**Name of the module:**

**RELIABILITY AND FAILURE MECHANISMS OF MATERIALS IN MICROELECTRONICS AND MEMS**

**365/2/6931**

**Number of module: 365-2-6011**

BGU Credits: 3

ECTS credits: 4

Academic year: …2011-2012

Semester: Autumn semester

Hours of instruction: 3 hours per week

Location of instruction: ME department

Language of instruction: **English**

**All the students will receive the detailed synopsis of ALL THE LECTURES in English**

Cycle: Second cycle

Position: An advanced course for graduate students in Materials Engineering Department

Field of Education: Materials Engineering, Microelectronic Materials

Responsible department: Materials Engineering

General prerequisites: Introduction to MSE

Grading scale: the grading scale would be determined on a scale of 0 – 100 (0 would indicate failure and 100 complete success 0 to 100), passing grade is 65.

Lecturer: Prof. Evgeny E. Glickman

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Office hours: Thursday 12- 14 AM

Module evaluation: at the end of the semester the students will evaluate the module, in order to draw conclusions, and for the university's internal needs.

**Course Description:**

Modern ULSIs contain ~109 transistors, several kilometers of thin metal film conductors (‘interconnects ‘), and many thousands of contacts – all packed into an area the size of a thumbnail. The ability to implement these designs is limited by the *reliability concerns*. This places great demands on understanding specific *failure mechanisms of materials, mostly nano-structured thin film materials*, used in advanced microelectronics.

How should we select / develop the material, which can resist electric breakdown in 1nm thick under-gate dielectric, or electromigration failures in 25 nm Cu interconnects, or the material that will work as a 100nm spring in MEMS gyroscope? Even such a ‘trivial’ task as measuring the reliability turns out to be rather challenging because each component on the chip must nowadays have the lifetime of mega-years.

This course introduces students to the fundamentals of material reliability in micro- electronics and MEMS devices; most of these materials are *nano-structured* and feature a jump-wise transition to new materials and reliability physics.

**Aims and Objectives of the module:**

To teach students having the background in materials science and engineering how the fundamental MSE concepts, together with advanced ideas from the science and technology of smallness, can be successfully applied to understanding “exotic” failure mechanisms of materials in microelectronics and MEMS.

**Learning outcomes of the module**:

On successful completion of the course the students should be able to:

•to understand physical mechanisms and kinetic models used to explain major degradation processes

•to recognize specific failure mechanisms and the critical defects involved

• to predict real reliability based on the accelerated testing

• to appreciate future material reliability issues in ULSI and MEMS smallness

**Attendance regulation:**

Attendance and participation in the class is mandatory (at least 80%).

**Teaching arrangement and method of instruction**: lectures, which include the examples for solving problems

Confirmation: the syllabus was confirmed by the faculty academic advisory committee to be valid on 2012-2013.

Last update: 04.09.2012

**Assignments**: three home works of about 15 problems taken together.

**Exam** that consists of 5-6 numerical problems and conceptual questions

**Assessment:**  Exam: 75%. Home works: 25%.

**Time required for individual work**: in addition to attendance in class, the students are expected to do their assignment and individual work: at least 2 hours per week.

**Module Content and 3 h Lecture Outline:**

1. Reliability and material issues in microelectronics: historical perspective. Accelerated testing. 0.1 FIT and six-sigma goals. Failure rates .Weibull, Lognormal, Exponential Distributions. Reliability physics vs. reliability statistics.

2. Failures as Kinetic Processes. Load -Strength interaction. The bathtub curve and its physical interpretation. Condition for changes: atom movements and thermodynamic driving forces.

3. Chemical potential and diffusional drift: the Nernst-Einstein equation and its application to failure kinetics in external potential fields.

4. Thin films in VLSI’s and MEMS: their micro/nano structure and chemistry. Intrinsic and Thermal Stresses in thin films. Stress measurement.

5. Fast diffusion pathways along internal interfaces. Diffusion mechanism maps for thin films

6. Electromigration (EM) physics: electron wind, electro-transport, role and origin of EM flux divergences. The Blech drift velocity test: role of stress gradients and creep. Hillocks.

7. Electromigration in practice: effects of conductor geometry, current

crowding and temperature gradients in interconnects. Mitigation of EM. EM in CNTs and Graphene. ‘Electro-capillary’ and ‘electrochemical annealing’ effects in surface mobility in electric field and failure mechanisms of thin film electrodes.

8. Physical mechanisms of Stress –migration and Voiding (SMV) in ULSI Interconnects. Crack and void kinetics. Synergism between electro- and stress-migration. Mitigation of SMV.

9. Packaging failures: thermo-fatigue cracks and whiskers in Pb-free solder joints, Electrolytic migration and corrosion reactions in thin films of Al and Cu.

10. Dielectric/gate oxide breakdown: elemental theory and testing routes. Electrostatic discharge failures and guarding against them.

11. Reliability issues and material selection for MEMS and NEMS: stiction, reaction fatigue and stress corrosion cracking of SiO2/Si and similar structures.

12. from micro- to nano: size effects in electrical, magnetic and mechanical properties of thin film electronic materials. Reliability limits.

13. TBA

## Literature to the course:

1**.** M. Ohring, *Reliability and Failure of Electronic Materials and Devices*, Academic Press, Boston (1998)

2**.** J.W. McPherson**,** *Reliability Physics and Engineering: Time –to-Failure Modeling***,** Springer(2011**)**

3. M. Ohring, *The Materials Science of Thin Films,* Academic Press, Boston, 2nd edition (2006)

4. K.-N. Tu, J. W. Mayer, and L.C. Feldman, *Electronic Thin Film Science for Electrical Engineers and Materials Scientists,* Macmillan (1993)

5**.**  K. T. Ramesh, *Nanomaterials: mechanics and mechanisms* , Springer (2009)