National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

The department of technology of inorganic substances, water purification and general chemical technology

Modern nanotechnologies

Work program of the educational component (Syllabus)

Requisites for the educational component	
High level of education	***Second (Magister)***
Field of knowledge	*16 Chemical and bioengineering*
Specialty	*161 Chemical technologies and engineering*
Educational program	*Chemical resource efficient technologies of inorganic and organic substances, materials and coatings*
Status of the educational component	*Regulatory*
Form of study	*Full-time / Mixed / On-line*
Preparatory year, semester	*1 year, spring term*
Total amount of the educational component	*4 credits*
Semester control/control activities	*Credit*
Lessons schedule	*Lecture 1 hour per week (1 pair per 2 terms), laboratory works 2 hours/ week (see the site rozklad.kpi.ua)*
Study language	*Ukrainian*
Information about Course director / trainers	*Lecturer: Dr. Sci, Associate Professor Tetiana Dontsova, t.dontsova@kpi.ua* *Laboratory: Ph.D., Senior Lecturer Svitlana Kyrii, kysvit@gmail.com*
Course location	*Google Classroom (Google G Suite for Education, domen LLL.kpi.ua, platform Sikorsky-distance); access by the teacher request*

Program of educational component

1. Description of the educational component, its goal, subject of study and learning outcomes

The educational component "Modern nanotechnologies" belongs to the disciplines of professional and practical training and is the basis for profile disciplines in the curriculum of master's training.

The educational component "Modern nanotechnologies" is taught according to the curriculum of masters and is based on the following disciplines: "Applied Chemistry", "Physics", "General and Inorganic Chemistry", "Organic Chemistry", "Physical Chemistry", "Surface Phenomena and Dispersed Systems", "Material Science", "Crystallography", "General Chemical Technology" and "Chemical Technology of Inorganic Substances" and is designed to provide students with experience in the latest technologies of functional materials (bioinorganic materials, nanomaterials, photocatalysts, sensors, etc.), and technologies of specific processing of inorganic and organic materials, analytical studies of initial and final products, environmental protection.

***The aim** of the course unit is to form in students the ability to use theoretical knowledge and practical skills to master the basics of the theory and methods of chemical and technological research in the technology of fine inorganic synthesis; use modern ideas about the prospects and foundations of*

nanotechnology, the principles of monitoring, assessing the impact of chemical technologies on the environment state and wildlife protection, knowledge and application in practice of the principles of constructing environmentally friendly industries, understanding social and environmental consequences of their professional activities; research skills.

Main tasks of the educational component
*Students, after mastering the course unit "Modern nanotechnologies", must demonstrate **knowledge** in:*

- *Modern trends in the technology of inorganic substances for various industries, including science-intensive technologies;*
- *Traditional and special methods of obtaining traditional and functional materials, including nanomaterials;*
- *Modern environmental technologies.*

*Students must also demonstrate the following **skills**:*

- *To carry out search and analysis of modern literature sources;*
- *To choose reasonably appropriate research technologies and methods of functional materials and nanomaterials;*
- *To create flexible technological schemes for integrated processing of natural raw materials, anthropogenic wastes and environment protection;*
- *To carry out research in scientific laboratories in accordance with the safety rules and environment safety;*
- *To anticipate the possibility of artifact occurrence and its prevention;*
- *To choose correctly the strategy of preparative obtaining of target products with given properties based on their purpose.*

***To gain experience** of using modern and newest literature sources for scientific substantiation of synthesis methods for functional materials and nanomaterials, development of technological schemes with physical and chemical justification of each stage of material obtaining; implementation of modern science-intensive technologies into laboratory workshops (to create a pilot installation).*

2. Pre-requisites and post-requisites of the educational component

The list of educational components, knowledge and skills which are necessary for successful master's degree students of the educational component:

Pre-requisites:	
Bachelor's level	*Knowledge in chemical technology and engineering at the bachelor's level.*
Post-requisites:	
Educational component 2 of F-catalogue	*To understand the general principles of using new functional materials in innovative technologies.*
Educational component 4 of F-catalogue	*To understand the general principles of chemical synthesis of nanoscale and nanostructured materials, new functional materials and to use them in modern technologies and engineering.*
Scientific work	*The ability to think abstractly, analyze and synthesize, the ability to carry out original research, to achieve scientific results that create new knowledge in chemical technology and engineering and related to them interdisciplinary fields of chemical and bioengineering.*
Completion of a master's thesis	*The ability to identify, set and solve problems in the field of chemical processes and apparatuses, to assess and ensure the quality of the research carried out. Dedication to the development of technological indicators of obtaining and practical use of new functional materials.*

This educational component forms the basis for further study at the PhD level.

3. Contents of the educational component

Section 1. *Modern advanced technologies in industry*

Classification and characterization of modern inorganic functional materials. Their features and requirements to them. Areas of application. Characteristics of synthesis methods. Obtaining functional materials from liquid phase: chemical precipitation from aqueous and non-aqueous solutions. Synthesis of materials by sol-gel technology. Essence and physical and chemical bases of hydrothermal and plasmochemical methods and cryochemical technology. Obtaining functional materials from gas phase (CVD and PVD methods). Template synthesis method of inorganic materials. Criteria for determining nanomaterials: critical size and functional properties. Size effect. Classification of nanomaterials: 0D-, 1D-, 2D-structures. Application areas of nanomaterials. Examples of natural nanomaterials. Their features. Self-organization of nanomaterials. Use of nanomaterials in medicine, energy sector, catalysis and environment protection. Basic physical, chemical and physicochemical methods of nanomaterial study. Characterization of nanomaterials by means of diffraction, spectral, thermal methods and electron microscopy. Characteristics of biomaterials. Interaction of biomaterials with tissues. Requirements for biomaterials. Materials based on calcium phosphates. Phosphate-calcium cements. Bioceramics and biocomposites. Physicochemical basis for obtaining biomaterials of inorganic origin. Calcium phosphates – basic materials as implants for bone tissue. Bone structure. Basic requirements for materials used as implants. Classification and selection of semiconductors for use in optoelectric materials. Quantum-size effects. Areas of application. Synthesis of quantum dots and their characterization. Types of magnetic materials. Magnetically hard and magnetically soft materials and their application. Synthesis features of ferrofluid based on magnetite. Ferrofluids and their use in medicine.

Section 2. *Modern advanced technologies for environment protection*

Homogeneous and heterogeneous photocatalysis in water purification. Essence of AOP methods. Advantages and disadvantages. Photocatalytic materials and their characteristics. Use of photocatalysts in environment protection and in energy sector. Mechanism of heterogeneous photocatalysis. Features of photocatalysis in the processes of waste water treatment and air purification from organic pollutants and water photolysis. Ways to increase photocatalytic activity of catalysts under visible light spectrum. Classification of chemical sensors. Sensors based on metal oxides. Design and principle of work of the sensors based on tin (IV) oxide. Main characteristics of gas sensors. Ways to increase sensor signal and operation duration of metal-oxide sensors.

4. Teaching materials and resources

Teaching materials listed below are available in the library of the university and in the library of the Department of Technology of inorganic substances, water treatment and general chemical technology. Required to study the basic literature, other materials - optional. The topics, which the student has to get acquainted with independently, the teacher notes at the lectures and practical sessions.

Basic

1. Донцова Т.А. Сучасні проблемні питання хімічної технології неорганічних речовин [Електронний ресурс]: Навч. посіб. / Т.А. Донцова, І.М. Астрелін. – К.: НТУУ «КПІ», 2011. – 146 с.

2. Інноваційні неорганічні технології [Електронний ресурс] : підручник для студ. спеціальності 161 «Хімічні технології та інженерія», спеціалізації «Хімічні технології неорганічних речовин та водоочищення» / Т. А. Донцова ; КПІ ім. Ігоря Сікорського ; уклад. Т. А. Донцова – Електронні текстові данні (1 файл: 11,0 Мбайт). – Київ : КПІ ім. Ігоря Сікорського, 2018. – 291 с.

Additional

3. Мельников Б.І. Технологія тонкого неорганічного синтезу [Текст] / Б.І. Мельников. – Дніпропетровськ, 2000. – 150 с.

4. Johari A. Characterization and Ethanol Sensing Properties of Tin Oxide Nanostructures / A. Johari, V. Rana, M. Bhatnagar // Nanomater. nanotechnol. – 2011, Vol. 1. – № 2. – P. 49-54.

Information resources

5. http://tnr.xtf.kpi.ua/n/dis/suchasni-problemni-pytannya

7. http://www.http.com.ua//tnr.xtf.kpi.ua/n/dis/suchasni-problemni-pytannya/suchasni-problemni-pytannya-khtnr-navchalnyy-posibnyk/view

Learning content

5. Techniques for mastering the educational component

Lecture classes

Reading out lectures on the educational component is carried out in parallel with their consideration of the issues submitted for independent work. During the lectures, video conferencing tools (Zoom) and illustrative material in the form of presentations posted on the Sikorsky-distance platform are used. Before each lecture, it is recommended to get acquainted with the lecture materials, as well as with the materials recommended for independent study.

№	Date	Description of the class
1	1 work week of the semester	***Section 1. Modern advanced technologies in industry*** *Classification and characterization of modern inorganic functional materials. Their features and requirements to them. Areas of application. Characteristics of synthesis methods. Obtaining functional materials from liquid phase: chemical precipitation from aqueous and non-aqueous solutions. Synthesis of materials by sol-gel technology.*
2	3 work week of the semester	***Continuation of Section 1*** *– Essence and physical and chemical bases of hydrothermal and plasmochemical methods and cryochemical technology. Obtaining functional materials from gas phase (CVD and PVD methods). Template synthesis method of inorganic materials. Criteria for determining nanomaterials. Critical size and functional properties. Size effect. Classification of nanomaterials: 0D-, 1D-, 2D-structures.*
3	5 work week of the semester	***Continuation of Section 1*** *– Application areas of nanomaterials. Examples of natural nanomaterials. Their features. Self-organization of nanomaterials. Use of nanomaterials in medicine, energy sector, catalysis and environment protection. Basic physical, chemical and physicochemical methods of nanomaterial study. Characterization of nanomaterials by means of diffraction, spectral, thermal methods and electron microscopy.*
4	7 work week of the semester	***Continuation of Section 1*** *– Characteristics of biomaterials. Interaction of biomaterials with tissues. Requirements for biomaterials. Materials based on calcium phosphates. Phosphate-calcium cements. Bioceramics and biocomposites. Physicochemical basis for obtaining biomaterials of inorganic origin.*
5	9 work week of the semester	***Continuation of Section 1*** *– Calcium phosphates – basic materials as implants for bone tissue. Bone structure. Basic requirements for materials used as implants.*
6	11 work week of the semester	***Continuation of Section 1*** *– Classification and selection of semiconductors for use in optoelectric materials. Quantum-size effects. Areas of application.*

		Synthesis of quantum dots and their characterization. Types of magnetic materials. Magnetically hard and magnetically soft materials and their application. Synthesis features of ferrofluid based on magnetite. Ferrofluids and their use in medicine.
7	*13 work week of the semester*	***Section 2. Modern advanced technologies for environment protection*** *Homogeneous and heterogeneous photocatalysis in water purification. Essence of AOP methods. Advantages and disadvantages. Photocatalytic materials and their characteristics. Use of photocatalysts in environment protection and in energy sector.*
8	*15 work week of the semester*	***Continuation of Section 2*** *– Mechanism of heterogeneous photocatalysis. Features of photocatalysis in the processes of waste water treatment and air purification from organic pollutants and water photolysis. Ways to increase photocatalytic activity of catalysts under visible light spectrum.*
9	*17 work week of the semester*	***Continuation of Section 2*** *– Classification of chemical sensors. Sensors based on metal oxides. Design and principle of work of the sensors based on tin (IV) oxide. Main characteristics of gas sensors. Ways to increase sensor signal and operation duration of metal-oxide sensors.*

Laboratory works

The purpose of laboratory work is to consolidate the theoretical knowledge acquired during the lectures, as well as acquiring practical skills on the topic of educational component. For this purpose, the laboratory classes in detail look at modern methods of creating functional materials and study their functional properties. The obtained materials are investigated by means of various physical and chemical methods – X-ray phase and X-ray structural analysis, electron microscopy, thermal analysis, infrared spectroscopy, etc. Individual work with literary sources in the study of the educational component "Modern nanotechnologies" is also envisaged. In the laboratory classes in detail, attention is paid not only to the development of practical skills, but also to the acquisition of experience in the field of nanomaterials.

Week	***Topic***	***Description of planned work***
1	*Synthesis of flat ceramic membranes by sintering method*	*Formation of ceramic membranes. Determination of phase composition and porosity*
2	*Defence*	
3	*Purification of natural water objects by membrane technologies*	*Determination of selectivity and purification parameters for model natural aqueous solutions*
4	*Defence*	
5	*CW*	
6	*Separation of hydrogen from various gas mixtures on ceramic membranes*	*Features of ceramic membranes for hydrogen separation*
7	*Defence*	

8	*Neutralization of greenhouse gases using nanocatalysts*	*Types and synthesis of nanocatalysts for neutralization of greenhouse gases*
9	*Defence*	
10	*Defence CW*	
11	*Biofiltration denitrification*	*Membrane biofilters and their modes of operation for denitrification*
12	*Defence*	
13	*Presentations*	
14	*Visualization and optimization of molecular structures*	*Visualization and optimization of molecular structures in the ChemDraw program*
15	*Defence*	
16	*Modeling of chemical adsorption kinetics*	*Modeling of chemical adsorption kinetics in KINET program*
17	*Defence*	
18	*Class credit*	*The number of points students have accumulated during the semester is noted*

6. Independent work of the students

Independent work of the student (IWS) during the semester includes the repetition of lecture material, preparation for tests, preparation for the control activities on the lecture material, preparation for the protection of laboratory works, performing calculations work, as well as the preparation for the exam. The recommended number of hours to prepare for these types of work:

Types of IWS	*The number of hours for preparation*
Preparing for classroom lessons: repeating lecture material, preparing for tests	*2 hours per week*
Preparing for the modular control work (MCW)	*5 hours*
Preparing for laboratory work	*15 hours*
Preparing the calculation work (CW)	*10 hours*

Policy and control

7. Policy of the educational component

In the normal mode of the university, lectures are held in the training classrooms. In the mixed mode, lectures are held through the Sikorsky distance learning platform, and laboratory work is conducted in the classrooms. In distance mode, all classes are conducted through the Sikorsky distance-learning platform. Attendance of lectures and laboratory works is obligatory.

At the beginning of some lectures, there is a test on the materials of previous lectures using interactive means (Google Forms). Before the beginning of the next topic, the lecturer sends lecture material with the use of interactive means in order to determine the level of awareness of applicants on the topic and increase interest. At the beginning of each practical session, there is a test on the materials of the previous one with the use of interactive means (Google Forms).

Rules for protection of practical and lecture works:

1. Students who have completed the work correctly are allowed to defend the work.

2. The defense is conducted in accordance with the schedule specified in paragraph 5 on individual assignments.

3. After the instructor checks the problem, a general grade is given in the defense and the work is considered defended.

Rules for Awarding Incentive and Penalty Points:

1. 1 penalty point (but no more than 5 points) will be awarded for each week of late submission.

2. For upgrading the work, 1 to 5 encouragement points are awarded;

3. Completion of tasks to improve didactic materials from the educational component earns 1 to 10 incentive points;

Policy on deadlines and revisions: clause 8 of the Regulations for current, calendar and semester control of learning outcomes in the KPI named after Igor Sikorsky

Academic Integrity Policy: determined by the Academic Integrity Policy and other provisions of the University Honor Code.

8. Types of control and rating system of evaluation of learning outcomes (RSE)

Types of control are established in accordance with the Regulations on the current, calendar and semester control of the results of training in Igor Skorsky KPI:

1. *Current control: observation of laboratory works, CW, MCW*
2. *Calendar control: carried out two times per semester as a monitoring of the current state of implementation of the requirements of the syllabus.*
3. *Semester control: written exam.*

Rating system for evaluating the results of the educational component "Modern nanotechnologies"

The rating of a student in the educational component is calculated based on a 100-point scale, the rating (during the semester) is composed of the points the student receives for:

1) active participation in all laboratory classes;

2) CW performance;

3) MCW performance;

4) Presentation.

1. *Laboratory works:*

«Excellent», creative disclosure of one of the issues, free mastery of the material – 5 points;

«Good», in-depth disclosure of one of the issues of the discussion – 4 points;

«Satisfactorily», active participation in the class – 3 point;

«Not satisfactory» – 0 points;

2. *CW:*

« Excellent », creative disclosure of one of the issues, free mastery of the material – 27-30 points;

« Good », in-depth disclosure of the issues of the discussion – 24–26 points;

«Satisfactorily», sufficient disclosure of issues – 18–22 points;

«Not satisfactory» – 0 points;

3. *MCW:*

«Excellent», complete answer (at least 90% of the required information) – 10 points;

«Good», sufficiently complete answer (at least 75% of the required information), or complete answer with minor inaccuracies –8–9 points;

«Satisfactorily», incomplete responses (at least 60% of the required information) and insignificant mistakes – 6–7 points;

«Not satisfactory», unsuccessful answer (does not meet the requirements for 6 points) – 0 points.

4. *Presentations:*

- *«Excellent», complete answer (at least 90% of the required information) – 24–25 points;*
- *«Good», sufficiently complete answer (at least 75% of the required information, or minor inaccuracies) – 19–23 points;*

- *«Satisfactorily», incomplete answer (at least 60% of the required information and some mistakes)– 16–18 points;*
- *«Not satisfactory», unsuccessful answer – 0 points.*

The maximum numbers of points a student can earn during the semester (RC) are 100 points:

$$RC = r_{lab} + r_{cw} + r_{mcw} + r_{pres} = 5 \cdot 7 + 30 + 10 + 25 = 100 \text{ points.}$$

Table of correspondence of rating grades to the university scale:

Number of points	*Rating*
100-95	*Excellent*
94-85	*Very good*
84-75	*Good*
74-65	*Completely*
64-60	*Satisfactorily*
Less 60	*Not satisfactory*
The admission conditions are not met	*Not acceptable*

If student does not agree with the scored points, he writes a credit control work, which is estimated at 70 points, where points are also added for CW.

9. Additional information on the educational component

The list of questions for MCW and the credit control work are given in Google Classroom "Modern nanotechnologies" (Sikorsky-distance platform).

The work program of the educational component (Syllabus):

Compiled by Head of the Department of technology of inorganic substances, water treatment and general chemical technology, Associate Professor Tetiana Dontsova

Approved by the Department of technology of inorganic substances, water treatment and general chemical technology (№ 22 of 29.06.2022)

Approved by the Methodological Committee of the Chemical-Technology Faculty (№ 10 of 23.06.2022)