MECH 424 - *Design and Fabrication of Micromachines and Micromechanisms/*
ENGR 6371 - *Micromechatronic Systems and Applications*

(3.5/4.0 credits), winter, 2011-2012

Instructor: Dr. Ion Stiharu

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Lectures: --W-F 10:15 - 11:30, room H-620

Telephone: 3152

Office hours: --T, W: 11:45 - 12:45

Laboratory: TBA

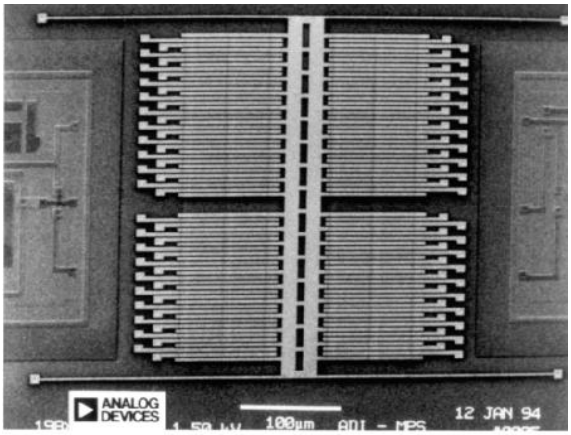
COURSE DESCRIPTION AND REQUIREMENTS

Prerequisite: **MECH 311 and MECH 343 for MECH 424, no prerequisite for ENGR 6371**

Lectures: three hours per week. Laboratory: Sessions of laboratory demonstrations will be organized at specific times that will be announced in the class and usually carried after the midterm break.

Brief description

Micromachining is an emerging way to accomplish electro-mechanical systems with integrated controls built in, by means of the integrated circuits technology. The technology is a natural continuation of the progress in microelectronics, and emerged as a need to implement high reliability, small sized and low cost sensors and microactuators towards the extension of the human senses and actions.



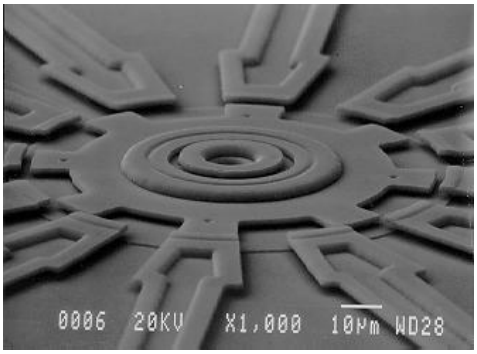
Same as microelectronics, micromachining is a constantly evolving technology with permanent effort and resources directed into the R & D, as well as in the fundamental research. There are exciting but yet unexplored avenues for new measurement principles, sensors, which will be soon implemented by the new generation of designers.

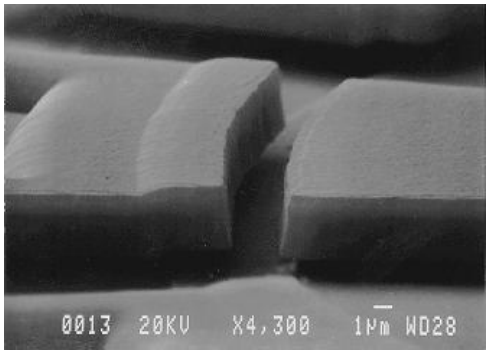
A good understanding of the standard integrated circuits fabrication technologies backed by a perfect comprehension of the behavior of the miniature systems is essential to uphold the creativity of a designer. Sensors like accelerometers, pressure, rate gyroscopes, thermal, radiation, tactile arrays, gas and chemical, systems like micromotors, micro-pumps, micro-valves, and micro-fluidic elements are already available on the market. They have few common features, apart from the common fabrication technology: most of them make use of special shaped flexible structures, beams or plates, which by deflection, move or change a physical quantity that is further detected. The detection is performed with built-in electronic circuitry, which is made at the same time with the sensitive/mobile part. It has been revealed that the properties and phenomena encountered at microscopic level differ from the same properties and phenomena occurring at the macroscopic level. These differences must be understood and modeled, such that the design process evolves from trial and error to the optimal design.

Engineering Attributes: The course is conceived to enable the students to develop "soft engineering skills". Thus, Problem Analysis is facilitated: the ability to identify, formulate, research and solve complex engineering problems reaching substantiated conclusions. Also, the Investigation skills are developed: this is the ability to conduct investigations of complex problems including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions. Finally, Design skills are enabled: An ability to design solutions for complex engineering problems and to design systems, components or processes that meet specified needs with appropriate consideration for public health and safety (bio-MEMS), cultural, societal, and environmental considerations (nano-technologies applications).

Course Content

Introduction to micromachining processes; mechanical properties of materials used in micro-electromechanical systems:





design and fabrication of free standing structures; sacrificial and structural layers; finite element modeling, micromechanical components, solid lubrication of micro bearings; special techniques; double side photolithography, anodic bonding, electrochemical drilling, deep etching, LIGA process, laser micro-fabrication, influence of IC fabrication processes on the mechanical properties; applications in microdevices; simulation and packaging.

Lectures will include but would not be limited to the following topics:

1. Introduction to sensors and micromachining, materials used for micro-electromechanical systems (MEMS).
2. Properties of materials used in micromachining; basic fabrication processes.
3. Specific fabrication processes.
4. Mechanical sensors, piezoresistive and capacitive sensors, applications.
5. Acoustic sensors, piezoelectric materials.
6. Thermal sensors.
7. Magnetic sensors and actuators.
8. Chemical and biochemical sensors.
9. Packaging.
10. Modeling of MEMS.
11. CMOS standard process.
12. CAD tools in MEMS design.
13. Micromotors and micropumps.
14. Integration principles, interface electronics.
15. Examples of integrated systems. LIGA process.

Recommended textbook: none (materials will be posted on moodle and handed in during class period)

Assignments: The course requires the completion of a number of five assignments that will be integral part of the project. The term work requires a relatively high effort to understand, formulate and solve specific problems related to MEMS and microstructures. An introduction to FEA techniques FEMLAB/ANSYS will be carried out in one or two of the lectures. However, the students are encouraged to start up to model their device from the fourth week of classes, using any FEA package (FEMLAB). The assignments will be

submittedas milestones of the projects will be send as attachment by e-mail to *istih@encs.concordia.ca* before the set deadline, that will be announced during the class. Thus, the assignments have to be solved and edited using PC available programs only. Matlab, Mathcad, Feamlab, MEMS Pro, CADENCE, MS Office are not only strongly recommended but mandatory.

During the second week of classes each student must choose one subject. Teams of two (2) for MECH 424 and one (1) for ENGR 6371are recommended. The team members must work together on the topic. The work would be distributed among the group members and a synergetic result is expected to be delivered through the report. All designs will be implemented in MUMPS technology with the help of the laboratory instructor in the coming run. All the layout designs would be performed by March 15, 2012 if intended to be implemented in a future design.
February 1st will be the deadline of the first assignment: literature review and feasibility study of the selected device. The assignment will be electronically submitted to *istih@encs.concordia.ca* and on paper to the marker/lab instructor.

Laboratory (MECH424 only):

The laboratory is part of the course. Laboratory will include apart from the technology lab, computer labs, library labs and search labs. The laboratory (the location should be established) is not capable to accommodate more than 4 students at a time. On specific days, groups of students will be attending demonstrations held by the course instructor. You could contact the laboratory instructor. His/her coordinates will be posted on the moodle of the course

Structure of the course:
The course will be organized as follows:
18 standard lectures of 1.5 hours each
4 class tests - brief quiz questions that cover the past 4 to 6 lectures.
1 introductory lecture
1 closing remarks lecture
2 open lectures - invited talks.

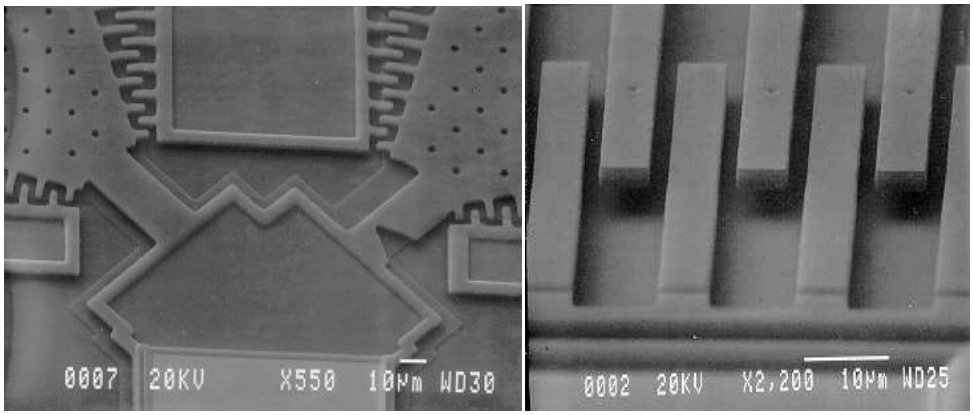
Grading for MECH 424:
The assignments will be the interim reports of the final formal report. The comprehensive project will count for 40% of the final grade. The same grade will be counted to each member of the same research team.
Class tests will count each for 15%. A passing grade (more than 50%) in the class test will be mandatory in passing the course. A grade below 50% in the class test will impose the student to write a 3 hours final exam. One missed class test will also require the student to write the final test. The final test will be comprehensive substitute the grade in the class test. The final test will be worth 60% in the final

grade. For ENGR6371, a final formal project is required in lieu of the five assignments.

The formal project:
The formal project will be structures as follows:

- Literature review and rationale – the conceptual analysis of the product
- Conceptual design scheme and synthesis
- Analysis, modeling and re-iteration of the original design – FEA model and analysis
- Layout design for MUMPS technology
- Test scheme and matrix and conclusions assuming that the designed system is available

The layout design will be carried out using MEMS Pro software (a license is available in one of the MEMS labs).



MEMS Designer Tasks

Establish commercial or research need in the light or conventional competition.
Understand the basic physics and operating principles, including scaling laws.
Understanding the important issues in designing macroscopic and micromachined versions.
Survey prior work in micromachined versions, as well as "natural" biological analogs (benchmarking or nature benchmarking).
Consider the potential need to integrated on-chip circuitry (now or in the future).
Design a feasible, not overly complex, and reasonably priced fabrication process.
If active circuits are, or may be, required, be sure to allow for that by avoiding incompatible steps.
Consider the issue of packaging. Can existing packages be adapted.
Consider realistic testing methods that suit the market (100% or statistical).
Estimate the final cost of the "ready to use" or "ready to ship" device (does it make sense?).
Consider the possibilities of evoking the design in the future to improve

performance, reduce cost, etc. (this may feed back into the process design, for example).
Make an overall decision as to feasibility prior to embarking on a research effort.

THE ASSIGNMENTS (MECH424 only)

The assignments will be submitted to the TA on paper and e-mailed to the course instructor Dr. I. Stiharu at istih@encs.concordia.ca.

The five assignments will be addressing the following aspects:

Assignment #1: Literature review on the selected subject of research and the rationale of the research. This assignment would not exceed 6 pages of text and will be submitted by February 1, 2012.

Assignment #2: The solution to the problem that is assumed to be the most suitable to the requirements, based on the literature review and the preliminary evaluations. A standard technology should be used for the problem, of preference MUMPS. This assignment will be submitted on February 15, 2012.

Assignment #3: The model of the microsystem and preliminary results of the simulations. Details will be established individually for each and every project. This assignment will be submitted on March 2, 2011.

Assignment #4: Optimization of the structure based on the results of the simulation – redesign. This assignment is due on March 17, 2011.

Assignment #5: Layout design and the test matrix. This assignment is due on April 2nd, 2012.

The graduate students will submit the first part of the project with the rationale of the work, the critical literature review and the plan of work during or after the midterm break. Within few days you will receive the comments on the future plans and on the progress of the work in general. If followed, the suggestions may lead one to publish a paper on the subject of interest.