WARP:
A Centralized Repository for Physics-Based Models

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2012 Physics-Based Modeling in Design and Development for U.S. Defense
Outline

- Introduction
- WARP Objective and Concept
- WARP Tasking
- WARP Database Record Types
- Features of the WARP Website
- Current Status/Future Work
- Contact Information
Introduction

- Current Trend in Reliability is Towards Physics-Based Approaches to Design for Reliability (DFR)
- No Centralized Repository for Physics-of-Failure Models
- PoF Models Have Received Limited Exposure and Acceptance Despite Greater Recognition of Value
- RIAC Funded by Defense Technical Information Center (DTIC) to Develop the Web-Accessible Repository of Physics-Based Models (WARP)
  - Effort was completed in May 2012
  - Quanterion Solutions Incorporated (Model Research/Database Development/Website Development)
  - University of Maryland Center for Risk and Reliability (Model Research)
WARP Objective and Concept

- Collect, Analyze and Catalog the Existence and Characteristics of PoF Models
- Provide a Centralized Web-based Repository of PoF Models for Researchers and Engineers
- Promote Understanding of:
  - What PoF models are needed to fully characterize component reliability (major failure mechanisms, including package-related)
  - What PoF models already exist to meet that need
  - What PoF models are missing to fill the gap (presents opportunities for research)
  - What data/information is required to exercise a specific model
  - Where can the required data/information be obtained
WARP Objective and Concept

Web-Based PoF Model Submittal or “Model Needed” Request

Model Info Submittal or Request Requires Member Registration & Login

RIAC Confirms WARP Membership and Reviews PoF Model Source Document Before Approving

Web-Based PoF Model User (no member registration or login required)

RIAC Confirms WARP Membership and Reviews PoF Model Source Document Before Approving

Additional Area Accessible Only to WARP Model Contributing Members

Additional Area Accessible Only to RIAC Administrators

Establishes separate Search, Forum, Help and Feedback Areas for Users/ Members
WARP Objective and Concept

- Rules for Submitting PoF Models to WARP
  - Submitted information based on source document “facts”
  - No copyright violations
  - Editorial comments on a specific model restricted to WARP Forum (monitored by RIAC)
  - Editorial comments must be accompanied by supporting rationale and/or data/documentation

- Rules for Suggesting PoF Models
  - PoF model does not appear in WARP or the literature
    - Represents a “gap” in the PoF Model domain (research opportunity)
  - Associated component/technology types must be identified
WARP Development Process

- Develop Taxonomy of Component/Technology Types to which PoF Models Should Apply
  - Based on Draft MIL-HDBK-217G and RIAC NPRD publication

- Research and Collect Failure Mechanism Models
  - Over 150 resources were evaluated as potential PoF model sources (published literature, RIAC/UMD/DTIC libraries, research reports, etc.)

- Develop Database and Website
WARP Database Record Types

- **Four Major Types**
  - PoF Failure Mechanism Model Technical Record
  - Bibliographic Citation Record
  - Point-of-Contact Records:
    - For obtaining copy of document
    - For contacting the model developer
    - For contacting the person submitting validation data
  - Model Validation Record
WARP Database Record Types

Validation Data for Existing or New PoF Model Info Submitted by Registered “User” on RIAC Website

Validation Data for PoF Confirmed and Qualified by RIAC

RIAC Repository Administrator Creates and Appends Validation Record(s)

PoF Model Info Submitted by Registered “User” on RIAC Website

PoF Model Info and Source Confirmed and Qualified by RIAC

RIAC Repository Administrator Creates Record

PoF Model Validation Data Record (Many-to-1 Relationship to PoF Model Technical Record)

PoF Model Technical Record (“x” of Many)

Published Literature

Model taken from...

Non-Published Sources

PoF Model Validation Data Record

Bibliographic Citation Record (1-to-1 Relationship to PoF Model Technical Record)

Point-of-Contact Record (1-to-1 Relationship to Bibliographic Citation Record and/or PoF Model Technical Record)

Output PoF Model Technical Record to:
- Report
- Screen
- Hardcopy
- File
Add to RIAC Website (includes User Capability to Generate Output Reports)
Overview of WARP PoF Model Record

- PoF Model Title: Analysis of the Effects of Compressive Stresses on Fatigue Crack Propagation Rate
- Primary Model Image: 
- Model Tree Diagram: 
- Primary Model Parameters:
  - \( \frac{da}{dN} = C[1 - \gamma \left( \sigma_{\text{max}} / \sigma_p \right)]^{\phi} (K_{\text{max}})^{2(\alpha + \beta + 1)} \) (Click on an image to see full size version)
  - Parameters:
    - \( C \): Material constant
    - \( \gamma \): Bauschinger effect parameter
    - \( \sigma_{\text{max}} \): Maximum compressive stress level of the stress cycle
    - \( \sigma_{\text{YS}} \): Material yield stress
    - \( \beta \): Constant
    - \( K_{\text{max}} \): Maximum stress intensity factor corresponding to the maximum applied stress
    - \( \alpha \): Constant
  - Units:
    - \( \frac{da}{dN} \): Fatigue crack propagation rate
    - \( C \): Material constant
    - \( \gamma \): Bauschinger effect parameter
    - \( \sigma_{\text{max}} \): Maximum compressive stress level of the stress cycle
    - \( \sigma_{\text{YS}} \): Material yield stress
    - \( \beta \): Constant
    - \( K_{\text{max}} \): Maximum stress intensity factor corresponding to the maximum applied stress
    - \( \alpha \): Constant
  - View Sub-Model
  - Value
  - Units
  - View
  - \( \sigma_{\text{YS}} \): Not Specified
  - \( K_{\text{max}} \): Not Specified
  - \( \alpha \): Not Specified
  - \( C \): Not Specified
  - \( \gamma \): Not Specified
  - \( \sigma_{\text{max}} \): Not Specified
  - \( \sigma_{\text{YS}} \): Not Specified
  - \( K_{\text{max}} \): Not Specified
  - \( \alpha \): Not Specified
  - \( C \): Not Specified
  - \( \gamma \): Not Specified
  - \( \sigma_{\text{max}} \): Not Specified
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  - \( \alpha \): Not Specified
  - \( C \): Not Specified
  - \( \gamma \): Not Specified
  - \( \sigma_{\text{max}} \): Not Specified
  - \( \sigma_{\text{YS}} \): Not Specified
  - \( K_{\text{max}} \): Not Specified
  - \( \alpha \): Not Specified
### Failure Mechanism Addressed by Model

<table>
<thead>
<tr>
<th>Failure Mechanism</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td></td>
</tr>
</tbody>
</table>

### Component/Technology Types

<table>
<thead>
<tr>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallic Materials</td>
</tr>
</tbody>
</table>

### Characteristics of Model Development (as Described in Source Document)

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effect of Compressive Stresses</td>
<td>This model was developed to more accurately account for the effect of compressive stresses on fatigue crack growth; specifically for constant amplitude loading when the stress ratio (R) is less than 0. The effects are due to the continuous increase of the size of the reverse plastic zone with the increase of the applied compressive stress.</td>
</tr>
<tr>
<td>Finite Element Analysis</td>
<td>FEA was used in this study to understand the change of near crack tip opening displacement and the plasticity around the crack tip under tension-compression loading. The analysis considered a center crack panel (CCP) specimen with a crack length of 2mm. The applied stress ratio (R) was -1.</td>
</tr>
<tr>
<td>Maximum Reverse Plastic Zone Size</td>
<td>Under tension-compression loading and small scale yielding, the maximum reverse plastic zone size (a parameter affecting crack growth) can be expressed as a function of the maximum stress intensity factor (Kmax), and the maximum applied compressive stress (sigma maxcom).</td>
</tr>
<tr>
<td>Bauschinger Effect</td>
<td>For materials with strong anisotropic hardening or softening behavior, the Bauschinger Effect is the most important plastic cyclic property in terms of negative loading effect on fatigue crack growth. It strongly influences the reverse plasticity and near crack tip opening displacement. Its influence is reflected by parameter gamma of this model.</td>
</tr>
<tr>
<td>Kmax for R&lt;0</td>
<td>The maximum stress intensity factor (Kmax) for tension-compression constant amplitude loading with stress ratio R&lt;0 is determined from a modification to Kmax for R&gt;0 constant amplitude loading.</td>
</tr>
<tr>
<td>Parameters α and β</td>
<td>Parameters α and β can be calculated from two positive constant amplitude loading fatigue crack propagation test results. However, as these aren't always available, a previous reference developed the following relationships to determine the values of these two parameters. β=2α, and 2(β+α+1)=m, where m represents the exponential constant in Paris' crack growth law.</td>
</tr>
</tbody>
</table>
Overview of WARP PoF Model Record

Model Assumptions, Limitations, Constraints and Uncertainty Limits (as described in Source Document)

Data/Information Needed to Exercise the Model
Overview of WARP PoF Model Record

### Bibliographic Citation

<table>
<thead>
<tr>
<th>Published Status</th>
<th>Source Type</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Published</td>
<td>Article/Paper</td>
<td>Analysis of the Effects of Compressive Stresses on Fatigue Crack Propagation Rate</td>
<td>J. Zhang, S. Y Dai, X. D He</td>
</tr>
</tbody>
</table>

### Abstract/Summary

In this study, the effects of compressive stresses on the crack tip parameters and its implication on fatigue crack growth have been studied. Elastic-plastic finite element analysis has been used to analyse the change of crack tip parameters with the increase of the applied compressive stress level. The near crack tip opening displacements and the reverse plastic zone size around the crack tip have been obtained. The finite element analysis shows that when unloading from peak tensile applied stress to zero applied stress, the crack tip is still kept open and the crack tip opening displacement gradually decreases further with the applied compressive stress. It has been found that for a tension-compression stress cycle these crack tip parameters are determined mainly by two loading parameters, the maximum stress intensity $K_{max}$ in the tension part of the stress cycle and the maximum compressive stress $\maxcom$ in the compression part of the stress cycle. Based on the two parameters, $K_{max}$ and $\maxcom$, a fatigue crack propagation model for negative $R$ ratios only has been developed to include the compressive stress effect on the fatigue crack propagation rate. Experimental fatigue crack propagation data sets were used for the verification of this model, good agreements have been obtained.

<table>
<thead>
<tr>
<th>Report #</th>
<th>Publication Name</th>
<th>Volume #</th>
<th>Publisher Name</th>
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<tbody>
<tr>
<td>N/A</td>
<td>International Journal of Fatigue</td>
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<tr>
<td>2007-01-04</td>
<td>1751–1756</td>
<td><a href="http://www.sciencedirect.com">http://www.sciencedirect.com</a></td>
<td>2007 Elsevier Ltd. All rights reserved</td>
</tr>
</tbody>
</table>

### Technical Point of Contact (PoC)

**J. Zhang**  
Personally Developed Model

If you would like to contact this person:

[Send a message](#)

### Model Usefulness Rating

1 for not useful and 5 for very useful.

[Rate this model](#)
Overview of WARP PoF Model Record

Direct Link to WARP Forum for This Specific Model

Add Model Validation Data (Contributing Members Only)

Validation data can be added by the original model developer, the author, or by independent contributors
Features of the RIAC WARP Website

- Registered Members can Submit Models, Suggest Gaps Where Models are Needed, Participate in Forum
  - Forum promotes constructive discussion
  - Specific WARP Forum topic area set up to suggest “gaps”
- Select Models by Component Type or Failure Mechanism
- Search by Component/Technology Type, PoF Failure Mechanism, or any Keyword
  - General or Advanced Search
- Conceptual “Matrix” of Component/Technology Type vs. Applicable PoF Models
- Individual PoF Model Records Highlight When Data or Information is Needed from an Internal Test or an External Source (e.g., Dimensions/Properties) to Exercise the Model
Submit Models/Suggest Gaps

Model Submission Page

- Model Title: Example Model Development
- Failure Mechanism:
  - Indicates a Failure Mechanism which can be used but has not been approved.
  - Add a comment: □
- User Created Image Upload:
  - Valid Extensions: gif, jpeg, png, swf, psd, bmp, tiff, gif, htm, xhtm, and ico
  - Add a comment: □
- Model Parameters:
  - Parameter Type | Value | Units
  - Add a comment: □
- Model Component Types:
  - Add a comment: □

Current Model Tree:

- Example Model Development

Suggest A Component Type

- Please specify the component type's name, whether it is electronic or non-electronic, and any known failure mechanisms of the part.
- Note: All components suggested and relations of those components to failure mechanisms will be subject to an approval process.

Suggest A New Component Type

- Component Type Name: □
- Electronic: □
- Non-Electronic: □

All Failure Mechanisms:
- Anomalous Charge Loss
- Capacitance Degradation
- Conductive Filament Formation
- Corrosion Fatigue
- Creep
- Creep Fatigue
- Creep-Rupture
- Crystal Quality Degradation
- Delamination
- Dielectric Degradation
- Dielectric Thinning
- Electromigration
- Erosion
- Fatigue
- Fatigue, Thermomechanical
- Hot Carrier Injection
- Insulation Resistance Degradation
- Interface trap annihilation
- Low Temperature Data Retention
- Negative Bias Temperature Instability

This Component's Failure Mechanisms:
Participate in Forum

![Image of the RAC Reliability Information Analysis Center website](Image)

<table>
<thead>
<tr>
<th>Thread / Thread Starter</th>
<th>Rating</th>
<th>Last Post</th>
<th>Replies</th>
<th>Views</th>
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<td>Analysis of the Effects of Comprehensive Stresses on Fatigue Crack Propagation Rate</td>
<td></td>
<td>Today 01:34 PM by WARP-ADMIN</td>
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<td>Deep Trap SILC (Stress Induced Leakage Current) Model For Nominal and Weak Oxides</td>
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<tr>
<td>Fatigue Life of 63Sn-37Pb Solder Related to Load Drop Under Uniaxial and Torsional Loading</td>
<td></td>
<td>09-07-2012 11:18 AM by WARP-ADMIN</td>
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<td>10</td>
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<td>Chip Scale Package (CSP) Solder Joint Reliability and Modeling</td>
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<td>03-23-2012 04:27 PM by WARP-ADMIN</td>
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<td>Threshold Voltage Shift in 0.1 μm Self-Aligned Gate GaAs MESFETs Under Bias Stress</td>
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<td>03-22-2012 04:12 PM by WARP-ADMIN</td>
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<td>Charge Trapping Mechanism under Dynamic Stress and its Effect on Failure Time</td>
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<td>03-22-2012 10:30 AM by WARP-ADMIN</td>
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<td>Polarity-Dependent Device Degradation in SONOS Transistors Due to Gate Conduction</td>
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<td>01-18-2012 04:40 PM by WARP-ADMIN</td>
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<td>Stabilization Breakdowns and Reliability of Solid Tantalum Capacitors</td>
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<td>Thin-Gate Oxide Breakdown and CPU Failure-Rate Estimation</td>
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<td>01-16-2012 10:40 AM by WARP-ADMIN</td>
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<td>Re-consideration of Influence of Silicon Wafer Surface Orientation on Gate Oxide Reliability</td>
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<td>01-13-2012 09:29 PM by WARP-ADMIN</td>
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<td>Ultrathin Gate-Oxide Breakdown—Reversibility at Low Voltage</td>
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<td>01-13-2012 10:17 AM by WARP-ADMIN</td>
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<td>Reliability Properties of Low-Voltage Ferroelectric Capacitors and Memory Arrays</td>
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<td>Statistical Modeling for Postcycling Data Retention of Split-Gate Flash Memories</td>
<td></td>
<td>01-12-2012 10:20 AM by WARP-ADMIN</td>
<td>0</td>
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</tbody>
</table>

**The Reliability Analysis and Control (RAC) is a Department of Defense Information Analysis Center sponsored by the Defense Technical Information Center.**
Select Models By Type or Mechanism

Select Models By Component Type

Instructions For Selecting Models By Component Type

To view a model first select a component type below.

Pressing the + button will expand the group of component types.

The number of pending models associated with that metric type is displayed in brackets and italicized [n].

The number of approved models associated with that metric type is displayed in parentheses (#).

Selecting a component type will display all the approved models associated below the component type.

Selecting a model title will display that model.

The selected component type is displayed in white text with a red background.

Model titles are displayed in blue text, with a bullet before the title of the model.

Click here to suggest a new component type.

Electronic Component Types

Approved Component Types

With Models

Capacitor, Fixed, Chip, Multilayer, Ceramic Dielectric // (4)

- Accelerated Life Testing and Reliability of High K Multilayer Ceramic Capacitors
- Capacitor, Fixed, Electrolytic (Solid), Tantalum (1)
- Capacitor, Fixed, Electrolytic (Solid), Tantalum Chip (1)
- Capacitor, Fixed, Supermetallized Plastic Film Dielectric // (1)
- Capacitor, Monolithic Microwave Integrated Circuit (MMIC) // (2)
- Capacitor, Silicon Nitride (1)
- Capacitor, Thin Film Ferroelectric (2)
- Interconnection Assembly, Plated-Through Holes (3)
- Interconnection Assembly, Surface Mount (3)

Select Models By Failure Mechanism

Instructions For Selecting Models By Failure Mechanism

To view a model first select a failure mechanism below.

The number of pending models associated with that metric type is displayed in brackets and italicized [n].

The number of approved models associated with that metric type is displayed in parentheses (#).

Selecting a failure mechanism will display all the approved models associated below the failure mechanism.

Selecting a model title will display that model.

The selected failure mechanism is displayed in white text with a red background.

Model titles are displayed in blue text, with a bullet before the title of the model.

Click here to suggest a new failure mechanism.

Failure Mechanisms

Approved Mechanisms

With Models

Anomalous Charge Loss (1)
- Physical Charge Transport Models for Anomalous Leakage Current in Floating Gate-Based Memory Cells
- Capacitance Degradation (2)
- Conductive Filament Formation (3)
- Corrosion Fatigue (2)
- Creep (1)
- Creep-Fatigue (2) (1)
- Creep-Rupture (1)
- Crystal Quality Degradation (1)
- Delamination (1)
- Dielectric Degradation (1) (2)
- Electromigration (1) (2)
Search By Component or Mechanism

Search Results

This field allows the user to search the repository for specific words/phrases and returns the approved models with fields that contain those terms. If you would like to narrow the results by only searching specific model fields, click the 'Advanced Search' button.

- **Capacitor**
- **Search Models**
- **Advanced Search**

Accelerated Life Testing and Reliability of High K Multilayer Ceramic Capacitors

\[ I = AV^{-n} \exp\left(\frac{E_a}{kT}\right) \]  

The reliability of high K multilayer ceramic capacitors was evaluated using accelerated life testing. The degradation in insulation resistance was characterized as a function of voltage (two to eight times rated) and temperature (85 to 110°C).

Silicon Nitride MIM Capacitor Reliability for Multiple Dielectric Thickness

\[ \tau(V_d) = \frac{C}{V_d} \exp\left(-\frac{D(V_d)}{kT}\right) \]  

A single GaAs MMIC fabrication flow produces three different types of silicon nitride capacitors, with 50 nm, 200 nm, and 250 nm nominal dielectric thickness. Ramp-up data indicates that all three types are reliable. The results are compared to predictions of the linear field and Frenkel-Poole conduction models for capacitor lifetime at fixed voltages.

The Reliability Study of MIM Capacitor Built On Top of Backside Via In III-V Compound MMIC

\[ QBD = J \cdot tBD \]  

We report a compact and reliable MIMCAP directly on backside through via (MIMCAP-ON-Via). The potential performance effects of a capacitor on backside via is explored with charging via density and the total number of vias.

Scintillation Breakdowns and Reliability of Solid Taunum Capacitors

\[ TF = t \cdot \exp\left\{ \frac{M}{kT} \times \left[ 1 - \frac{V}{V_c} \right] \right\} \]  

Scintillations are moment-to-moment local breakdowns in tantalum capacitors, which are often considered as failures rather than failures. However, this paper shows that scintillations are damaging for more than 30% of part types and up to 100% for some lots.

Reliability Properties of Low-Voltage Ferroelectric Capacitors and Memory Arrays

\[ \tau(V_d) = \exp\left(-\frac{D(V_d)}{kT}\right) \]  

We report on the reliability properties of ferroelectric capacitors and memory arrays embedded in a 130-nm CMOS logic process with ILD Cu/FSI. Low voltage (<1...
Advanced Search

Search Results

This field allows the user to search the repository for specific words/phrases and returns the approved models with fields that contain those terms. If you would like to narrow the results by only searching specific model fields, click the "Advanced Search" button.

Dielectric

Select the model fields within which you would like to search:

- Titles:
- Abstracts:
- Component Types:
- Failure Mechanisms:
- Bibliographic Citations:
- Characteristics:
- Variables:
- Assumptions:
- Constraints:
- Limitations:
- Authors:
- Any of the query:
- All of the query:

A New TDDB Degradation Model Based On Cu Ion Drift in Cu Interconnect Dielectrics

\[ \tau_{\text{TDDB}} \approx \frac{E^2}{kT} \exp \left( -\frac{q}{kT} \left( \frac{q}{\pi e^2} \right)^{1/3} \sqrt{E} \right) \]

A new physical model of Time-Dependent Dielectric Breakdown (TDDB) in Cu interconnect dielectrics is proposed. TDDB occurs due to the drift of Cu ions under an electric field E...

A Physical Model of Time-Dependent Dielectric Breakdown In Copper Metallization

\[ \tau_{\text{TDDB}} = B \exp \left( \frac{E_s - q\lambda E}{kT} \right) \]

A physical model of copper interconnect dielectric breakdown is studied. The general continuity equation about Cu diffusion and drift is evaluated...
Select Models by Failure Mechanisms and Related Components

Instructions

This page displays approved models by both the failure mechanism and component type.

The number of approved models associated with that component type is displayed in parentheses (#). The number of pending models associated with that component type is displayed in brackets and italicized [/#].

Selecting a component type under a failure mechanism will display all the approved models associated with the failure mechanism/component type combination below the component type. Selecting a model title will display that model.

The selected component type is displayed in white text with a red background. Model titles are displayed in blue text, with a bullet before the title of the model.

This page is sorted by failure mechanisms. Click here to sort by components.

Failure Mechanisms and Related Components

Approved Failure Mechanism
With Approved Component Types

- Anomalous Charge Loss
  - Microcircuit, Monolithic, Bipolar, Memory (1)
  - Microcircuit, Monolithic, MOS, Memory (1)

- Capacitance Degradation
  - Capacitor, Fixed, Supremetalized Plastic Film Dielectric /[1]
### Assumptions

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Flow</td>
<td>Assumes that a molecular flow is the dominant mechanism of moisture ingress for leaks less than $10E-4$ atm cm$^{-2}$/s.</td>
</tr>
<tr>
<td>Initial Pressure</td>
<td>It's assumed that there is an initial partial pressure ($P_{in}$) of contaminant gas in the package.</td>
</tr>
<tr>
<td>Initial Moisture in Package</td>
<td>For simplicity, it is assumed that there is no initial moisture in the package.</td>
</tr>
<tr>
<td>Probability of Successful Operation</td>
<td>Functional dependence of the probability of successful operation [$R(0)$] is assumed to be linear.</td>
</tr>
<tr>
<td>Induction Time</td>
<td>Induction time is generally assumed to correspond to the time for condensation of three molecular layers of moisture.</td>
</tr>
</tbody>
</table>

### Limitations

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallization</td>
<td>The model focuses on aluminum metalization corrosion resulting from chlorine-based contaminants.</td>
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### Constraints

<table>
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### Uncertainty Limits

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### Data or Information Needed from Outside Sources

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<tbody>
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<td>Scaling Factor</td>
<td>User</td>
<td>Model constant ($\alpha_0$) which is a function of the contaminants, corroding materials, and the bias; testing required.</td>
</tr>
</tbody>
</table>

### Bibliographic Citation

...
Required Data/Information for Models

**A Fracture Model of Corrosion Fatigue Crack Propagation of Aluminum Alloys Based on the Material Elements Fracture Ahead of a Crack Tip**

**Model Parameters**

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Units</th>
<th>View Sub-Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(da/dN)c</td>
<td>Corrosion fatigue crack propagation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B_ref</td>
<td>CFCP coefficient</td>
<td></td>
<td>View</td>
</tr>
<tr>
<td>ΔK</td>
<td>Stress intensity factor amplitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔK_thref</td>
<td>CFCP threshold</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Failure Mechanism**

- Corrosion Fatigue

**CFCP Hypothesis**

Fractured. Furthermore, this model is based on a static model (developed by Lal and Weiss) for crack propagation where the crack propagates when a tensile load exceeds the fatigue limit.

**Limitations**

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental Verification</td>
<td>The model agreed with the data when the samples had a constant stress ratio (R).</td>
</tr>
<tr>
<td>Corrosive Environment</td>
<td>The model is said to accurately predict the CFCP rate for aluminum alloys in a 3.5% NaCl environment.</td>
</tr>
</tbody>
</table>

**Constraints**

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Loading Frequency</td>
<td>For alloys 7075-T7651 and 7049-T73, the model showed agreement with experimental data when the loading frequencies were between 0.1 and 10 Hz.</td>
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</tbody>
</table>

**Uncertainty Limits**

<table>
<thead>
<tr>
<th>Type</th>
<th>Uncertainty</th>
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<tbody>
<tr>
<td>N/A</td>
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</table>

**Data or Information Needed from Outside Sources**

<table>
<thead>
<tr>
<th>Category</th>
<th>Source</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Physical Dimension(s)</td>
<td>User</td>
<td>Crack propagation length, from mechanical loading (x_d)</td>
</tr>
<tr>
<td>Physical Dimension(s)</td>
<td>User</td>
<td>Additional crack propagation length from corrosion (x_c)</td>
</tr>
<tr>
<td>Mechanical Properties</td>
<td>User</td>
<td>Stress intensity factor amplitude (ΔK)</td>
</tr>
<tr>
<td>Mechanical Properties</td>
<td>User</td>
<td>CFCP threshold (ΔK_thref)</td>
</tr>
</tbody>
</table>

**Bibliographic Citation**

<table>
<thead>
<tr>
<th>Published Status</th>
<th>Source Type</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
</table>

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**Dimensions/Properties**
Current Status

- Over 5000 Technical Papers Evaluated
- Over 200 PoF Models Identified and Being Processed into the WARP Database:
  - Wear, creep, fatigue, time-dependent dielectric breakdown (TDDDB), negative bias temperature instability (NDTI), hot carrier injection (HCI), electromigration
- RIAC WARP Website Went Public in August 2011
  - Over 275 Registered Members
  - Over 25 Registered Contributors

http://www.theriac.org/WARP/login/main_login.html
Future Work

- RIAC Core Operations and General Community Support Will Keep WARP Viable

- Original Intended Feature was On-Line Calculations and Output for Each PoF Model in WARP
  - Required software effort was cost-prohibitive
  - Negative impact on ability to populate WARP database
  - Emphasis placed on PoF model quantity and quality

- Adding This Capability Would Be a Valuable Asset for the PoF Community
Contact Information

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