

**Micro and Nanosystems**

Code: 103298  
ECTS Credits: 6

| Degree                                 | Type | Year | Semester |
|----------------------------------------|------|------|----------|
| 2501922 Nanoscience and Nanotechnology | OB   | 4    | 1        |

**Contact**

Name: Núria Barniol Beumala  
Email: nuria.barniol@uab.cat

**Use of Languages**

Principal working language: catalan (cat)  
Some groups entirely in English: No  
Some groups entirely in Catalan: Yes  
Some groups entirely in Spanish: No

**Teachers**

Francesc Torres Canals

**Prerequisites**

It is recommended to attend the subject simultaneously or later to Nanofabrication.

**Objectives and Contextualisation**

The general objective of the course is that the student knows the main principles of transduction, the different structures and also the architectures involved in sensing and actuation with a micro/nanometric scale device. Special emphasis will be made for the effects of the reduction of the dimensions to the nanometer scale

**Competences**

- Adapt to new situations.
- Apply the concepts, principles, theories and fundamental facts of nanoscience and nanotechnology to solve problems of a quantitative or qualitative nature in the field of nanoscience and nanotechnology.
- Apply the general standards for safety and operations in a laboratory and the specific regulations for the use of chemical and biological instruments, products and materials in consideration of their properties and the risks.
- Communicate clearly in English.
- Communicate orally and in writing in one's own language.
- Demonstrate knowledge of the concepts, principles, theories and fundamental facts related with nanoscience and nanotechnology.
- Handle the standard instruments and materials of physical, chemical and biological testing laboratories for the study and analysis of phenomena on a nanoscale.
- Interpret the data obtained by means of experimental measures, including the use of computer tools, identify and understand their meanings in relation to appropriate chemical, physical or biological theories.
- Learn autonomously.
- Manage the organisation and planning of tasks.

- Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
- Operate with a certain degree of autonomy.
- Propose creative ideas and solutions.
- Reason in a critical manner
- Recognise and analyse physical, chemical and biological problems in the field of nanoscience and nanotechnology and propose answers or suitable studies for their resolution, including when necessary the use of bibliographic sources.
- Recognise the terms used in the fields of physics, chemistry, biology, nanoscience and nanotechnology in the English language and use English effectively in writing and orally in all areas of work.
- Resolve problems and make decisions.
- Work correctly with the formulas, chemical equations and magnitudes used in chemistry.
- Work on the synthesis, characterisation and study of the properties of materials on a nanoscale from previously established procedures.

## Learning Outcomes

1. Adapt to new situations.
2. Apply the acquired theoretical contents to the explanation of experimental phenomena.
3. Characterise micro and nanosystems to extract their main transducing characteristics.
4. Communicate clearly in English.
5. Communicate orally and in writing in one's own language.
6. Correctly observe protocols for using instrumentation, reagents and chemical waste in laboratories related to the subject.
7. Correctly use specific physical and electronic simulation programs to study electronic devices.
8. Critically evaluate experimental results and deduce their meaning.
9. Describe the elements, architectures and principles of MEMS and NEMS systems and identify their main applications.
10. Describe the existing relationship between transducer elements and specific technologies for their manufacture.
11. Describe the principles of modelling and its main tools for the simulation of transducer elements
12. Describe the principles of transduction to produce sensors and actuators and the effects of a decrease in dimensionality.
13. Design micro and nanosystems in accordance with specifications and in consideration of the technology.
14. Draft and present reports on the subject in English.
15. Identify the main transducer elements and their physical and chemical principles in mechanical structures, basic electronic devices and specific materials for transduction.
16. Interpret and rationalise the results obtained both in the laboratory and in simulation of the characterisations of micro and nanosystems and relate them with transducer processes.
17. Interpret and rationalise the results obtained in the laboratory in processes related with physics and chemistry in nanoscience and nanotechnology.
18. Interpret discrepancies between theoretical and practical results (including simulation) found in the characterisations of electronic devices.
19. Interpret texts in English on aspects related with the physics and chemistry of nanoscience and nanotechnology.
20. Learn autonomously.
21. Manage the organisation and planning of tasks.
22. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
23. Operate with a certain degree of autonomy.
24. Perform bibliographic searches for scientific documents.
25. Perform characterisation studies of materials and nanomaterials to extract their transducing properties in micro and nanosystems.
26. Predict behavioural changes in transducers and devices in accordance with a decrease in their size to the nanometric scale.
27. Propose creative ideas and solutions.

28. Rationalise the results obtained in the laboratory in terms of physical magnitudes and their relation with the observed physical phenomena.
29. Reason in a critical manner
30. Recognise and propose figures of merit for micro and nanosystems.
31. Recognise the terms used in the physics and chemistry of surfaces, supramolecular chemistry and molecular recognition.
32. Resolve problems and make decisions.
33. Resolve problems with the help of the provided complementary bibliography.
34. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

## Content

### Unit 1. Introduction

Definition of basic concepts (sensor / actuator / transducer). Micro and nanosystems versus micro and nanoelectromechanical systems (MEMS-NEMS). Historical origin Micro and nanosystem technology. Relationship with microelectronics technology and micro and nanofabrication techniques. Industrial applications and market prospects.

### Unit 2. Transducer elements.

Basic MEMS mechanical structures: levers, bridges, membranes. Materials and principles of transduction: piezo-resistive, piezoelectric, electrostatic, optical, electromagnetic.

### Unit 3. Architectures and principles of operation

Micro and nanosystems DC (static) and AC (dynamic or resonant). Techniques of actuation and detection. Digital and analogue architectures for the transduction, conditioning, amplification and transmission of the signal.

### Unit 4. Modeling and simulation

Modeling and simulation of transducer elements: finite element simulation tools (FEM). Mechanical, electronic, electromagnetic and other transduction domains. Modeling and simulation at the system level.

### Unit 5. Dimensional scaling

Study of the effects of dimensional scaling on the characteristics and merit figures of micro and nanosystems. Advantages of microsystems with respect to systems of millimetric dimensions. Limits of scaling in the nano regime.

### Unit 6. Applications of micro and nanosystems

Sensors: temperature, pressure, displacement, acceleration, force, flow, gases, mass. Applications to chemical and biological sensing. Optical applications Actuators: micromotors, microvalves, microswitches. Signal processors: RF-MEMS, micro oscillators, filters, mixers. Power generation: scavengers, fuel micropiles.

### Practices

-Design and simulation of an M / NEMS

## Methodology

Theoretical classes Explanation by the teacher of the fundamental concepts of each of the topics. Part of the concepts will be introduced as a resolution of specific cases.

Problem classes Resolution and discussion of from the exercises and problems delivered to students.

Laboratory. Practical work in the specific laboratory. Part of the work will have a specific section that will require a previous resolution based on mathematical calculations or by simulation tools.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

## Activities

| Title                                                     | Hours | ECTS | Learning Outcomes                                                      |
|-----------------------------------------------------------|-------|------|------------------------------------------------------------------------|
| Type: Directed                                            |       |      |                                                                        |
| Concepts and theoretical teaching                         | 27    | 1.08 | 1, 2, 5, 9, 12, 10, 13, 15, 19, 23, 26, 27, 29, 31, 30, 14             |
| Laboratory                                                | 15    | 0.6  | 1, 2, 8, 4, 5, 3, 18, 17, 16, 22, 23, 27, 28, 29, 25, 14, 32, 34, 7, 6 |
| Practical lessons with exercises                          | 10    | 0.4  | 2, 20, 13, 24, 21, 19, 22, 23, 26, 27, 29, 25, 30, 33, 32              |
| Type: Autonomous                                          |       |      |                                                                        |
| Exercises solving                                         | 20    | 0.8  | 20, 13, 24, 21, 19, 23, 26, 27, 29, 30, 33, 32                         |
| Reading, resolution and writing of the laboratory reports | 20    | 0.8  | 2, 8, 5, 13, 18, 17, 16, 23, 26, 28, 14, 34, 7                         |
| Study for the assimilation of concepts                    | 46    | 1.84 | 2, 20, 24, 16, 19, 22, 30, 33                                          |

## Assessment

The evaluation of the subject will have 3 differentiated sections:

a) There will be compulsory two written examinations on the concepts taught in the theoretical and problems (with a weight of 25% for each partial exam). For averaging a minimum qualification of 3.5 is needed in each partial exam. At the end of the course there will be a final final examination so that students can approve or improve their qualification. Students must do both partial examinations for attend this final exam. In the event that the student is not presented at both partial sessions, the student will be qualified as "non-evaluable". A minimum qualification of 4,5 is required in this section to make the weighting with sections b) and c).

b) A design project of a micro-nanosystem will be proposed. The work must be performed in a team and will be presented in the form of a poster at the end of the course. The weight of this work will be 20%. Obligatory and non-recoverable activity.

c) The practices, which are mandatory, will have a final weight of 30%. The evaluation of the same will be done with two written reports made by the students in which the experimental results of the practices will be detailed, valuing the interpretation and discussion of the results insofar as they are theoretically and / or simulated.. Obligatory and non-recoverable activity.

## Assessment Activities

| Title                                                               | Weighting | Hours | ECTS | Learning Outcomes                                                                     |
|---------------------------------------------------------------------|-----------|-------|------|---------------------------------------------------------------------------------------|
| Delivery of a written report on the design of a Micro / nanosystem. | 20%       | 4     | 0.16 | 1, 20, 4, 5, 9, 10, 13, 24, 21, 15, 16, 19, 22, 23, 26, 27, 29, 31, 30, 14, 33, 34, 7 |
| Laboratory work evaluation                                          | 30%       | 2     | 0.08 | 2, 8, 4, 5, 13, 3, 24, 21, 18, 17, 16, 22, 23, 27, 28, 29, 25, 31, 30, 14, 34, 7, 6   |
| Written partial exams (2)                                           | 25% per   | 6     | 0.24 | 5, 9, 12, 11, 10, 13, 15, 18, 17, 16, 19, 26,                                         |

## Bibliography

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Sensors, Actuators and their interfaces: a multidisciplinary introduction. Ida, N. 978-1-61353-006-1 (2020), eBook

Analysis and design principles of MEMS devices. Minhang, Bao. ISBN: 978-0-444-51616-9, (2005), eBook

Sensors, Actuators and their interfaces: a multidisciplinary introduction. Ida, N. 978-1-61353-006-1 (2020), eBook

Understanding MEMS : Principles and Applications, Luis Castañer, Wiley, ISBN: 978-1-119-05542-6 (2015), eBook

-MEMS Mechanical Sensors (Artech House microelectromechanical systems (MEMS) series), Steve Beeby et al. ISBN: 978-1-58053-536-6 (2004), eBook

*Handbook of Nanotechnology*. B. Bhushan. Springer-Verlag, (2004).

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- Handbook of Transducers. Harry N. Norton. Ed. Prentice-Hall. Englewood Cliffs, NJ, 1989.

- Semiconductor Sensors, S.M. Sze editor, Ed. John Wiley & Sons, New York, 1994

- Sensor Materials, P.T.Moseley and A.J. Crocker, Ed. Institute of Physics Publishing (IOP), London 1996

- Sensor technology and devices, L. Ristic editor, Ed. Artech House, Boston 1994

- Microsensors, Principles and Applications, J.W. Gardner, Ed. John Wiley & sons, Chichester, 1994

- Sensors and Transducers, M.J. Usher and D.A. Keating, Ed. Macmillan, London, Second Edition 1996

## Software

Elmer, software finite elements modelization, <http://www.elmerfem.org/blog/documentation/>

Salome, software for the design of the systems for software Elmer, <https://www.salome-platform.org/>

Pspice, software for the electrical simulation, <https://www.orcad.com/pspice-free-trial>