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Modeling and Simulation for Lifetime Predictions

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Physics of Failure: Modeling and Simulation for Lifetime Predictions

Naval Postgraduate School

Background

- Current reliability lifetime predictions are reliant on MILHDBK-217F and other outdated historical data sources
- Desire to move toward a probabilistic physics of failure-based approach to assessing system reliability and availability
- Need for method to combine physics of failure models to develop more accurate and comprehensive reliability prediction

Unreliable components can cause system failures.

Failure Mechanism	Failure Sites	Failure Causes	Failure Models	Equations
Fatigue	Die attach, Wirebond/TAB, Solder leads, Bond pads, Traces	Cyclic Deformations (Δ T, Δ H, Δ V)	Nonlinear Power Law (Coffin-Manson)	$N_f^{\beta} \Delta\gamma^{p} = C^{p}$
Corrosion	Metallizations	M, ΔV, T, chemical	Eyring (Howard)	$t_f = \frac{w * l * h * n * d * F}{M * V} * \frac{\rho}{t}$
Corrosion (electrolytic)	Metallizations	Δ H, T, ΔV	Peck	$t_f = A_o * RH^{-n} * f(v) * e^{-\frac{E_a}{kT}}$
Electromigration	Metallizations	T, J	Eyring (Black)	$MTF = \frac{A}{j^2} * e^{\left(\frac{E_a}{kT}\right)}$
Conductive Filament Formation	Between Metallizations	M, ΛV	Power Law (Rudra)	$t_f = \frac{af(1000L_{eff})^n}{V^m(M - M_t)}$
Time Dependent Dielectric Breakdown	Dielectric layers	V, T	Thermochemical (E Model)	$T_{BD} = A_o e^{[-\gamma \varepsilon_{OX}]} e^{\left[\frac{E_a}{kT}\right]}$
Δ: Cyclic range V: Voltage Λ: gradient M: Moisture T: Temperature J: Current density H: Humidity σ: Stress				

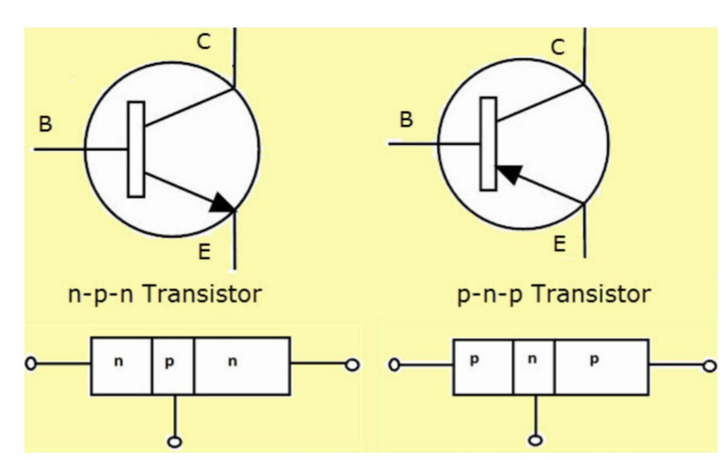
Common failure mechanisms for microelectronics

Approach

- We are evaluating physics of failure models and probabilistic approaches to combine failure mechanisms for microelectronics such as a transistor
- Subsequent FY20 and beyond work may examine how to combine other circuit card component information into a circuit card-level analysis
- Eventually, the research may provide a method of analyzing an entire system for reliability using a merged probabilistic physics of failure approach

Big Picture Implications

- There is dissatisfaction in the reliability community over using historical data approaches that rely on old data sources
  - Reliability predictions using traditional methods are highly dependent upon the interpretation of the data source and can lead to conservative or overly optimistic results
- A merged probabilistic physics of failure approach to reliability for lifetime predictions may help to bring more reality to the process
- Realistic lifetime predictions allow stakeholders and program managers to make informed design, procurement, maintenance, and sustainment decisions



Transistors are a critical component of many systems that have reliability concerns

Future Partners

- We are working with SSP to develop this work to be useful for their systems
- We are looking for more partners who may be interested in participating

Future Work

- Desire to more closely integrate lifetime prediction and reliability with availability metrics and other important system requirements
- System design methodology based on physics of failure reliability analysis

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