Basics of Physics of Failure of Materials

ENMA 426

UPDATED Course Syllabus

Course Objectives:
Failure mechanisms in reliability engineering will be taught from a basic materials and defects point of view. The methods of predicting the physics of failure of devices, materials, components and systems are reviewed. The main emphasis will be given to basic degradation mechanisms through understanding the physics, chemistry, and mechanics of such mechanisms. Mechanical failures are introduced through understanding fatigue, creep and yielding in materials, devices and components. The principles of cumulative damage and mechanical yielding theory are taught. The concepts of reliability growth, accelerated life testing, environmental testing are introduced. ***Effective 31 March, the course will be taught on line using ZOOM. All homework is to be submitted on line, and any other examination will be taken at home. The course project will be presented also using ZOOM. You may connect with ZOOM through CANVAS.***

Physical, chemical and thermal related failures are introduced through a basic understanding of degradation mechanisms such as diffusion, electromigration, defects and defect migration. The failure mechanisms in basic material types will be taught. Failure mechanisms observed in real electronic devices and electronic packaging will also be presented. Problems related to manufacturing, and microelectronics will be analyzed. Mechanical failures are emphasized from the point of view of complex fatigue theory.

Course Instructor: Professor Aris Christou
Office Hours: By arrangement after March 31, 2020. Questions via e mail only.

Course Texts: "Reliability Physics and Engineering" by J.W. McPherson, Published by Springer. ISBN 978-1-4419-6347 (2010). Edition 1 or 2
Also (not required) : " Practical Reliability Engineering" by Patrick O'Conner, published by Wiley, Fourth Edition
References:

1. "Reliability and Quality in Microelectronic Die Manufacturing" by Aris Christou and Willie M. Webb,
   Published by Reliability Information Analysis Center, 2006.
   ISBN-10 1-933904-15-1 (reference).
2. "Failure Mechanisms in Semiconductor Devices", Second Edition by A. A. Amerasekera and F. N. Najm, published by Wiley.

3. "Failure of Materials in Mechanical Design" Jack A. Collins, second edition, 1993, published by Wiley.

Course Notes in Failure mechanisms are provided by the instructor to supplement the required text books.

Course Notes and Assignments: Posted on Canvas. All solutions as well as the the power point presentation of each lecture is presented.

Grading: Homework Assignments: 10%
Homework Assignments are due the following week after assigned.
No late homework!
Two Mid Terms: 40% and Final Exam: 25 %. Project: 25%

Course Outline

Detailed Outline of ENMA 426: Basic Physics of Failure in Reliability

Wk 1 Engineering Approach to Reliability vs. Statistical Approach to Reliability
Wk 1 Relationship Between Quality and Reliability.
Wk 2-3 Reliability Math, Theories and Models of Basic Materials Failure ; Defect Based Theories of Material Failure.
Wk 4 Time to Failure Models, Failure Rate Models, based on the MacPherson Degradation Parameter S.
Midterm Exam 1, after completion of reliability mathematics.

March 31- April 14, Electrical Failure Mechanisms

- Devices and Packaging
- Metal Interconnects degradation-electromigration
- Dielectric degradation-oxide breakdown, TDDB and NBTI
- Hot Elecxtron Injection
- ESD and ESS effects
- Whisker Formation
- Cathode –Anode Filament Formation
- Degradation of Solder Materials

April 16-April 28 Mechanical Failure Mechanisms

- Elastic Deformation
- Plastic Deformation
- Defects: zero, one dimension, two dimensions: Vacancies, dislocations and grain boundaries
- Temperature and deformation rate effects

- Creep Deformation, and temperature dependence of creep: The four theories of Creep, Predicting Time to Rupture.
- Cyclical deformation: Introduction to Fatigue
- Dislocation mechanisms of Fatigue.
- Grain boundary sliding, diffusion, void nucleation
- Fracture, and Nucleation of Fracture
- LEFM
- EPFM

Second Midterm Exam after completion of electrical and mechanical failure mechanisms. This is an exam to be taken at home.

One Lecture on Environmental and Chemical Failure Mechanisms

- Theories of Corrosion, Calculating Time to Corrosion Failure
- Eight different mechanisms for corrosion degradation
- Stress Corrosion and Fatigue Corrosion, Defect Models
- Methods for corrosion mitigation

May 5 and May 7th Project Presentations-On Line

Two Midterms 1 hr 10 min duration for first (second exam at home)
One Final Exam, (at home)
One week of project presentations.