adolphe merkle institute
excellence in pure and applied nanoscience

Curriculum for the award of the degree of

Specialised Master of Science in Chemistry and Physics of Soft Materials

Accepted by the Faculty of Science on 29.February.2015

UNIVERSITÉ DE FRIBOURG FACULTÉ DES SCIENCES
UNIVERSITÄT FREIBURG MATHEMATISCH-NATURWISSENSCHAFTLICHE FAKULTÄT

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1 Introduction

The Specialised MSc in Chemistry and Physics of Soft Materials is an interdisciplinary programme in the field of soft matter science at the Faculty of Science of the University of Fribourg. The students will be based at the Adolphe Merkle Institute (AMI).

The programme requires 120 ECTS[1] to complete, and can normally be completed within two years. The first semester consists of compulsory courses, and the practical basic laboratory skills course. The second and third semester consist of compulsory and elective courses and a short project each. The selection of elective courses, while maintaining the interdisciplinary nature of the curriculum, allow the student to acquire the knowledge required for the masters thesis. The first three semesters (75 ECTS) are designed to strengthen and complete the students existing knowledge of chemistry and physics as well as give them an introduction into biology of soft materials. The final part of the programme is dedicated to a research project of 45 ECTS in total, which includes the writing of a masters thesis and an oral presentation of the work. It is carried out in the 3rd and 4th semester and should normally be completed by the beginning of the following academic year. Some of the courses offered are taught jointly with other departments at the University of Fribourg and the University of Bern.

This document provides a summary of the course. The formal, legally binding document is available at http://www.unifr.ch/science/plans/plans_e.php.

2 Course Units

2.1 Lectures

The lectures are subdivided into the following modules:

- **Soft materials basics**: The teaching units Nanomaterials, Fundamentals in Cell Biology, and Basic Polymer Chemistry, Soft Matter Physics and Biophysics teach basic concepts in soft materials science. The advanced compulsory courses and elective courses build on these 5 courses.
- **Essential experimental techniques**: The courses Microscopy, Statistics and Experimental Design, and Scattering Techniques, teach the students the concepts underlying important experimental methods used in soft matter science.
- **Soft skills**: The courses Materials Science in a Social Context, Science Writing and Ethics, and Innovation teach the soft skills which prepare the students to professional and academic life.
- **Advanced courses** include Functional Materials and Biological Materials and all elective courses. They will allow the students to extend the basic knowledge and customise their study programme to suit their individual goals.

2.2 Practical Elements

Practical work in the laboratories is an essential element of the programme throughout the four semesters. The practical class "Basic Laboratory Skills" offered in the first semester teaches the students the proficiency of working in scientific laboratories and introduces important experimental procedures and the use of most experimental instrumentation at the AMI. This is followed by two short projects in the second and third semester, which will be carried out in the research laboratories of the Adolphe Merkle Institute (AMI). These will deepen practical laboratory skills and expose the students to the research carried out in the AMI. These projects can also be carried out at other laboratories of the University of Fribourg. During the project, the student will become intimately familiar with

[1] ECTS stands for European Credit Transfer System, see http://ec.europa.eu/education/ects/ects_en.htm for more information.

the experimental techniques and/or theoretical methods applicable to the chemical, physical and biological problems encountered in soft materials research. It should consist of an experimental and/or theoretical project within a research group carrying out soft matter science at the Faculty of Sciences of the University of Fribourg. Alternatively, this mini research project can be carried out in industry, or in the framework of an international exchange at another University abroad, under the supervision of one of the professors teaching in Fribourg.

2.3 The Seminar of the Adolphe Merkle Institute

The AMI host a scientific seminar series , where soft-matter scientists from around the world present their latest results. Attendance of this seminar series is compulsory for all students.

2.4 The Courses

Semester 1 (Autumn): Compulsory Courses

Title	tot. h	ECTS
Nanomaterials (lecture)	28	3
Nanomaterials (exercises)	14	1.5
Fundamentals in cell biology (lecture)	28	3
Fundamentals in cell biology (exercises)	14	1.5
Microscopy (lecture)	28	3
Statistics and experimental design (lecture)	28	3
Scientific writing (lecture)	28	3
Basic laboratory skills (practical course)	200	9
Seminar attendance	14	0.5

Semester 2 (Spring): Compulsory Courses

Title	tot. h	ECTS
Scattering techniques (lecture)	28	3
Basic polymer chemistry (lecture + exercises)	42	4.5
Soft Condensed Matter Physics (lecture)	28	2
Soft Condensed Matter Physics (exercises)	14	1.5
Biophysics (lecture)	28	3
Biophysics (exercises)	14	1.5
Short project I (practical course)	100	4.5
Seminar attendance	14	0.5

Semester 3 (Autumn): Compulsory Courses

Title	tot. h	ECTS
Functional materials (lecture)	28	3
Functional materials (exercises)	14	1.5
Biological materials (lecture)	28	3
Biological materials (exercises)	14	1.5
Innovation (lecture)	14	1.5
Short project II (practical course)	100	4.5
Seminar attendance	14	0.5

Semester 4 (Spring): Compulsory

Title	ECTS
Master Thesis	45
Seminar attendance	0.5

Elective Courses

Elective courses are offered in the 2nd or 3rd Semester. 11 ECTS are required. The list of elective courses changes every year and the updated list is published on the web-page of MScSoft softmatter.ch. Typically offered elective courses include:

Title	tot. h	ECTS
Advanced polymer chemistry (lecture)	28	3
Polymer engineering (lecture)	28	3
Exercises in polymer engineering (exercises)	14	1.5
Physical chemistry of self assembly (lecture)	14	1.5
Applied biomaterials (lecture)	28	3
Soft matter modelling and simulation techniques (lecture)	28	3
Soft matter modelling and simulation techniques (exercises)	14	1.5
Materials for energy applications (lecture)	28	3
Risk-assessment and toxicology of modern materials (lecture)	14	1.5
Biomembranes (lecture)	28	3
Principles and materials for solar energy conversion (lecture)	28	3
Selected topics in materials and inorganic chemistry (lecture)	28	3

Elective courses offered in the MSc in Physics and Chemistry and elective courses offered in other MSc programmes at the Universities of Fribourg, Bern and other Swiss universities can be accredited.

2.5 Course Descriptions

Nanomaterials

The course will give a broad overview on nanomaterials, their synthesis, physicochemical properties, functionalisation, characterisation and application. The lectures will cover theoretical aspects just as well as practical approaches to these materials. A particular focus lies on magnetic and optical properties, top down and bottom up approaches will be introduced, and ethical concerns will be discussed in this course.

Fundamentals in Cell Biology

This course will teach the fundamentals in cell biology including cell structure and function. Regulation of genes, the structure and synthesis of proteins, how these molecules are integrated into cells, and how these cells are integrated into multicellular systems and organisms will be covered.

Microscopy

Aim of this lecture series is to give a broad overview into high-end microscopy including light and electron microscopy techniques.

Statistics and Experimental Design

The lectures cover basic probability (concepts of probability, important distributions) and statistics (parameter estimation, hypothesis testing, linear regression) with focus on biological applications and introduce all important concepts used in the courses in the following courses.

Scientific Writing

This course teaches the skills required to write and publish scientific articles.

Scattering Techniques

The scattering of light, electrons, x-rays and neutrons provides a non-destructive way to analysis the internal structure of materials. This course will provide the theoretical background and applications for of a range of scattering methods.

Basic Polymer Chemistry

This course will introduce the most important principles and concepts of polymer chemistry, provide an overview of reactions to synthesise polymers, discuss physical properties of polymers in solution and the solid state, and give a first overview of the properties of polymers.

Soft Condensed Matter Physics

This course discusses the physics of materials that combine aspects of liquids and solids. It encompasses the physical properties of polymers, colloids, gels, and soft materials in nature.

Biophysics

This course will teach the fundamental concepts of biophysics and discuss modern techniques to study cells and biological molecules. The practicals associated with this lecture will provide students with hands-on training in Fluorescence Recovery After Photobleaching (FRAP) experiments, in Fluorescence Correlation Spectroscopy (FCS), and in Electrophysiology for ion channel and nanopore recordings.

Functional Materials

Polymers with dynamic covalent bonds, Healable Polymers, Mechanochemistry in Polymers, Mechanically Adaptive Polymers, Shape Memory Materials. Electrically Conducting Polymers, Light-Emitting Polymers, Photovoltaic Polymers, other photovoltaic materials, nonlinear optical materials Synthesis, Physics, and Devices.

Biological Materials

The curse will cover the chemistry and material science of materials occurring in the living world, such as polysaccharides, proteins, nucleic acids, lignin, rubber, other naturally occurring polymers, composites and biominerals. Moreover, characterisation methods for biological materials will be introduced.

Innovation

This module will introduce the important steps on the way from a discovery in the lab to a product on the market. Students will learn to evaluate research results, secure intellectual property, evaluate its commercial value, and develop a business model. The students will also learn the difference in managing incremental vs. disruptive innovation and the differing approaches of innovation management in start-up companies vs. corporate technology enterprises.

Advanced Polymer Chemistry

Topics of this course include mechanistic and kinetic aspects of anionic and cationic polymerisation, olefin metathesis polymerisation, controlled radical polymerisation, ring opening polymerisation, and Ziegler Natta polymerisation. Additional topics that will be discussed include polymers from renewable sources, biopolymers, and reactions that permit post-polymerisation functionalisation.

Polymer Engineering

This class is an introduction to the engineering and technology of polymeric materials. Topics include: an introduction to the structure and properties of polymers in the solid state, structural organisation (i.e., crystallinity, liquid crystallinity, phase separation), thermal transitions, viscoelastic behaviour, rubber elasticity, mechanical properties, additives, blends and composites, polymer processing, and polymer recycling.

Physical Chemistry of Self-Assembly

The course will offer an overview on self-assembly of amphiphilic molecules (surfactants) as well of nanoparticles. The topic will be addresses from a physicochemical perspective, starting from the fundamental thermodynamic properties of surfaces.

Advanced Biomaterials

The chemistry and material science of hybrid materials comprising biological and synthetic building blocks will be taught. Moreover, the course will cover applications of biological materials as engineering materials, in nanotechnology and as biomaterials.

Applied Biomaterials

The course provides the basis for understanding material properties with respect to chemistry and atomic structure and specifically the ability to tailor chemistry and structure of materials. The different classes of materials, in particular metals, ceramics and polymers are introduced and discussed when appropriate, with state-of-the-art problems from medical technology to illustrate the structure-property relationship in materials. Further, examples will be given to discuss the manipulation of these structure-property relationships in terms of the engineering of materials. Properties ranging from mechanical, thermal, electrical, and the interaction with cells and tissues will all be considered.

Soft Matter Modelling and Simulation Techniques

A range of different computer modelling approaches are routinely used to predict the structural, mechanical, electrical, optical, rheological, etc. properties of newly developed materials. Modelling

can also help to interpret the results of complex measurement techniques. This course will introduce several modelling techniques that are routinely used in soft-matter science.

Materials for Energy Applications

The manufacture of solar cells, batteries, fuel-cells, etc. employs soft materials in many different ways. This course will discuss recent developments in the material development for energy applications and how soft-matter science can contribute to these.

Risk Assessment and Toxicology of Modern Materials

This course will describe and explain the basic principles of the emerging discipline of nanotoxicology. Multidisciplinary implementation of material science techniques based on in vitro and in vivo toxicological methods will be considered when assessing the risk of engineered nanomaterials for human health and the environment.

Biomembranes

This course focuses on the biochemistry and biophysics of transport and signalling processes through biomembranes as well as on the relevance of these processes for human disease. It discusses the molecular details of membranes, including: (1) Structure and composition of biomembranes; (2) Structures and properties of lipids; (3) Lateral and transverse asymmetry in membranes: (4) Model membranes; (5) Membrane dynamics and protein-lipid interactions; (6) Interaction of small molecules with membranes: partitioning, permeability, and electrical effects; (7) Methods for studying biomembranes; (8) Porins, ion channels, and transporter proteins; (9) Membrane enzymology; (10) Cell Surface: receptors, membrane recycling, and signal transduction.

Selected Topics in Materials and Inorganic Chemistry

Latest development in the (nano-) material sciences, both soft and hard.

3 Exams and Assessment

Each teaching unit is assessed by a written or oral exam, written report, and participation in the exercise classes. The details of the examinations can be found at http://www.unifr.ch/science/gestens.

A minimum of 40 assessed ECTS should be acquired after the first year in order to continue the programme into the second year. In addition to the compulsory courses, a sufficient number of elective courses must be completed with a passing grade so that the total number of ECTS points add up to 120. Examinations must be taken within one year of course attendance. Every exam can be repeated only once, and the repeat examination must be taken within six months after the first exam. A non-passing grade in the repeat exam results in the final failure of the course.

3.1 Master's Thesis and Exam

The MSc thesis should last about eight months. It will start during the 3rd semester and will extend over the entire period from the end of the third semester to the beginning of the following academic year. It is research work that the student carries out under the supervision of active researchers in the field of soft materials science. The student chooses a project supervisor and a co-supervisor, who

are selected from different scientific disciplines. The project work will normally be carried out in the research group of the principal supervisor. The project encompasses extensive literature research, a detailed project plan, experimental work and/or a theoretical study and a critical discussion of the results. This work has to be carried out according to accepted ethical standards (i.e. the code of conduct of the Adolphe Merkle Institute).

The work will be presented as a formal written document, the Masters Thesis. As a rule this thesis should be of the quality of a research publication and it is the intention to submit the contents of the thesis for publication in a scientific journal.

The Masters Thesis will be examined by two examiners. The examination consists of a 20-minute oral presentation of the thesis by the student, followed by questions from the examiners. The Masters Thesis and the exam will be judged on the 1 (totally unacceptable) to 6 (excellent) scale.

Successful completion of the entire programme results in the right to the title Specialised Master of Science in Physics and Chemistry of Soft Materials (Sp. MSc), issued by the University of Fribourg.

4 Admission

4.1 Formal Requirements

Admission to the Masters programme may be granted provided the following three conditions have been met by the applicant:

- The student possesses a Bachelors degree in Physics or Chemistry. Candidates with a Bachelor from a different discipline in Science may be admitted subject to approval by the Committee of Student Requests.
- The student successfully passes an admission procedure consisting of a written application and an interview
- Satisfying the University admission requirements as defined in the Admission Regulations of the University of Fribourg

Candidates with a BA degree from the University of Fribourg are eligible for direct application for admission to the programme. Candidates with degrees other universities required to submit an application, in writing, to the Committee of Student Requests (Commission des requêtes des étudiant-es, care of: Office of the Dean, Faculty of Science, Muse 8, CH-1700 Fribourg, Switzerland), which will decide on eligibility. In some cases, endorsement may be conditionally based on additional coursework requirements: these may be satisfied in parallel with the regular master's work, or the student may be required to enter as a qualifying student. Final acceptance in the Specialised Master's programme for a qualifying student is contingent on the successful completion of these pre-requirements.

4.2 Admission Procedure

Every applicant will be assessed individually. The students will be assessed in terms of three criteria:

1. academic ability and potential
2. independent thought and creativity
3. enthusiasm and motivation for the master programme

The assessment of the applications according to these criteria will take place in a two stage process.

Stage one consists of a written application, containing a curriculum vitae, certificates of earlier education, a letter of motivation, and two letters of reference. The letter of motivation is particularly

important and should explain the students motivation for choosing the programme, an explanation in how far he/she will be able to follow the curriculum, and in which way the programme will contribute to his/her further career. The letter of motivation should further demonstrate the three key aspects listed above.

The application committee will rank all applications according the three listed criteria, and decide which applications will enter the second stage.

The second stage of assessment will consist of a personal interview by the admission committee at the Adolphe Merkle Institute. In exceptional cases (i.e. where visa requirements prevents travel to Switzerland), the candidate will be interviewed by a video link, (e.g. Skype or WebEx). The interview will last 20 minutes, and focus on the three criteria listed above. All candidates will be ranked, and the admission committee will decide which of the candidates will gain entry to the programme.

Following both admission stages, all candidates will be notified of the outcome of their application by electronic mail. A list of successful candidates will be submitted to the Committee for Student Requests which, together with the Faculty Council, will make the final decision of admission.

The deadline for submission of the written application is March 1st of every year. The interviews will typically take place in April and May, and the final decision will usually be communicated by the end of May.

5 Costs

5.1 Semester Fees

The semester fees (registration and tuition) for Swiss master students or students whose parents have a permanent residence (C-permit) in Switzerland or Liechtenstein amounts to CHF 655 per semester. The fee for foreign students is CHF 805 per semester. Details about the fees can be found at http://www.unifr.ch/admission/en/unifr/finance/finance. Information about subsidies, grants and loans can be found at http://www.unifr.ch/uni-info/en/index/subsidies.

5.2 Cost of Living

Typical monthly cost of living for a student in a shared apartment lies in the CHF 1500 – CHF 1700 range. For details see: http://studies.unifr.ch/en/vie-a-fribourg/habiter/cout.

5.3 Total Expenses

Depending on lifestyle, the typical monthly budget of a student in Fribourg is about CHF 1600 – 1900. It comprises living expenses and the semester fee, calculated on a monthly basis.