Biomedical Microdevices

Academic Year: (2024 / 2025) **Review date: 25-04-2024**

Department assigned to the subject: Bioengineering Department

Coordinating teacher: MUÑOZ BARRUTIA, MARIA ARRATE

Type: Electives ECTS Credits : 6.0

Year : 4 Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

It is strongly advised to have completed:
- Introduction to the design of biomedical instrumentation; and
- Medical instrumentation and devices.

SKILLS AND LEARNING OUTCOMES

RA3: Be able to carry out conceptual designs for bioengineering applications according to their level of knowledge and understanding, working in a team. Design encompasses devices, processes, protocols, strategies, objects and specifications broader than strictly technical, including social awareness, health and safety, environmental and commercial considerations.
RA4: Be able to use appropriate methods to carry out studies and solve problems in the biomedical field, commensurate with their level of knowledge. Research involves conducting literature searches, designing and carrying out experimental practices, interpreting data, selecting the best approach and communicating knowledge, ideas and solutions within their field of study. May require consultation of databases, safety standards and procedures.
RA5: Acquire intermediate/advanced knowledge of engineering and biomedical sciences and demonstrate an understanding of the theoretical and practical aspects and methodology of work in their field of study.
CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3: Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4: Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5: Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG2: Ability to design, draft and develop scientific-technical projects in the field of biomedical engineering.
CG4: Ability to solve problems with initiative, decision-making, creativity, and to communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the biomedical engineer's activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG6: Knowledge of current standards, regulations and legislation and ability to apply them to bioengineering projects. Bioethics applied to biomedical engineering.
CG7: Drafting, representing and interpreting scientific-technical documentation.
CG8: Ability to solve mathematical, physical, chemical and biochemical problems that may arise in biomedical engineering.
CG9: Ability to analyse and conceptually design electronic devices to solve problems in biology and medicine.
CG15: Ability to apply microfabrication, microfluidics, nanotechnology and 3D printing techniques in the field of biomaterials.
CG20: Ability to design instruments for medical applications, from surgical instruments to micro and

nanometric biosensors.
CG21: Ability to analyse complex and multidisciplinary problems from the global point of view of Biomedical Instrumentation.
CT1: Ability to communicate knowledge orally and in writing to both specialised and non-specialised audiences.
CT2: Ability to establish good interpersonal communication and to work in multidisciplinary and international teams.
CT3: Ability to organise and plan their work, making the right decisions based on the information available, gathering and interpreting relevant data in order to make judgements within their area of study.

OBJECTIVES

This course aims to provide the students with a comprehensive understanding of the biophysical and chemical principles of biomedical micro-electro-mechanical systems, also known as BioMEMS, and their applications in multidisciplinary fields such as medicine and clinical sciences and surgery, material sciences, and engineering.

The study of the basis of microfabrication techniques, micropatterning, microfluidic systems, and biosensors will be completed with examples of current applications of BioMEMS such as biomechanical, optical, and electrochemical transducers used for in vivo and in vitro measurements, microdevices for molecular and cell biology, microfabricated approaches for analysis and diagnosis, hybrid technologies oriented to tissue microengineering and organ development, implantable microdevices based on biomedical microelectronics, micro-tools for surgery, point-of-care devices and world-to-chip interfacing and packaging processes.

In particular, at the end of the course, each student will be able to:

- Integrate knowledge of life and medical science learned in previous courses to create implementable solutions to microengineering problems.
- Select appropriate materials for the construction of biomedical microdevices.
- Understand the basic principles of microfabrication and systems integration of BioMEMS devices.
- Design and construct simple microfluidic systems and perform experiments using these devices.
- Describe different biosignal transduction mechanisms and choose the appropriate one for a given application.
- Have an appreciation and understanding of the technical challenges and opportunities that biomedical microdevices bring to life and medical sciences.
- Function effectively as a part of a group in the practical sessions and problem-solving sessions.
- Acquire through reading, practice exercises, and self-initiated research technical knowledge related to the course content, including the emerging applications of biomedical microdevices.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Introduction

Part I. BioMEMS fundamentals

2. BioMEMS Materials
3. Microfabrication methods and processes for BioMEMS
4. Microfluidic systems
5. Lab-on-a-Chip or Micro Total Analysis Systems
6. Sensing and detection methods

Part II. BioMEMS applications

7. 'Chips' for or biotechnology and molecular biology
8. BioMEMS for cell biology
9. Clinical monitoring and therapeutic intervention

Part III. Practical sessions

1. Design of a PDMS microdevice
2. PDMS microdevices fabrication and characterization
3. Paper microfluidics design and characterization
4. Glucometer design and calibration

5. Flexible electronics
6. Analysis of flow cytometer data

LEARNING ACTIVITIES AND METHODOLOGY

The teaching methodology will be mainly based on lectures, seminars, and practical sessions.

LECTURES:
Due to the large number of topics covered and their multidisciplinary nature, it is very convenient that the student read the assigned documentation before the lectures and, when required, complement it provided with additional information through personal work.

1) Lectures: The teachers will use them to stress and clarify some challenging and exciting points from the corresponding lesson previously prepared by the student.

2) Seminars: They will be mainly dedicated to presentations given by invited speakers related to the course subject and interactive discussions with the students. During the discussion sessions, exercises will be provided and solved in small groups of 2-3 students. On some occasions, the activities will be assigned as homework. All assignments are due by the corresponding deadline through the course platform.

3) Oral presentations: At least once during the course, each student will have the chance to do a short oral presentation on a topic related to the course. These oral presentations will be prepared individually or in groups of two and have a duration of approximately 15 minutes per student.

Help sessions and tutorial classes will be held before the final exam. Attendance to lectures, short exams, or submission of possible homework is not compulsory.

PRACTICAL SESSIONS:
The practical sessions may include visits to research, clinical centers, or laboratory work.

1) Visits to research or clinical centers: These visits to centers designing, fabricating, or using bioMEMS will aim to expose the students to the practicalities of the subject. The students will prepare a short report about the visit to consolidate the learned concepts.

2) Laboratory practices: Each experiment will be performed in groups of no more than three students for these sessions. Simple experiments will familiarize the students with BioMEMS devices during these sessions. Experimental data will be obtained, analyzed, and presented as a scientific report.

Attendance to practical sessions is mandatory.

Tutorship sessions and schedules will be announced in Aula Global.

ASSESSMENT SYSTEM

% end-of-term-examination:	40
% of continuous assessment (assigments, laboratory, practicals…):	60

Grading will be based on continuous evaluation and a final exam covering the whole subject, including invited lectures and seminars. Tutorship sessions and tutorial classes will be held before the final exam upon students' request. Failure to attend any test or submit the exercises before the deadline will result in a zero mark in the corresponding continuous evaluation block (see below).

GRADING:
Total score: 10 points
Continuous evaluation: 6 points out of 10
Final exam: 4 points out of 10

CONTINUOUS EVALUATION: It accounts for up to 60% of the final score of the subject (6 points of the total score), and includes two components:
1) Homework and midterm exams: Three points of the total score. Deadlines and test dates will be announced at least one week in advance.
2) Laboratory practices and exercises: Three points of the total score.

FINAL EXAM: The final exam will cover the whole subject, including invited lectures and seminars, and

% end-of-term-examination:	40
% of continuous assessment (assigments, laboratory, practicals…):	60

will account for 40% of the final score (4 points). The minimum score in the final exam to pass the subject is 4 over 10, notwithstanding the mark obtained in continuous evaluation.

EXTRAORDINARY EXAM: The mark for students attending any extraordinary examination will be either
a) 100% extraordinary exam mark, or
b) 40% extraordinary exam mark and 60% continuous evaluation, if available in the same course, at the student's request.

ACADEMIC CONDUCT: Unless specified, all exams will be closed-book, closed-notes, no PC or mobile phone, or anything other than writing instruments and the exam itself. Plagiarism, cheating, or other acts of academic dishonesty will not be tolerated. Any infractions will result in a failing grade.

BASIC BIBLIOGRAPHY

- Albert Folch Introduction to BioMEMS, CRC Press, 2013

- Albert Folch Hidden in Plain Sight, The MIT Press, 2022

- Ellis Meng Biomedical Microsystems, CRC Press, 2011

ADDITIONAL BIBLIOGRAPHY

- Simona Badilescu, Muthukumaran Packirisamy BioMEMS: Science and Engineering Perspectives, CRC Press, 2016

- Stephen D. Senturia Microsystems Design, Kluwer Academic Publishers, 2001