

# Reliability Physics and Engineering

J. W. McPherson

# Reliability Physics and Engineering

Time-to-Failure Modeling

Second Edition

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*To my family:  
Victoria, Cameron, Brandi,  
Austin and Gabrielle*

# Preface

All engineers could benefit from at least one course in *Reliability Physics and Engineering*. It is very likely that, starting with your very first engineering position, you will be asked—how long is your newly developed device expected to last? This textbook was designed to help answer this fundamentally important question. All materials and devices are expected to degrade with time, so it is very natural to ask—how long will the device last?

The evidence for *material/device degradation* is apparent in nature. A fresh coating of paint on a house will eventually crack and peel. Doors in a house can become stuck due to the shifting of the foundation. The new finish on an automobile will oxidize with time. The tight tolerances associated with finely meshed gears will deteriorate with time. Critical parameters that are associated with precision semiconductor devices (threshold voltages, drive currents, interconnect resistances, capacitor leakages, etc.) will degrade with time. In order to understand the lifetime of the material/device, it is important to understand the *reliability physics (kinetics)* for each of the potential failure mechanisms and then be able to develop the required *reliability engineering* methods that can be used to prevent, or at least minimize, the occurrence of device failure.

Reliability engineering is a fundamental part of all good electrical and mechanical engineering product designs. Since proper *materials selection* can also be a critically important reliability factor, reliability engineering is also very important to *materials scientists*. Reliability is distinguished from *quality* in that quality usually refers to time-zero compliance or conformance issues for the material/device. Reliability refers to the time-dependence of material/device degradation. All devices (electrical and/or mechanical) are known to degrade with time. Measuring and modeling the *degradation rate*, the *time-to-failure*, and the *failure rate* are the subjects of reliability engineering.

Many electrical and mechanical devices, perhaps due to performance and/or cost issues, push their standard operating conditions (use conditions) very close to the intrinsic strength of the materials used in the design. Thus, it is not a question of whether the device will fail, but when. Reliability engineering methods permit the electrical engineer, armed with accelerated testing data, to claim with confidence that a newly designed integrated circuit will last at least 10 years under specified voltage and temperature operating conditions. Reliability engineering

methods permit the mechanical engineer to claim that the newly-designed engine will last for 180,000 miles at 3000 rpm with an oil change required every 6,000 miles. Reliability engineering methods enable the materials scientist to select a cost-effective material which can safely withstand a specified set of high-temperature and high-stress use conditions for more than 10 years.

This textbook provides the basics of reliability physics and engineering that are needed by electrical engineers, mechanical engineers, civil engineers, biomedical engineers, materials scientists, and applied physicists to help them to build better devices/products. The information contained within should help all fields of engineering to develop better methodologies for: more *reliable product designs*, more *reliable materials selections*, and more *reliable manufacturing processes*—all of which should help to improve product reliability. A mathematics level through differential equations is needed. Also, a familiarity with the use of excel spreadsheets is assumed. Any needed statistical training and tools are contained within the text. While device failure is a statistical process (thus making statistics important), the emphasis of this book is clearly on the *physics of failure* and developing the *reliability engineering tools* required for product improvements during *device-design* and *device-fabrication* phases.

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# Contents

<b>1</b>	<b>Introduction</b> . . . . .	1
<b>2</b>	<b>Materials and Device Degradation</b> . . . . .	5
1	Material/Device Parameter Degradation Modeling . . . . .	5
1.1	Material/Device Parameter Decreases with Time . . . . .	6
1.2	Material/Device Parameter Increases with Time . . . . .	9
2	General Time-Dependent Degradation Models . . . . .	12
3	Degradation Rate Modeling . . . . .	13
4	Delays in the Start of Degradation . . . . .	15
5	Competing Degradation Mechanisms . . . . .	19
<b>3</b>	<b>From Material/Device Degradation to Time-to-Failure</b> . . . . .	29
1	Time-to-Failure . . . . .	29
2	Time-to-Failure Kinetics . . . . .	32
<b>4</b>	<b>Time-to-Failure Modeling</b> . . . . .	37
1	Flux-Divergence Impact on Time-to-Failure . . . . .	37
2	Stress Dependence and Activation Energy . . . . .	40
3	Conservative Time-to-Failure Models . . . . .	45
4	Time-to-Failure Modeling Under High-Stress . . . . .	46
	Bibliography . . . . .	49
<b>5</b>	<b>Gaussian Statistics: An Overview</b> . . . . .	51
1	Normal Distribution . . . . .	51
2	Probability Density Function . . . . .	53
3	Statistical Process Control . . . . .	56
	Bibliography . . . . .	60
<b>6</b>	<b>Time-to-Failure Statistics</b> . . . . .	61
1	Lognormal Probability Density Function . . . . .	61
2	Weibull Probability Density Function . . . . .	65



- 3 Multimodal Distributions . . . . . 67
  - 3.1 Multimodal Distribution (Separated in Time) . . . . . 67
  - 3.2 Mixed Multiple Failure Mechanisms . . . . . 70
- Bibliography . . . . . 74
  
- 7 Failure Rate Modeling . . . . . 75**
  - 1 Device Failure Rate. . . . . 75
  - 2 Average Failure Rate. . . . . 76
    - 2.1 Lognormal Average Failure Rate. . . . . 77
    - 2.2 Weibull Average Failure Rate. . . . . 77
  - 3 Instantaneous Failure Rate . . . . . 79
    - 3.1 Lognormal Instantaneous Failure Rate . . . . . 79
    - 3.2 Weibull Instantaneous Failure Rate . . . . . 79
  - 4 Bathtub Curve . . . . . 81
  - 5 Failure Rate for Electronic Devices. . . . . 82
  - Bibliography . . . . . 89
  
- 8 Accelerated Degradation. . . . . 91**
  - 1 Metastable States . . . . . 91
  - 2 Impact of Temperature on Degradation Rate . . . . . 93
  - 3 Free Energy of Activation . . . . . 95
  - 4 Impact of Stress and Temperature on Degradation Rate. . . . . 96
    - 4.1 Real Versus Virtual Stresses . . . . . 96
    - 4.2 Impact of Stress on Materials/Devices . . . . . 97
  - 5 Accelerated Degradation Rates . . . . . 100
  - Bibliography . . . . . 103
  
- 9 Acceleration Factor Modeling . . . . . 105**
  - 1 Acceleration Factor . . . . . 105
  - 2 Power-Law Versus Exponential Acceleration . . . . . 108
  - 3 Cautions Associated with Accelerated Testing . . . . . 110
  - 4 Conservative Acceleration Factors. . . . . 110
  - Bibliography . . . . . 115
  
- 10 Ramp-to-Failure Testing. . . . . 117**
  - 1 Ramp-to-Failure Testing . . . . . 117
  - 2 Linear Ramp Rate. . . . . 118
    - 2.1 Linear Ramp with Exponential Acceleration. . . . . 118
    - 2.2 Linear Ramp with Power-Law Acceleration . . . . . 120
  - 3 Breakdown/Rupture Distributions . . . . . 122
  - 4 Cautions for Ramp-to-Failure Testing . . . . . 124
  - 5 Transforming Breakdown/Rupture Distributions  
into Constant-Stress Time-to-Failure Distributions . . . . . 125

5.1	Transforming Breakdown/Rupture Distribution to Time-to-Failure Distribution Using Exponential Acceleration . . . . .	125
5.2	Transforming Breakdown/Rupture Distribution to Time-to-Failure Distribution Using Power-Law Acceleration . . . . .	126
6	Constant-Stress Lognormal Time-to-Failure Distributions from Ramp Breakdown/Rupture Data . . . . .	126
6.1	Exponential Acceleration . . . . .	126
6.2	Power-Law Acceleration. . . . .	127
7	Constant-Stress Weibull Time-to-Failure Distributions from Ramp Breakdown/Rupture Data . . . . .	127
7.1	Exponential Acceleration . . . . .	128
7.2	Power-Law Acceleration. . . . .	128
	Bibliography . . . . .	132
<b>11</b>	<b>Time-to-Failure Models for Selected Failure Mechanisms in Integrated Circuits . . . . .</b>	<b>133</b>
1	Electromigration . . . . .	133
2	Stress Migration . . . . .	142
2.1	SM in Aluminum Interconnects. . . . .	143
2.2	SM in Cu Interconnects . . . . .	146
3	Corrosion . . . . .	150
3.1	Exponential Reciprocal-Humidity Model . . . . .	154
3.2	Power-Law Humidity Model. . . . .	155
3.3	Exponential Humidity Model . . . . .	155
4	Thermal-Cycling/Fatigue Issues . . . . .	156
5	Time-Dependent Dielectric Breakdown . . . . .	161
5.1	Exponential E-Model . . . . .	161
5.2	Exponential 1/E-Model. . . . .	164
5.3	Power-Law Voltage V-Model . . . . .	165
5.4	Exponential $\sqrt{E}$ -Model . . . . .	165
5.5	Which TDDDB Model to Use? . . . . .	165
5.6	Complementary Electric Field and Current-Based Models . . . . .	168
6	Mobile-Ions/Surface-Inversion . . . . .	171
7	Hot-Carrier Injection . . . . .	173
8	Negative-Bias Temperature Instability . . . . .	178
	Bibliography . . . . .	186
<b>12</b>	<b>Time-to-Failure Models for Selected Failure Mechanisms in Mechanical Engineering . . . . .</b>	<b>193</b>
1	Molecular Bonding in Materials . . . . .	193
2	Origin of Mechanical Stresses in Materials . . . . .	197

- 3 Elastic Behavior of Materials . . . . . 198
- 4 Inelastic/Plastic Behavior of Materials . . . . . 202
- 5 Important Defects Influencing Material Properties. . . . . 205
  - 5.1 Vacancies . . . . . 205
  - 5.2 Dislocations . . . . . 206
  - 5.3 Grain Boundaries. . . . . 209
- 6 Fracture Strength of Materials . . . . . 211
- 7 Stress Relief in Materials . . . . . 213
- 8 Creep-Induced Failures . . . . . 214
  - 8.1 Creep Under Constant Load/Stress Conditions . . . . . 215
  - 8.2 Creep Under Constant Strain Conditions . . . . . 223
- 9 Crack-Induced Failures . . . . . 227
  - 9.1 Stress Raisers/Risers at Crack Tips . . . . . 228
  - 9.2 Strain-Energy Release Rate. . . . . 230
  - 9.3 Fast Fracture/Rupture. . . . . 232
- 10 Fatigue-Induced Failures . . . . . 234
  - 10.1 Fatigue for Materials (No Pre-Existing Cracks). . . . . 235
  - 10.2 Low-Cycle Fatigue . . . . . 235
  - 10.3 High-Cycle Fatigue . . . . . 236
  - 10.4 Fatigue for Materials (With Pre-existing Cracks). . . . . 239
- 11 Adhesion Failures . . . . . 241
- 12 Thermal-Expansion-Induced Failures. . . . . 242
  - 12.1 Thermal Expansion . . . . . 242
  - 12.2 Constrained Thermal-Expansion . . . . . 244
  - 12.3 Thermal-Expansion Mismatch. . . . . 244
  - 12.4 Thin Films on Thick Substrates. . . . . 246
- 13 Corrosion-Induced Failures. . . . . 248
  - 13.1 Dry Oxidation . . . . . 249
  - 13.2 Wet Corrosion. . . . . 255
  - 13.3 Impact of Stress on Corrosion Rates . . . . . 259
- Bibliography . . . . . 264
  
- 13 Conversion of Dynamical Stresses into Effective Static Values . . . . . 267**
  - 1 Effective Static-Stress Equivalent Values . . . . . 267
  - 2 Effective Static-Stress Equivalent Values When Using Power-Law TF Models . . . . . 269
  - 3 Effective Static-Stress Equivalent Values When Using Exponential TF Models . . . . . 271
  - 4 Conversion of a Dynamical Stress Pulse into a Rectangular Pulse Stress Equivalent . . . . . 272
    - 4.1 Effective Rectangular Pulse Stress-Equivalent Values for Power-Law TF Models . . . . . 272
    - 4.2 Effective Rectangular Pulse Stress-Equivalent Values for Exponential TF Models . . . . . 273

4.3	Numerical Integration . . . . .	273
5	Effective Static Temperature Equivalents . . . . .	277
6	Mission Profiles . . . . .	280
7	Avoidance of Resonant Frequencies . . . . .	286
<b>14</b>	<b>Increasing the Reliability of Device/Product Designs . . . . .</b>	<b>291</b>
1	Reliability Enhancement Factor . . . . .	292
2	Electromigration Design Considerations . . . . .	292
3	TDDDB Design Considerations . . . . .	293
4	Negative-Bias Temperature Instability Design Considerations . . . . .	294
5	HCI Design Considerations . . . . .	294
6	Surface Inversion Design Considerations . . . . .	295
7	Creep Design Considerations . . . . .	295
7.1	Creep in Rotors . . . . .	296
7.2	Creep in Pressurized Vessels . . . . .	297
7.3	Creep in a Leaf Spring . . . . .	297
7.4	Stress Relaxation in Clamps/Fasteners . . . . .	298
8	Fatigue Design Considerations . . . . .	299
8.1	Fatigue in Storage Vessels . . . . .	299
8.2	Fatigue in Integrated Circuits (ICs) . . . . .	300
<b>15</b>	<b>Screening . . . . .</b>	<b>303</b>
1	Breakdown/Strength Distribution for Materials and Devices . . . . .	303
2	Impact of Screening Stress on Breakdown Strength . . . . .	304
2.1	Screening Using Exponential TF Model . . . . .	305
2.2	Screening Using Power-Law TF Model . . . . .	307
3	Screening Effectiveness . . . . .	309
3.1	Screening Effectiveness Using Exponential TF Model . . . . .	310
3.2	Screening Effectiveness Using Power-Law TF Model . . . . .	313
<b>16</b>	<b>Heat Generation and Dissipation . . . . .</b>	<b>319</b>
1	Device Self-Heating and Heat Transfer . . . . .	319
1.1	Energy Conservation . . . . .	320
1.2	General Heat Flow Equation . . . . .	322
2	Steady-State Heat Dissipation . . . . .	324
3	Effective Thermal Resistance . . . . .	327
4	General Transient Heating and Heat Dissipation . . . . .	331
4.1	Effective Thermal Resistance Revisited . . . . .	332
4.2	Heat Capacity . . . . .	333
5	Modeling Dynamical Heat Generation and Dissipation . . . . .	333
5.1	Thermal Relaxation . . . . .	335
5.2	Thermal Rise with Constant Input Power . . . . .	338
5.3	Thermal Rise and Relaxation with Single Power Pulse . . . . .	339

- 5.4 Thermal Rises and Relaxations with Periodic Power Pulses . . . . . 339
- 6 Convection Heat Transfer . . . . . 344
- 7 Radiation Heat Transfer . . . . . 346
- 8 Entropy Changes Associated with Heat Transfer . . . . . 348
- Bibliography . . . . . 353
- 17 Sampling Plans and Confidence Intervals . . . . . 355**
  - 1 Poisson Distribution . . . . . 355
    - 1.1 Poisson Probability for Finding Defective Devices . . . . . 356
    - 1.2 Poisson Sample Size Requirements . . . . . 358
  - 2 Binomial Distribution . . . . . 360
    - 2.1 Binomial Probability for Finding Defective Devices . . . . . 360
    - 2.2 Binomial Sample Size Requirements . . . . . 361
  - 3 Chi Square Distribution . . . . . 363
    - 3.1 Chi Square Confidence Intervals . . . . . 363
    - 3.2 Chi Square Distribution for Defect Sampling . . . . . 364
  - 4 Confidence Intervals for Characteristic Time-to-Failure and Dispersion Parameters . . . . . 367
    - 4.1 Normal Distribution Confidence Intervals . . . . . 367
    - 4.2 Lognormal Distribution Confidence Intervals . . . . . 368
    - 4.3 Weibull Distribution Confidence Intervals . . . . . 370
    - 4.4 Chi Square Distribution Confidence Intervals for Average Failure Rates . . . . . 372
  - Bibliography . . . . . 376
- Appendices . . . . . 377**
- Index . . . . . 391**