ITMO UNIVERSITY

SCAMT

Master degree program

Chemistry of Applied Materials

Place of Study: Russia, St. Petersburg
Duration: 2 years (120 credits)
Language: English
Admission Requirements: Bachelor degree in Chemistry, Chemical Engineering or related field with excellent/good grades. Upper intermediate level of English language (B2 according to CEFR)

"Chemistry of Applied Materials" program is aimed at training highly qualified specialists in the field of nano-engineering. This program is made for those who want to do world-level science during the master study.

A special feature of the program is the use of an innovative interdisciplinary approach, namely, a unique combination of modern information technologies and practical methods with the goal of developing innovative materials and technologies. The program is based on synergies between experiments and modeling in nanotechnology.

This interdisciplinary course is focused on understanding molecular self-assembly processes and using these processes in the design of functional materials. The main areas of application of the planned approaches will be implemented in new biomedical materials, fuel cells, surfactants and gels, nanocrystals, coatings, films, and more.

The practical component of the master's program is accompanied by a number of theoreticalcourses from leading scientists specializing in the fields of catalysis, green chemistry, materials science, molecular modeling, sol-gel chemistry and technology.

You can make a research project in one of the research groups or work on your own start-up in the industrial laboratory. Depending on your project from the second semester, you choose an individual educational trajectory in one of the following specializations:

- **Nanopharmacy**
- **Computational Design of materials**
- **Applied materials**
- **Industrial brokerage in the field of biotechnology**

Read more

Study plan

Intro modules: 1 discipline from each block

University modules 1 choice
4 credits

Creative Technologies

High Tech Business Creation

Thinking (Conceptual Analysis of Trends in Science Today)

Soft Skills 1 choice
4 credits

Negotiations, Influence and Conflict Management

Emotional Intelligence

Internationalization of Research

Digital culture 1 choice
3 credits

Applied Artificial Intelligence (basic level)

Applied Artificial Intelligence (advanced level)

Digital culture 1 choice
3 credits

Data Processing and Analysis (basic level)

Data Processing and Analysis (advanced level)

General modules: all mandatory

Foreign language (4 credits)
Inorganic Chemistry of Materials (6 credits)
Nanobiotechnologies (3 credits)
Advanced materials (6 credits)
Advanced methods in chemical nanoengeneering (6 credits)
Nanoengineering and nanofabrication (6 credits)

Specializations: 1 choice

Computational design of materials
15 credits

Computational methods and modeling in materials chemistry (3 credits)

Catalysts and green chemistry (6 credits)

Molecular electronic structure and band theory (6 credits)

Applied Materials
15 credits

Smart Materials (3 credits)

Advanced materials for biomedical applications (6 credits)

Solution chemistry of materials (6 credits)

Nanopharmaceutics
15 credits

Preclinical studies (3 credits)

Nanotoxicology (6 credits)

Advanced materials for biomedical applications (6 credits)

Industrial Brokerage in the field of biotechnology and nanoengineering
15 credits

Modern technologies for manufacturing nanoscale objects and materials (3 credits)

Creation, implementation and promotion new technology and materials into the global market (6 credits)

Technological Forecasting and Marketing (6 credits)

Practice: all mandatory

Research Internship (36 credits)
Research Internship (6 credits)
Senior Internship (12 credits)
Thesis defense preparation and thesis defense

Electives: multiply choice

Regulation of the emotional state in professional activity (3 credits)
Military training (5 credits)
Preclinical studies (3 credits)
Molecular Oncology (3 credits)
Proteomics (3 credits)
Modern technologies for manufacturing nanoscale objects and materials (3 credits)
Nanotoxicology (6 credits)
Advanced biochemistry (6 credits)
Molecular biorobotics (6 credits)
Creation, implementation and promotion new technology and materials into the global market (6 credits)
Advanced materials for biomedical applications (6 credits)
Fundamentals of cell metabolism and signaling (6 credits)
Molecular neuroscience (6 credits)
Technological Forecasting and Marketing (6 credits)
Computational methods and modeling in materials chemistry (3 credits)
Catalysts and green chemistry (6 credits)
Molecular electronic structure and band theory (6 credits)
Smart Materials (3 credits)
Solution chemistry of materials (6 credits)

Modules description (in alphabetical order)

Advanced biochemistry

The goal of this course is to refresh and deepen knowledge of classical biochemistry and use it to analyze the most important discoveries that have won the Nobel Prize as well as the latest biochemical developments, including DNA nanotechnology, synthetic biology, epigenetics, RNA visualization in cells, CRISPR, and high throughput DNA sequencing.

Advanced materials

Overview of properties, and methods for creating and applying new(multi)functional materials. The focus will be on the relationship between the structure and the properties of technical materials.

Advanced methods in chemical nanoengineering

The Advanced Machine Learning course is studied only by those masters who have chosen an advanced trajectory. It touches upon the issues of reducing the dimension of a set of features and methods of factor analysis, multiclass logistic regression. And also the tasks solved using reinforcement learning.

Advanced materials for biomedical applications

This course covers the most important aspects of creating modern biological and molecular sensors, including the use of antibodies for laboratory and medical analyses; biological receptors and the concept of artificial nose; enzyme / substrate interactions and enzymatic sensory systems; nucleic acid probes, molecular beacons, Tuckman samples, deoxyribozymes, apta-sensors, and bio-electro sensors.

Applied Artificial Intelligence (basic level)

The Introduction to Machine Learning course introduces the types of machine learning, demonstrates practical examples of solving problems using machine learning methods. The main focus is on the types of regression, classification and clustering problems.

Applied Artificial Intelligence (advanced level)

The Advanced Machine Learning course is studied only by those masters who have chosen an advanced trajectory. It touches upon the issues of reducing the dimension of a set of features and methods of factor analysis, multiclass logistic regression. And also the tasks solved using reinforcement learning.

Creative Technologies

In the course you will study the tools for analyzing the modern world and interacting with it in the digital environment, which has already become a big part of it. Together we will use those tools in the real space of the city of St. Petersburg and fill it in the virtual space, combining your imagination, urban environment and technology. We will choose a relevant topic and create group projects that will be included in our joint project - the common digital portal of the city of the future. Everyone will be a creator, researcher, artist, and together we will change the physical environment around us through the virtual.

Creation, implementation and promotion new technology and materials into the global market

As part of the course, you will learn to evaluate the readiness of technology (product or service) to enter foreign markets, learn international business practices, and analyze successful practices of modern entrepreneurs. You will also be trained to analyze markets, conduct competitive analysis, work with unions and entrepreneurial associations. The course includes security issues, international intellectual property, intellectual property as a product, and the assessment of intellectual property protection capabilities. You will be taught the first steps of business, namely how to register a company and interact with banks, local authorities, and the business community.

Computational methods and modelling in materials chemistry

The course reproduces basic methods of computational chemistry, their basic principles, and their application limits; focuses on the application of modern quantum chemistry and statistical thermodynamics; utilises computer modelling to effectively solve problems in material chemistry; aims to fulfil the technical requirements for composite nanomaterials and patent purity, and to formulate technical specifications; contains a description of using computer programmes to monitor equipment operation.

Catalysts and green chemistry

The goal of this course is to familiarize students with the concepts of green chemistry and sustainable development in the chemical and energy industries. The main emphasis is on introducing students to modern approaches to reducing the environmental impact of chemical industries, intensifying conservation measures, and increasing energy efficiency. The majority of the course is devoted to the role of nanotechnology in the development of solar energy, the use of renewable sources and alternative resources, as well as reviewing the most recent well-known catalytic processes that have found application in areas such as natural gas processing, petrochemicals, and hydrogen technology.

Data Processing and Analysis

Students will learn the fundamentals and role of information in the development of modern society; basic principles of collecting and preparing raw data; basic methods of data analysis; the stages and technology of software development for solving data processing problems; to use mathematical tools for processing, analyzing and systematizing information on the research topic. Students will study to remove basic methods of data collection and tools for information processing; factor and cluster analysis skills; data processing methods; and design and automated system operation skills.

Emotional Intelligence

Emotional intelligence (EI) is a key leadership skill that helps people to achieve goals, high performance, and productivity at work as well as to maintain effective personal relationships. It includes the ability to perceive, facilitate, understand, and manage emotions. It is a skill that can be developed. This course is based on the materials acknowledged worldwide, the latest research, and authorized practices. Through reading, listening, and discussing EI concepts, mastering the five core skills of EI, observing peers, and writing reflection journals, students will deepen their awareness of their emotional life, needs, and motivation. As a result, they will understand others better and enhance their skills for effective communication. Such practical activities as case studies, simulations, and group discussions will help students to apply this new experience in real-life social situations.

English for Specific Purposes

The course combines specific elements of spoken English (presentation skills, professional immersion) and academic English (critical and analytical thinking, academic writing).

Foreign language

The purpose of the course is to learn how to use a foreign language to communicate on professional topics: to use modern communication technologies, including in foreign language (s), for academic and professional interaction, observing the principles of corporate and professional ethics.

High Tech Business Creation

The main objectives of the course are to study the projects types, their life cycle, project development features, assessment of technological readiness for commercialization in the real economy sector. You will learn how to assess risks, resources, organize a team work and, most importantly, attract funding for the project implementation.

Internationalization of Research

Internationalization of research course will provide you with the tools that help us organize ourselves in research environment, build a research team or become a part of one successfully, choose suitable research methods, share your findings with the scientists in an oral or written form (presentation skills), present your research or pitch your ideas to the investors. You will be able to write a decent resume, take the most of a multicultural environment, learn scientific reference management, know how to write a scientific paper, locate funding to scaffold your research (apply for grants) and perform effectively in business communication. In a nutshell, this course will teach you everything that an aspiring researcher needs to know to be successful.

Inorganic Chemistry and Materials

This course gives a complete overview of the existing fundamental theories and laws that govern the characteristics of inorganic and hybrid materials, while highlighting potential applications. Particular attention is paid to their syntheses, properties, and possible application of nanostructured inorganic and hybrid organo-inorganic materials. Furthermore, how the chemical structure of these nanoparticles influences the physicochemical properties of materials made from them is examined in detail

Modern technologies for manufacturing nanoscale objects and materials

This course contains a description of the life cycle stages of the designed or studied research objects in the field of nanostructured materials. It is designed to analyze the economic, environmental, and social restrictions of nano-object and nanomaterial production; tracks current trends in nanoparticle use as well as current nanostructure standardization and certification methods; includes a description of modern methods for producing catalysts and functional coatings, their characterization, development of technological lines and the integration of science and business.

Molecular electronic structure and band theory

This course imparts basic concepts of the theory of magnetism, and the scope of the quantum theory of solids in materials science; describes models of almost free electrons, and approximations of strongly bound electrons; gives an idea of the analysis of physical and environmental restrictions in the field of application of zone theory for practical purposes; demonstrates new ways of using devices in applied tasks; describes the behavior of electrons in the presence of a periodic potential - the main physical parameters.

Negotiations, Influence and Conflict Management

In a fast-paced world we all need extra negotiation skills that open new perspectives on reaching our goals and help us find creative solutions to daily challenges, taking into consideration interests of both sides. This course covers “Harvard” method, and “Kremlin School” approach. Among other things, the students will learn what the “bargaining arena” and the best alternative are. We will talk about getting out of standard negotiation traps and come to mutually beneficial agreements.

Nanoengineering and nanofabrication

In this course, various nanofabrication technologies used for the production of modern devices and their application will be considered.

Nanobiotechnologies

The course includes the following topics: modern approaches to the use of nanobiotechnology, modern materials for nanobiotechnology, biological characterization of materials, molecular mechanisms of the cellular antioxidant system, molecular aspects of nervous function, nanobiosensors.

Nanotoxicology

This course highlights the fundamentals of synthesizing nanoparticles with various composition and morphology; describes the main methods of research and prediction of toxicity of nanoparticles in vitro models; aims to conduct cytotoxicological experiments, organize and control preclinical studies of drugs and clinical trials of drugs; substantiates the use of nanoparticles in biomedicine, and current trends in their use in the pharmaceutical industry.

Project Management

As part of the course, you will consider the following sections: types of projects; the uniqueness of a startup as a project; project evaluation; features of a startup assessment; project risk assessment and start-up. You will also get acquainted with project management in the professional field: international project, examples of successful projects; project management technology; the use of the latest information systems in the project management process; project effectiveness assessment.

Preclinical studies

This course describes the fundamentals of preclinical studies, namely GLP, GCP, and pharmacokinetic parameters; aims to teach the principles of writing reports on preclinical studies, legal compliance and standards governing conduct; highlights phases of clinical trials; substantiates research methods for acute and chronic toxicity, as well as specific toxicity; describes test systems for studying the effectiveness of drugs, and the stages of planning a preclinical experiment.

Smart Materials

This course teaches one to analyze and practice various techniques for conducting qualitative and semi-quantitative assessments of the structure and properties of smart materials in accordance with the research plan; includes a description of the physical phenomena that determine the functional response of materials (electrical, optical, magnetic, mechanical); highlights methods for obtaining materials in a design with predetermined or controlled functional characteristics and methods for their improvement.

Solution chemistry of materials

This course considers solution-based synthesis as the most promising way to effectively mass produce nanomaterials, namely metal, oxide, and chalcogenide nanoparticles - which are now used in a wide range of areas, including catalysis, energy production and storage, sensors, and nanotherapy.

Technological Forecasting and Marketing

This course includes the following sections: an introduction to forecasting; modern practices for forecasting the development of global markets; global challenges; forecasting methods for the scientific and technological development and global markets; planning research and development on forecast basis; the analysis of global market forecasts in the field of bioengineering.

Thinking (Conceptual Analysis of Trends in Science Today).

When we speak about science in terms of this course we mean a special kind of intellectual activity that is governed by its own rules and can be analyzed in terms of procedures and concepts that constitute scientific research. Main types of reasoning in science and the analysis of its fundamental concepts will be introduced in the course. The course consists of two parts. The procedures that define the theoretical field of scientific research today are analyzed in the first part:

- Scientific Reasoning: deduction, induction, abduction;
- Scientific Explanation: statistical explanation, prediction, mechanism, unification;
- Causal Reasoning I: classical accounts: regularities, counterfactuals, processes, probabilities, and interventions;
- Causal Reasoning II: causal modelling approaches: explanation, inference, and control.

How science is interconnected with and defined by the non-scientific realm will be explained in the second part of the course. The task will be realized by means of 1) the analysis of the role and meaning of categories of subjectivity and objectivity in science, and 2) the demonstration of how linguistic, ethical, cultural, and epistemic aspects of research serve simultaneously as its constituents and as restrictors. The lectures of the second part of the course are given by Dr. Mavrinskiy (ITMO University).

Electives

Advanced biochemistry

The goal of this course is to refresh and deepen knowledge of classical biochemistry and use it to analyze the most important discoveries that have won the Nobel Prize as well as the latest biochemical developments, including DNA nanotechnology, synthetic biology, epigenetics, RNA visualization in cells, CRISPR, and high throughput DNA sequencing.

Fundamentals of cell metabolism and signaling

This course includes the following topics: cell communications principles, main types intercellular interactions: contacts, vesicles, hormones, nervous synapse, immunological synapse, electrical and chemical processes for transmission information between cells, cell contacts with pathogens, implants, nanoparticles, non-cellular microenvironment, extracellular matrix for cancer and aging, cellular interaction and microenvironment in genetically modified body, artificial cell system communication and programming.

Molecular biorobotics

During the course, you will study the structure and functions of natural protein machines, myosin, kinesin and dynein, as well as modern achievements in the field of creating an artificial molecular machine for biomedical applications.

Molecular neuroscience

The course provides the fundamentals of comparative and evolutionary molecular neuroscience; highlights neurophysiological mechanisms for the implementation of cognitive functions, the molecular mechanisms of interneuronal interactions, and current methods of studying neuropsychophysiological states; briefly describes the main facilities and apparatuses used to solve research problems in the field of molecular neuroscience; describes the structure and principles of neuronal membrane function, especially proteins, lipids and energy in the central nervous system.

Molecular Oncology

This course teaches the fundamentals of molecular oncology; describes the main molecular signs of cancer, changes in the metabolism of the tumor cell, and changes to the immune system due to cancer; conveys methods for studying the cell cycle, apoptosis, intracellular signal transmission, mechanisms for regulating the cell cycle, mechanisms of invasion, metastasis, and angiogenesis; is aimed at teaching methods of tumor cell analysis - immunoblotting, flow cytometry, analysis of the effectiveness of the production of targeted drugs and cell cycle inhibitors.

Proteomics

This course includes a description of the methods of stabilization and regeneration of enzymatic systems used in biotechnology; provides an understanding of the structural foundations of protein function and the thermodynamic foundations of the functioning of enzymes in extreme conditions; is focused on predicting the results of the influence of exogenous and endogenous environmental factors on the molecular genetic organization of proteins; describes the fundamental and applied aspects of structural and functional proteomics, and examples of the use of biocatalysts in science, medicine, technology, and industry.

Scientific laboratories

All labs

Nanopharmacy

- drugs for targeted delivery and prolonged action
- bioceramic materials for medical application
- smart inorganic scaffolds for theranostics

Run by Vladimir Vinogradov

Read more

Inkjet Printing of Functional materials

- optical nanostructures
- non-invasive biosensors
- Li-ion rechargeable batteries
- photoactive and conductive coatings

Run by Alexander Vinogradov

Read more

Computational modeling for the design of functional materials

- predictive modeling of chemical processes
- new technologies for green chemistry and its sustainable development

Run by Evgeny Pidko

Read more

Ceramic and Natural Nanomaterials

- ceramic nanostructured materials
- nanotechnologies for the prevention and elimination of technogenic disasters
- nanobioarchitectonics: directed design of hybrid materials

Run by Pavel Krivoshapkin

Read more

Nanobiotechnology

- optically active platforms for wound healing dressings
- 3D printing of materials to protect products
- "smart" packaging for the food industry

Run by Elena Krivoshapkina

Read more

Chemistry Neuroeducation

- social issues in education (hidden potential, phobias)
- experimental research methods (EEG, HRV, eye-tracking)
- immersive virtual reality learning environments

Run by Mikhail Kurushkin

Read more

3D printing of functional nanomaterials

- Multifunctional, “programmable” wound dressings
- Ion-scavenging and ion- sensing hydrogels
- Modular stimuli-responsive hydrogels
- Bioprinted cell scaffolds

Run by Eugenia Kumacheva

Read more

Sustainable electrochemistry

- electroorganic transformations for sustainable chemistry
- design and synthesis of advanced materials for electrocatalysis
- carbon dioxide and wastewater utilization

Run by Klinkova A.A, Krivoshapkina E.F.

Read more

Industrial Lab

- applied solution chemistry
- nanopharmaceuticals
- therapeutical drugs
- functional coatings

Read more