

UNIVERSITY OF CRETE



**DEPARTMENT OF MATERIALS SCIENCE AND
ENGINEERING**

**STUDY GUIDE
OF THE NEW MSc PROGRAMME
“Soft Matter Science and Engineering”**

APRIL 2025

UNIVERSITY OF CRETE

STUDY GUIDE

MSc PROGRAMME

“SOFT MATTER SCIENCE AND ENGINEERING”

DEPARTMENT OF MATERIALS SCIENCE AND
ENGINEERING



2025

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Overview of the Department of Materials Science and Engineering

The Department of Materials Science and Engineering (MSE) was founded 2001, and the first undergraduate students were enrolled in the academic year 2001-2002. The postgraduate (MSc) program was initiated shortly after, in the academic year 2003-2004. The Department is located in the Voutes campus. Its Secretariat can be found in the Mathematics Building, lecture rooms and undergraduate laboratories are spread in the buildings of the School of Science and Technology. The infrastructure of the adjacent Foundation for Research & Technology – Hellas (including the laboratories of microelectronics, polymers, semiconductors, superconductors, surfaces, biochemistry, biomaterials, medical applications, laser applications for materials processing) is also available to conduct senior thesis and post-graduate (MSc, PhD and Post-Doc level) research work in conjunction with the various group leaders.

The aspiration of the Department of Materials Science and Engineering is emerge as a first-rate centre for teaching and research in this cutting-edge field, and prepare its students to meet the needs of industry and society.

The Department's research activities focus on the development of new materials through the understanding of the composition – structure – processing – properties interplay. The current program leads to the Master of Science (M.Sc.) degree.

Departmental Administration

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I. REGULATIONS AND CURRICULUM

1. Subject of the Programme

The Department of Materials Science and Engineering of the University of Crete offers an MSc programme with title “**Soft Matter Science and Engineering**” in collaboration with academic institutions in Italy (University of Napoli), Israel (Ben Gurion University of the Negev), Cyprus (University of Cyprus) and India (Indian Institute of Technology, Kanpur) and the participation of academics from other departments of the of the University of Crete (Chemistry Department and Department of Mathematics and Applied Mathematics), the Foundation for Research and Technology and external collaborators from other Greek universities.

The aim of the programme is to advance the education and research in Soft Matter, which is an interdisciplinary field at the forefront of the current research and technological developments worldwide and combines the disciplines of Material Science, Engineering, Physics, Chemistry and Biology. The goal of the programme is to educate the next generation of researchers-professionals in the field of Soft Matter, who will combine an interdisciplinary theoretical background with practical laboratory experience (compulsory research work during the diploma thesis in the second year of the programme and three-month internship in a related industrial organization)

The collaboration of the University of Crete with three top class Universities abroad (University of Napoli, Italy, Ben Gurion University of the Negev, Israel, University of Cyprus, Cyprus and Indian Institute of Technology, India) ensures the high standards of the programme offering courses with important learning outcomes and a high quality Research Thesis in the second year.

The graduates can be hired in posts relevant to their expertise, either in the public (polymer recycling, microplastic management, etc) or the private (plastics, elastomers, cosmetics and household products, food, etc) sector, or can continue to pursue an academic-research career in Universities of Research Organizations.

The field of Soft Matter is growing rapidly during the last 60 years, and in particular during the last decade while addressing the major environmental issues faced by the society, such as the management of plastics in the landfills and the microplastics in the sea, as well as the recycling of plastics (circular economy).

2. Academic Staff

The academic staff of the programme comprises of Faculty, Laboratory Instructors, Special Technical Personnel, Scientific Collaborators of the Department of Material Science and Engineering. Academic staff from other Departments of the School of Science and Technology of the University of Crete, the Foundation for Research and Technology, other well-known academic institutions in Greece and four collaborating institutions abroad, in Italy (University of Napoli), Israel (Ben Gurion University of the Negev), Cyprus (University of Cyprus) and India (Indian Institute of Technology, Kanpur). The programme’s academic staff combines a wide range of backgrounds and specialities (chemistry, physics, biology and engineering) that provide the necessary interdisciplinary mix for the implementation of the educational goals of the curriculum.

The academic staff of the programme is listed below:

Staff Member	Area of Expertise
Anastasiadis Spiros	Soft Matter Physics
Chatzinokolaidou Maria	Biomaterials in Tissue Engineering
Chrissopoulou Kiriaki	Soft Matter Physics
Chronis Nikos	Biomaterials for Biomedical Applications
Dimakopoulos Yannis	Soft Matter Mechanics
Filippidi Emmanouela	Soft Matter Science and Applications
Floudas George	Soft Matter Physics
Georgiou George	Soft Matter Theory and Simulations
Glynos Emmanuel	Soft Matter Physics
Harmandaris Vangelis	Soft Matter Theory and Simulations
Ianniruberto Giovanni	Soft Matter Mechanics
Iatrou Hermis	Soft Matter Synthesis
Karatasos Kostas	Soft Matter Theory and Simulations
Loppinet Benoit	Soft Matter Physics
Mavrantzas Vlasis	Soft Matter Theory and Simulations
Mitraki Anna	Natural Biomaterials
Pavlopoulpou Eleni	Soft Matter Physics
Petekidis George	Soft Matter Physics
Pispas Stergios	Soft Matter Synthesis
Pitsikalis Marinos	Soft Matter Synthesis
Sakellariou George	Soft Matter Synthesis
Theodorou Doros	Soft Matter Theory and Simulations
Tzeranis Dimitris	Biomaterials for Biomedical Applications and/or Tissue Engineering
Vamvakaki Maria	Soft Matter Synthesis
Velonia Kelly	Soft Matter Synthesis
Vlassopoulos Dimitris	Soft Matter Mechanics
Yerushalmi-Rosen Rachel	Soft Matter Physics
Joshi Yogesh	Soft Matter Mechanics
Seminar Speakers (various)	

Laboratory Instructors

Konstantinos P. Papadopoulos

Emmanouil Spanakis

Stamatis Stamatiadis

Emmanouil Stratakis

Emmanouil Tillianakis

Dimitrions Stefanakis

Special Technical Personnel

Dimitrios Theodoridis

3. Curriculum Structure and Learning Outcomes

The curriculum of the programme comprises core courses, which are compulsory and elective courses (for which the student is required to choose from a group of courses).

The following table (Table I) summarizes the courses and their individual characteristics, namely the semester of study of each course, its weight in ECTS units, whether it is a compulsory (C) or elective (E) course. The list of elective courses (from which the student is expected to choose at least two each semester) is indicative. Upon approval of the department's meeting and before the new academic year begins, new courses may be added whenever possible.

Table I: Courses of the Programme per Semester

COURSE ID	COURSE TITLE	Hours per week	Compulsory/ Elective	ECTS
Year 1	<i>1st SEMESTER</i>			
SM 1	Applied mathematics and methods of analysis	3	C	5
SM 2	Thermodynamics and transport processes for soft materials	3	C	5
SM 3	Synthetic methodologies and characterization of Soft Matter	3	C	5
SM 4	Soft matter characterization	3	C	5
SM 5	Soft matter seminar	3	C	5
SM11	Advanced synthesis of soft materials	3	E	5

SM13	Soft materials for energy and the environment	3	E	
SM16	Advanced topics II (examples: new modeling/simulation methods, AI)	3	E	5
SM17	Advanced topics III (examples: active matter, vitrimers, cell mechanics, new instrumentation)	3	E	5
Year 1	2nd SEMESTER			
SM 6	Introduction to biophysics and biopolymers	3	C	5
SM 7	Interfacial phenomena in soft matter	3	C	5
SM 8	Polymer and colloid physics	3	C	5
SM 9	Mechanics of soft materials: rheology, processing and mechanical properties	3	C	5
SM 10	Soft matter seminar	3	C	5
SM12	Computational methods in soft matter	3	E	5
SM14	Soft biomaterials for biomedical applications	3	E	5
SM15	Advanced topics I (examples: responsive materials, mechanochemistry, supramolecular chemistry, sustainable polymers)	3	E	5
SM18	Course from other Departments (see below)	3	E	5
				ECTS of Courses: 60
2nd Year				
SM RT	Research Thesis		C	60
				Graduation with 120 ECTS

The courses SM 1-10 and the Research Thesis SM-RT are compulsory. In addition, the students must choose two courses among the SM11-SM18 (three courses will be offered every semester). Upon the successful examination in the courses the students will receive their degree with 120 ECTS. A student can attend more courses (with the agreement of the course tutor) if they wish, and provided they have collected the required ECTS. The extra courses will be listed in the diploma supplement.

The weight of each course is stated in European Credit Transfer System (ECTS) units. The six-month workload of a student is the sum of the ECTS units of the courses in which this semester is enrolled. Enrolment is at most eight (8) courses per semester.

The MSc programme is summarized as follows:

- Six courses per semester, which sums up to 60 ECTS for the first year
- A compulsory Research thesis (SM-RT) of 60 ECTS in a topic related to **Soft Matter Science and Engineering**, which is implemented during the 2nd year after the approval by the Programme Steering Committee
- Compulsory attendance of the departmental seminars in the field of Soft Matter, which will be accompanied by discussion with the supervisor and a short project in the topic to be presented by the student (under the guidance of the supervisor)

Courses from other departments of the University of Crete: Students of the programme can attend courses offered by other departments of the University of Crete, provided they are taught in English. These options are updated and announced every six months by the Programme Steering Committee (PSC), based on the courses offered by the other Departments of the University.

All the courses will be taught in physical presence at the University of Crete, but there is an option of online teaching, at a percentage of 50% of the total teaching hours per course (up to 20 hours), if this is necessary, and after sufficient justification and approval by the the (PSC). For the online teaching, the electronic infrastructure of the University of Crete will be used and in specific the e-class platform (<https://eclass.edc.uoc.gr/>).

The courses will be taught at the predetermined dates and times following the Η διδασκαλία των μαθημάτων του ΠΜΣ γίνεται κατά τις καθοριζόμενες ημέρες και ώρες από το programme timetable. The students are obliged to attend all the courses and the activities of each course and to comply with the decisions of the PSC and the academic ethics. The absence in more than 3 lectures leads automatically in the failure of the specific course and the student is obliged to follow the course again the next semester it is offered paying also the respective fees. Failure in a course is only accepted once, while in case of a second time failure the student is expelled from the programme.

The PSC designates an academic advisor for each student who follows the progress and advises the student during the programme.

The anticipated Learning Outcomes of the Postgraduate Programme for the MSc Degree in “Soft Matter Science and Engineering” are the following: to acquire the interdisciplinary knowledge and scientific background of Soft Matter Science and its applications in the current technological advancements, to promote students' free, creative and critical thinking, develop their ability to analyze, evaluate and solve contemporary problems related to the Soft Matter Science and Engineering, develop a spirit of collaboration and teamwork, and specialize in modern research methods in cutting-edge and interdisciplinary optional scientific fields. Ee

The Learning Outcomes of the Curriculum correspond to the 7th level of the EU classification for educational qualifications.

4. Obtaining a degree

The exam for each course is given at the end of the respective semester the course is taught. The assessment of the student takes also into account their participation in the course lectures during the semester, their performance in the homework and projects assigned by the tutor. The assessment for each course is defined by the tutor. The tutors are obliged to give the grades of their course at a maximum of three (3) weeks after the final exam. In case there are more than one tutors in a course the assessment is decided by both tutors and are announced to the students at the beginning of the course.

The grade for each course is between 0 and 10 with graduations of 0.5. To successfully pass the course a minimum of six (6) is required as the final grade. The degree is awarded to a student when the average grade of all courses (including the Research Thesis) is at least seven (7), which is the final grade of the Master Degree.

5. Diploma thesis

The Research Thesis corresponds to 60 ECTS and is implemented during the second year of the programme. It is research intensive and is supervised by a three-member committee. The committee includes the supervisor of the research thesis and, comprises faculty members and researchers from the University of Crete or the collaborating organization. Researchers from well-known institutions from Greece or abroad that possess a PhD, can also act as co-supervisors of the students. The members of the committee should have the same or similar specialty to that of the research thesis.

The students apply for the research thesis after they have collected 60 ECST. During the first semester, the interested tutors and other members of the programme present shortly the offered research topics. The students have the chance to discuss with them and possibly start studying the topic before they undertake the thesis officially.

The implementation process of the research thesis after the approval of the PSC is as following:

- α) Following the agreement of the supervisor the PSC approves the topic and the three-member committee of the research thesis.
- β) After the completion of the thesis, the date of the presentation/defense is announced following the agreement of the three-member committee.
- γ) The thesis is handed in electronic form to the three committee members. The thesis should be handed to the committee at least ten (10) days before the defense. The defense takes place only after the agreement of all committee members. Possible objections from the committee members can be expressed at the latest two (2) days before the defence.

The committee members assess the thesis in terms of its originality and innovation nature, the literature review, scientific methodology, the research perspectives and the implementation of the experiments and analysis of the results, as well as the presentation of the work by the student. The procedure is completed with the assessment of the presentation of the thesis and the respond of the student to the questions raised by the examiners. The research thesis is evaluated as “satisfactory” or “unsatisfactory”.

If a research thesis is assessed as “unsatisfactory”, the student must make the necessary corrections/improvements following the recommendations of the examination committee. Then a second defense follows at a date that is defined by the members of the committee and within six (6) months after the first defense. If the thesis is assessed again as “unsatisfactory”, no third chance is given. In this case the student is not awarded the MSc degree, but rather receives a certificate stating that they have successfully completed the postgraduate courses.

6. Student internships

At the end of the first year, the students have the opportunity to work during the summer months in organizations and companies of the public and private sector on activities relevant to the programme, either in Greece or abroad. Through these internships the students aim to gain experience, expand the knowledge and specialize in subjects related to soft materials and their technological applications. The internships also give the students the opportunity to adapt and function within a professional environment and to develop the skills related to teamwork. To enroll in the internship program, the students need to apply. Their record and specific requirements of different positions will be considered by the PSC which shall decide. Within one month upon completion of the internship, the student shall submit a written 'activity report' and present a seminar based on the work performed. The student's overall performance shall be assessed by the PSC. The internship is an elective course offering 5 ECTS credits upon successful completion.

Students also have the option to participate in internships programs abroad, in Universities or Research Centers and Institutions in the context of ERASMUS+ program. The same rules apply (activity report, seminar, 5 ECTS).

Students are selected by the PSC. The results of the selection are announced to the students by email by the Secretariat. Appeals to the selection decision can be submitted within 5 working days after the announcement of the results. Complaints are examined by the appeals committee.

7. Programme language

All courses of the programme, including the writing of the diploma thesis, are taught in English which is the official language of the programme

II. ANALYTICAL DESCRIPTION OF COURSES

SM1. Applied mathematics and methods of analysis

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with basic methods of mathematical analysis (for example statistical analysis of data, defining initial/boundary conditions and solving simple differential equations).
2. use their knowledge for simplifying equations developed in modeling and solve them.
3. appreciate the limiting cases of complex differential equations (for example, steady state).
4. properly use software packages to solve equations.

Syllabus

1. Review of statistics. Averages, standard deviation, and moments. Error analysis.
2. Vector and tensor calculus.
3. Dimensional analysis
4. Ordinary differential equations: theory and applications
5. Partial differential equations. Separation of variables.
6. Laplace and Fourier transformations.
7. Special topics of differential equations in science & engineering.

Bibliography

- J. D. Logan, Applied Mathematics 3rd Edition, Wiley, 2006
- K. F. Riley, M. P. Hobson, S. J. Bence, Mathematical Methods for Physics and Engineering: A Comprehensive Guide 3rd Edition, Cambridge, 2006
- L. A. Glasgow, Applied Mathematics for Science and Engineering 1st Edition, Wiley, 2014
- L. A. Pipes, L. R. Harvill, Applied Mathematics for engineers and physicists, 3rd Ed., Dover, 2014

SM2. Thermodynamics and transport processes for soft materials

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with laws of thermodynamics and their importance in understanding equilibria in soft materials and phase transitions.
2. use their knowledge for determining phase diagrams and understanding stability of phases
3. understand how phase transitions are affected by external conditions (temperature, pressure, additive)
4. be familiar with Boltzmann's entropy and, in a broader sense, the importance of entropy for soft materials.

Syllabus

1. The laws of thermodynamics. Applications to heat engines.
2. General equation of thermodynamics. Free energy and chemical potential.
3. Simple phase diagrams and stability.
4. Colligative properties. Osmosis.
5. Chemical reaction thermodynamics.
6. Elements of statistical thermodynamics. Boltzmann's entropy and applications to soft materials.
7. Elements of non-equilibrium thermodynamics.

Bibliography

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- R. Hentschke, Thermodynamics for physicists, chemists and material scientists, 2nd Ed., Springer 2022
- A.Z. Panagiotopoulos, Essential Thermodynamics, Drios Press, 2011.

SM3. Synthetic methodologies and characterization of Soft Matter

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with the principles of synthesis and molecular/macromolecular characterization of soft materials.
2. understand the advantages and limitations of the polymer and polymer colloid synthesis techniques.
3. be able to select the appropriate method for the targeted polymer synthesis

The student's familiarization with the field is based on the learning of the basic principles in combination with the presentation of selected examples from the recent scientific literature.

Syllabus

1. Basic Concepts – Polymer Nomenclature
2. Classification of polymers
3. Polymer Microstructure: Monomer architecture, orientation, tacticity, isomers
4. Average molecular weights - Properties
5. Size and shape of macromolecules
6. Synthesis
 - 6.1 Polymerization methods:
 - Step-growth-Polycondensation

- Addition, Free-radical polymerization
 - “Living”/controlled polymerizations
 - anionic - cationic
 - ATRP
 - RAFT
 - Ring opening polymerization
- 6.2 Polymerization techniques
- Emulsion – Dispersion polymerization (Polymer colloid synthesis)
7. Molecular/macromolecular characterization
- Methods to determine the polymer molecular weight and molecular weight distribution
 - Determination of the chemical polymer structure and composition by ¹H-NMR, FTIR, UV-Vis spectroscopies

Bibliography

- Lodge T.P., Hiemenz, P.C., Polymer Chemistry, 3rd Edition, CRC Press, 2020.
- Young, R.J., Lovell, P.A., Introduction to Polymers, 3rd Edition, CRC Press, 2011.
- Allcock, H.R.; Lampe, F.W. Contemporary Polymer Chemistry, 3rd Edition, Prentice Hall, 2003.

SM4. Soft matter characterization

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with the different methods/techniques to characterize materials.
2. use their knowledge for deciding the main material features/properties that should be assessed
3. understand the importance/consequence of ill-characterized materials in assessing properties/performance
4. understand the importance of material characterization in designing new materials/formulations

Syllabus

1. Molecular parameters for material characterization.
2. Light scattering
3. X-ray and neutron scattering
4. Optical microscopy
5. Electron microscopy
6. Vibrational spectroscopy (IR, Raman, NMR)
7. AFM and surface techniques
8. Thermal analysis
9. Dynamic mechanical analysis
10. In-situ experimentation (rheo-physics)

Bibliography

- L. Yang, Materials Characterization, 2nd Ed., Wiley, 2013
- R. Borsali, R. Pecora (eds.), Soft Matter Characterization, Springer, 2008

SM5. Soft matter seminar

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. have a broad overview of current trends and challenges in soft materials research.
2. understand the importance of soft materials in contemporary societal challenges (environment, energy, circular economy, biomedicine)

Syllabus

1. Weekly seminars by experts in different types/applications of soft materials
2. Presentation skills
3. Reporting skills
4. Criteria for assessing presentations.

Bibliography

- [W. van Saarloos](#), [V. Vitelli](#), [Z. Zeravcic](#), Soft Matter: concepts, phenomena and applications, Princeton, 2024
- I.W. Hamley, Introduction to soft matter, revised ed., Wiley, 2007
- T.C. B. McLeish, Soft matter: a very short introduction, Oxford, 2020.

SM6. Introduction to biophysics and biopolymers

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. distinguish biomaterials from synthetic materials
2. use their knowledge to understand the main features of biological materials in different functions (regenerative medicine, drug delivery)

3. understand the role of interactions and molecular features of specific biomaterials in different applications

Syllabus

1. Energies and interactions in biological materials
2. Biological macromolecules vs synthetic macromolecules
3. DNA, RNA and protein folding
4. Polysaccharides and molecular recognition
5. Molecular biology of the cell, cell-biomaterial interactions
6. Membranes
7. Movement of organisms
8. Drug delivery systems
9. Tissue engineering
10. Clinical applications
11. Nerve signaling, movement of organisms

Bibliography

- H. Schiessel, Biophysics for beginners, 2nd ed., Jenny Stanford Publishing, 2021.
- [C. M. Agrawal](#), [J. L. Ong](#), [M. R. Appleford](#), [G. Mani](#), Introduction to biomaterials, Cambridge 2014.
- R. Cotterill, Biophysics: an introduction, Wiley, 2002.

SM7. Interfacial phenomena in soft matter

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the importance of interfaces in the properties of soft materials
2. use their knowledge to develop criteria for tailoring/improving material properties using interfacial characteristics (miscibility, interactions, laden interfaces, dynamics)
3. acquire skills to further explore interfacial phenomena and the structure and dynamics of soft materials near interfaces

Syllabus

1. Liquid and solid surfaces
2. Thermodynamics of interfaces
3. Surface forces, charged interfaces
4. Contact angle phenomena and wetting
5. Adsorption
6. Friction, lubrication, wear
7. Surface modification
8. Surfactants, micelles, emulsions, foams, colloidal stability, interfacial adhesion
9. Thin films
10. Surface modification

Bibliography

- P. Lang, Y. Liu (eds.), Soft matter at aqueous interfaces, Springer, 2016

- [H-J. Butt](#), [K. Graf](#), [M. Kappl](#), Physics and Chemistry of Interfaces, 3rd. ed., Wiley, 2013

SM8. Polymer and colloid physics

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the essential differences between polymers and colloids and the role of these two classes of materials as pillars of soft matter research and technology
2. use their knowledge to develop criteria for manipulating the properties of composite materials (for example, reinforcement, depletion gelation)
3. know the basic ingredients needed to design or modify materials with desired properties for targeted applications

Syllabus

1. Basics of soft matter: molar mass, length, time and energy scales, entropy, Brownian motion
2. Classification: macromolecular architecture, copolymers, supramolecular polymers, soft and hard colloids, shape effects.
3. Ideal polymers, sizes, distributions, entropy elasticity
4. Real polymers, excluded volume
5. Polymer blends, solutions: miscibility
6. Dynamics, coarse graining. Bead-spring models. Rouse, reptations.
7. Linear viscoelasticity
8. Colloidal interactions, volume fraction
9. Diffusion and viscosity
10. Colloidal phase diagrams, gels and glasses
11. Non-spherical colloids and mixtures

Bibliography

- M. Rubinstein, R. H. Colby, Polymer physics, Oxford, 2003
- J. Mewis, N. J. Wagner, Colloidal suspension rheology, Cambridge, 2011.
- N. J. Wagner, J. Mewis, Theory and applications of colloidal suspension rheology, Cambridge, 2021.
- R. A. L. Jones, Soft condensed matter, Oxford, 2002

SM9. Mechanics of soft materials: rheology, processing and mechanical properties

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the basic properties involved in the flow, mechanical properties and processing of soft materials
2. use their knowledge to develop criteria for tailoring/improving the rheology and processability of soft materials
3. select materials with anticipated response in specific applications

Syllabus

1. A primer on rheology: stress and deformation tensors, Newton's and Hooke's laws, shear and extension
2. Linear viscoelasticity, Boltzmann's superposition, time-temperature superposition
3. Nonlinear rheological phenomena
4. Rheometry, shear thinning/thickening, extension hardening, instabilities
5. Mechanical models, constitutive equations
6. Examples of processing flows and link to material properties (extrusion, calendaring, blow molding)
7. Adhesion and fracture of soft materials
8. Experimental tests (optional)

Bibliography

- R. G. Larson, Structure and rheology of complex fluids, Oxford, 1999
- W. W. Graessley, Polymeric liquids and networks: dynamics and rheology, Garland, 2008
- R. I. Tanner, Engineering rheology, 2nd ed., Oxford, 2000
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- R. Long, C-Y. Hui, J. P. Gong, E. Bouchbinder, The Fracture of Highly Deformable Soft Materials: A Tale of Two Length Scales, Annual Review of Condensed Matter Physics 12:71-94, 2021
- C. Creton, C. Ciccotti, Fracture and adhesion of soft materials: a review, Rep. Prog. Phys. 79 (2016) 046601

SM10. Soft matter seminar

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. have a broad overview of current trends and challenges in soft materials research.
2. understand the importance of soft materials in contemporary societal challenges (environment, energy, circular economy, biomedicine)

Syllabus

1. Weekly seminars by experts in different types/applications of soft materials
2. Presentation skills
3. Reporting skills
4. Criteria for assessing presentations

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- [W. van Saarloos](#), [V. Vitelli](#), [Z. Zeravcic](#), Soft Matter: concepts, phenomena and applications, Princeton, 2024
- I.W. Hamley, Introduction to soft matter, revised ed., Wiley, 2007

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SM11 Advanced synthesis of soft materials

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with the kinetics of the polymerization reactions and their effect on the macromolecular characteristics.
2. consolidate the basic principles of the polymerization kinetics and be able to predict the macromolecular characteristics.
3. use their knowledge for deciding the polymer synthesis method to prepare a polymer with certain characteristics

The student's familiarization with the field is based on the learning of the basic principles in combination with the presentation of selected examples from the recent scientific literature.

Syllabus

1. Step-growth Polymerization
 - Type of step reactions
 - Molecular weight and polydispersity
 - Kinetics of condensation polymerization
 - Examples
2. Free-radical Polymerization
 - Mechanism of free-radical polymerization
 - Molecular weight and polydispersity
 - Kinetics of free-radical polymerization
 - Examples
 - Copolymerization and kinetics
3. Anionic Polymerization
 - Mechanism of anionic polymerization
 - Molecular weight and polydispersity
 - Kinetics of anionic polymerization
 - Macromolecular architectures accessible via anionic polymerization
4. Group Transfer Polymerization
5. Coordination Polymerization
6. Cationic Polymerization
 - Mechanism of cationic polymerization
 - Molecular weight and polydispersity
 - Kinetics of cationic polymerization
7. Controlled Radical Polymerization
 - Mechanisms of NMP, ATRP and RAFT
 - Molecular weight and polydispersity
 - Kinetics of controlled radical polymerization
8. Ring Opening Polymerization
 - Mechanism of ring opening polymerization
 - Monomers and related polymers
 - Kinetics of ring opening polymerization

9. Post-polymerization modification reactions
10. Synthesis of polymer gels and hydrogels
11. Synthesis of grafted polymer chains on flat and curved surfaces

Bibliography

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- Allcock, H.R.; Lampe, F.W. Contemporary Polymer Chemistry, 3rd Edition, Prentice Hall, 2003.
- Matyjaszewski, K.; Müller, A. H. E. Controlled and Living Polymerizations: From Mechanisms to Applications, John Wiley & Sons, 2009.
- Matyjaszewski, K. Controlled/living Radical Polymerization: Progress in ATRP, American Chemical Society, 2009.

SM12 Computational methods in soft matter

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. have developed a good understanding of the key principles of equilibrium statistical mechanics (theory of statistical ensembles)
2. be familiar with the basic methods of computation at different levels (molecular dynamics, Brownian dynamics, dissipative particle dynamics, Monte Carlo) in various ensembles
3. have developed a background on coarse graining and reverse mapping techniques
4. properly use software packages (e.g., LAMMPS, GROMACS, Chameleon)
5. apply new knowledge and skills to solve simple problems in soft matter with the help of the computational tools developed in the course

Syllabus

1. quantitative analysis using appropriate tools (software packages). For example, given a classical trajectory from such a simulation, to compute thermodynamic and structural properties of the system of interest, also to use fundamental theorems of classical statistical mechanics to compute time autocorrelation and cross-correlation functions and extract from them important transport properties (e.g., viscosity and diffusivity).
2. develop critical and creative thinking – address phenomena at the microscopic level and connect them with macroscopic observables
3. Select and work with different ensembles, depending on the problem in question. Combine information from different areas and extract the punchline in a given problem.

Bibliography

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- D.N. Theodorou, V.G. Mavrantzas, Multiscale modelling of Polymers (Oxford Univ. Press, Oxford, 2024), in preparation.

SM13. Soft materials for energy and the environment

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the basic properties of soft materials necessary for applications related to energy and environment
2. use their knowledge to develop criteria for developing material formulations with desired properties in targeted applications

Syllabus

1. Main properties needed for applications in energy and environment: friction, mechanical strength, electric conductivity, miscibility, biodegradability.
2. Polymeric composites and gels for batteries and supercapacitors
3. Polymeric materials for renewable energy production
4. Microporous polymers for gas separation/purification
5. Recycling of thermoplastics
6. Recycling of elastomers
7. Microplastics management
8. Biodegradable polymers
9. Green/bio-based soft matter
10. Water purification and soil remediation
11. Turbulent drag reduction

Bibliography

Class notes and research papers/reviews for each topic covered

SM14. Soft biomaterials for biomedical applications

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. distinguish biomaterials from synthetic materials
2. use their knowledge to understand the main features of biological materials in different functions (regenerative medicine, drug delivery)

3. understand the role of interactions and molecular features of specific biomaterials in different applications

Syllabus

1. Synthetic, nature-inspired and natural biomaterials
2. Fabrication and mechanical properties of 3D scaffolds
3. Properties and applications of biomaterials in nanomedicine
4. Properties and applications of biomaterials in tissue engineering
5. Regeneration of skin, peripheral nerves, spinal cord, conjunctiva, myocardium
6. Properties and applications of biomaterials in biosensors
7. Special topics on biocompatibility and regulatory pathway.

Bibliography

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- I.V. Yannas, Tissue and organ regeneration in adults. Extension of the paradigm to several organs. Springer, 2015.
- De Witte et al. Bone tissue engineering via growth factor delivery: from scaffolds to complex matrices, Regenerative Biomaterials, 2018, 1–15, doi: 10.1093/rb/rby013
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SM15. Advanced topics I (examples: responsive materials, mechanochemistry, supramolecular chemistry, sustainable polymers)

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the basic features associated with the topics covered (e.g., responsive materials, mechanochemistry, supramolecular chemistry, sustainable polymers)
2. use their knowledge to discern materials (e.g., responsive materials from polymer thermal transitions in the bulk or sustainable from synthetic polymers) and consider applications related to the topics covered

Syllabus

1. Responsive polymers: polymers responding to physical, chemical and biochemical stimuli
2. Mechanism of response and effect on the materials properties
3. Basic principles of mechanochemistry in polymeric materials. Design and study of mechanophores
4. Selected mechanoresponsive polymers: comparison of properties and perspectives

5. Polymer self-assembly mechanisms: intermolecular interactions/host-guest interactions
6. Supramolecular assemblies and hierarchical superstructures: types and properties
7. Biobased monomers and polymers. Green material processing
8. Biocomposites: synthesis, properties and applications
9. Special topics (depending on students' interests)

Bibliography

Class notes and research papers/reviews for each topic covered

SM16 Advanced topics II (examples: new modeling/simulation methods, AI)

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with current trends in modeling and simulations
2. understand how to select a modeling or simulation approach to investigate the properties of a specific material or class of materials
3. understand the usefulness and challenges associated with the use of AI in materials science

Syllabus

1. Advanced modeling of polymers: dynamics in covalent and living chains
2. Advanced modeling of colloids: hydrodynamic interactions, friction, metastable systems
3. Advanced topics in simulations of soft materials: Gibbs ensemble simulations, accelerated simulations, atomistic molecular dynamics, hydrodynamic effects
4. Analysis of interfacial phenomena with soft materials
5. AI in soft materials science
6. Special topics (depending on students' interests)

Bibliography

Class notes and research papers/reviews for each topic covered

SM17. Advanced topics III (examples: active matter, vitrimers, cell mechanics, new instrumentation)

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

1st Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. understand the basic features associated with the topics covered (e.g., vitrimers, active matter)
2. use their knowledge to discern materials (e.g., vitrimers from elastomers or active from passive materials) and consider applications related to the topics covered

Syllabus

1. Active matter: synthetic and living
2. Transport properties of active materials
3. Associating polymers and vitrimers: comparison of properties and perspectives
4. Use of vitrimers as rheology modifiers
5. Mechanical and rheological properties of the cell
6. Instrumentation to probe the dynamics of living and biological matter
7. Special topics (depending on students' interests)

Bibliography

Class notes and research papers/reviews for each topic covered

SM18. Course from other Departments

E

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: Depends on course

2nd Semester

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be familiar with main concepts developed in the course
2. understand the usefulness of the taught topic in soft material science

Syllabus

Specific for each course

Bibliography

Specific for each course

SM RT. Research thesis

C

Teaching Hours: 3-0-0, ECTS: 5

Prerequisite Courses: -

2nd Year

Learning Outcomes

Upon completion of the course, the graduate students are expected to:

1. be able to undertake, run and complete, as well as present a research project
2. develop and articulate their own ideas

Syllabus

1. Thesis topic (provided by supervisor): understand the challenges, read literature
2. Divide work into tasks, work on each task
3. Analyze and interpret results
4. Write thesis
5. Present thesis

Bibliography

Literature to be searched, acquired and studied by the student