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

Department of Ecology and Technology of Plant Polymers

Fundamentals of the Theory of Obtaining and Practice of Using Nanomaterials from Plant Raw Materials

work program of the academic discipline (syllabus)

Details of the academic discipline

Level of higher education	***First (bachelor's)***
Branch of knowledge	*16 Chemical and Bioengineering*
Speciality	*161 Chemical Technology and Engineering*
Educational program	*Industrial ecology and resource efficient cleaner technologies*
Status of discipline	*Selective*
Form of training	*full-time(day)/evening(evening)/part-time/remote/mixed*
Year of preparation, semester	*4nd year, spring semester*
Volume of discipline	*4 credits (120 hours)*
Semester control	*Test*
Schedule of classes	*6 hours a week (4 hours of lectures and 2 hour of practical classes)*
Language of instruction	Ukrainian
Information about kerivnik course / teachers Lecturer:	Lecturer: PhD, professor Valerii Barbash, https://eco-paper.kpi.ua/pro-kafedru/vykladachi/barbash-valerij-anatolijovich.html; Practical classes: PhD, professor Valerii Barbash.
Course placement	*https://campus.kpi.ua/tutor/index.php?mode=mob&show&irid*

Program of discipline

1. Description of the discipline, its purpose, subject of study and learning results

In recent years, there has been a significant increase in scientific research in the field of nanomaterials and nanotechnologies, in particular the production and use of nanocellulose, which consists of nano-sized cellulose particles with at least one linear dimension up to 100 nm. This growing interest in the development of new biodegradable materials from plant raw materials is explained by the ability of nanomaterials to replace polymers that are made from exhaustible natural resources - oil, gas, coal, and cause irreparable damage to the environment due to a long period of their biodegradation. Nanocellulose has such unique properties as: high modulus of elasticity and large specific surface area, high transparency and density, biodegradability and biocompatibility, chemical reactivity and low coefficient of thermal expansion. It is widely used as a natural material to replace synthetic reinforcing substances in the paper, chemical, pharmaceutical, cement industries, in composite materials for organic packaging and green flexible electronics. Paper and cardboard, flexible sensors and solar batteries, flexible thermoelectric generators and ultraviolet screens, import substitute materials for industry and construction are examples of the use of nanocellulose.

The use of nanomaterials from cellulose-containing plant raw materials is considered as an alternative to plastics and can be a viable approach to reducing deforestation, increasing the use of agricultural surpluses and developing biodegradable materials, contributing to the sustainable development of society, solving economic and environmental problems.

The subject of the educational discipline *"Fundamentals of the Theory of Obtaining and Practice of Using Nanomaterials from Plant Raw Materials" is the study of the theoretical foundations of the extraction of nanomaterials from plant raw materials, in particular nanocellulose, and the practice of their use in various industries, medicine and everyday life, in composite materials for organic packaging, elements of green flexible electronics, micro- and nanoelectronic devices of the new generation, which have a short period of biodegradation.*

The purpose of the credit module *"Fundamentals of the theory of obtaining and practice of using nanomaterials from plant raw materials" is to train specialists in the field of chemical technologies and engineering, who are able to solve professional problems in practical situations on the basis of the acquired theoretical knowledge, as well as to form students' competencies:*

- knowledge and understanding of the subject area and understanding of professional activity (C 03);

- the ability to use the provisions and methods of the discipline to solve professional problems, to determine directions for the processing of plant raw materials (C 09);

- the ability to apply modern experimental methods of working with technological ones objects in industrial and laboratory conditions (C 18).

According to the requirements of the program of the academic discipline, after learning the credit module, students must demonstrate the following ***learning outcomes****:*

- correctly use the terminology and basic concepts of chemistry, chemical technologies, processes and equipment for the production of chemical substances and materials based on them in professional activities (PO 02);

- to know and understand the mechanisms and kinetics of chemical processes, to use them effectively in the design and improvement of technological processes and apparatus of the chemical industry (PR 03);

- to substantiate the choice of technological schemes of production on the basis of rational use of raw materials, energy, obtaining high-quality products, achieving high productivity with a simultaneous solution of environmental issues, calculating material and heat balances of processes, on their basis, finding costs of raw materials and energy resources (PO 15).

2. Prerequisitions and requisition of disciplines (place in the structural and logical scheme of training according to the relevant educational program)

The study of the academic discipline "Fundamentals of the theory of obtaining and practical use of nanomaterials from plant raw materials" is preceded by such academic disciplines as: "Organic chemistry", "Chemistry of high molecular compounds", "Chemistry of plant polymers", "Chemistry of delignification of plant raw materials", "Ether production technology and cellulose esters", "Technology and equipment for the production of pulp", "Paper and cardboard technology", it provides the disciplines "Technology of providing special properties of paper and cardboard", "Resource-saving technologies for the production of cardboard and paper products", "Technological processes of waste management ". The educational discipline belongs to the cycle of professional training (selective educational components from the cathedral's F-catalogue).

3. Contents of the discipline

Chapter 1. Characteristics of nanomaterials from plant raw materials

Topic 1. *The purpose of the discipline and its tasks in the training of specialists. Classification of nanomaterials from plant raw materials and their general characteristics.*

Topic 2. *Dynamics of production and application of nanocellulose in various industries. Requirements for raw materials for obtaining nanomaterials. Characteristics of the unique properties of nanocellulose.*
Topic 3. *Physico-chemical methods of determining the characteristics of nanocellulose. Scanning electron microscopy, transmission electron microscopy, atomic force microscopy. X-ray structural analysis. Thermogravimetric analysis.*

Chapter 2. Methods of obtaining nanocellulose from vegetable raw materials.

Topic 4. *Mechanical methods of obtaining nanocellulose from vegetable raw materials. Types of equipment and characteristics of the obtained nanocellulose.*
Topic 5. *Chemical methods of obtaining nanocellulose from vegetable raw materials. The main reagents and technological parameters of obtaining nanocellulose by chemical methods.*
Topic 6. *Biotechnological methods of obtaining nanocellulose from vegetable raw materials and the main characteristics of bacterial nanocellulose.*

Chapter 3. Main fields of application of nanomaterials.

Topic 7. *The use of nanomaterials from plant raw materials in the pulp and paper industry. The use of nanocellulose in the production of paper and cardboard.*
Topic 8. *The practice of using nanocellulose in the chemical, pharmaceutical and cement industries, in composite materials, medicine and construction.*
Topic 9. *Nanocellulose application technologies in green flexible electronics. Production of flexible temperature, humidity and bending sensors, solar batteries, thermoelectric generators, ultraviolet protective screens.*

4. Educational materials and resources

Basic literature

1. Pylypchuk L.L., Blyznyuk V.M. Nanomaterials in chemistry and pharmacy. Study guide.- 2020.- 168 p., ISBN: 978-966-289-351-9
2. Analytical research methods. Spectroscopic methods of analysis: theoretical foundations and methods: a study guide for the preparation of students of higher educational institutions / D.O. Melnychuk, S.D. Melnychuk, V.M. Voytsitskyi et al.: edited by Acad. TO. Melnychuk. - K.: CP "Comprint", 2016. - 289 p.
3. Barbash V. A. Innovative technologies of plant resource conservation. Education manual. Kyiv: Caravela, 2016. - 288 p.
4. Barbash V.A. Technologies for processing non-wood plant raw materials into cellulose-containing products: monograph. — Kyiv: Caravela, 2022. – 360 p.

Additional literature

5. Handbook of Nanocellulose and Cellulose Nanocomposites. Editors: H. Kargarzadeh, I. Ahmad, S. Thomas, A. Dufresne. John Wiley & Sons, 2017
6. Moon R. J., Martini A., Nairn J., Simonsenf J., Youngblood J. Cellulose nanomaterials review: structure, properties and nanocomposites. Chem. Soc. Rev., 2011, 40, 3941–3994.
7. Klemm D., Kramer F., Moritz S., Gray D. Nanocelluloses: A New Family of Nature-Based Materials. Angew. Chem. Int. Ed. 2011, 50, 5438 – 5466. doi: 10.1002/anie.201001273
8. Ao Li, Dezhong Xu, Lu Luo, Yalan Zhou, Wen Yan, Xin Leng, Dasong Dai, Yonghui Zhou, Hassan Ahmad, Jiuping Rao, and Mizi Fan. Overview of nanocellulose as additives in paper processing and paper products. Nanotechnology Reviews 2021; 10: 264–281
9. Lavoine N., Desloges I., Dufresne A., Bras J. Microfibrillated cellulose – Its barrier properties and applications in cellulosic materials: A review. Carbohydrate Polymers, 2012, 90 (2), p. 735-764. https://doi.org/10.1016/j.carbpol.2012.05.026
10. V. Barbash and O. Yashchenko. Preparation, Properties and Use of Nanocellulose from Non-Wood Plant Materials/ Chapter in the book "Novel Nanomaterials" edited by Dr. Karthikeyan Krishnamoorthy, IntechOpen, October 27th 2020, pp. 1-23, DOI:10.5772/intechopen.94272

11. Klochko N.P., Barbash V.A., Petrushenko S.I., V.R. Kopach, D.O. Zhadan; O.V. Yashchenko. Thermoelectric textile devices with thin films of nanocellulose and copper iodide. J Mater Sci: Mater Electron. 2021, 32, 23246–23265. https://doi.org/10.1007/s10854-021-06810-9
12. Klochko N.P., Barbash V.A., Klepikova K.S., Khrypunova I.V., Kopach V.R.1, Petrushenko S.I., Zhadan D.O., Yashchenko O.V. Biodegradable flexible transparent films with copper iodide and biomass-derived nanocellulose for ultraviolet and high energy visible light protection. Solar Energy, 2021, 220, p. 852-863. https://doi.org/10.1016/j.solener.2021.04.014
13. Yong Yang, Zhou Chen, Junxiong Zhang, Guanchun Wang, Ruiqian Zhang. Preparation and Applications of the Cellulose Nanocrystal. International Journal of Polymer Science. 2019, Article ID 1767028, 10 p. https://doi.org/10.1155/2019/1767028
14. Hindi S.S.Z. Differentiation and Synonyms Standardization of Amorphous and Crystalline Cellulosic Products. Nanoscience and Nanotechnology Research, 2017, Vol. 4, No. 3, 73-85 http://pubs.sciepub.com/nnr/4/3/
15. V. A. Barbash, O. V. Yashchenko, A. S. Gondovska, I. M. Deykun Preparation and characterization of nanocellulose obtained by TEMPO-mediated oxidation of organosolv pulp from reed stalks. Appl Nanosci 2022, 12, 835–848. doi.org/10.1007/s13204-021-01749-z
16. Лапшуда В. А., Лiневич Я.О., Душейко М.Г., Коваль В.М., Барбаш В. А. Ємнiснi сенсори вологи на основi плiвок наноцелюлози для бiорозкладної електронiки. Мiкросистеми, Електронiка та Акустика, 2022. http://elc.kpi.ua/
17. Sigareva N.V., Barbash V.A., Yashchenko O.V., Shulga S.V. Influence of micro – and nanocrystalline cellulose on physical and mechanical parameters of epoxy composites. Biophysical Bulletin, 2020, 43, pp.57-70.

Інформаційні ресурси в Інтернеті

1. https://ela.kpi.ua/bitstream/123456789/40249/1/Yaschchenko_dys.pdf
2. https://lpnu.ua/pfn/naukova-diialnist-kafedry
3. https://www.health-medix.com/articles/misteztvo/2013-10-14/Nanotehnologii.pdf
4. https://doi.org/10.1007/s10570-020-03207-5
5. www.rsc.org/nanoscale
6. https://doi.org/10.1016/j.crcon.2018.05.004
7. https://doi.org/10.1016/j.carbpol.2020.115888

Educational contect

5. Methods of mastering the discipline (educational component)

Lecture classes

Lectures are aimed at forming in students a set of knowledge necessary for qualified management of technological processes of obtaining nanomaterials from plant raw materials and the practice of their use in various branches of industry, medicine and the production of composite consumer goods, as well as opportunities that open up during various transformations of plant raw materials for materials to improve these processes and create new, more efficient, environmentally cleaner productions.

No s/p	***Title of the lecture topic and list of main questions (list of didactic means, references to literature and tasks on the SRS)***	***Hours***
1	***Section 1. Characteristics of nanomaterials from plant raw materials*** *Topic 1. The purpose of the discipline and its tasks in the training of specialists. Classification of nanomaterials from plant raw materials and their general characteristics.* *Literature: [1, p. 1-18; 6; 7]* *Task on SRS: Characteristic properties of nanomaterials from plant raw materials.*	***2***

2	*Topic 2. Dynamics of production and application of nanocellulose in various industries. Requirements for raw materials for obtaining nanomaterials. Characteristics of the unique properties of nanocellulose.* *Literature: [4, p. 212-224; 10, p. 1-5].* *Tasks on SRS: Normative documents on the terminology of nanocellulose and components based on it*	2
3	*Topic 3. Physico-chemical methods of determining the properties of nanocellulose. Scanning electron microscopy, transmission electron microscopy, atomic force microscopy.* *Literature: [2, pp. 1-23; 6, 14].* *Tasks on SRS: Examples of determining the characteristic features of the structure of plant raw materials, cellulose and nanocellulose by scanning electron microscopy*	2
4	*Topic 3. Physico-chemical methods of determining the characteristics of nanocellulose. X-ray structural analysis. Thermogravimetric analysis.* *Literature: [2, pp. 24-34; 10, p. 176-185].* *Task on SRS: Comparison of crystallinity indices values of plant raw materials, cellulose and nanocellulose, obtained by different methods from different plant raw materials*	**2**
5	***Section 2. Methods of obtaining nanocellulose from vegetable raw materials.*** *Topic 4. Mechanical methods of obtaining nanocellulose from vegetable raw materials. Types of equipment and characteristics of the obtained nanocellulose.* *Literature: [1, p. 19-31; 7].* *Task on SRS: Examples of production and comparative characteristics of nanocellulose obtained by mechanical methods*	**2**
6	*Topic 5. Chemical methods of obtaining nanocellulose from vegetable raw materials. The main reagents and technological parameters of obtaining nanocellulose by chemical methods. The main technological parameters of the cellulose hydrolysis process for obtaining a transparent nanocellulose hydrogel.* *Literature: [10, p. 6-9]* *Task on SRS: Advantages and disadvantages of using different acids in cellulose hydrolysis processes to obtain nanocellulose*	**2**
7	*Topic 6. Chemical methods of obtaining nanocellulose. The main technological parameters of the process of obtaining nanocellulose by the method of oxidation with the use of various types of oxidants.* *Literature: [1, 32-46; 15]* *Tasks on SRS: Peculiarities of using the reagent 2,2,6,6-tetramethylpiperidine-oxyl (TEMPO) for obtaining nanocellulose*	**2**
8	*Topic 7. Biotechnological methods of obtaining nanocellulose and the main characteristics of bacterial nanocellulose.* *Literature: [1, p.47-54, 13, c.1-5]* *Tasks on SRS: Types of bacteria used in the enzymatic process of nanocellulose production and characteristics of bacterial nanocellulose*	**4**
9	***Chapter 3. Main fields of application of nanomaterials.*** *Topic 8. The use of nanomaterials from plant raw materials in the pulp and paper industry. The use of nanocellulose in the production of paper and cardboard.* *Literature: [1, p. 67-72; 10, p. 10-15; 8]* *Tasks on SRS: Peculiarities of the use of nanocellulose in the technological processes of adding nanocellulose to the fibrous mass of paper or cardboard.*	**4**

10	*Topic 8. The use of nanomaterials from plant raw materials in the pulp and paper industry, in particular in the production process of organic cardboard packaging.* *Literature: [1, p. 75-85; 10, p. 16-22; 9]* *Task on SRS: Peculiarities of using nanocellulose in the technological processes of applying nanocellulose to the surface of paper or cardboard.*	***2***
11	*Topic 9. The practice of using nanocellulose in the chemical, cement industries and construction.* *Literature: [1, c. 88-104; 3, c.179-215]* *Task on SRS: The influence of nanocellulose additives on the parameters of cement mixtures*	***4***
12	*Topic 9. The practice of using nanocellulose in the pharmaceutical industry and medicine.* *Literature: [1, c. 106-112; 6]* *Task on SRS: Improving the indicators of medicinal products due to the addition of nanocellulose*	***2***
13	*Topic 9. The practice of using nanocellulose in materials* *Literature: [1, c. 114-126; 7]* *Task on SRS: Effect of nanocellulose additives to composite epoxy mixtures.*	***2***
14	*Topic 9. Nanocellulose application technologies in green flexible electronics in the production of flexible temperature, humidity and bending sensors.* *Literature: [1, c. 127-152; 16]* *Tasks on SRS: Methods of applying conductive layers on nanocellulose films*	***2***
15	*Topic 9. Nanocellulose application technologies in the production of solar batteries and thermoelectric generators, ultraviolet protective screens.* *Literature: [1, c. 152-170; 11, 12]* *Task on SRS: Biodegradable flexible transparent films based on nanocellulose for protection against ultraviolet and visible light spectrum*	***2***
Total		***36***

Practical classes

As part of the teaching of the academic discipline "Fundamentals of the theory of production and practice of using nanomaterials from plant raw materials", it is planned to conduct practical classes that occupy 18 hours of classroom work. The main tasks of practical classes are:

- help students systematize, consolidate and deepen their knowledge of the theoretical nature of the basics of the technological processes of obtaining nanomaterials from plant raw materials;
- get acquainted with modern experimental physico-chemical methods of determining the characteristics of nanocellulose;
- to teach students to determine directions of use of various representatives of plant raw materials and cellulose in the technological processes of obtaining nanomaterials from them and their use in various branches of industry, medicine, in the production of composite consumer goods;
- teach students to work with scientific and reference literature, regulatory and technical documents in the field of technological processes of obtaining nanomaterials from plant raw materials;
- learn practical skills of methods of obtaining nanocellulose by the method of hydrolysis and oxidation of cellulose in the TEMPO environment.

Topics of practical classes:

No s/p	***The name of the topic of practical training and the list of main questions (list of didactic support, references to literature and tasks to the SRS)***	***Hours***

1	Topic 1. Nomenclature and classification of nanomaterials based on vegetable raw materials and their general characteristics. Literature: [1, p. 1-8; 6; 7] Tasks on SRS: Basic concepts and terminology of nanomaterials.	***2***
2	Topic 2. Characteristic properties of nanocellulose: modulus of elasticity and specific surface area, transparency and density, biodegradability and biocompatibility, coefficient of thermal expansion and chemical activity. Literature: [1, p. 19-26; 3] Task on SRS: Value of Young's modulus and specific surface area of different types of nanocellulose from vegetable raw materials	***2***
3	Topic 3. Physico-chemical methods of determining the properties of nanocellulose. Peculiarities of preparing samples of plant raw materials, cellulose and nanocellulose for testing by special physico-chemical methods of analysis. Literature: [1, p. 24-36; 2, p. 3-27] Task on SRS: The principle of operation of scanning electron microscopy devices for determining the structure of plant raw materials, cellulose and nanocellulose	*2*
4	Topic 4. Physico-chemical methods of determining the properties of nanocellulose. Analysis of X-ray diffractograms of cellulose samples from various vegetable raw materials after various stages of its thermo-chemical processing. Advantages and disadvantages of Segal's method for calculating the crystallinity index of cellulose-containing materials. Literature: [4, p. 220 - 221; 2] Task on SRS: Methods of determining the values of crystallinity indices of plant raw materials, cellulose and nanocellulose	*2*
5	Topic 5. Using the Fourier transform infrared spectroscopy method to characterize cellulose-containing products and nanomaterials. Literature: [1, p. 193-206; 2] Task on SRS: Methodology for calculating the crystallinity of cellulose based on the data of infrared spectroscopy	*2*
6	Topic 6. Physico-chemical methods of determining the characteristics of nanocellulose. Scheme of operation of transmission electron microscopy devices for determining the size of nanocellulose particles. Literature: [1, p. 24-36; 2] Assignment at SRS: Examples of using atomic force microscopy to determine the nanosize of cellulose particles from various plant raw materials	*2*
7	***Writing a modular test***	***2***
8	**Protection of Home Control Work**	***2***
9	***Test***	***2***
	Total	***18***

6. Independent work of a student/postgraduate student

Independent work of students makes up 55% of course study, includes preparation for includes preparation for practical classes, writing homework and module tests, and preparation for assessment. The main task of students' independent work is the acquisition of scientific knowledge in the field of chemical technologies, which is not included in the list of lecture questions and practical classes, through independent study of material based on educational literature, personal search for information, formation of active interest in a creative approach in educational work. In the process of independent work within the framework of the credit module, the student must learn to deeply analyze the issues of the theoretical foundations of the extraction of nanomaterials from plant raw materials, in particular nanocellulose, and the practice of their use in various industries, medicine and everyday life, in composite *materials of organic packaging, elements of green flexible electronics, micro - and nanoelectronic devices of a new generation.*

No s/p	***Name of the topic submitted for self-study***	*Number of hours of SRS*
Section 1. Characteristics of nanomaterials from plant raw materials		
1	*Nomenclature and classification of nanomaterials based on vegetable raw materials.raw materials Basic concepts and terminology of nanomaterials. Normative documents on the terminology of nanocellulose.* *Literature: [1, p. 1-18]* *Dynamics of production and application of nanocellulose in various industries. Requirements for raw materials for obtaining nanomaterials. Characteristics of the unique properties of nanocellulose.* *Literature: [4, p. 212-224; 10, p. 1-5;].* *Comparison of the characteristics of plant raw materials as a source of nanomaterials. Chemical composition of representatives of plant raw materials. Morphological structure of plants: from micrometers to nanoscale.* *Literature: [4, p. 213-214; 10]* *Values of Young's modulus and specific surface area of different types of nanocellulose from vegetable raw materials depending on the conditions of their production.* *Literature: [1, p. 18-23; 10; 11]* *The principle of operation of scanning electron microscopy devices for determining the structure of plant raw materials, cellulose and nanocellulose* *Literature: [1, 24-36; 2; 6; 14]* *Methods of determining the values of crystallinity indices of plant raw materials, cellulose and nanocellulose according to X-ray structural analysis data, their advantages and disadvantages. Comparison of values of crystallinity indices of plant raw materials, cellulose and nanocellulose, obtained by different methods from different plant raw materials* *Literature: [10, p. 3-15; thirteen].* *The method of calculating the crystallinity of cellulose based on the data of infrared spectroscopy* *Literature: [2, p. 25-34].* *Examples of using atomic force microscopy to determine the characteristics of nanocellulose from various plant materials* *Literature: [2, c. 12-18].* *Thermogravimetric analysis of vegetable raw materials, cellulose and nanocellulose. Comparison of the dependence of gravimetric and differential thermal analysis of nanocellulose obtained by different methods of extraction from plant raw materials.* *Literature: [4, p. 221-22$ 102]* *The use of atomic force microscopy to determine the nanosize of cellulose particles from vegetable raw materials.* *Literature: [2, p. 35-38].*	*20*
Section 2. Methods of obtaining nanomaterials from plant raw materials		
	Mechanical, chemical and biological methods of extraction of nanocellulose from vegetable raw materials. *Literature: [4, p. 213-214; 7]* *Examples of production and comparative characteristics of nanocellulose obtained by mechanical methods.* *Literature: [1, p. 19-31; 4, p. 213-214]*	

2	*Advantages and disadvantages of using different acids in cellulose hydrolysis processes to obtain nanocellulose. Dependence of the properties of nanocellulose films on the technological parameters of the hydrolysis process.* *Literature: [4, p. 223-224; 10, p. 6-9]* *Peculiarities of using the reagent 2,2,6,6-tetramethyl-piperidine-oxyl (TEMPO) for obtaining nanocellulose.* *Literature: [1, 32-46; 15]* *Types of bacteria used in the enzymatic process of obtaining nanocellulose and characteristics of bacterial nanocellulose* *Literature: [1, pp. 47-54; 13, c.1-5]* *Methods of surface modification of nanocellulose and properties of such products* *Literature: [2, p. 3-9; 7; thirteen]* *Examples of determining the characteristic features of the structure of plant raw materials, cellulose and nanocellulose by scanning electron microscopy.* *Literature: [2, p. 9-13; 4, 223-224]* *Examples of the use of atomic force microscopy to determine the nanosize of cellulose particles from various plant raw materials* *Literature: [4, p. 213-214; 14]*	16
	Section 3. The main fields of application of nanocellulose	
3	*The use of nanomaterials from plant raw materials in the process of paper and cardboard production. Peculiarities of the use of nanocellulose in the technological processes of introducing nanocellulose into the fibrous mass of paper and cardboard.* *Literature: [1, p. 67-72; 10, p. 10-15; 8]* *Peculiarities of the use of nanocellulose in the technological processes of applying nanocellulose to the surface of paper and cardboard.* *Literature: [1, p. 75-85; 10, p. 16-22; 9]* *The influence of nanocellulose additives on the strength indicators of cement mixtures.* *Literature: [1, c. 88-104; 3, c.179-215]* *Improving the indicators of medicinal products due to the addition of nanocellulose to their composition.* *Literature: [1, c. 106-112; 6]* *Effect of nanocellulose additives on quality indicators of composite epoxy mixtures.* *Literature: [1, c. 114-126; 7, 17]* *Thermoelectric generators on nanocellulose films. Biodegradable flexible transparent films based on nanocellulose for protection against ultraviolet and visible light spectrum* *Literature: [1, c. 152-170; 11, 12]*	8
4	***Preparation for modular control work (MCW) on chapters 1-3***	4
5	***Working on home control work (HCW)***	8
6	***Preparation for the test***	6
	Total hours	***66***

Politics and contect

7. Policy of discipline (educational component)

Rules for attending classes and behavior in classes

Attending classes is a mandatory component of assessment. Students are obliged to take an active part in the educational process, not to be late for classes and not to miss them without a good reason, not to interfere with the teacher to conduct classes, not to be distracted by actions that are not related to the educational process.

Rules for assigning incentive and penalty points

• encouraging points can be credited by the teacher only for the performance of creative works in the discipline or additional passage of online specialized courses with the receipt of the appropriate certificate.
However, their amount cannot exceed 25% of the rating scale. Penalty points within the discipline are not provided.

Deadline and overlay policy
In case of debts in the discipline or any force majeure circumstances, graduate students should contact the teacher through accessible (provided by the teacher) communication channels to solve problematic issues and coordinate the algorithm of actions for working out.
Academic Integrity Policy
Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the absence of references when using printed and electronic materials, quotes, opinions of other authors. Invalid hints and write-offs when writing tests, conducting classes; passing the credit for another graduate student; copying of materials protected by the copyright system without the permission of the author of the work.
The policies and principles of academic integrity are defined in Section 3 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"https://kpi.ua/code.
Policy of academic behavior and ethics

Students should be tolerant, respect the opinion of others, object to formulate in the correct form, constructively maintain feedback in the classroom.
The norms of ethical behavior of students and employees are defined in Section 2 of the Code of Honor of the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" https://kpi.ua/code.

8. Types of control and rating system for evaluating learning outcomes (RCOs)
Distribution of educational time by types of classes and tasks in the discipline according to the working curriculum:

Semester	*School time*		*Distribution of training hours*				*Control measures*		
	credits	*acad. H.*	*Lecture*	*Practical*	*Labor. work*	*SRS*	*MCW*	*HCW*	*Semester control*
8	***4***	***120***	***36***	***18***	***-***	***18***	***1***	***1***	***Test***

The rating system for evaluating learning outcomes (RSO) of a student in a discipline consists of the points he receives for answers during express control at lectures; answers in practical and laboratory classes; execution of a modular control work, which can be divided into two 45-minute or three 30-minute works.

System of rating (weighted) points and evaluation criteria

1) Answers during express control at lectures:
Weight score - 3. Weight coefficient - 0.15. The maximum number of points for all lectures is equal to: 18 lectures (answers) x 3 points x 0.15 = 8 points
Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors

0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

2) Answers in practical classes:
Weight score - 3. Weight factor - 0.6. The maximum number of points in all laboratory classes is equal to: 9 practicals. (answers) x 3 points x 0.6 = 16 points
Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

3) Completion of a modular control work, which consists of answers to 6 questions from different sections of the academic discipline and is performed in written form by one's own hand without the use of computer equipment.
Weight score - 3. Weight factor - 1.0. The maximum number of points for a modular test is: 6 questions x 3 points x 1.0 = 18 points
Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

4) Completion of a home control work, which consists of answers to 6 questions from different sections of the academic discipline and is performed in written form by one's own hand without the use of computer equipment.
Weight score - 3. Weight factor - 1.0. The maximum number of points for a modular test is: 6 questions x 3 points x 1.0 = 18 points
Answer evaluation criteria:

Points	Completeness of the answer
3	"excellent", Complete answer (at least 90% of the required information)
2	"good", incomplete disclosure of one of the questions or a complete answer with minor inaccuracies
1	"satisfactory", incomplete disclosure of the question (at least 60% of the required information) and minor errors
0	Unsatisfactory work (does not meet the requirements for 3 Unsatisfactory work (does not meet the requirements for 3 points).

Calculation of the rating scale (R).

The rating scale of the discipline (R) is 100 points and is formed as the sum of all the rating points of the starting scale (Rc), received by the student based on the results of current control measures, and the rating scale (Rч) of the rating. The size of the starting scale (Rc) of the Rc rating is 60 points: Rc = 8 + 16 + 18 + 18 = 60 points, and the size of Rз = 40 points. Thus, the rating scale for the discipline is: R = RS + Rz = 60 + 40 = 100 points.

Semester control is test. Criteria: The answer to four questions, each of which has a weighting point of 10. The maximum number of points is 10 x 4 = 40 points.

According to the results of academic work in the first 7 weeks, a student can score 20 points. At the first certification (8th week), the student receives "credited" if his current rating is at least 10 points. According to the results of 13 weeks of study, the student must score 40 points. At the second certification (14th week), the student receives "passed" if his current rating is at least 20 points.

Regular positive answers in lectures, practical and laboratory classes, writing a modular test, as well as a starting rating (Rc) of at least 40% of Rc, i.e. 24 points, are a necessary condition for admission to the credit. A student who scored a rating of less than 0.6 Rs during the semester completes a credit test. At the same time, all points received by him during the semester are cancelled. The task of the control work contains questions related to different sections of the program. The list of assessment questions is given in Chapter 9.

In order for a student to receive a passing grade, the sum of all rating points R earned during the semester is converted according to the table:

Number of points	Evaluation
95...100	excellent
85...94	very good
75...84	*good*
65...74	satisfactory
60...64	*enough*
RD < 60	unsatisfactory
Unfulfilled conditions of admission	are not admitted

9. Additional information on the discipline (educational component)

Approximate list of questions submitted for semester control

1. Nomenclature and classification of nanomaterials based on vegetable raw materials. Basic concepts and terminology of nanomaterials. Normative documents on the terminology of nanocellulose and components based on it.
2. Dynamics of production and application of nanocellulose in various industries. Requirements for raw materials for obtaining nanomaterials. Unique properties of nanocellulose.
3. General characteristics of physico-chemical methods for determining the parameters of nanocellulose, transmission electron microscopy, atomic force microscopy, X-ray structural analysis. Thermogravimetric analysis.
4. Scanning electron microscopy. The principle of operation of scanning electron microscopy devices for determining the structure of plant raw materials, cellulose and nanocellulose.
5. Methods of determining the values of crystallinity indices of plant raw materials, cellulose and nanocellulose according to X-ray structural analysis data. Comparison of values of crystallinity indices of plant raw materials, cellulose and nanocellulose, obtained by different methods from different plant raw materials.
6. Transmission electron microscopy (TEM) and atomic force microscopy (AFM). Examples of using TEM and AFM to determine the nanosize of cellulose particles from various plant materials.

7. Thermogravimetric analysis of plant raw materials, cellulose and nanocellulose. Comparison of the dependence of gravimetric and differential thermal analysis of nanocellulose obtained by different methods of extraction from different plant materials
8. Mechanical, chemical and biological methods of extraction of nanocellulose from vegetable raw materials. Examples of production and comparative characteristics of nanocellulose obtained by mechanical methods. Types of mechanical methods of obtaining nanocellulose.
9. Chemical methods of obtaining nanocellulose. Advantages and disadvantages of using different acids in cellulose hydrolysis processes to obtain nanocellulose. Dependence of the properties of nanocellulose films on the technological parameters of the hydrolysis process
10. The main technological parameters of the process of obtaining nanocellulose by the method of oxidation using various oxidants. Peculiarities of using the reagent 2,2,6,6-tetramethylpiperidine-oxyl (TEMPO) for obtaining nanocellulose. Influence of technological parameters of the oxidation process on the properties of nanocellulose.
11. Biotechnological methods of obtaining nanocellulose and the main characteristics of bacterial nanocellulose. Types of bacteria used in the enzymatic process of obtaining nanocellulose and characteristics of bacterial nanocellulose
12. The use of nanomaterials from plant raw materials in the process of paper and cardboard production. Peculiarities of the use of nanocellulose in the technological processes of introducing nanocellulose into the fibrous mass of paper or cardboard
13. The main fields of application of nanomaterials in the pulp and paper industry. Peculiarities of the use of nanocellulose in the technological processes of applying nanocellulose to the surface of paper or cardboard
14. Nanocellulose application technologies in the chemical, cement industries and construction. The influence of nanocellulose additives on the parameters of cement mixtures.
15. The practice of using nanocellulose in the pharmaceutical industry and medicine. Improving the indicators of medicinal products due to the addition of nanocellulose Improving the indicators of medicinal products due to the addition of nanocellulose
16. The influence of nanocellulose additives on quality indicators of composite epoxy mixtures.
17. Nanocellulose application technologies in green flexible electronics in the production of flexible temperature sensors.
18. Technologies for the use of nanocellulose in the production of flexible humidity and bending sensors.
19. Technologies for the use of nanocellulose in the production of solar batteries and thermoelectric generators
20. Production technologies of biodegradable flexible transparent films based on nanocellulose for protection against ultraviolet and visible light spectrum.

Work program of the academic discipline (syllabus):

Compiled by professor, Ph.D. Valerii Anatoliyovych Barbash

Approved by the ___ETRP___ department *(protocol No. _14_ from _06.08.2022_)*

Agreed by the ECF Methodical Commission *(protocol No. _10_ from _24.06. 2022_)*