2007 International Reliability Physics Symposium Tutorial

Sample Slides From INTRODUCTION TO IC RELIABILITY TUTORIAL

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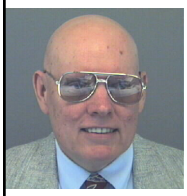
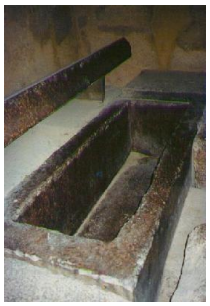
Material is from the 3-day Introduction to IC Reliability Course

Speaker's Bio



Dr. Ted Dellin is the Chief Scientist Emeritus of the Microsystems Center at Sandia National Laboratories having retired from full time work after 35 years at Sandia. He still runs the Microsystems University that he established at Sandia. Dr. Dellin has led the development of the reliability section of the International Technology Roadmap for Semiconductors since the 1990s and is a member of the Sematech Reliability Technical Advisory Board. He is a past chair of the IEEE Nonvolatile Memory Workshop and has given 4 tutorials at the International Reliability Physics Symposium. He has also taught a series of short course in microelectronics and reliability for organizations in the U.S. and Europe. He is a coauthor with Arlene Dellin of the 21st Century Semiconductor Technology Handbook and he contributed the Submicron CMOS chapter to the ASM Failure Analysis Desk Reference. Dr. Dellin has a PhD in physics from the City University of New York.

Unfortunately for the Pharaoh Cheops The Great Pyramid's Reliability = 0

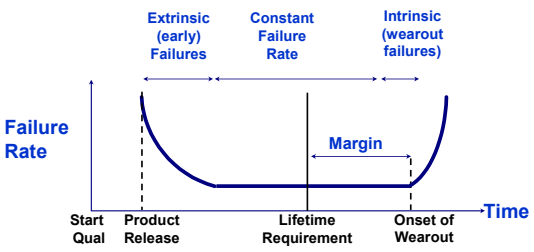


- What was its specified function?
  - *To protect the Pharaoh and his possessions*
- What was the specified environment?
  - *Anything that happened*
- What was the specified lifetime?
  - *Eternity*
- What was the reliability
  - *Tomb broken into in antiquity*
  - *Reliability, R = 0*

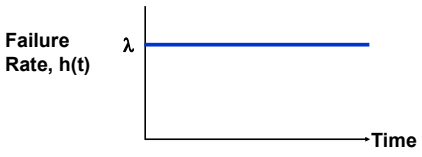
Why is Reliability So Challenging?

- There are multiple failure mechanisms
  - *Mechanisms change with new materials and new devices*
- For each failure mechanism there is a distribution of lifetimes
- Reliability lifetime requirements are too long for real-time testing
- Failure rate requirements are so low that a very large number of samples are required
- Reliability cannot be independently optimized. It must be traded off against performance, cost, time to market, …

Intrinsic and Extrinsic Defects Lead to the "Bathtub Curve"

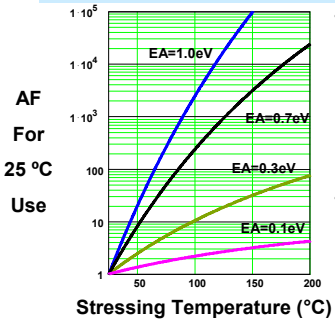


Exponential Distribution: *Failure Rate, h(t)*



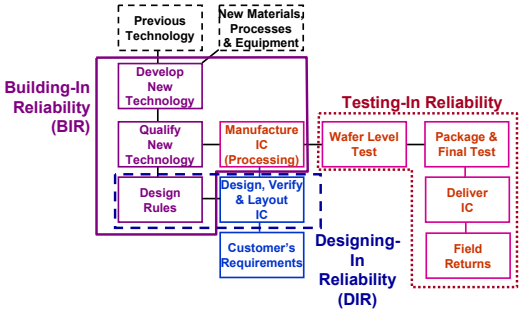
- Only distribution with a constant failure rate
- "Lack of Memory" Instantaneous failure rate the same no matter how long the part has been operated

Acceleration Factor For Room Temperature Use (25 ºC)

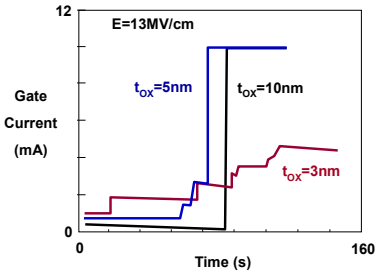


- Curve shows the acceleration factor for a part used at 25ºC as a function of
  - *Temperature it is stressed at for accelerated aging*
  - *Activation energy*
- Acceleration factor increases with
  - Increasing temperature
  - Increasing activation energy

Building-In (BIR), Designing-In (DIR) and Testing-In Reliability



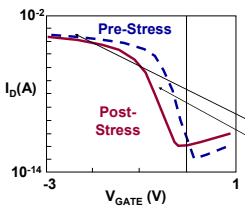
The Oxide Breakdown Depends On Oxide Thickness



- Stressed at same E field
- As oxides are thinned below 5nm change from sudden breakdown to a more gradual degradation

John Suhle, NIST

Negative Bias Temperature Instability (NBTI) In p Channel MOSFETS



- Physics
  - Low stress voltages
  - Increase in + oxide charge
  - Increase in interface states
- Cause gradual degradation in device properties
  - Saturation current
  - Threshold voltage
- Appears to get worse with scaling down of channel length and oxide thickness
- Burn-in could be a problem

Al to Cu: Electromigration (EM) Issues

Aluminum		Copper
Higher diffusivity (Worse for EM)	⇒	Lower diffusivity (Better for EM)
Lowest energy diffusion along grain boundaries	⇒	Lowest energy diffusion along surfaces
No EM in Tungsten vias	⇒	EM in Cu vias
Capping layers can shunt current across voids	⇒	Barrier layer an ineffective shunt
Better understood process and failure mode	⇒	Newer, less well understood

To Learn More

- The complete 3-day Integrated Circuit Reliability Short Course, July 10-12, 2007, Albuquerque
- Meeting the Submicron CMOS Challenge, May 16-17, 2007, Albuquerque
- Semiconductor Technologies with MEMs, August/September, 2007, Albuquerqu,
- For more information, including sample slides, visit www.quickstartmicro.com