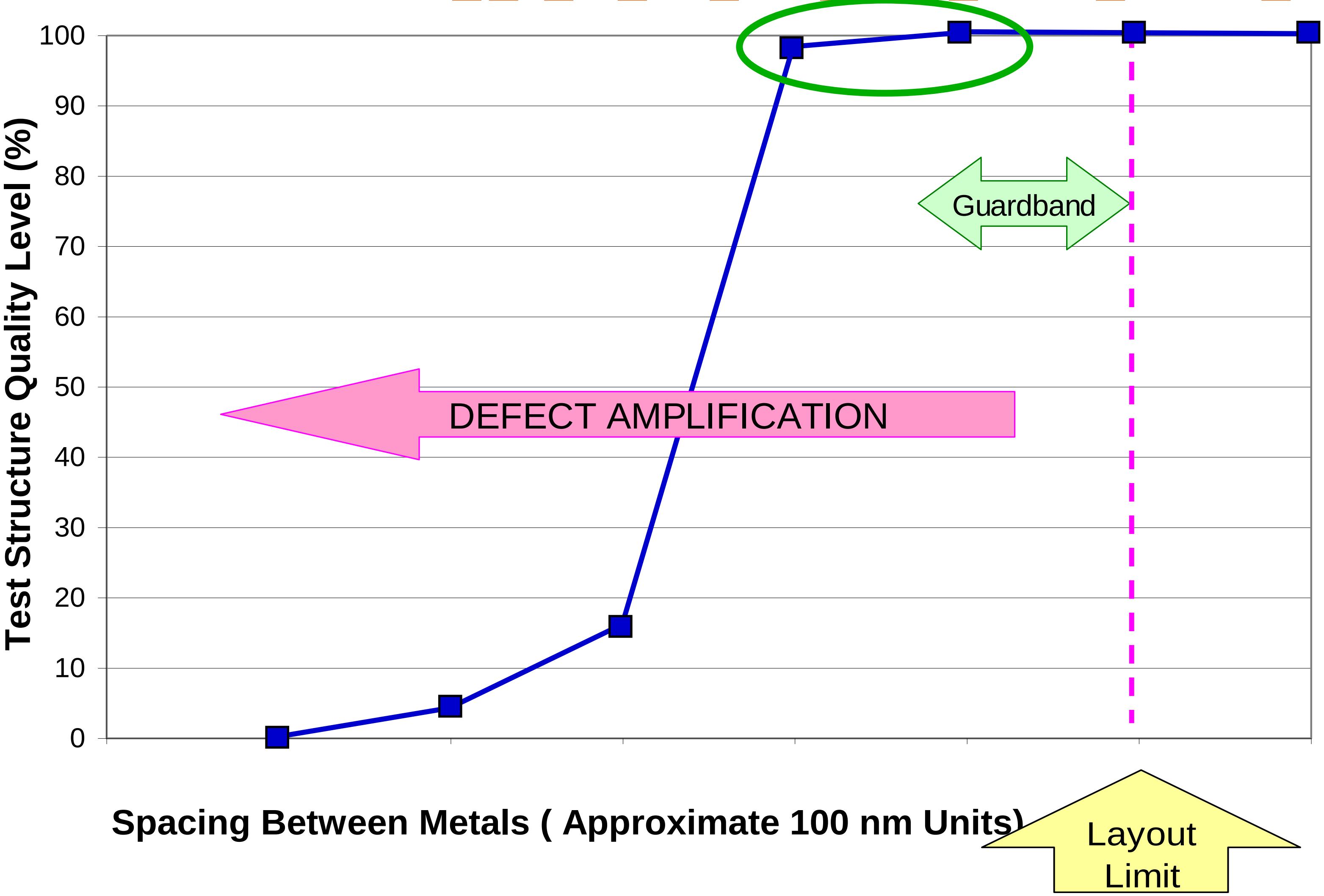
Reliability Concerns (Near Shorts)

Unknown?

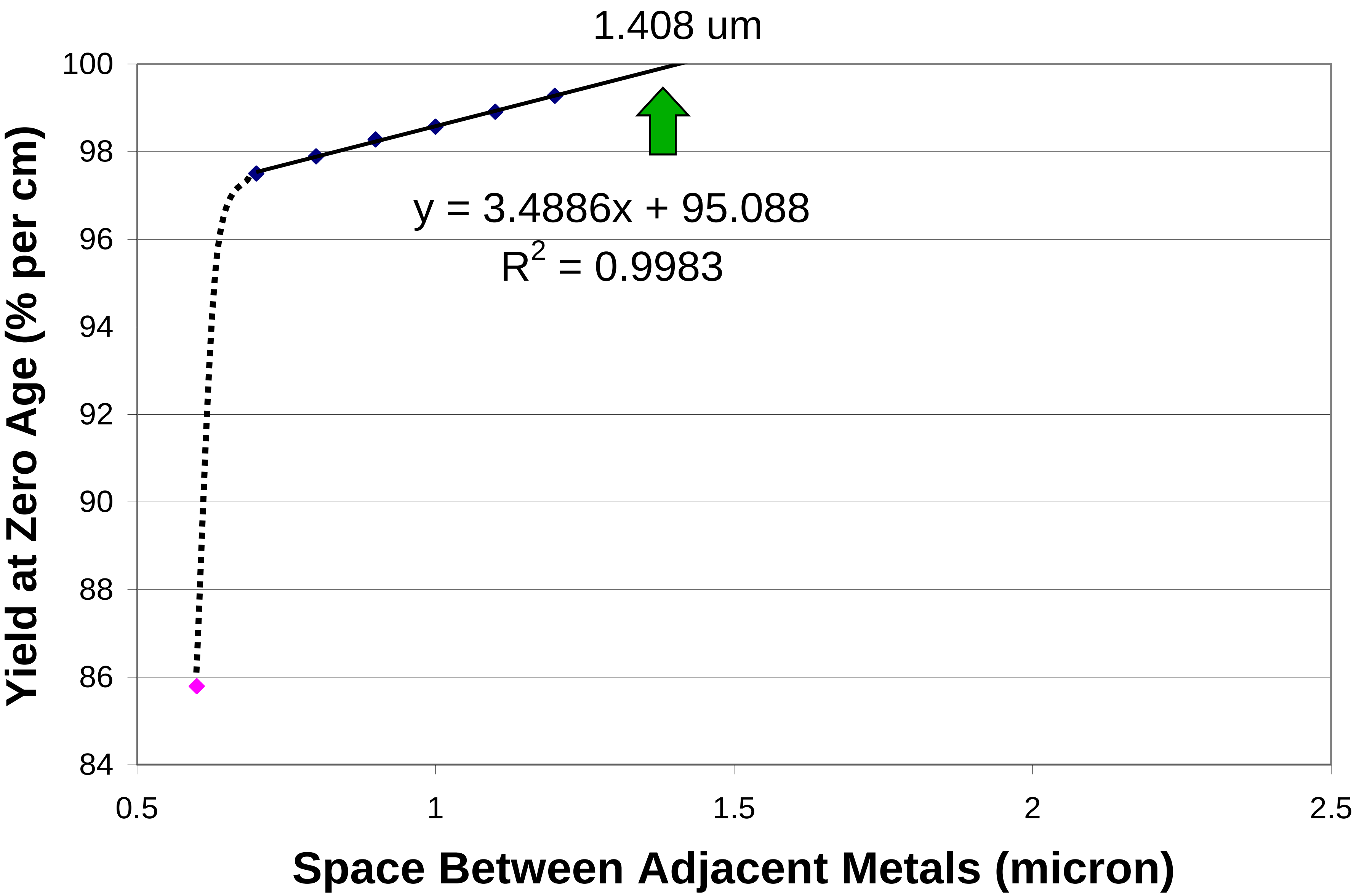


Approach

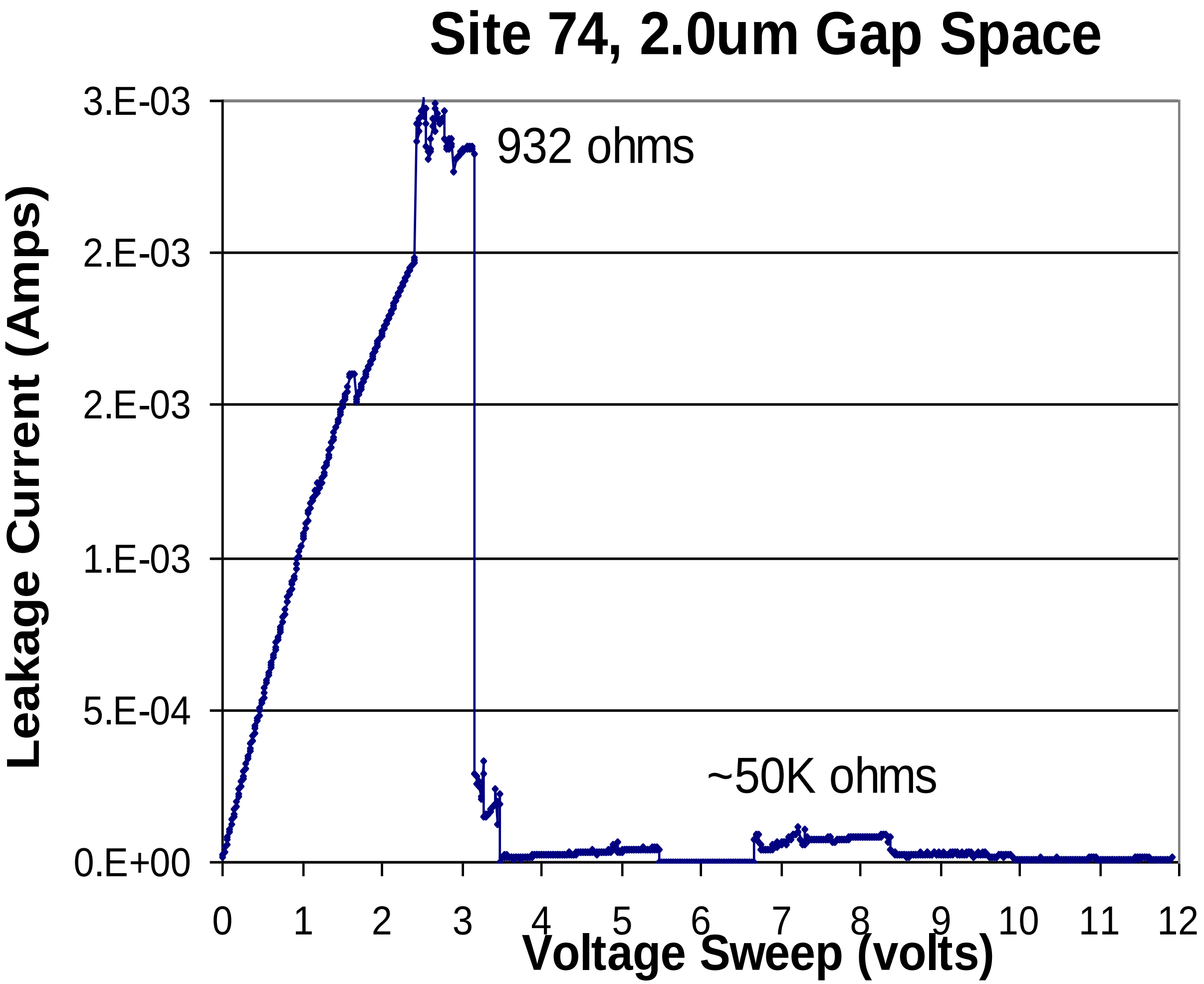

Defect
Metal Trace


Test Structure Quality Level (%)
100
90
80
70
60
50
40
30
20
10
0
Guardband
DEFECT AMPLIFICATION
Spacing Between Metals (Approximate 100 nm Units)
Layout Limit

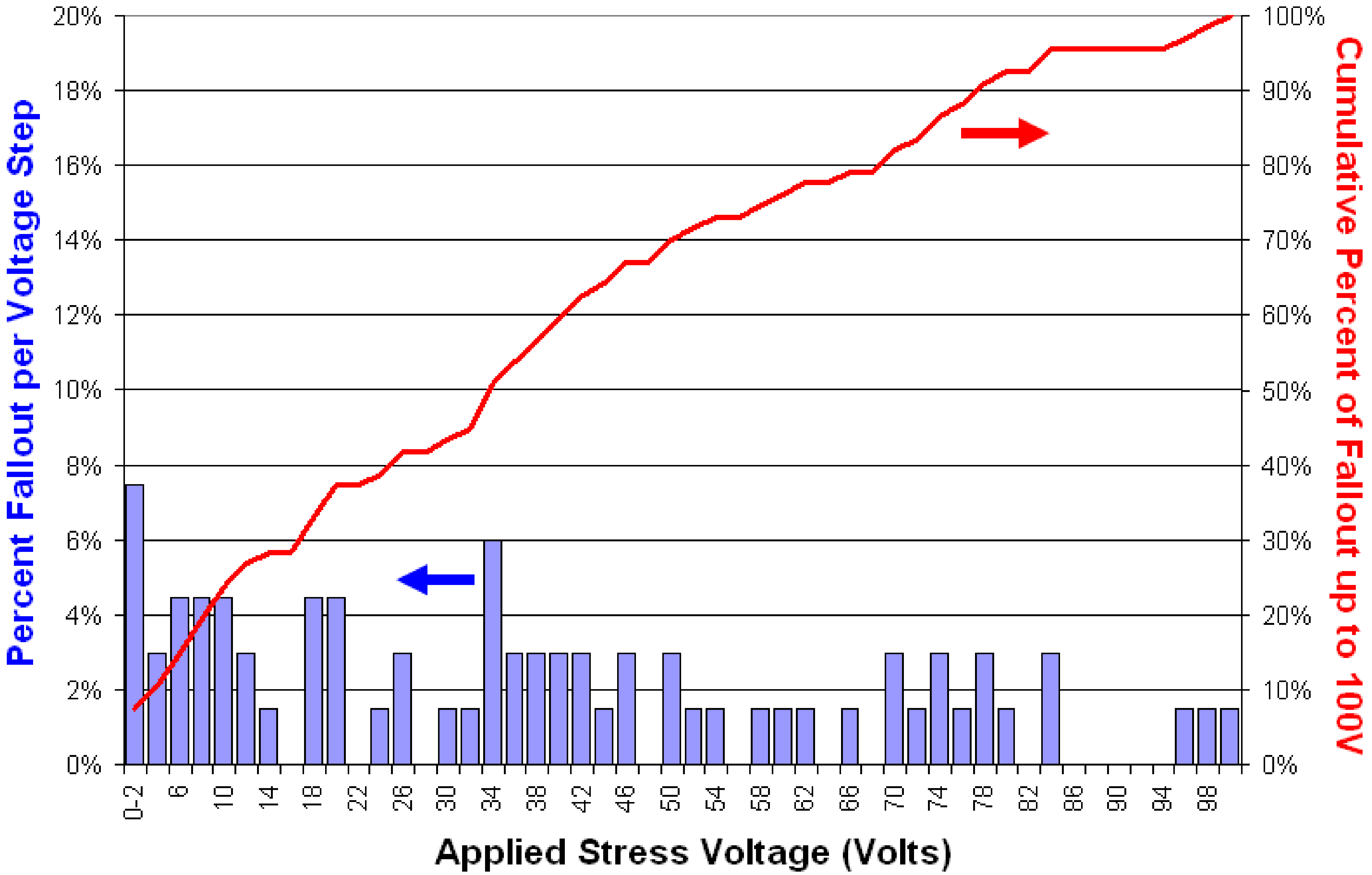
Yield as a Function of Spacing



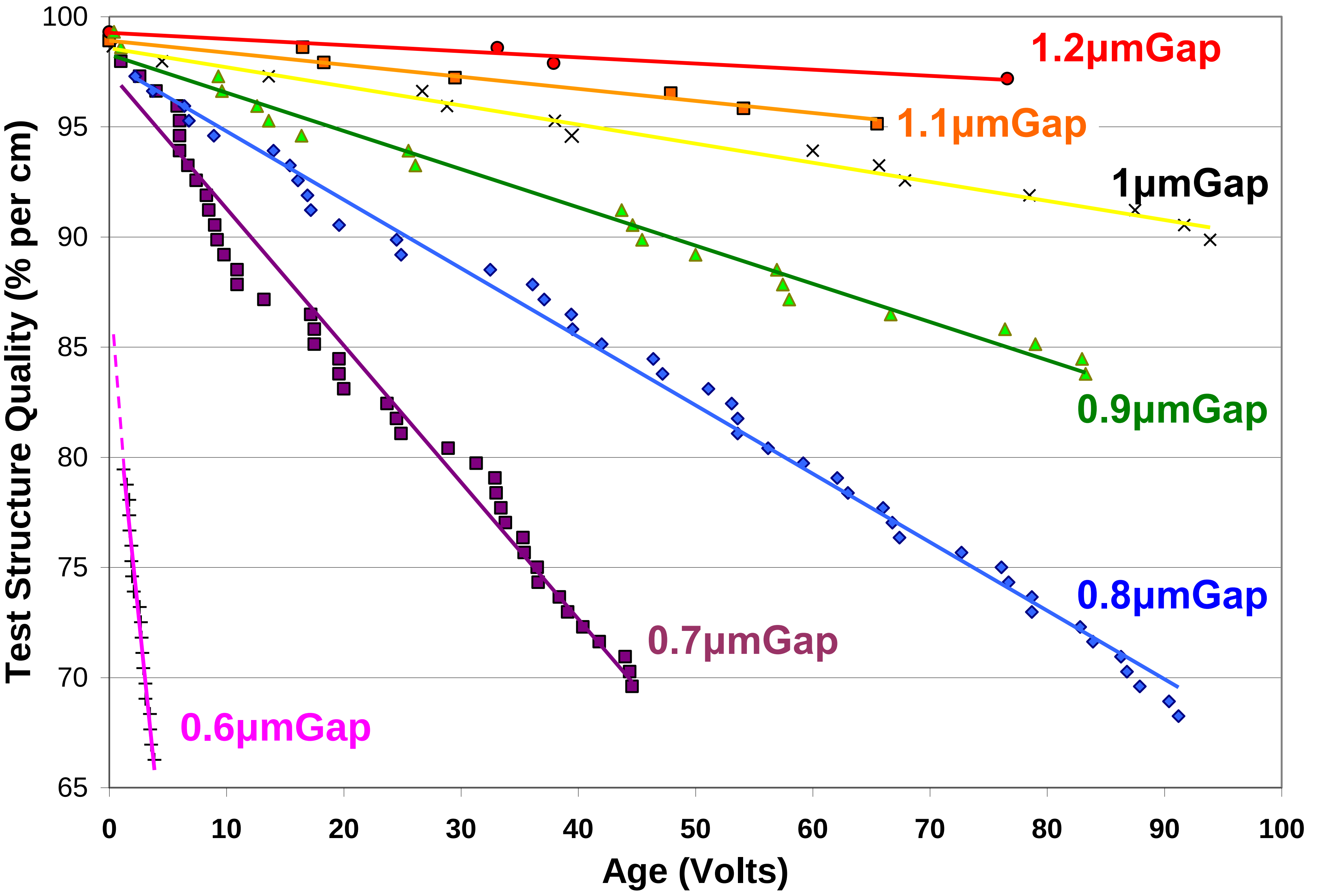
What Voltage?



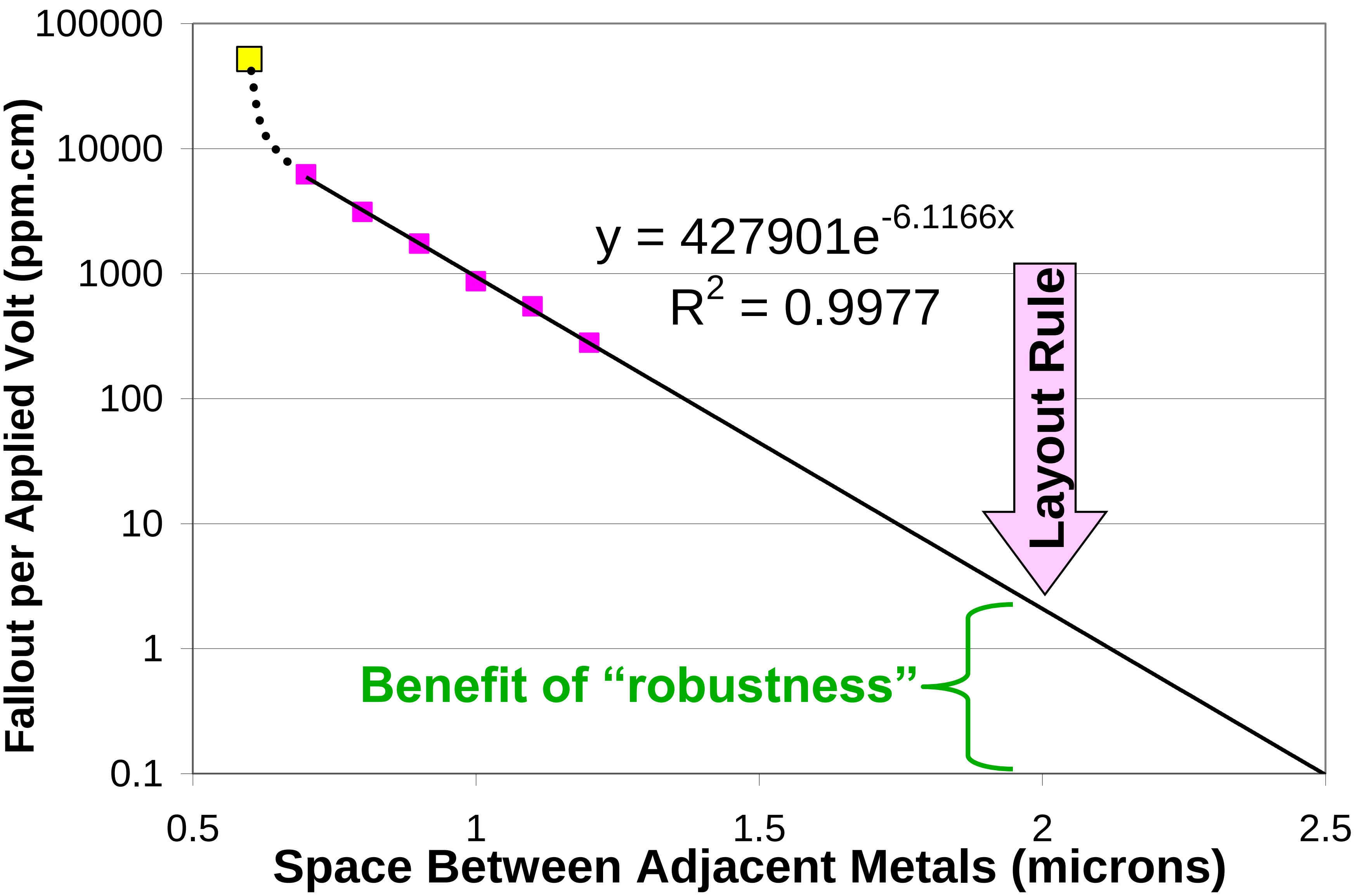
Looking for Voltage… found acceleration



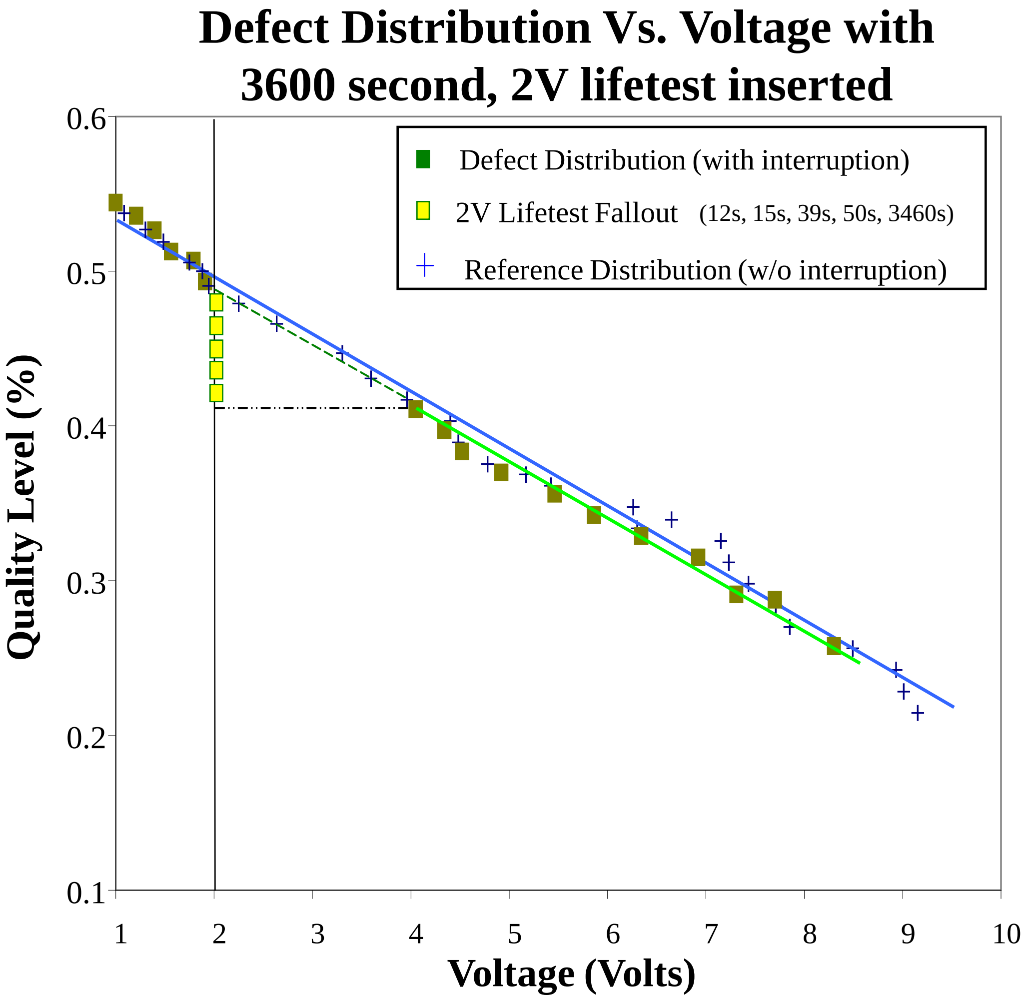
Voltage Acceleration + Physical Amplification



Reliability as a Function of Spacing



Voltage Aging Effects – Narrow Gap



Voltage and time relationships are similar between capacitors and amplified interconnect.

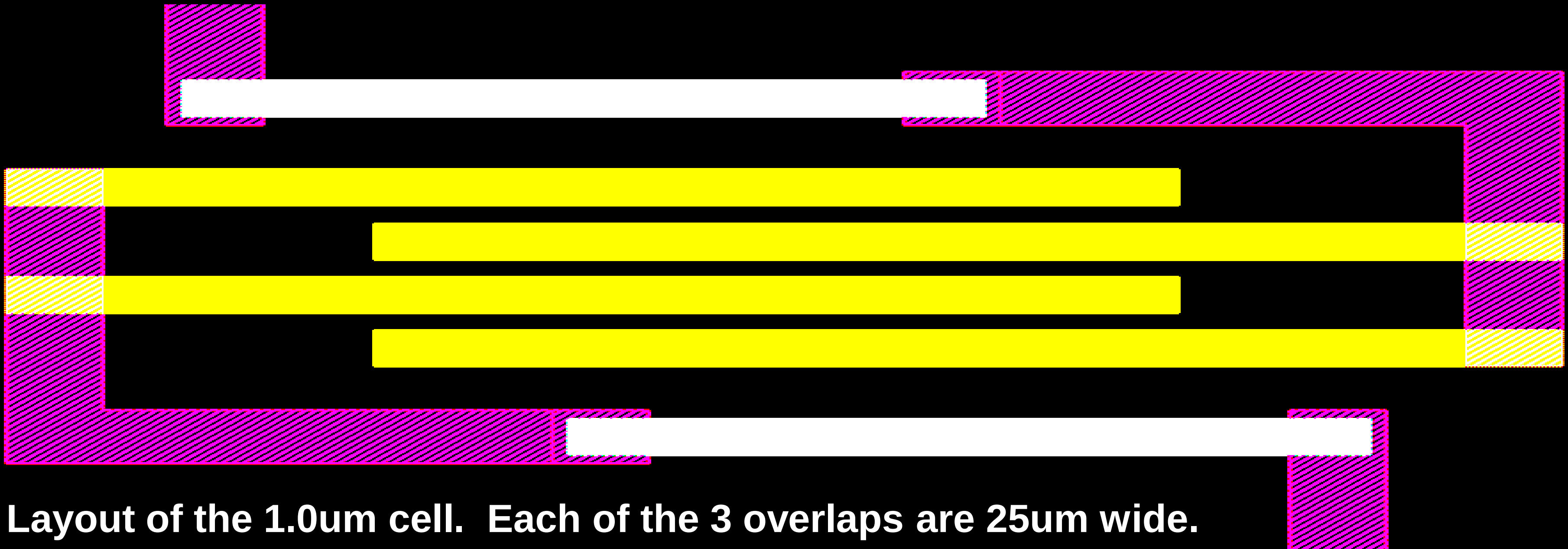
Original SCALE Structure

(Spacing between interdigitated fingers in Microns)

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

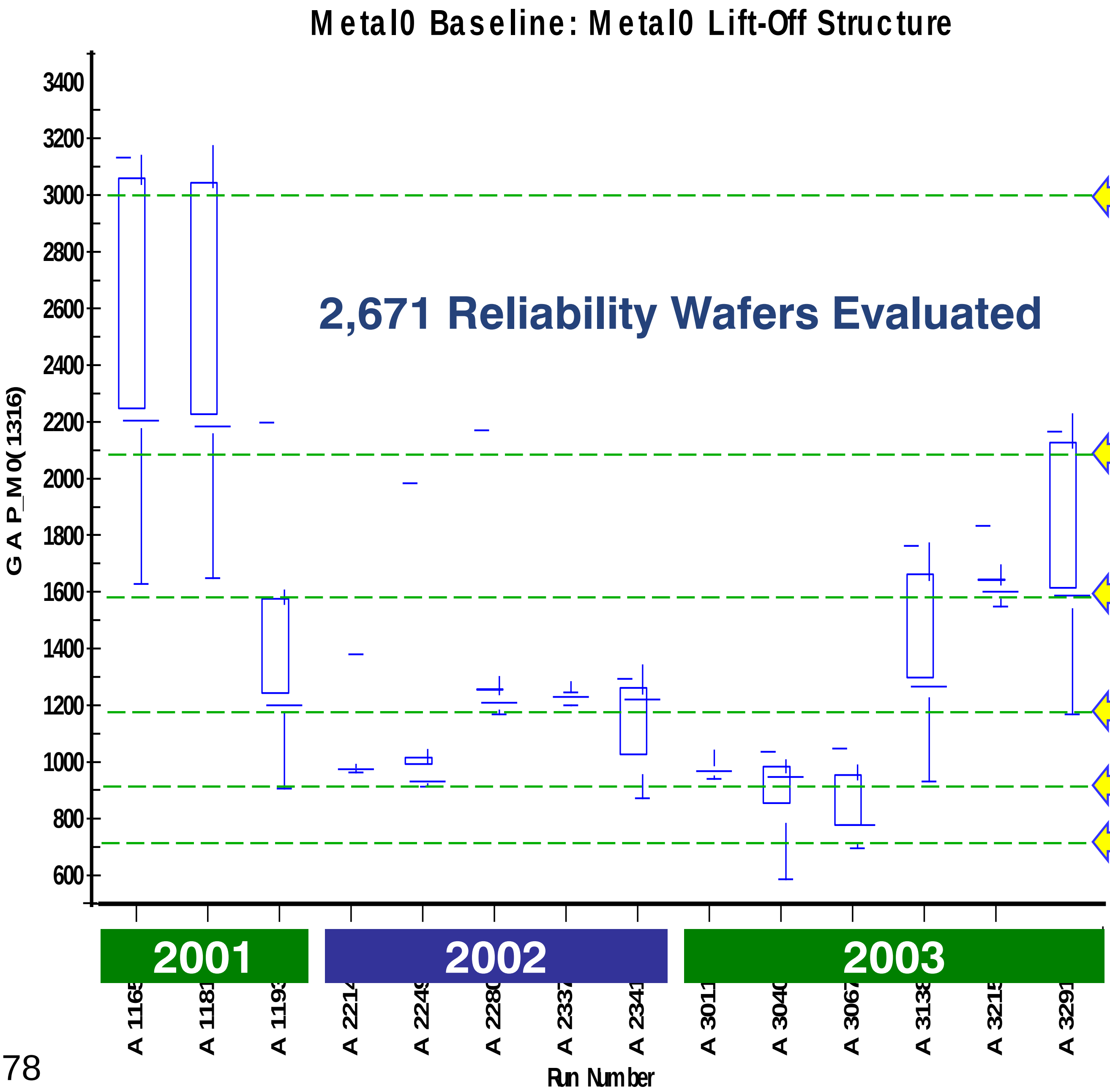
10K 9K 8K 7K 6K 5K 4K 3K 2K 1K

(Series resistors in Ohms)



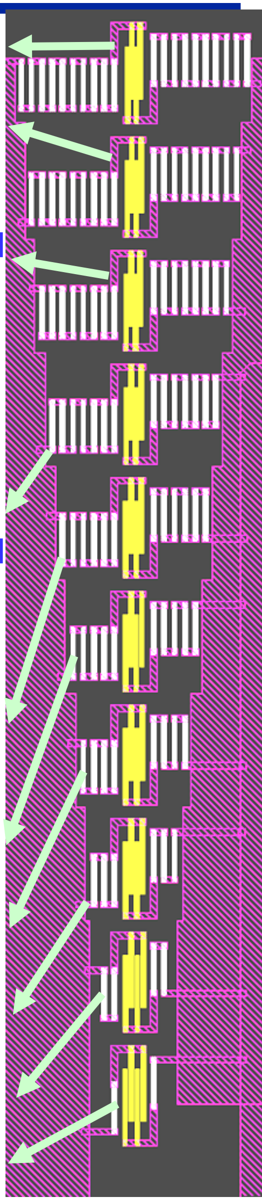
Layout of the 1.0um cell. Each of the 3 overlaps are 25um wide.

Scale Sensitivity Over Time (Single V Measurement)



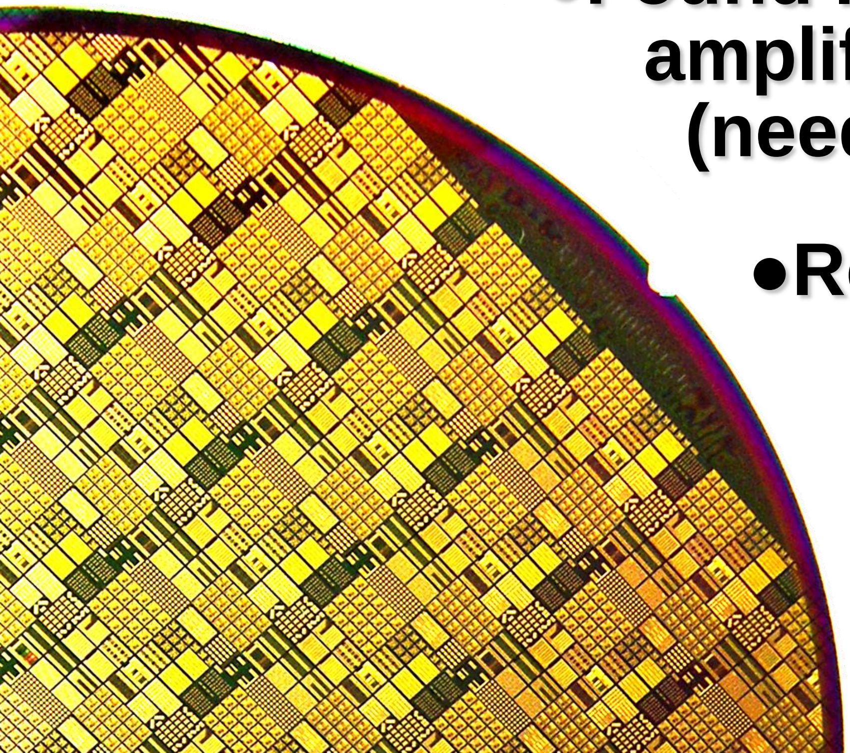
2,671 Reliability Wafers Evaluated

10.KΩ=0.1μ
4.8KΩ=0.2μ
3.0KΩ=0.3μ
2.1KΩ=0.4μ
1.6KΩ=0.5μ
1.2KΩ=0.6μ
936 Ω=0.7μ
724 Ω=0.8μ
547 Ω=0.9μ
385 Ω=1.0μ



Applicability of Amplification

- Sampled meter-sized periphery to estimate for centimeters and below.
- Verified layout rules and applicability of periphery amplification.
- Found lower limits of gap amplification, not upper limits. (need more periphery)
- Relationships between Yield & Reliability were demonstrated.



Outline

Basics

- A little about Compound Semiconductors
- Vocabulary
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Beyond the Basics . . . What's manufacturability got to do with it?

- Learning from customers: it's a *Natural*
- Breaking the cycle of learning curves
- Tipping your cap
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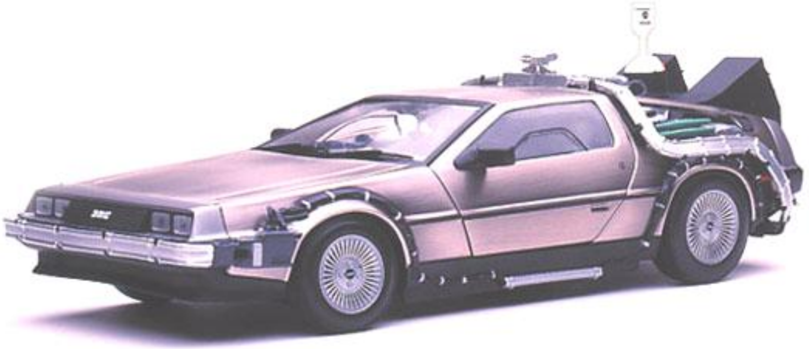
- The new PC

Finding the “right” stress

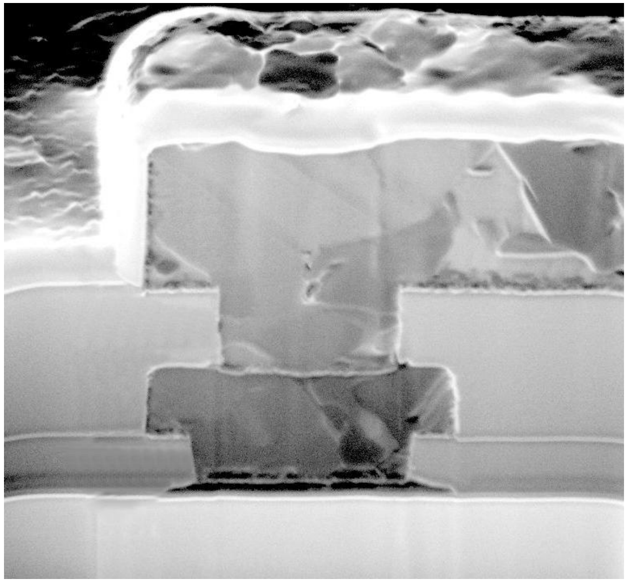
- **Acceleration Factors known for Temperature, Voltage, Current.**
- **Experience from the field does not match wearout mechanisms.**
- **Causes of reliability test and field failures indicate “excursions.”**
- **Samples: special lot available.**

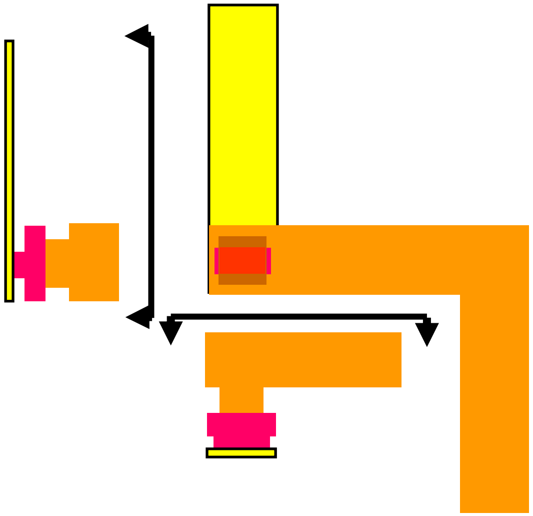


Thermal Excursions - Background

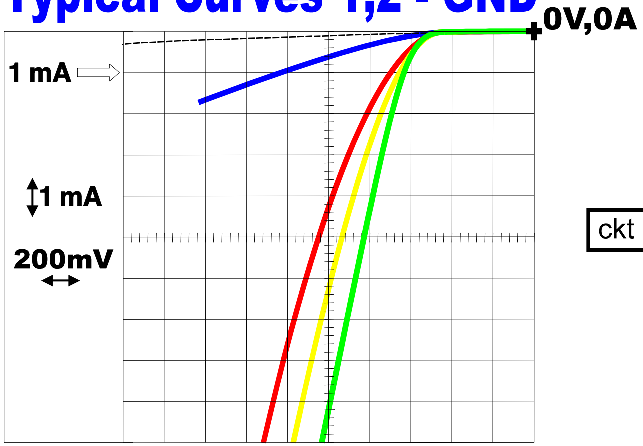
- “Special” Lot
- 13,000 samples per wafer
- 14 wafer lot (5 anomalous)
- 200 additional lots screened

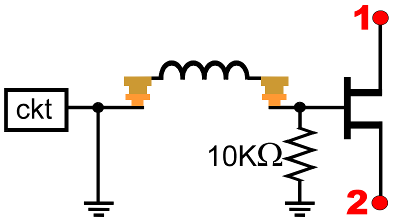
  (representing 2.6 million)
- >130,500 tested for one mechanism





Typical Curves 1,2 - GND



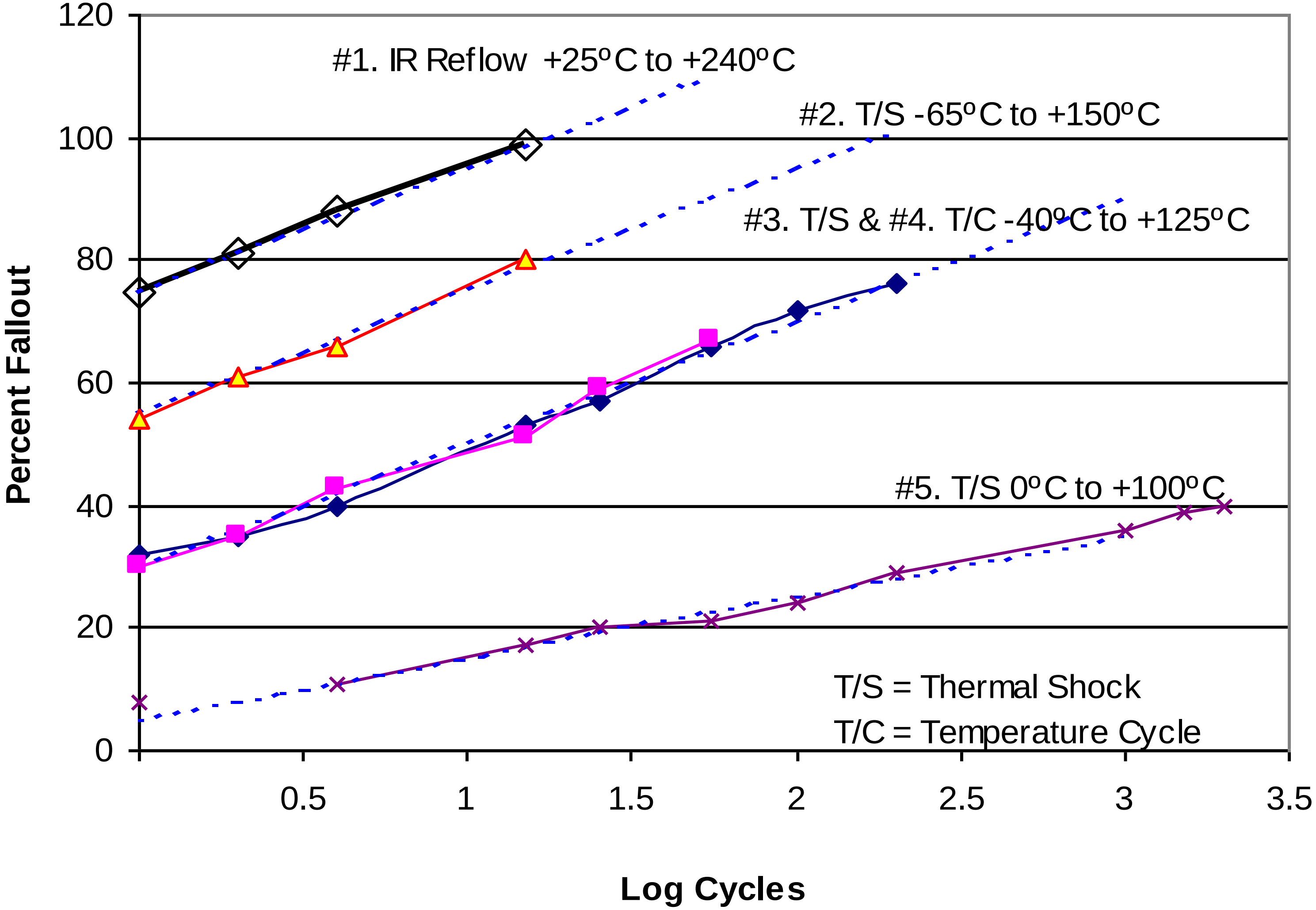


Excursions: Methods - Tests

Test	Type	JEDEC	Range	Cycles
1	**Infrared Reflow**	**JESD22-A113-B**	**+25ºC to +240ºC**	**<20**
2	**Thermal Shock**	**JESD22-A106-A Condition D**	**-65ºC to +150ºC**	**<20**
3	**Thermal Shock**	**JESD26A Condition C-1**	**-40ºC to +125ºC**	**<100**
4	**Temperature Cycle**	**JESD22-A104-A Condition G**	**-40ºC to +125ºC**	**<500**
5	**Thermal Shock**	**JESD22-A106-A Condition B**	**0ºC to +100ºC**	**<2500**

Test	Type	Maximum Transfer Time	Minimum Dwell Time Time	Maximum Time to Temperature
1	**Infrared Reflow**	**~140 seconds**	**20 seconds**	**6 minutes**
2	**Thermal Shock**	**10 seconds**	**2 minutes**	**5 minutes**
3	**Thermal Shock**	**10 seconds**	**2 minutes**	**5 minutes**
4	**Temperature Cycle**	**1 minute**	**10 minutes**	**15 minutes**
5	**Thermal Shock**	**10 seconds**	**2 minutes**	**5 minutes**

Thermal Excursion Aging Results



Absolute temperature range is significant compared to various rates of change for thermal shock and temperature cycle.

Thermal Excursions: Acceleration

8 Thermal Shocks
-65ºC to +150ºC

or

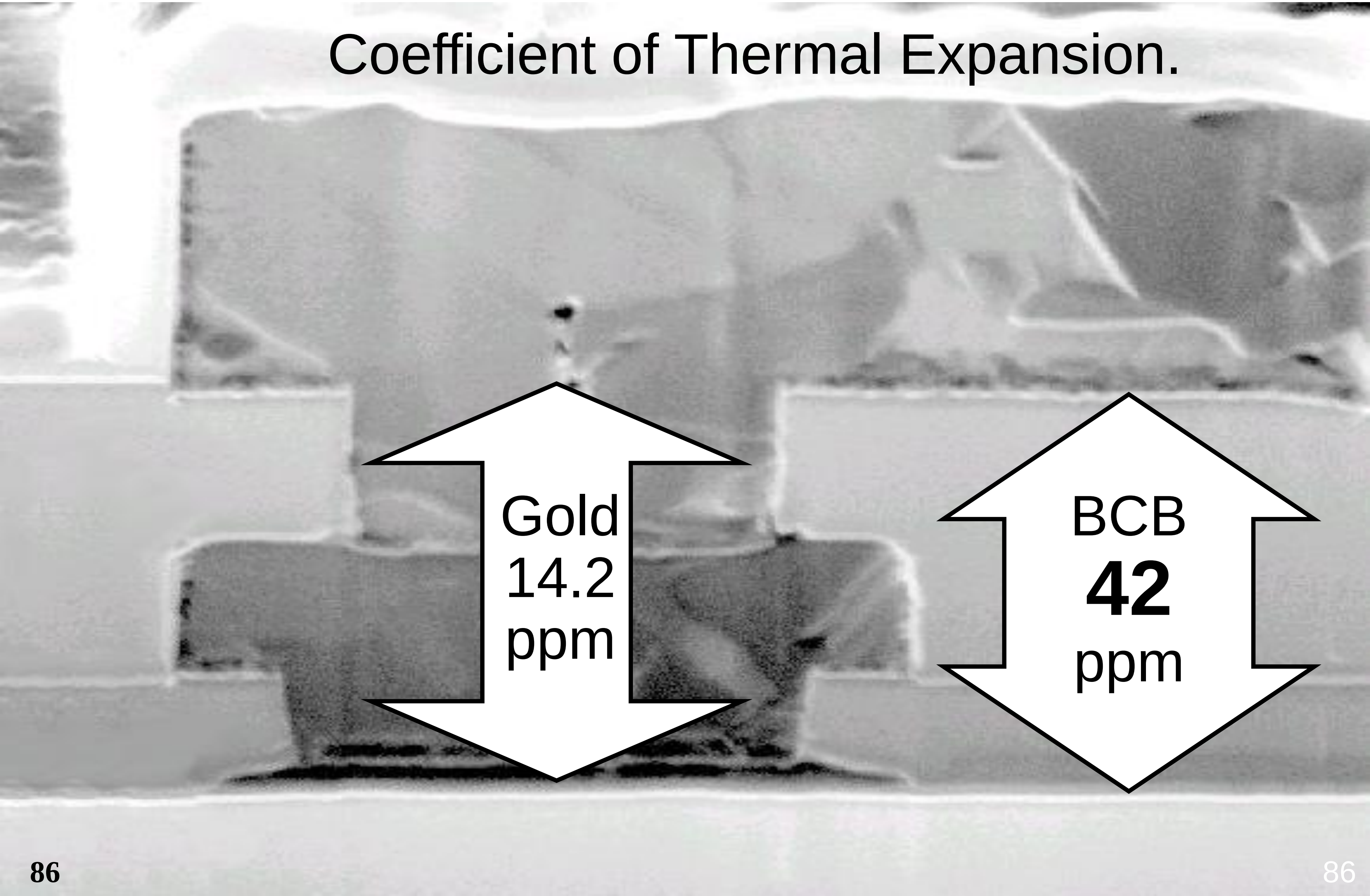
1 Solder Reflow = 144 Cycles
-40ºC to +125ºC

or

4.99 Million Cycles
0ºC to +100ºC

Why Excursions Work?

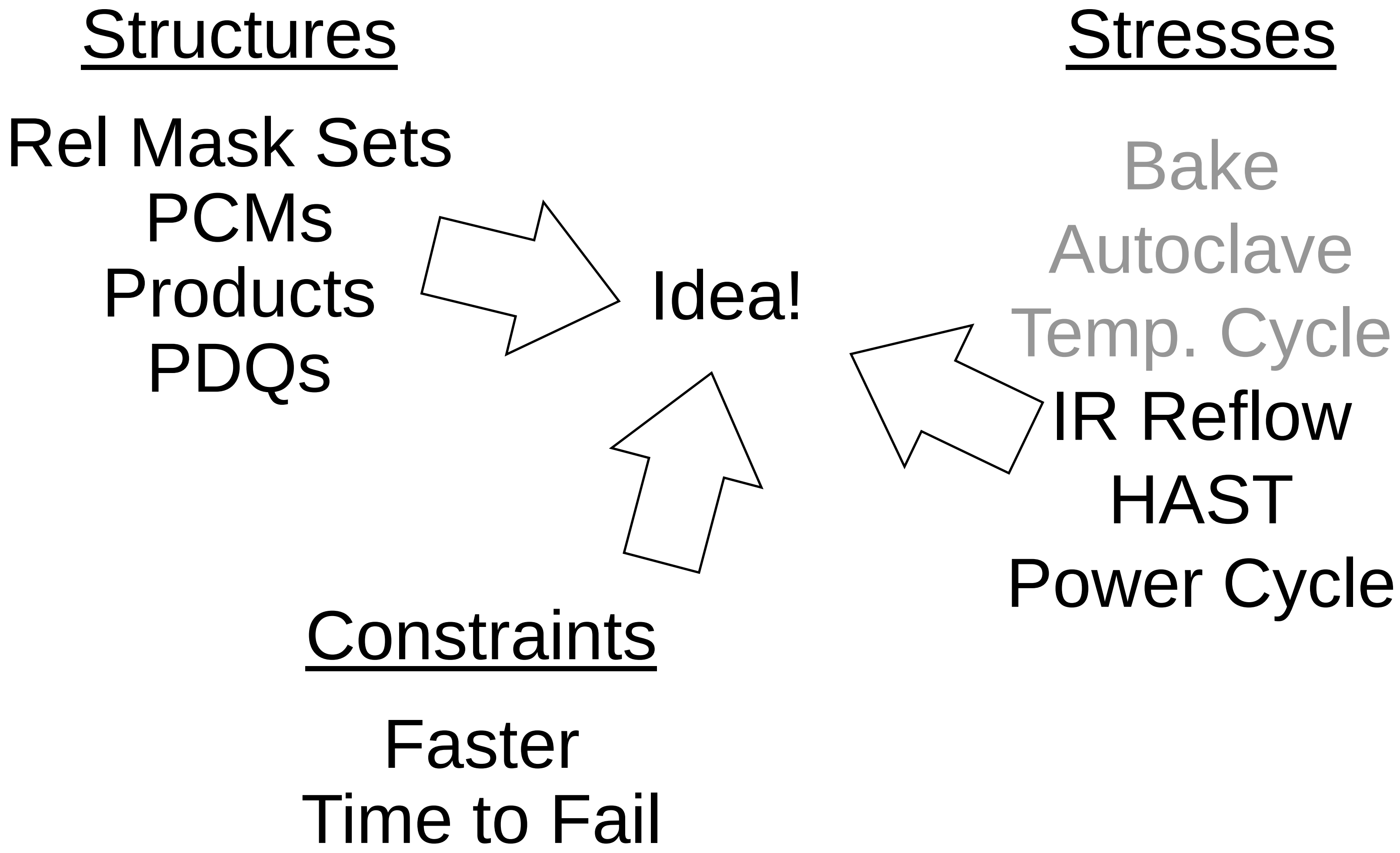
Coefficient of Thermal Expansion.



Gold 14.2 ppm

BCB **42** ppm

Excursions: Building on the Tool



Structures

Rel Mask Sets
PCMs
Products
PDQs

Idea!

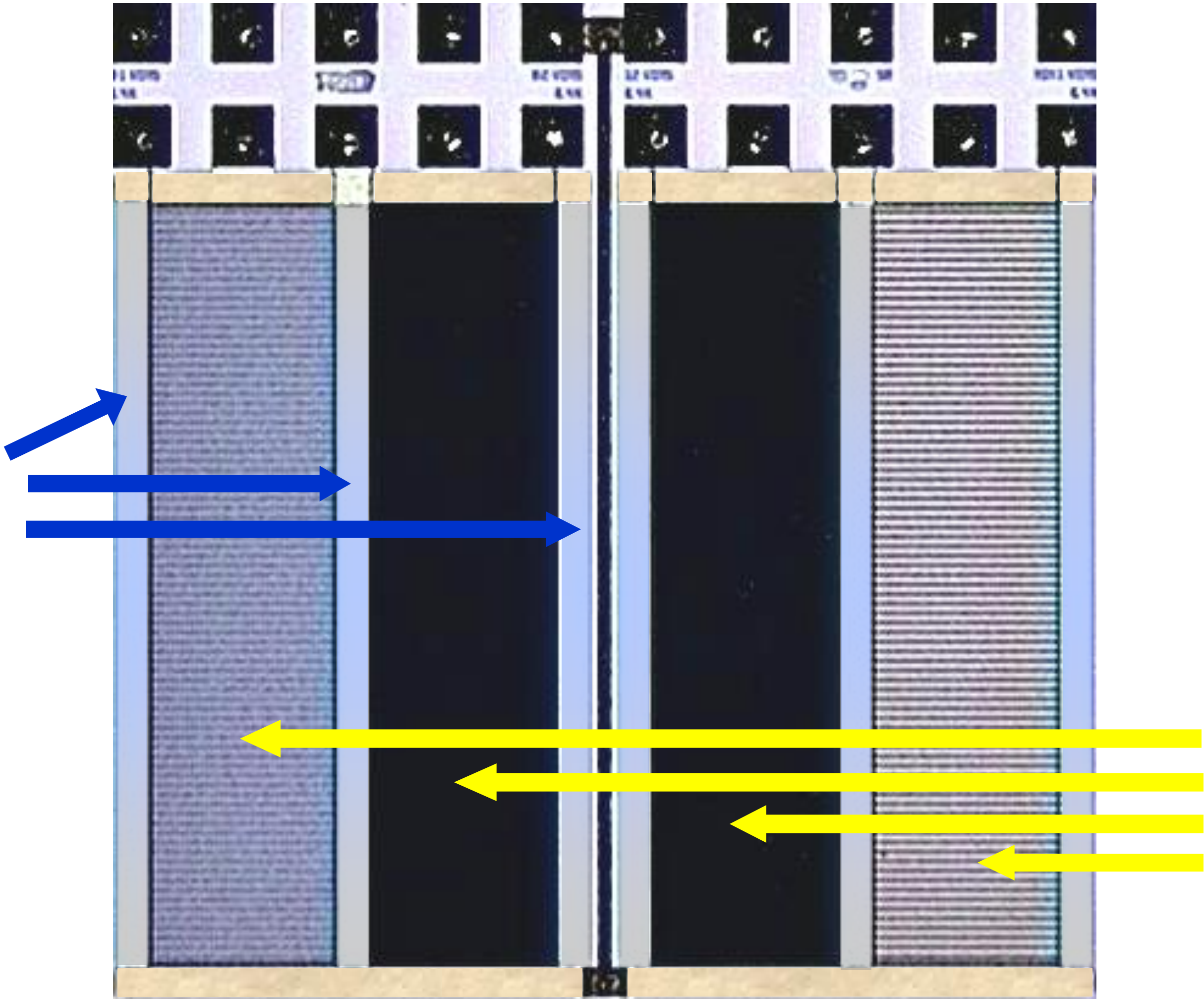
Stresses

Bake
Autoclave
Temp. Cycle
IR Reflow
HAST
Power Cycle

Constraints

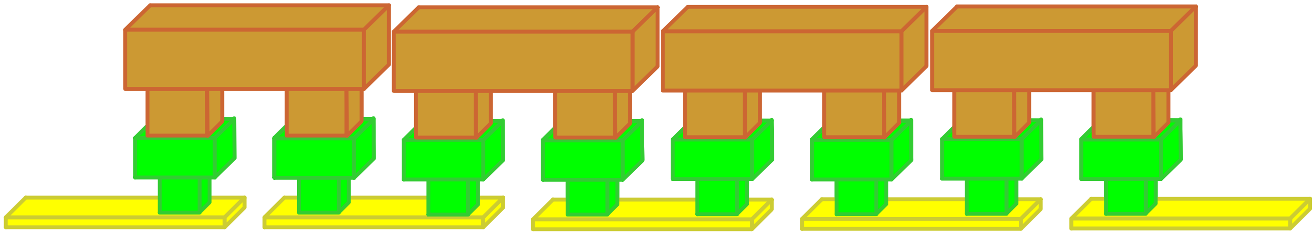
Faster
Time to Fail

Investigation: Via Chains & Power Cycling

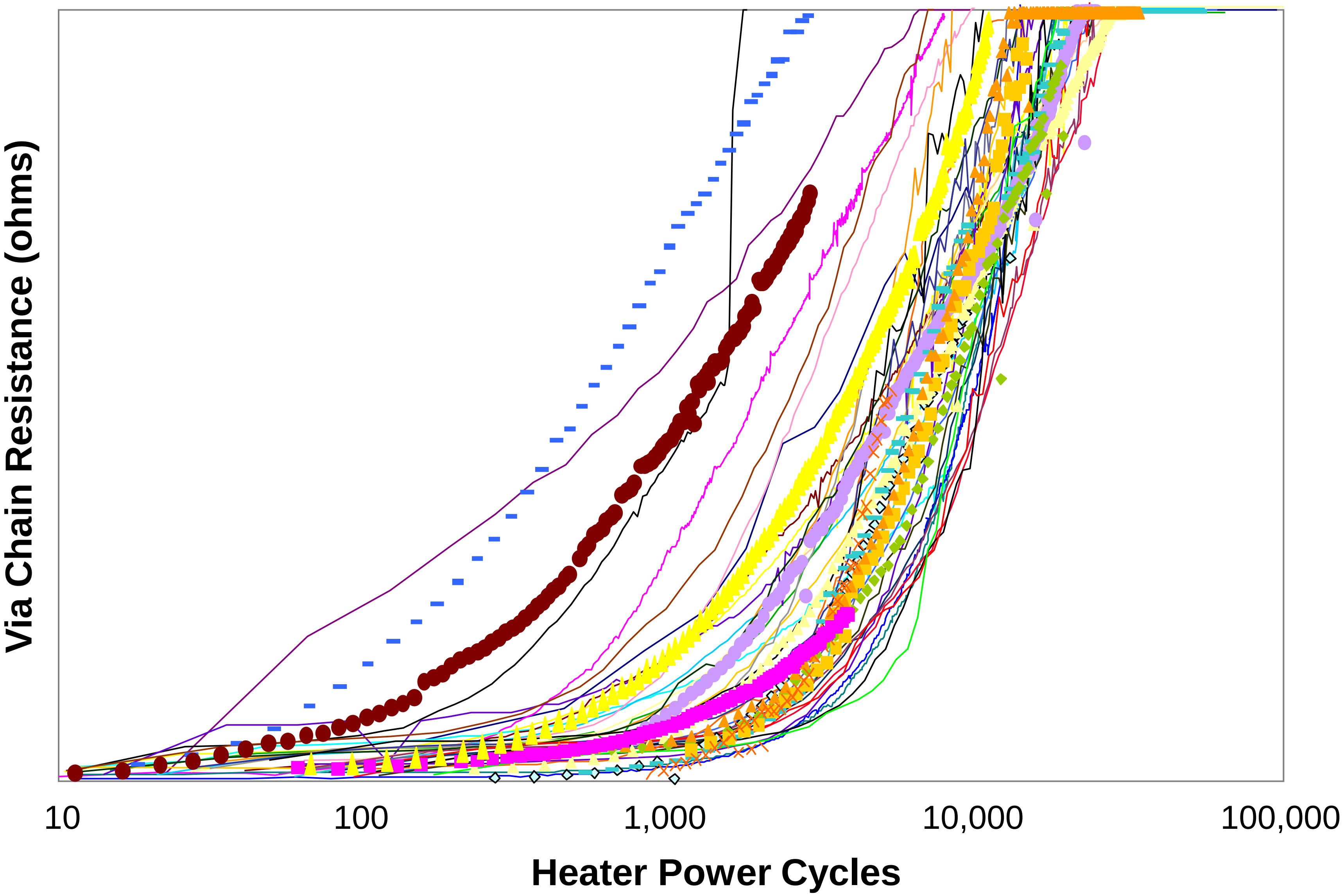


Each Array Surrounded by NiCr “heater” Resistors.

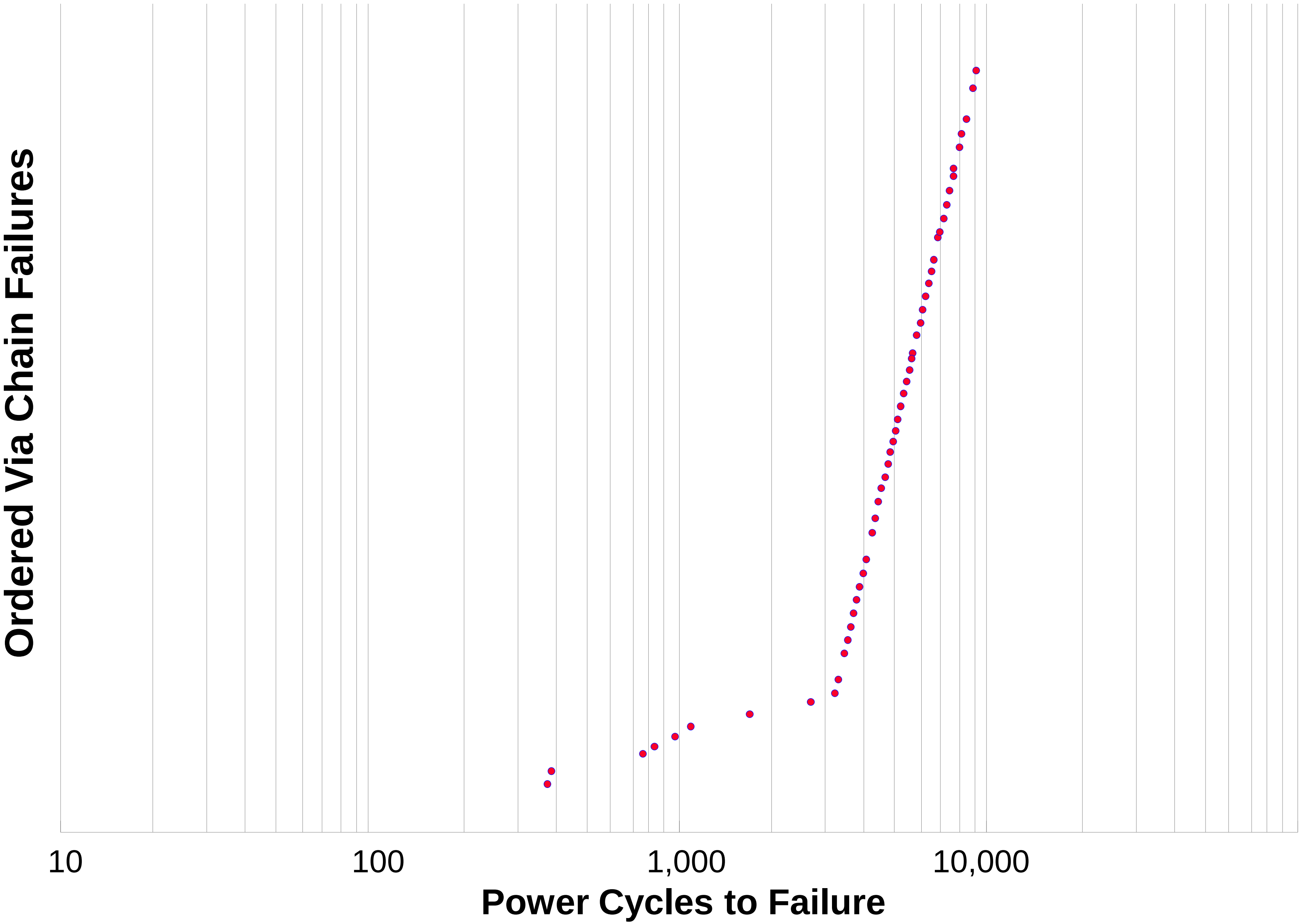
Four Via Chain Arrays. Up to 6,500 links each.



Investigation: Preliminary Results



Ramp Cycle to Failure Plot ("TDDB" for power cycling)



Thermal Excursions - Summary

1. **Log Distribution.**

2. **Shock = Cycle. (-40ºC to +125ºC)**

3. **Rate decrease with delta.**

4. **Solder reflow: most severe stress.**

5. **Failures are <u>not</u> random.**

Summary

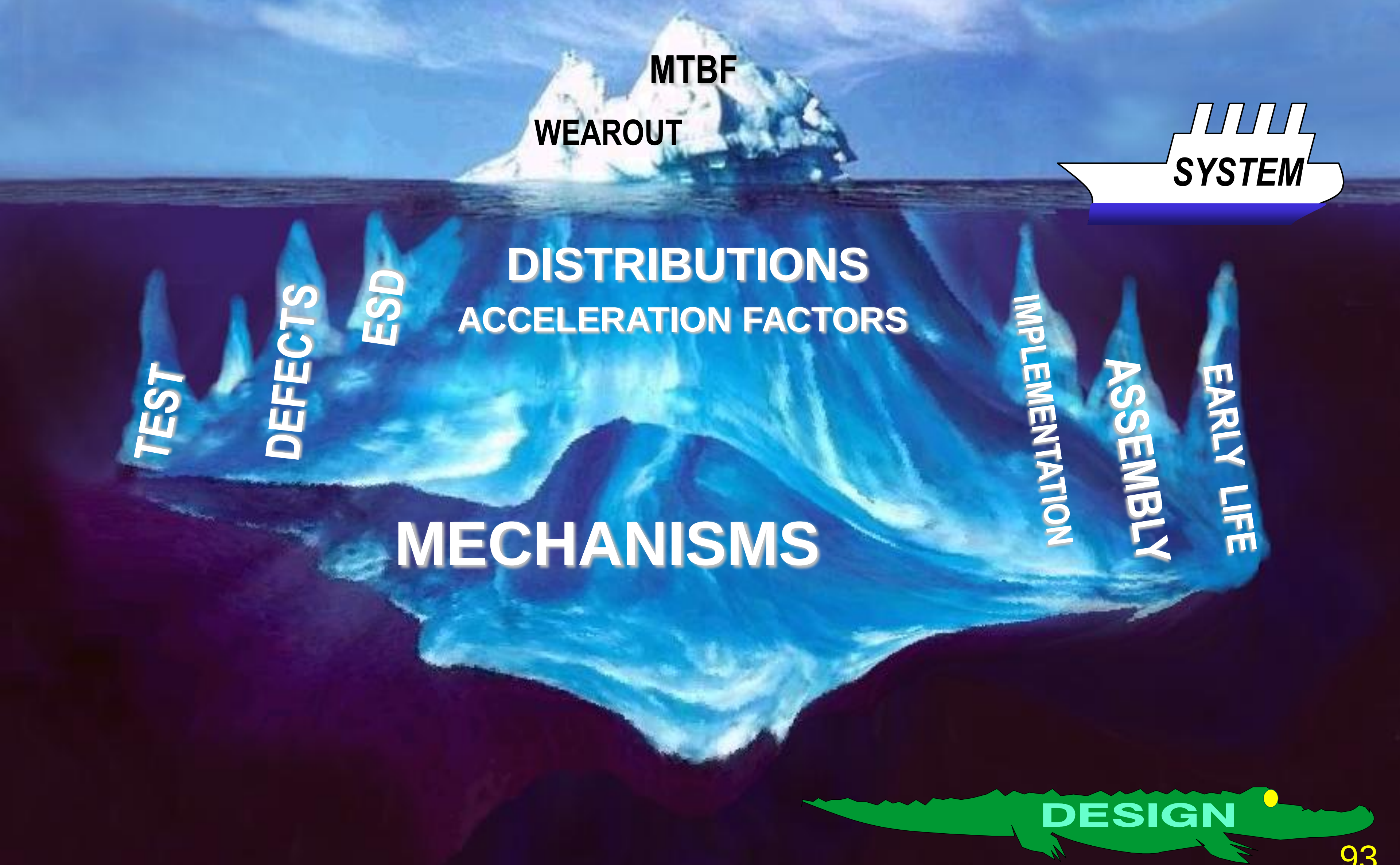
Basics

- A little about Compound Semiconductors
- Vocabulary
- A new era for reliability
- Arrhenius methodology review

Beyond the Basics . . .

- **Learning from customers: it's a *Natural*** Natural Failure Mechanisms
- **Breaking the cycle of learning curves** Manufacturability
- **Tipping your cap** Using Capacitor Voltage Example for FETs
- **The Black magic of current density** Black's Equation for HBTs
- **Amped up on defects** Amplification of Defects with spacing & V
- **The new PC** Power Cycling is a new acceleration option

User Perspective



Acronym List

2DEG: Two Dimensional Electron Gas
AB: Airbridge
A/C: Autoclave
BCB: Benzocyclobutene, *Cyclotene*
BD: Base Dielectric
BFET: Interdigitated FET layout approximately 300um Gate
BIR: Building-In Reliability or Built-In Reliability
CS: Compound Semiconductor
CSs: Compound Semiconductors
DFET: Depletion Mode FET
DPM: Defects Per Million
Ea: Activation Energy
EFET: Enhancement Mode FET
ELFR: Early Life Failure Rate
EOS: Electrical OverStress
ESD: ElectroStatic Discharge
FET: Field Effect Transistor (MESFET or pHEMT)
FIB: Focused Ion Beam
GaAs: Gallium Arsenide
HAST: Highly Accelerated Stress Test
HBT: Heterojunction Bipolar Transistor
HP: Hair Pin (emitter shape layout for HBTs)
ILD: InterLayer Dielectric
IR: InfraRed or sometimes Infrared Reflow
IRPS: International Reliability Physics Symposium
LA: Liftoff Assist, a layer to aid liftoff patterning
M1: Metal One, first layer global interconnect, plated-up Gold
M2: Metal Two, Second layer global interconnect, plated-up Gold
MESFET: MEtal Semiconductor Field Effect Transistor
M0 or MET0: Metal Zero, the local interconnect liftoff layer
MIM: Metal Insulator Metal capacitor, top plate liftoff metal of capacitors
MMIC: Monolithic Microwave Integrated Circuit
MTBF: Median Time Between Failures
NiCr: Nickel Chromium thin film resistor
P/C: Preconditioning
PECVD: Plasma Enhanced Chemical Vapor Deposition
pHEMT: pseudomorphic High Electron Mobility Transistor
PR: PhotoResist
PIN: Diode with an intrinsic region.
PPM: Parts Per Million
RF: Radio Frequency
RH: Relative Humidity
REDC: Recombination Enhanced Defect Reaction
ROCS: Reliability Of Compound Semiconductors Workshop.
    Formerly known as the GaAs REL Workshop from 1985-2003.
SBC: Standard Bipolar Cell
SEM: Scanning Electron Microscope
Si_xNi_x: Silicon Nitride
SIP: System In Package (module)
SOC: System On Chip (integrated solution)
STEM: Scanning Transmission Electron Microscope
SPC: Statistical Process Control
Svia: Substrate via, interconnect through the wafer
T/C: Temperature Cycle
TDDB: Time Dependent Dielectric Breakdown
TFR: Thin Film Resistor
TQS: TriQuint Semiconductor
WLR: Wafer Level Reliability
WSR: Wafer Scale Reliability

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