

WORCESTER POLYTECHNIC INSTITUTE

MECHANICAL ENGINEERING DEPARTMENT

COURSE No.: ME-593M, Spring'2002

COURSE NAME: MEMS and Nanotechnology

TEXTBOOK: *MEMS & microsystems: design and manufacture*, T-R. Hsu, McGraw-Hill, 2002

INSTRUCTORS: C. Furlong

cfurlong@wpi.edu

HL-151

(508) 831-5126

R. J. Pryputniewicz

rjp@wpi.edu

HL-152

(508) 831-5536

REFERENCES: • *Notes on MEMS/micromechatronics*, R. J. Pryputniewicz, WPI-ME/CHSLT-NEST, 2001

• *Mechanical microsensors*, M. Elwenspoek and R. Wierink, Springer-Verlag 2001

• *Micromachined transducers sourcebook*, G. T. A. Kovacs, McGraw-Hill, 1998

• *Microsystem design*, S. D. Senturia, Kluwer, 2001

• <http://www.wpi.edu/~chslt>

OFFICE HOURS: Everyday from 9:00 to 10:30 AM or by appointment

LECTURES: Fridays: 4:00 PM to 7:00 PM, HL-102

SUBJECT: Final course outline

DATE: 15 January 2002

NOTE: HOMEWORK problems are assigned at the end of each lecture, these problems are due at the beginning of the next lecture. There will be *two* EXAMS and *one* TOPICAL PROJECT, scheduled as indicated in the outline. In this course, evaluation will be based on the PROJECT REPORT, HOMEWORK, EXAMS, and PARTICIPATION in the class. In all solutions, state explicitly every assumption and/or approximation made, explain every procedure and justify its use. Dimensional analyses are absolutely necessary. All results must be expressed in appropriate units. PLEASE, ALWAYS SHOW ALL WORK, while writing your solutions only on one side of a sheet(s) of paper; start every problem on a new sheet of paper.

WEEK	TOPICS	SUGGESTED READING	HOMEWORK ASSIGNMENT
1. Jan 14	Course overview. Introduction to MEMS. Fundamentals of MEMS design, analysis, fabrication, NDT, and representative applications. MEMS for the future. "There's plenty of room at the bottom."	Ch 1, Hsu Ch 1, RJP	1.1, 1.2, 1.3
	Lithography. Photolithography. Photolithography resolution. Proximity printing. Contact printing. Modulation transfer function. Spatial coherence. Resists. Masks. Basic IC process steps. Moore's law. Glossary. Sensor market. Microscale and nanoscale devices. Integrated microsystems.	Ch 8, Hsu Ch 2, Kovacs	2.1, 2.2, 2.3, 2.4. Topical project <i>summaries</i> due on Week 9; <i>reports</i> due on Week 15.

WEEK	TOPICS	SUGGESTED READING	HOMEWORK ASSIGNMENT
2. Jan 21	Engineering mechanics for microsystems design. Stress and strain. Residual stresses. Static bending of thin plates. Mechanical vibration. Thermomechanics. Fracture mechanics. Thin-film mechanics. General materials considerations.	Ch 4, Hsu	3.1, 3.2 3.3, 3.4
3. Jan 28	Principles of measuring mechanical quantities. Deformation sensors. Force and pressure sensors. Resonant sensors. Thermofluid sensors.	Ch 2 and 4, Hsu	4.1, 4.2 4.3, 4.4
4. Feb 4	Scaling laws. Sizes of “things.” Scaling in geometry. Scaling in dynamic forces. Force scaling vector. Scaling in acceleration, time, power, power density. Scaling in electrostatic forces. The Paschen’s effect. Scaling in electromagnetics and piezoelectricity. Scaling in fluidics and heat transfer.	Ch 6, Hsu	5.1, 5.2 5.3, 5.4
5. Feb 11	Microfabricated actuators. Fundamentals of microactuation. Parallel plate electrostatic actuation. Electrostatic pressure. Comb drive actuator. Drive force relationships. Optimal shape design of an electrostatic comb drive in microelectromechanical systems.	Ch 2, Hsu	6.1, 6.2 6.3, 6.4
6. Feb 18	Analysis of a microengine. Kinematic diagram. Complex notation. Euler identity. Determination of linear and angular positions. Initial conditions. Determination of linear and angular velocities. Determination of linear and angular accelerations. Sample calculations.	Ch 4, RJP Ch 4, Hsu	7.1
7. Feb 25	Kinematics and kinetics of a MEMS microengine. Mathematical modeling. Determination of a force acting on an input gear. Force components in the Cartesian representation. Force components in polar representation. Forces as functions of rpm. Sample calculations. Experimental and analytical characterization of dynamic effects in electrostatic microengines. Frictional effects in MEMS. Integrated microsystems.	Ch 5, RJP Ch 4, Hsu	8.1, 8.2

WEEK	TOPICS	SUGGESTED READING	HOMEWORK ASSIGNMENT
8. Mar 4	Materials for MEMS and microsystems. Microfabrication processes. Oxidation. Deposition. Sputtering. Etching. Bulk micromachining. Surface micromachining. High aspect ratio micromachining. LIGA. Assumptions, approximations, modeling, error, dimensional, and uncertainty analyses. Review of topics covered.	Ch 6 and 7, RJP Ch 7, 8, and 9, Hsu	9.1, 9.2, 9.3
9. Mar 11	EXAM No. I.	-----	Topical project <i>summaries</i> due; <i>reports</i> due on Week 15.
10. Mar 18	Review of Exam No. I. Nanotechnology. Nanomachines. Nanorobots. Nanotubes. Nanowires. Nanomechanical amplifiers. Nanotransistors. Tera-storage devices. Molecular engineering. DNA computing. Nanomedicine. Smart pills. Nanofabrication of structures. <i>Interim discussion of topical projects.</i>	Ch 2, Kovacs Notes-RJP	10.1, 10.2, 10.3
11. Mar 25	Design rules for fabrication. Integrated CMOS design. Hybrid design. Sensors. Design and analysis software. CAD for MEMS. CFD micromesh. FEM for MEMS/NEMS. <i>Interim discussion of topical projects.</i>	Ch 10, Hsu	11.1, 11.2, 11.3
12. Apr 1	Design constraints. Selection of materials. Selection of fabrication processes. Selection of functional operation characteristics. Analysis, modeling, and simulation for MEMS. <i>Interim discussion of topical projects.</i>	Ch 10, Hsu Ch 2, Kovacs	12.1, 12.2, 12.3
13. Apr 8	Packaging of MEMS. Dicing. Wafer level packaging. Alignment during bonding. Connections between layers. Self-assembly. Packaging materials. Higher level packaging. <i>Interim discussion of topical projects.</i>	Ch 11, Hsu	13.1, 13.2 13.3, 13.4

WEEK	TOPICS	SUGGESTED READING	HOMEWORK ASSIGNMENT
14. Apr 15	Metrology methods for MEMS. Nondestructive testing. OELIM methodology. Static and dynamic measurements of displacements. Measurements of deformations and absolute shape. <i>Interim discussion of topical projects.</i>	Notes-RJP WWW, CHSLT	14.1, 14.2 14.3, 14.4
	Current trends and future directions in MEMS and NEMS. Applications. Review of topics covered.	Notes-RJP	15.1, 15.2 15.3, 15.4
15. Apr 22	EXAM No. II.	-----	Topical project reports due.

NOTE: The course evaluation will be based 30% on the HOMEWORK, 30% on the EXAMS, 30% on the PROJECT REPORT, and 10% on the PARTICIPATION in the class.

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