ELEC9703
Microsystems Design and Technology

Course Outline – Semester 2, 2016

Never Stand Still | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Course Staff

Course Convener: Prof. Chee Yee KWOK, Room 751 MSEB, cy.kwok@unsw.edu.au

Consultations: You are encouraged to ask questions on the course material, during and after the lecture class times in the first instance, rather than via email. Lecturer consultation times will be advised during lectures. You are welcome to email the lecturer, who can answer your questions on this course and can also provide you with consultation times. ALL email enquiries should be made from your student email address with ELEC9703 in the subject line, otherwise they will not be answered.

Keeping Informed: Announcements may be made during classes, via email (to your student email address) and/or via online learning and teaching platforms – in this course, we will use Moodle https://moodle.telt.unsw.edu.au/login/index.php. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Course Summary

Microsystems technology is ***multidisciplinary*** in nature. It is also known as MEMS technology. The most important disciplines needed for Microsystems work are electrical engineering, mechanical engineering, microelectronic engineering, physics, material science, chemistry, fluidic engineering, photonics, biomedical engineering, biosciences etc. MEMS is truly an *enabling technology* which has penetrated into and begun to change the way major discipline do things, including biotechnology, storage technology, instrumentation, telecommunications, optical communications, MEMS device packaging, medical technology etc. etc. MEMS research and engineering development and manufacture requires close integration and collaborative interactiion of experts from many disciplines. On the other hand MEMS researchers and engineers must be willing to cross interdisciplinary boundaries and acquire knowledge outside their discipline of expertise. Examples of MEMS devices produced in large volumes include, pressure sensors, flow sensors, inertial measurement units(IMU) like accelerometers and gyroscopes, micro-valves, projection display chips, biosensors, inkjet nozzle arrays, optical cross-switches, RF switches, Lab on a Chip, etc., etc.

In short, this course will cover a wide range of topics related to MEMS fabrication technology and expand on to some of the design issues, bearing in mind the technology constraints. Can it manufactured?! It will include examples of the design and fabrication of physical sensors like gyroscopes, accelerometers, etc. Furthermore, a course is not complete if we do not know what the current market drivers are for MEMS products and where the future holds for this exciting and fast expanding technology. Many people do not realise that the numerous savvy features we have in our smart devices stem from advances in MEMS technology.

Contact Hours

This postgraduate course consists of 3 hours of lectures in the evenings. Problem discussions are included in the lectures and will not be treated as separate tutorials. The lectures will be recorded and students can refer to them at a later date. Note that this is not a replacement for lecture attendance.

Lectures	Day	Time	Location
	Tuesday	6-9pm	Rm 214

Context and aims

The entire field of research in microsensors and microactuators has evolved at an exceedingly rapid pace over the past 25 years. It is often referred to as MEMS (MicroElectroMechanical Systems) or Microsystems Technology. Signals from the physical world around us are always in analog form. Yet, much of the signal processing is done in digital form by microelectronic circuits. Microsensors and microactuators are the interfaces between the digital electronic domain and the physical world. Sensors and actuators in various forms have been around for centuries but significant miniaturisation was not possible until the last couple of decades due to the significant technological advances in microfabrication techniques. In many cases, these new devices bring along new advantages over the traditional components like several orders of magnitude in size reduction, new functionality, and possibly integration of on-chip signal processing circuit (smart sensors/actuators). Many of the micro-fabrication techniques originate from the wealth of processes developed for the fabrication of integrated circuits. Yet, the MEMS business cannot be simply compared to the IC(Integrated Circuits) business. ICs deal with electrical signals whereas MEMS devices are interfaces to the physical world from the electrical domain. As such, one would expect a more diverse, a more complicated overall environment, interacting effectively and accurately between the electronic domain and the outside world. The natural outcome of this is the vast and diverse range of MEMS devices. In fact, if one word were to be used to characterize the field of MEMS or Microsystems, it would be its ***multidisciplinary*** nature. The most important disciplines needed for Microsystems work are electrical engineering, mechanical engineering, microelectronic engineering, physics, material science, chemistry, fluidic engineering, photonics, biomedical engineering, biosciences etc. MEMS is truly an *enabling technology* which has penetrated into and begun to change the way major discipline do things, including biotechnology, storage technology, instrumentation, telecommunications, optical communications, MEMS device packaging, etc. etc. MEMS research, engineering development and manufacture must require close integration and collaborative interaction of experts from many disciplines. On the other hand MEMS researchers and engineers must be willing to cross interdisciplinary boundaries and acquire knowledge outside their discipline of expertise. Examples of MEMS devices produced on large volumes include, pressure sensors, accelerometers, microvalves, projection display chips, biosensors, injet nozzle arrays, optical crosswitches, RF switches, etc. .

Aims:

The course aims to expose students to the MEMS fabrication technology and the may design approaches, and enable them to appreciate the many advances in the technology that has become the ‘enabling technology’ for many other disciplines. It is also the aim of the course to highlight the multidisciplinary nature of the course and its impact on design issues.

Indicative Lecture Schedule

Period	Summary of Lecture Program	
Week 1 (26/7)	Introduction to Microsystems: an overview and technology trends. Lithography.	
Week 2 (2/8)	Thin Film Processes	
Week 3 (9/8)	Bulk Silicon Micromachining	
Week 4 (16/8)	Surface micromachining	
Week 5 (23/8)	Bonding Processes, High Aspect Ratio Micromachining (HARM)	Quiz1
Week 6 (30/8)	Electroplating techniques and miscellaneous processes	Assignment 1 due.
Week 7 (6/9)	Mechanics: Properties of materials, structures, energy methods	
Week 8 (13/9)	Actuation mechanisms: Electrostatic, Electromagnetic, Electrothermal, and Piezo-electric	
Week 9 (20/9)	Lumped modelling with circuit elements and system dynamics	
	Mid-Session break	
Week 10 (4/10)	Introduction to ANSYS Simulation: Electro-thermal, Piezoelectric and Electrostatic	Quiz2
Week 11 (11/10)	Inertial sensors: Accelerometer, Gyroscope, pressure transducers	
Week 12 (18/10)	Optical MEMS, Microfluidic basics and Bio-MEMS	Assignment 2 due
Week 13 (25/10)	Course review	

Assessment

Assignments (2)	25%
Quizes (2)	10%
Final Exam (3 hours) – OPEN BOOK	65%

Course Details

Credits

This is a 6 UoC course and the expected workload is 5-10 hours per week throughout the 13 week semester.

Relationship to Other Courses

This is a postgraduate course offered to students in the Master of Engineering Science (8338) and Master of Engineering Coursework (8621) in the Faculty of Engineering at the University of New South Wales. ELEC 9704 provides some of the ground work required for this course.

Pre-requisites and Assumed Knowledge

There is no specific pre-requisite for the course. However, it will be beneficial for students who are familiar with semiconductor technology which is covered in ELEC9704.

It is further assumed that the students are familiar with some basic chemistry, physics, mechanics, electrical engineering etc. The course is very multidisciplinary in nature and students are challenged to do this course with <u>an open mind</u> to learn, be creative and innovate.

Following Courses

ELEC9704 is not a pre-requisite for ELEC9703 but could be helpful.

Learning outcomes

After the successful completion of the course, the student will be able to:

1. Understand a range of technologies used for micro-fabrication.
2. Understand the principle of operations of micro-sensors and micro-actuators.
3. Analysing and designing of micro-sensors and micro-actuators.
4. Understand the design flow procedure for MEMS device .
5. Exposure to the use of ANSYS simulation.
6. Ability to devise process flow to micro-fabricate MEMS devices.
7. Appreciate the multi-disciplinary nature of micro-systems.

This course is designed to provide the above learning outcomes which arise from targeted graduate capabilities listed in ***Appendix A***. The targeted graduate capabilities broadly support the UNSW and Faculty of Engineering graduate capabilities (listed in ***Appendix B***). This course also addresses the Engineers Australia (National Accreditation Body) Stage I competency standard as outlined in ***Appendix C***.

Syllabus

Introduction to Microsystems: an overview and trends ; Lithography and Thin Film Processes ; Surface micromachining **;** Bonding Processes; High Aspect Ratio Micromachining (HARM); Mechanics: Properties of materials, structures, energy methods ; Actuation mechanisms: Electrostatic, Electromagnetic, Electrothermal, and Piezo-electric ; Lumped modelling with circuit elements and system dynamics ; Introduction to ANSYS Simulation: Electro-thermal, Piezoelectric and Electrostatic ; Optical MEMS, Microfluidic basics and Bio-MEMS.

Teaching Strategies

Delivery Mode

The teaching in this course aims at establishing a good fundamental understanding of the areas covered using:

- Formal face-to-face lectures, which provide you with a focus on the core analytical material in the course, together with qualitative, alternative explanations to aid your understanding;

- There are no separate tutorials but may be done during lectures from time to time. Some self-paced exercises will be given.
- Where possible, lectures will be videoed and uploaded to the school website for students to clarify specific aspects of the lecture. It is not a substitute for missed lectures.

Learning in this course

You are expected to attend all lectures and attempt all quizzes and assignments in order to maximise learning. In addition to the lecture notes/video, you should read relevant sections of the recommended and reference text and journal papers. Reading additional texts will further enhance your learning experience. Group learning is also encouraged. UNSW *assumes* that self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Tutorial classes

There are no separate tutorial classes.

Laboratory program

There are no laboratory programs. A brief lab tour of the Australian National Fabrication Facility will be conducted at an agreed time, outside the 6-9pm lecture times.

Assessment

Assignments (2)	25%
Quizes (2)	10%
Final Exam (3 hours) -open book	65%

The assessment scheme in this course reflects the intention to assess your learning progress through the sessions by means of short quizzes and assignments. Students are strongly advised not to presume that an open book exam would be simpler than a closed book exam.

Final Exam

The exam in this course is an open-book 3 hour written examination, comprising four compulsory questions. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Quiz	x	x	x	x			x
Assignment	x	x	x		x	x	
Final exam	x	x	x	x		x	x

Course Resources

Textbooks

In the view of the wide range of disciplines in this course, there is no single textbook that appropriately covers all the course material. Hence, it does not have prescribed textbook. However, the following reference books and articles are recommended:

1. MJ Madou, “Fundamentals of Microfabrication”, CRC Press (good text to buy)
2. GTA Kovacs, “Micromachined Transducers sourcebook,” McGraw Hill, 1988.
3. S D Senturia, “Microsystems Design”, KAP, 2001.
4. L. Ristic, “Sensor Tchnonology and Devices”, AH, 1994.
5. P. Rai-Choudhury, “Microlithography, Micromachining, and Microfabrication”, Vo..2, SPIE Press, 1997.
6. M Elwenspoek and HV Jansen, “Silicon Micromachining,” CUP 1998.
7. SA Campbell, “The Science and Engineering of Microelectronics Fabrication”
8. S. SZE, “VLSI Technology”, McGrawHill
9. Gere & Timoshenko, “Mechanics of Materials”
10. Roark, “Roark’s Formula for Stress and Strain,” McGrawHill, 6th Ed, 1989.
11. M Lambrechts &W Sansen, “Biosensor- Micorelectromechanical devices”, IOP, 1992.
12. JW Gardner, “Microsensors”, Wiley, 1994.
13. IEEE Journal of Micro-Electro-Mechanical Systems
14. Sensors and Actuators A: Physical
15. Journal of Micromechanics and Microengineering
16. Proceedings from Transducers conferences
17. Proceedings from IEEE MEMS conferences
18. Proceedings from EUROSENSOR conferences
19. Procedia Engineering

On-line resources

Moodle

As a part of the teaching component, Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.

Mailing list

Announcements concerning course information will be given in the lectures and/or on Moodle and/or via email (which will be sent to your student email address).

Other Matters

Academic Honesty and Plagiarism

Plagiarism is the unacknowledged use of other people’s work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism, see http://www.lc.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Student Responsibilities and Conduct

Students are expected to be familiar with and adhere to all UNSW policies (see https://my.unsw.edu.au/student/atoz/ABC.html), and particular attention is drawn to the following:

Workload

It is expected that you will spend at least **ten to twelve hours per week** studying a 6 UoC course, from Week 1 until the final assessment, including both face-to-face classes and *independent, self-directed study*. In periods where you need to need to complete assignments or prepare for examinations, the workload may be greater. Over-commitment has been a common source of failure for many students. You should take the required workload into account when planning how to balance study with employment and other activities.

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment.

General Conduct and Behaviour

Consideration and respect for the needs of your fellow students and teaching staff is an expectation. Conduct which unduly disrupts or interferes with a class is not acceptable and students may be asked to leave the class.

Work Health and Safety

UNSW policy requires each person to work safely and responsibly, in order to avoid personal injury and to protect the safety of others.

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff. For more detail, consult https://my.unsw.edu.au/student/atoz/SpecialConsideration.html.

Continual Course Improvement

This course is under constant revision in order to improve the learning outcomes for all students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process. You can also provide feedback to ELSOC who will raise your concerns at student focus group meetings. As a result of previous feedback obtained for this course and in our efforts to provide a rich and meaningful learning experience, we have continued to evaluate and modify our delivery and assessment methods.

Administrative Matters

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School and UNSW policies:
http://www.engineering.unsw.edu.au/electrical-engineering/policies-and-procedures
https://my.unsw.edu.au/student/atoz/ABC.html

Appendix A: Targeted Graduate Capabilities

Electrical Engineering and Telecommunications programs are designed to address the following targeted capabilities which were developed by the school in conjunction with the requirements of professional and industry bodies:

- The ability to apply knowledge of basic science and fundamental technologies;
- The skills to communicate effectively, not only with engineers but also with the wider community;
- The capability to undertake challenging analysis and design problems and find optimal solutions;
- Expertise in decomposing a problem into its constituent parts, and in defining the scope of each part;
- A working knowledge of how to locate required information and use information resources to their maximum advantage;
- Proficiency in developing and implementing project plans, investigating alternative solutions, and critically evaluating differing strategies;
- An understanding of the social, cultural and global responsibilities of the professional engineer;
- The ability to work effectively as an individual or in a team;
- An understanding of professional and ethical responsibilities;
- The ability to engage in lifelong independent and reflective learning.

Appendix B: UNSW Graduate Capabilities

The course delivery methods and course content directly or indirectly addresses a number of core UNSW graduate capabilities, as follows :

- Developing scholars who have a deep understanding of their discipline, through lectures and solution of analytical problems in tutorials and assessed by assignments and written examinations.
- Developing rigorous analysis, critique, and reflection, and ability to apply knowledge and skills to solving problems. These will be achieved by the laboratory experiments and interactive checkpoint assessments and lab exams during the labs.
- Developing capable independent and collaborative enquiry, through a series of tutorials spanning the duration of the course.
- Developing independent, self-directed professionals who are enterprising, innovative, creative and responsive to change, through challenging design and project tasks.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	✓
	PE1.5 Knowledge of engineering design practice	✓
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	✓
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	