Course guide
295122 - 295II332 - Biofunctional Materials

Last modified: 02/10/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 702 - CEM - Department of Materials Science and Engineering.
713 - EQ - Department of Chemical Engineering.

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Optional subject).
MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2021). (Optional subject).
MASTER'S DEGREE IN ADVANCED BIOMEDICAL TECHNOLOGIES (Syllabus 2025). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: DANIEL RODRÍGUEZ RIUS

Others: Primer quadrimestre:
CARLOS ENRIQUE ALEMAN LLANSO - Grup: T11, Grup: T12
CONRADO JOSE APARICIO BADENAS - Grup: T11, Grup: T12
MARIA PAU GINEBRA MOLINS - Grup: T11, Grup: T12
MARIA GODOY GALLARDO - Grup: T11, Grup: T12
CARLOS MAS MORUNO - Grup: T11, Grup: T12
DANIEL RODRÍGUEZ RIUS - Grup: T11, Grup: T12

PRIOR SKILLS

Knowledge of Biomaterials science.
Knowledge of Chemistry (both organic and inorganic).

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-19. Develop translational applications with the aim of achieving a better understanding of physiological phenomena of clinical relevance and for the design of new applications in areas that have an impact on the health care of people. (Specific competence of the Healthcare and Biomedical Applications specialty)
CEMCEAM-03. (ENG) Realizar estudios de caracterización y evaluación de materiales según sus aplicaciones

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
K1. Relate advanced knowledge of biomechanics, biomaterials, implants and prostheses to the design of medical devices.
K3. Relate advanced knowledge of healthcare products and technological innovation concepts.

Skills:
S1. Develop kinematic and dynamic analyses of biomechanical systems using the finite element method.
S9. Plan the stages, tasks and activities involved in designing and developing biomedical devices and sensors or processing biomedical data.
S2. Appropriately use techniques for manufacturing, analysing and characterising biomaterials to choose them correctly and process them according to their properties and potential application.

Competences:
C3. Identify and analyse problems that require making autonomous, informed and reasoned decisions in order to act with social responsibility following ethical values and principles.
C5. Use scientific and technical information to respond to any demand for modification, innovation or improvement of devices, products and processes linked to biomedical engineering for new scientific or technological applications.

TEACHING METHODOLOGY

The subject is divided as follows:
- 15% lectures
- 5% seminars and problem sessions
- 15% laboratory sessions
- 65% self-directed learning

LEARNING OBJECTIVES OF THE SUBJECT

- Understand the biological mechanisms of cell-material interactions and their signaling cascades.
- Decide which type of cell is required for each biomaterial depending on the tissue/site of implantation.
- Discriminate between different in vitro and in vivo assays and select the appropriate method for a specific approach.
- Adjust biomaterial-tissue interactions at macro, micro and nano scale.
- Evaluate the best characterization techniques to analyze a biomaterial-tissue surface interaction.
- Design methods of surface functionalization to control cell and bacterial behavior on biomaterials.
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.
- Engineer self-assembling processes to obtain supramolecular structures with diverse biological functions.
- Analyze strategies to design drug delivery systems; awareness of interactions biomaterial-drug.
- Select the most suitable drug delivery analysis techniques and methods.
- Design methods for the generation of smart hydrogels with specific responses to different external stimuli.

STUDY LOAD

Type	Hours	Percentage
Hours large group	21,0	14.00
Self study	108,0	72.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

Unit 1: Cell/biomaterial interaction

Description:
- The extracellular matrix (ECM): composition and structure; functions; synthesis and remodeling; Fibronectin and other adhesive glycoproteins; collagens and collagen associated proteins; proteoglycans.
- Cell surface receptors: Integrins; syndecans; growth factor receptors; intracellular signaling pathways
- Extracellular control of cell behavior: cell division and mitogens; cell growth and growth factors; apoptosis and survival factors.
- Stem cells: origin and types; cloning; clinical applications.
- Host response to biomaterials: biomaterial-host interaction; inflammation; healing; foreign body response; biocompatibility; host response to naturally derived biomaterials.
- Biomaterials associated infection: bacteria and biofilms; host reaction to infection.

Specific objectives:
- Understand the biological mechanisms of cell-material interactions and their signaling cascades.
- Decide which type of cell is required for each biomaterial depending on the tissue were will be implanted.
- Discriminate between the different in vitro and in vivo assays and select the appropriate for a specific approach

Related activities:
Debates on papers and scientific news; Oral presentations; Tests.

Full-or-part-time: 34h
Theory classes: 5h
Laboratory classes: 4h
Guided activities: 1h
Self study : 24h

Unit 2: Topography

Description:
Introduction:
Roughness. Basic roughness parameters.
Porosity. Role of porosity in the biological interactions of materials.
Multiscale topography and porosity, at the macro, micro and nano scale.
Main characterization techniques (SEM, perfilometry, wettability, interferometry, AFM, MIP, Gas adsorption, microCT)

Specific objectives:
- apply the knowledge about topography and porosity to adjust biomaterial-tissue interactions at macro, micro and nano scale
- evaluate the best characterization techniques to analyze a biomaterial-tissue surface interaction

Related activities:
Laboratory session on roughness; Invited speakers, discussion of scientific publications, debates and oral / poster presentations.

Full-or-part-time: 28h
Theory classes: 4h
Laboratory classes: 4h
Guided activities: 2h
Self study : 18h

Unit 3: Surface biofunctionalization

Description:
- Introduction: current limitations of biomaterials; bioinertness vs. bioactivity; classical methods of functionalization (plasma spraying, chemical etching, electrochemical methods, sand blasting, etc.).
- Physical methods: plasma-based strategies to functionalize biomaterials; plasma-assisted polymerization.
- Chemical methods (I) - Inorganic coatings: hydroxyapatite coatings by plasma spray and electrodeposition; thermochemical treatments (Kokubo method); apatite formation in vivo.
- Chemical methods (II) - Organic coatings: SAMs; polymers and recombinamers; proteins; peptides; peptidomimetics; dendrimers and hierarchical structures; nanoparticles; multifunctional systems.
- Antibacterial coatings: the "race for the surface"; biofilms and antibiotics; anti-fouling coatings; bactericidal coatings (release-based); bactericidal coatings (immobilized).
- Characterization techniques: QCM-D, XPS.

Specific objectives:
- Design methods of surface functionalization to control cell behavior on biomaterials.
- Design methods of surface functionalization to inhibit bacterial adhesion on biomaterials.
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.

Related activities:
- Invited speakers, discussion of scientific publications, debates and oral / poster presentations.

Full-or-part-time: 34h
Theory classes: 5h
Laboratory classes: 4h
Guided activities: 1h
Self study : 24h

Unit 4: Peptide-based materials

Description:
- Fundamentals of chemistry and physics of peptide materials: 3D peptide structures; optical properties; quantum confinement and thermal phase transitions.
- Peptronics: Electron transfer through peptide materials in solution; supported peptide materials and their interactions; electron transfer through supported peptide materials; applications.
- Peptide nanostructures: molecular architectures with peptide assembling for nanomaterials; building blocks; shape driven nanostructures; function of peptide assemblies; peptide-based spherical and dendritic structures; applications.
- Peptide conjugates and hybrid peptide-based materials: peptide-polymer conjugates; block copolymers; peptide-based carbon nanotubes; hyperbranched polymers and dendrimers; applications.
- Characterization techniques: TEM, CD.

Specific objectives:
- Analyze strategies to mimic biologically complex scenarios on artificial scaffolds.
- Engineer self-assembling processes to obtain supramolecular structures with diverse biological functions.

Related activities:
- Invited speakers, discussion of scientific publications, debates and oral / poster presentations.

Full-or-part-time: 27h
Theory classes: 4h
Laboratory classes: 4h
Guided activities: 1h
Self study : 18h

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Unit 5: Drug delivery

Description:
- Introduction: basic concepts in drug delivery; conventional drug delivery formulations; systemic vs. local drug delivery, vectoring; Kinds of drugs & kinds of carriers; Formulation; Stability.
- Evaluation of release: Methods for drug testing (USP). Methods of analysis for evaluation of release (UV-VIS, HPLC). Interpretation of physical phenomena beyond release.
- Strategies for drug delivery from different materials / implants:
- Strategies for incorporating drugs to implants & modulating drug release, examples: Polymers (Films; fiber-based systems (textiles, stents); etc.); Bioinstructive / smart hydrogels; Bioceramics.

Specific objectives:
- Analyze strategies to design drug delivery systems; awareness off interactions biomaterial-drug
- Selection of the most suitable drug delivery analysis techniques and methods

Related activities:
Online tests, discussion of scientific publications, debates, oral / poster presentations.

Full-or-part-time: 27h
Theory classes: 4h
Laboratory classes: 4h
Guided activities: 1h
Self study : 18h

GRADING SYSTEM

Partial test 1: 35%
Partial test 2: 35%
Individual Reports: 10%
Laboratory: 20%

Attendance to Lab sessions and seminars is mandatory to pass the course.
This subject does not include a reevaluation test.

EXAMINATION RULES.

The use of any electronic equipment with wireless communication capabilities is strictly forbidden in the evaluations.

BIBLIOGRAPHY

Basic:
- Ratner, Buddy; Hoffman, Allan; Schoen, Frederick; Lemons, Jack. Biomaterials science : an introduction to materials in medicine. 3rd ed. Amsterdam: Academic Press, 2013. ISBN 9780123746269.

Complementary:
- Law, Kock-Yee; Zhao, Hong. Surface wetting : characterization, contact angle, and fundamentals [on line]. Springer International Publishing, 2016 [Consultation: 14/04/2020]. Available on: https://doi.org/10.1007/978-3-319-25214-8. ISBN 9783319252148.
- Haugstad, Greg. Atomic force microscopy : understanding basic modes and advanced applications. John Wiley & Sons, 2012. ISBN 9780470638828.