McMaster University, Department of Mechanical Engineering

ME 4E03
INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS

COURSE OUTLINE: Introduction to MEMS, Scaling Effects, Microfabrication fundamentals, Mechanics and transduction at the microscale, Actuation and sensing methods – Electrostatic, Piezoresistive, Piezoelectric, Thermal, Electromagnetic, Resonant and tunneling. Capacitative sensors, Resonators, Lab on Chip devices, Microfluidics. Assembly techniques for MEMS and packaging.

OBJECTIVE: To provide an overview of different applications of MEMS in sensing and actuation and provide a basic understanding of construction and mechanics underlying these systems.

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COURSE MATERIALS: Lecture Notes provided by the instructor + Journal papers

Reference Books (Course Reserve available in the library):

MEMS:

- N. Maluf, *An introduction to microelectromechanical systems engineering*, Artech House 2004, (e-book)
- W. Trimmer, *Micromechanics and MEMS: Classic and seminal papers to 1990*, IEEE
- G.T.A. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, 1998
- M. Gad-el-Hak, *MEMS Design and Fabrication*, CRC Press, 2005 (e-book)
- J.G. Korvink, O. Paul, MEMS: *A Practical Guide to Design Analysis and Applications*, Springer, 2006, (e-book)
- C.Liu, *Foundations of MEMS*, Prentice Hall, 2012

Microfluidics:

- G. Karniadakis, A. Beskok, N. Aluru *Microflows and Nanoflows: Fundamentals and Simulation*, Springer 2005. (e-book)
- O. Geschke**,** *Microsystem Engineering of Lab-on-a-chip Devices***,** Wiley, 2008
- P. Tabeling, *Introduction to microfluidics*, Oxford University Press, 2005. (e-book)
- J Kutter, Y. Fintshenko, *Separation methods in microanalytical systems*, Taylor & Francis 2006
- N. T. Nguyen, S. Wereley *Fundamentals and Applications of Microfluidics*, Artech House Publishers, 2006 (e-book)
- G.A. Urban, *BioMEMS*, Springer, 2012 (e-book)
- J. Berthier, *The physics of microdroplets*, Wiley, 2012

Design:

- Stephen D. Senturia, *Microsystem Design*, Kluwer Academic Publishers, 2000

Microfabrication:

- S. A. Campbell, *Science and Engineering of Microelectronic Fabrication*, Oxford University Press, 2005.
- M. Madou, *Fundamentals of Microfabrication*, New York: CRC Press, 2002

- M. Elwenspoek, H. Jansen, *Silicon Micromachining*, Kluwer Academic
- Publishers, 2001
- P. Van Zant, *Microchip fabrication: a practical guide*, McGraw Hill 2004
- D.V. Morga, K. Board, *An introduction to semiconductor technology*, Wiley 1990
- P. Gise, R. Blanchard, *Modern semiconductor fabrication technology*, Prentice Hall 1986.

GRADING SCHEME: Assignments (40%) (3 assignments), Research Presentation (40%) (2 short presentations + report), Laboratory Report (20%) (2 lab sessions).
Research Presentation: Two topics, one on microfabrication technique and another on the workings of a MEMS/microfluidic device that is currently used widely will be assigned to teams of 3-4 students. The team will have to make a presentation and submit a short report on their survey and analysis.
Assignments: 3 problem sets are planned for this course
Laboratory: There will be three laboratory sessions to help demonstrate some of the fabrication processes and MEMS/microfluidic concepts that are described in the lectures.

COURSE CONTENTS:
Introduction: MEMS definition, applications, markets, technology development, history, rationale, scaling of forces and dimension

Microfabrication: Bulk micromachining, surface micromachining, Non-conventional micromachining – microelectrodischarge machining, ultrasonic machining, laser micromachining, nano imprinting, focused ion beam machining, screen printing, soft lithography, injection molding, hot embossing, stereolithography.

Actuation and Sensing: Mechanics at microscale – microstructural elements, Stiction and control. Actuation principles – Electrostatic, Piezoresistive, Piezoelectric, Thermal, Electromagnetic, Resonant and tunneling.

MEMS Applications: Case studies of accelerometer, pressure sensor, microphones, ink-jet print heads, resonators, digital micromirrors and microfluidic devices.

Microfluidics: Fluid dynamics at the microscale, electrokinetics, surface tension driven transport, microfluidics for DNA analysis, Lab-on-Chip applications, Micropumps, microvalves, mixers.

Process Integration: Wafer bonding and packaging, Assembly techniques for MEMS.

LEARNING OUTCOMES: Upon successful completion of the course the student will have demonstrated the ability to:
1. Analyse dominant forces at the microscale and how they scale with dimension.
2. Deconstruct a 3D microstructure and devise a microfabrication process flow from it.
3. Analyse various transduction techniques that are commonly used in the microscale and design sensors or tranducers based on them.
4. Analyse fluid flow at the microscale and exploit the interesting phenomena that are observed at this scale to design functional devices.
5. Survey the literature and write a comprehensive analysis of a microfabrication method or a commercially available MEMS device and present it before a technical audience.