

# **A Preview of the Semiconductor Reliability Short Course**

**A totally new Semiconductor Reliability Short Course and Handbook has been developed to maximize your productivity by:**

**giving you a general understanding of Semiconductor Reliability  
making it easier to understand the mechanisms that cause  
complex circuits to degrade**

**providing you with the opportunity to learn how to determine the  
reliability of a component based on its failure mechanisms**

**The following pages provide an overview of the material typically  
presented in this unique course. The course is complemented by  
our 500+ page Handbook and a color CD ROM with a complete,  
full-color copy of the Handbook and all of the slides presented in  
the course.**

**We invite comparison with any other course.**

**To find the schedule of classes and to register visit  
[www.semitracks.com](http://www.semitracks.com)**



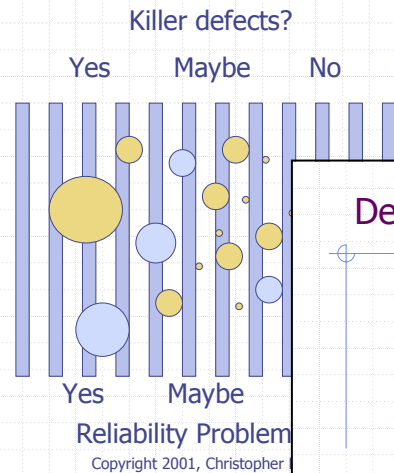
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Semiconductor, Microelectronics, Microsystems and Nanotechnology Training

**Semiconductor Reliability Short Course Preview 1**

# Learn the relationship between yield and reliability

## Defects and Reliability

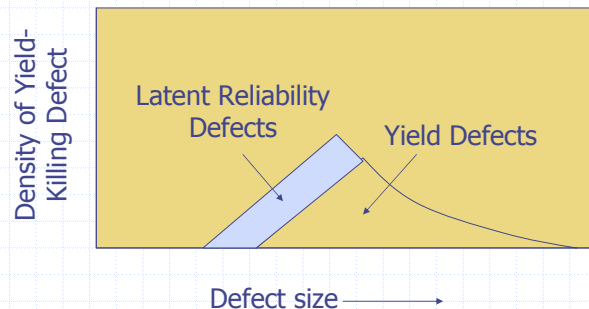


## Accept/Reject Lots Based on Yield

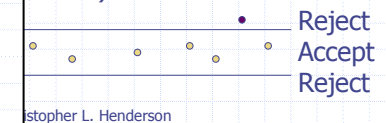
- Customers/manufacturers believe that reliability qualification was performed on a well controlled line
- Therefore we should reject lots with yield

## Density of Yield and Reliability Defects

The goal is to use the number of yield defects to predict the number of reliability defects



control (quality problem)  
yielding lots  
high-yielding lots (if process control)



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**Semiconductor Reliability Short Course Preview 2**

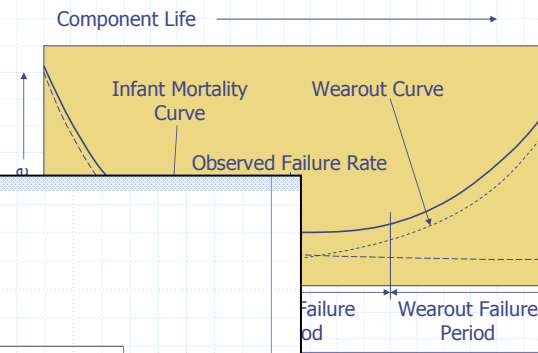
# Learn the statistics necessary to understand reliability calculations

## Probability Basics

- ◆ Probability – Expected relative frequency of occurrence of a specific event in a large group of possible outcomes
  - Coin toss example
- ◆ Conditional probability
  - $P(AB) = P(A)P(B|A)$  – one another, e.g. a
  - $P(AB) = P(A)P(B)$  – another, e.g. a coin

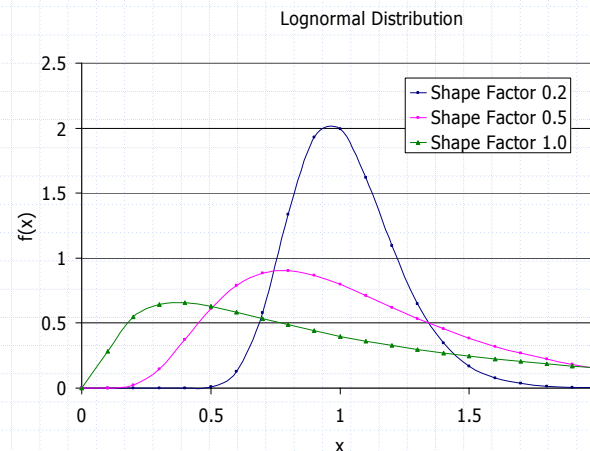
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## The Bathtub Curve for Failure Rates



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## The Lognormal Distribution



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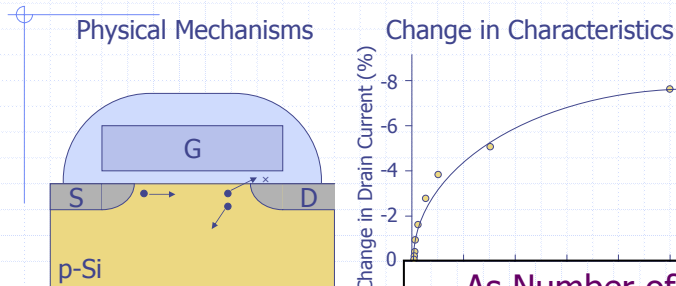
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**Semiconductor Reliability Short Course Preview 3**

# Learn how to use the appropriate distribution for the mechanism

## An Example – Hot Carrier Degradation

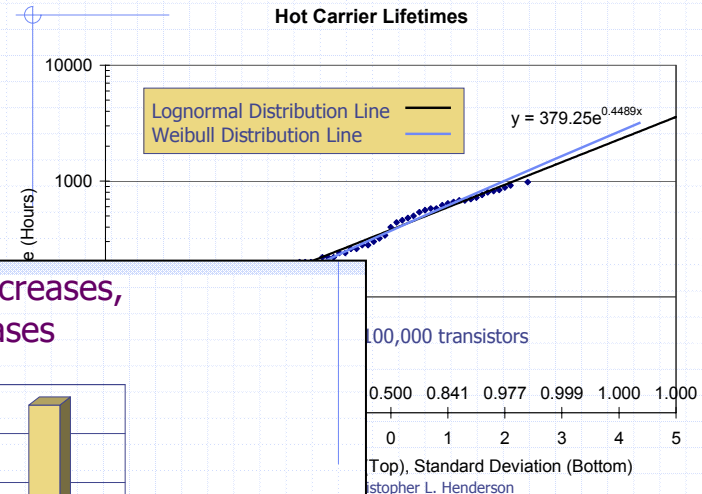


Large field near drain causes

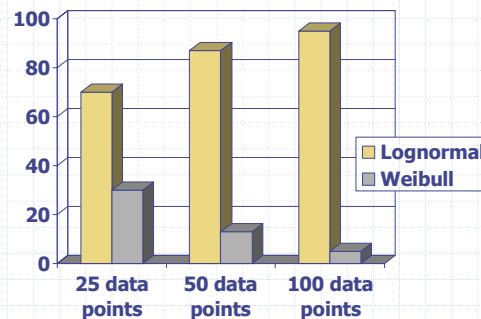
- Interface state generation
- Electron trapping/de-trapping
- Hole trapping/de-trapping

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## Distribution Type Changes Outcome



## As Number of Points Increases, Misidentification Decreases



After Bill Hunter  
TI, IRW, 1999

Conclusion: We need ~100 points to confidently distinguish between the two distributions.

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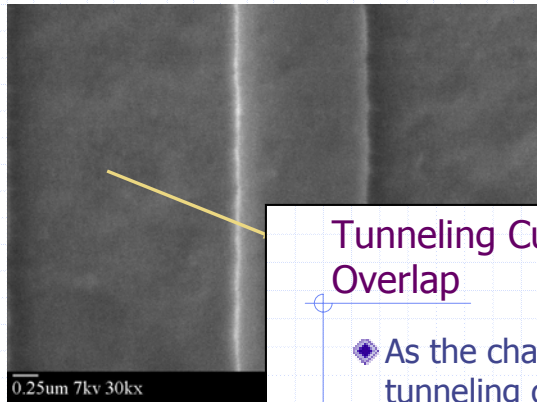
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# Learn the physics behind Time-Dependent Dielectric Breakdown (TDDB)

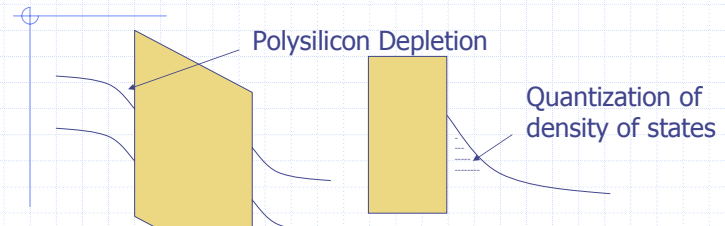
## Time Dependent Dielectric Breakdown



Results of Dielectric Breakdown

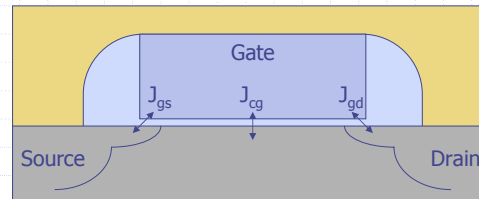
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## Voltage and Electric Field (cont.)



## Tunneling Current – Gate to Source/Drain Overlap

- ◆ As the channel length decreases, the tunneling current associated with the source/drain overlap region increases as a percentage of total current



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Polysilicon is important mainly because as the poly becomes depleted

(due to electric fields) the voltage drop across the gate includes the effects of density of states

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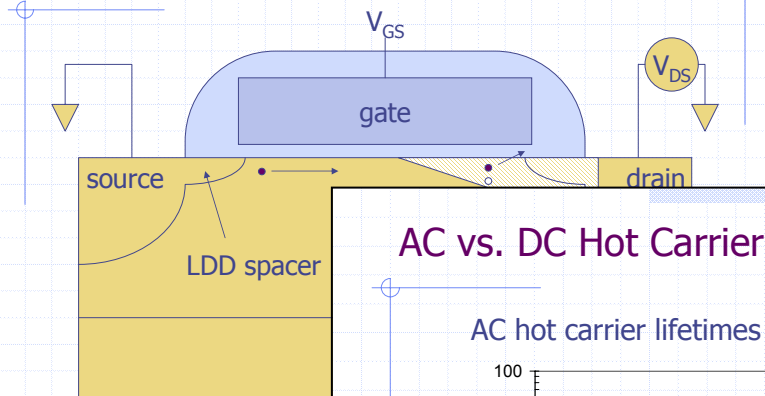
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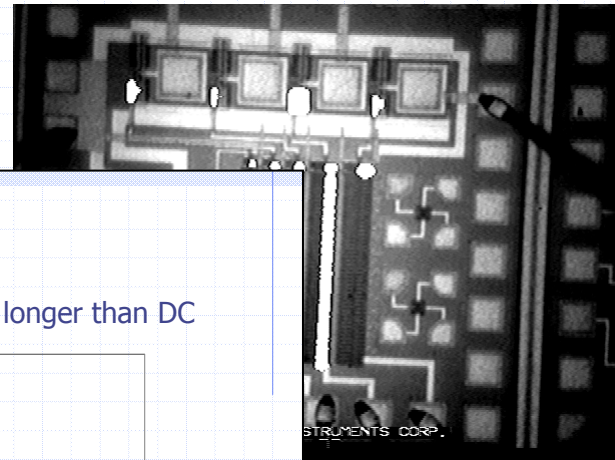
# Learn the physics behind Hot Carrier Injection

## Hot Carrier Degradation Mechanisms



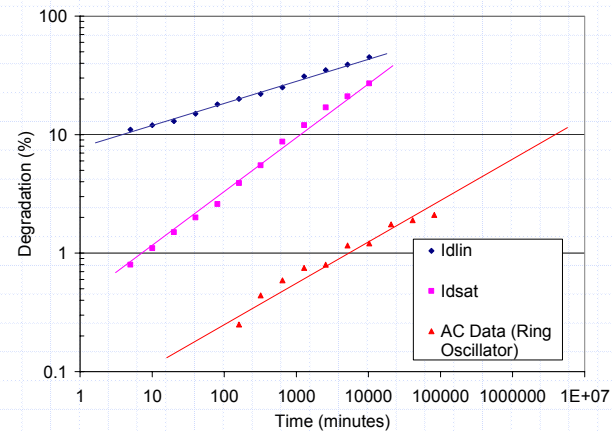
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## Light Emission Ring Oscillator (N-channel Devices in Saturation)



## AC vs. DC Hot Carrier Effects

AC hot carrier lifetimes are much longer than DC



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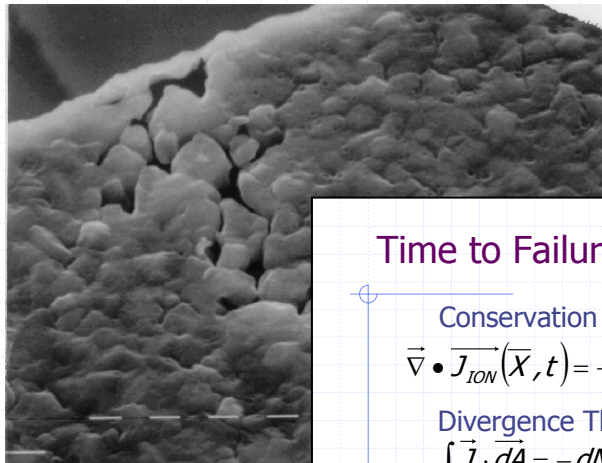
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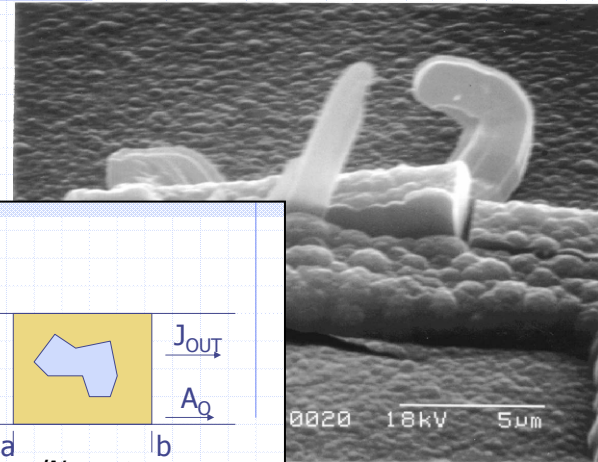
# Learn about electromigration and how to prevent it

Electromigration Failure - Open



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Electromigration – Metal Extrusion



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## Time to Failure Equation

Conservation of Mass

$$\vec{\nabla} \cdot \vec{J}_{ION}(X, t) = -\frac{\partial n(X, t)}{\partial t}$$

Divergence Theorem

$$\int_A \vec{J} \cdot d\vec{A} = -dN(t)/dt$$

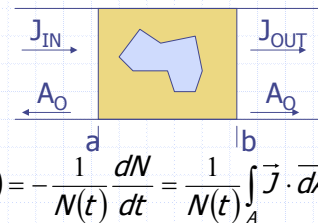
### Rate Equation

$$dN/dt = -\lambda(t) \cdot N(t)$$

### Time-to-failure Equation

$$TTF = \frac{LN(t_{crit})}{\left( \int \vec{J} \cdot d\vec{A} \right)}, \text{ where } t_{crit} = \frac{N(t=0)}{N(t=TTF)}$$

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$$\lambda(t) = -\frac{1}{N(t)} \frac{dN}{dt} = \frac{1}{N(t)} \int_A \vec{J} \cdot d\vec{A}$$

$$\frac{N(t)}{N_0} = \exp\left(\int_0^t \lambda(t) dt\right)$$



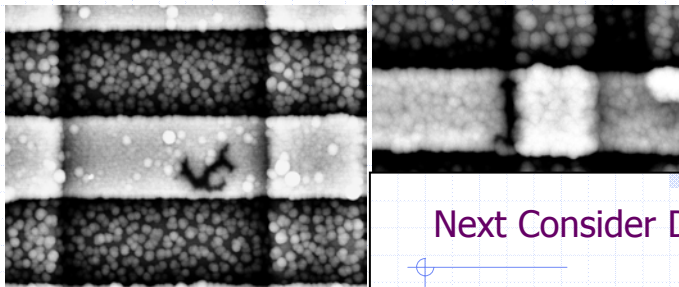
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# Learn the subtleties surrounding Stress Induced Voiding

## Another Example of Stress Voiding



- crack shape in evaporated metal
- can grow during processing or take years
- non-Arrhenius acceleration
- acceleration factor is small

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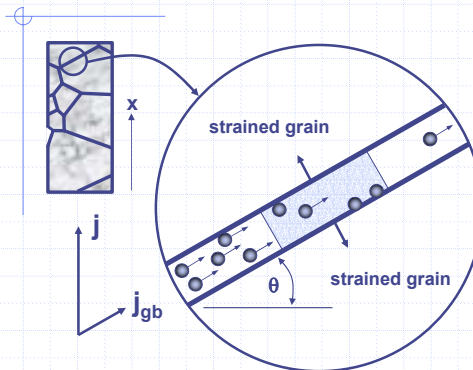
## Intermetallic Reaction Stress



	$\rho$ (gm/cc)	At. Wt. (gm/mole)	Molar Volume (cc/mole)
Ti	4.54	47.90	10.55
Al	2.70	26.98	9.99
Ti+3Al	-	-	40.53
TiAl <sub>3</sub>	3.36	128.84	38.38

$$\Delta V/V = (38.38 - 40.53)/40.53 = -5.3\%$$

## Next Consider Details at Grain Boundary



# atoms entering 'gray box' = # atoms leaving + # atoms staying to relax the stress

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$$j_{gb} = \frac{D \sin \theta}{kT} \cdot \frac{\partial \sigma}{\partial x}$$



$$\frac{x_{TiAl_3}}{x_{Ti}} = \frac{38.38}{10.55} = 3.64$$

ated film or interconnect, the volume

ated interconnect, volume cannot  
e stiff); strain is induced

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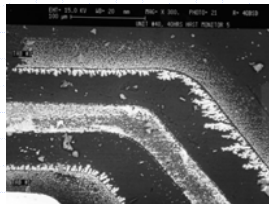


# Gain Insight into a Variety of Packaging-Related Failure Mechanisms

## Internal Moisture Mechanism

### ◆ TAB Interlead Leakage/Shorts

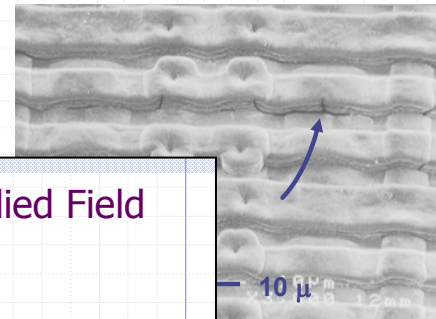
- Requires bias
- Accelerated by temperature & humidity
- Seen as early as 20 hrs HAST
- Highly dependent on device design



Copper dendrites after 40 hrs HAST

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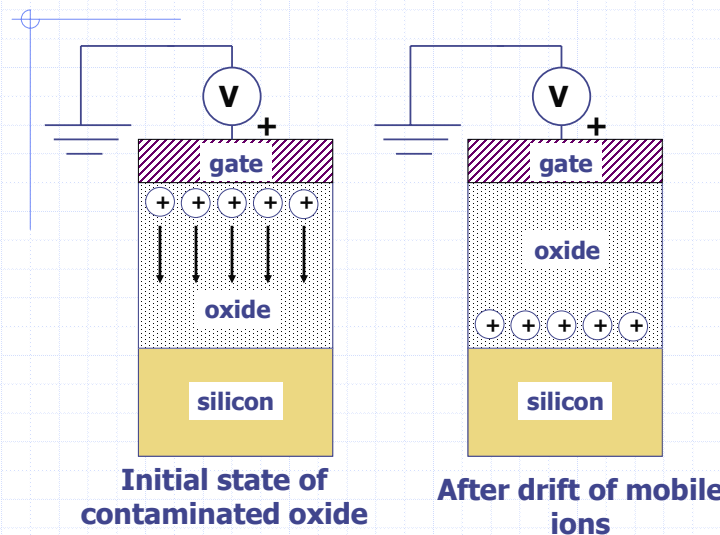
## Logic Failure Due to Passivation Damage



Logic device after HAST stress.  
M. Shew, Intel

Christopher L. Henderson

## Effect of Mobile Ion Under an Applied Field



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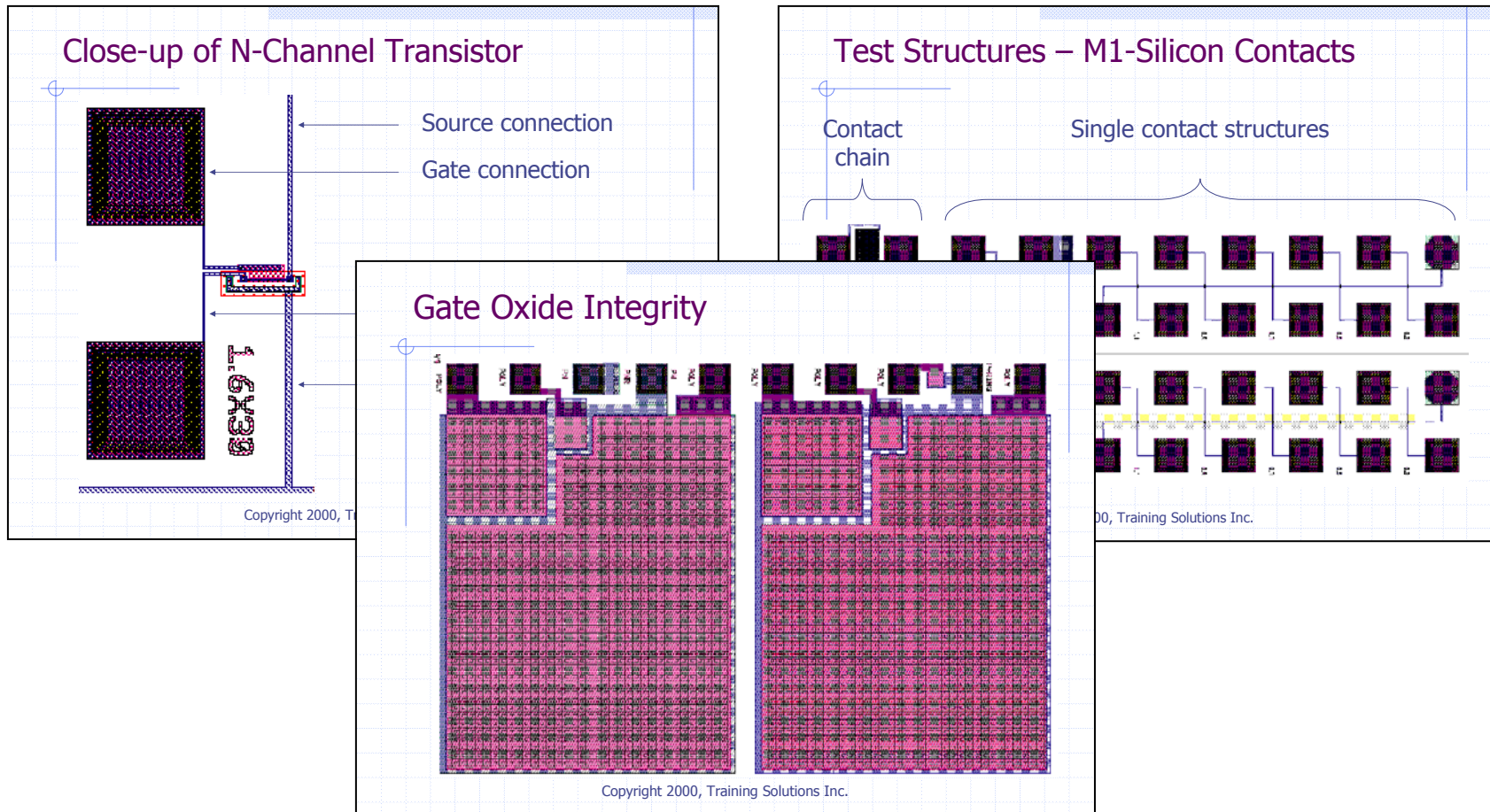


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**Semiconductor Reliability Short Course Preview 9**

# Learn How to Use Test Structures to Evaluate Reliability at the Wafer Level



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# Get Up-to-Date Information on the Latest in Reliability Test Equipment and Software

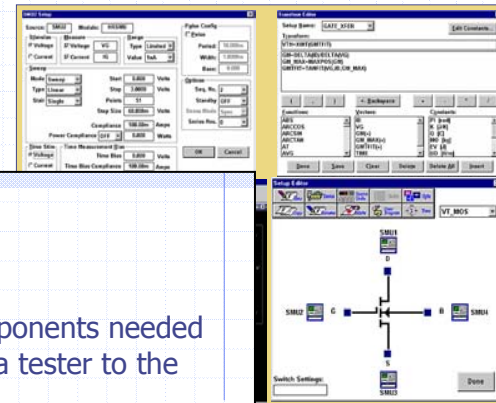
## Agilent HP 4070 Series



Measure

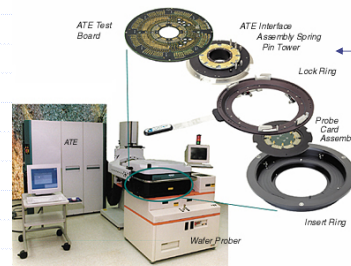
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## Metrics ICS Software



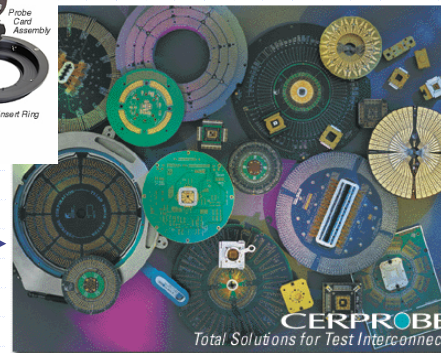
Interfaces with numerous probes and analyzers  
Christopher L. Henderson

## Cerprobe Technology



Various components needed to interface a tester to the wafer

Various probe cards



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# Make the Correct Decisions When Designing Screens and Burn-In Tests

## Burn-In Acceleration Factors

$$MTF = C_o e^{(E_A/kT)}$$

Let's assume an activation energy of 1eV and a stress of 125°C. What is the acceleration in mean time to failure?

$$\frac{MTF_{125}}{MTF_{25}} = \frac{C_o e^{(1\text{eV}/8.617 \cdot 10^{-5} \cdot 398)} }{C_o e^{(1\text{eV}/8.617 \cdot 10^{-5} \cdot 298)} }$$

In other words, the same device will fail at room temperature

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## Activation Energies for Common Mechanisms

Failure Mechanisms	Activation Energy	Reference
Metal Corrosion	0.3 to 0.6 eV	Hakim 1989
	0.77 to 0.81 eV	Peck 1986
Electromigration	0.5 eV (small grained Al)	Black 1982
	1.0 eV (large grained Al)	Jensen 1982
Metallization Migration	2.3 eV	Jensen 1982
Stress Induced Voiding	0.4 eV, 1.0-1.4 eV	McPherson 1987, Tezaki 1990
		Amerasekara 1987, Jensen 1982
		Hakim 1989
		Jensen, 1982
		Baglee 1984
		Hokari 1982, Crook 1979, Anolick 1979, McPherson 1985
		Anolick 1979
		Amerasekara 1987
		Hakim 1989, Mizugashira 1985

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## Arrhenius Type Model for Corrosion

Hallberg and Peck derived an equation to describe the relative life for the corrosion mechanism

$$RelativeLife = (85/RH)^n \cdot \exp[(E_A/k)(1/T - 1/358)]$$

Where RH is the relative humidity, n is a constant, EA is the activation energy for metallization corrosion, k is Boltzmann's constant and T is the absolute temperature in kelvin

Relative lifetime with respect to 85/85 conditions

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