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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
State Technical University of Azov
Faculty of ____ Information Technology _____
Chair _____ Biomedical Engineering _____

APPROVED
Dean of the Faculty
information technology
_____Vereshkun M.V.
"____" _____ 2019

PROGRAM OF THE EDUCATIONAL DISCIPLINE

_____ NANOSTRUCTURES AND NANOCAPULES _____
(Nanostructures and Nanocapsules)

field of preparation 163 "Biomedical Engineering"
(code and name of the training direction)

Developed as part of the Erasmus + (CBHE) BioArt project: "An innovative multidisciplinary artificial implant training program in bioengineering for bachelor's and master's degrees"

Developed in the frame of project «Erasmus+ (CBHE) Bio-Art: Innovative Multidisciplinary Curriculum in Artificial Implants for Bio-Engineering BSc/MSc Degrees» (586114-EPP- 1-2017- 1-ES-EPPKA2-CBHE- JP)

2019-2020 academic year

Course program__Nanostructures and nanocaps for students
(name of course)
in the field of preparation 163 "Biomedical Engineering".

Developers: Assoc., Ph.D. Sorochan O.M.
(indicate authors, their posts, academic degrees and academic titles)

The work program was approved at the meeting of the Department of Biomedical Engineering, Minutes of .2019 №

Head of the Department _____ (Azarkhov O.Y.)
(signature) (surname and initials)

Approved by the Faculty Methodological Commission
Minutes of "____" _____ 2019 №. ___

Chairman _____ (Cherevko O.O.)
(signature) (surname and initials)

1 Description of the course

Semester	Credit ECTS	Hours	Classroom hours				Individual work	Distribution by semesters		
			Total	Lectures	Practical	Laboratory		Exams	Offsets	Coursework
9	3	90	48	32	16	-	42	4	-	-

2 The purpose and objectives of the discipline

Nanostructures and nanocapsules have historically emerged as an interdisciplinary field at the intersection of physics, chemistry, biology, microelectronics and other sciences. Therefore, this discipline plays the role of a generalizer. Successful study requires knowledge acquired during all previous years of student's studies.

In particular, knowledge of mathematical analysis, analytical geometry, discrete mathematics, all different divisions of general physics, from mechanics to quantum theory, analog and digital electronics, theory, and theory, is required to successfully master the material of the discipline "Nanostructures and nanocapsules" - dynamics and quantum physics.

Information technology will also be helpful, from simple computer skills to writing object-oriented software for managing equipment and processing results. In addition, most of the information on nanotechnology is on the Internet, as paper publications do not keep up with the rapid development of this field.

Purpose of the course:

Introducing students to the latest achievements and direction-development of modern interdisciplinary field of practical scientific knowledge - nanostructures and nanocapsules.

Provision of knowledge on the application of the laws of physics as the basis of scanning probe microscopy (SPM), the basis of the theory of interaction of probes with the surface of solids.

Studying the principles of construction and operation of probe microscopes, methods of studying the physical properties of solids, methods of processing surface scan data.

Demonstration of the possibility of using SPM in physics, chemistry, molecular biology.

Overview of the basic types, directions of research and application of nanomaterials, nanotechnological processes and nanotechnical devices.
Discussion of the potential environmental and social non-safety of introducing nanomaterials and nano-devices into everyday human life.

Course objectives:

- **Theoretical**

As a result of studying this discipline students receive:

- knowledge of the basic known types of nanostructures in metals, semiconductors, polymers, and biological objects;
- knowledge of the laws of formation and modern methods of obtaining nanostructured materials;
- knowledge of the most sophisticated methods for the study of nanostructures, principles of operation of devices designed to study the structure and properties of nanomaterials;
- knowledge of the most promising directions of application of metal-oxide, semiconductor and medical-biological materials;
- a range of tasks that can be solved by using nanotechnology.

- **Practical**

As a result of studying this discipline, students should:

- free to navigate the main directions of nanotechnology development;
- understand the essence of the effects that determine the particular physicochemical properties of nanomaterials;
- to know the basic technological processes that are used in the removal of nanomaterials;
- have an idea of the possibilities of modern instrument-metrological base for the study of materials with nanometer spatial distribution.
- have a clear understanding of the general principles of scanning zone microscopes;

- understand the essence of the physical phenomena underlying the work of scanning tunneling and atomic force microscopes;
- know the basic techniques of scanning probe microscopy, which allow to study the mechanical, magnetic and electrical properties of the surface of solids of nanometer scale;
- have basic practical skills in measuring nanomaterials on a scanning probe microscope.

- **List of students' knowledge and skills**

After studying the course "Nanostructures and nanocapsules" the student should know:

- the physical basis of different scanning probe microscopy methods;
- theoretical basics of physics of interaction of local probes of different types (tunnel, atomic-power, optical near-field, etc.) with the surface of the studied objects, structure, physical principles of action and features of construction of different types of probe microscopes;
- the main areas of application of the SPM and the particularities of the techniques used in these fields;
- mathematical methods used for processing and analyzing SPM experimental data, theory of SPM image artifacts and methods for avoiding them in the process of experimentation, or compensation for data analysis;
- peculiarities of the flow of various physicochemical processes in the spatial regions of nanometer sizes;
- basic nanotechnological processes of nanomaterials creation;
- state of the art in nanoscale design and application;
- trends in nanotechnology in the world;

After studying the course "Nanostructures and nanocapsules" the student should be able to:

- to prepare samples for research on SPM;
- make new and sharpen damaged tunnel microscope probes;
- perform camera operations with a tunneling microscope to take pictures;
- to process, through a computer, the resulting image to eliminate artifacts and to identify useful information.

3 The discipline program

1. Introduction. The concept of nanotechnology, nanotechnology and nanomaterials. Classification of nano-objects. Position of nano-

objects on the scale of size. Physical causes of their specific behavior. Concepts of dimensional effects, self-organization, and self-assembly Two techno-logical paradigms: top-down and bottom-up. Nanotechnology as an interdisciplinary field at the intersection of physics, chemistry, material science, biology and medicine. History of nanotechnology. Works by R. Feinman and E. Drexler.

Probe Nanotechnology.

2. Scanning probe microscopy (SPM). General principles of scanning probe microscopy.
3. Scanning tunneling microscopy. The structure and physical principles of scanning tunneling microscope (STM) work. Tunnel sen-sor. Zone diagram of the tunnel contact of two conductors. The equation for tunneling current. Structure and principles of tunnel sensor operation. Scanning in DC and DC modes. Feedback system. Computer control and data processing. Method of manufacture and features of application of various STM probes.
4. Volt-ampere characteristic of tunnel contact. Scanning tunneling spectroscopy. Modes of voltage (V-modulation) and height (Z-modulation) modes. The influence of the surface condition of the sample on the features of physical processes in the tunnel contact and the operation of the tunnel sensor. STM in different media (vacuum, ha-x, liquids). Solid surface preparation for STM pre-tracing.
5. Atomic force microscopy (AFM). Physical principles of atomic force sensor operation. The structure of the AFM probe. The interaction of the AFM probe with the solid surface, the van der Waals force. Method of recording cantilever deviation. Forms of cantilevers, features and methods of their manufacture. AFM Scan Mode: Contact Mode (Continuous Force and Continuous Deviation, Latreral Force Mode, LFM. Z-Modulation); non-contact mode (non-contact mode) (amplitude-frequency and phase characteristics of cantilever); true non-contact fashion (True Non-Contact); periodic contact (Tapping Mode).
6. Sensors for various purposes. Magnetic Force Microscopy (Magnetic Force Microscopy, MFM). Electric Force Microscopy (Electric Force Microscopy, EFM). Kelvin Mode Scanning (Kelvin Mode). Scanning Capacitance Microscopy (SCM). Thermal Scanning Microscopy (TSM). Spreading Resistance Microscopy. Piezoelectric fashion.

7. Near-field scanning optical microscopy (BSOM). The theory of light diffraction on a subwave aperture. Light propagation in non-stationary optical waveguides. Structure and methods of manufacturing BSOM probes. Piezoelectric Tuning Fork Shear-Force Sensor. Application of BSOM for the study of nano-structures, elements of fiber and integral optics, in chemistry and molecular biology.
8. Scanners. Types of SPM scanners. Comparative characteristics of different designs of SCM scanners. Methods of linearization of character-junction of scanners. Piezoelectric motors. Characteristics of the piezoelectric materials used in SCM scans. Phenomena of nonlinearity and hysteresis of L – V characteristics, birthing, fatigue and their role in the formation of SPM artifacts. Computerized scanning management. Overview of SPM mass production. Amateur SPM projects.
9. Atomic manipulation and design, nanolithography. Power nanotesting of surface layers. Investigation of the force of the probe-surface interaction (F / S spectroscopy). Examples of application of force nanotesting in studies of mechanical properties are superficial. The use of STM for the investigation and modification of superficial solids.
10. Methods of visualization and processing of SPM images. Resolution, errors, distortions and artifacts in SPM. The Gwyddion program. Height color scale. Profilometry. Construction of three-dimensional images. Using the side-lighting effect. Methods for aligning SPM images. Statistical analysis of SPM data. Construction and processing of histograms of altitude distribution. Methods for digital filtering of SPM images. Bandpass filters. Convolution filters. Fourier analysis and filtering of SPM images. Detection and analysis of the granular structure of the surface image of the samples.

Nanomaterials and Their Applications.

11. Nanomaterials. Nanoparticles and nanopowders. Bulk Nanostructural Materials Nanocarbon. Fullerenes, nanotubes and nanostructures based on them. Graphene. Structure and basic properties (mechanical, electronic, etc.). Methods of obtaining fullerenes and nanotubes. Nanocomposite materials. Nanoporous materials. Semiconductor and dielectric materials. Nanorods. High-temperature superconductors. Magnetic materials. Materials with giant and colossal magnetoresistance. Materials with special mechanical properties. Tech-stylish nanomaterials. Intellectual materials. Thin films

and coatings. Polymeric, biological and biocompatible materials. Dendry Mayors are nanosize capsules. Self-organization of nano-objects and their use when creating nanomaterials. Nanochemistry. Meta-theories.

12. Nanoelectronics. Basic Functions of Nanoelectronics. Fundamental limitations of miniaturization. Basic materials and techno-technologies. Nanolithography. The main components of the circuits. Nano-electronics on nanotubes. Quantum devices. Molecular electronics. Organic LEDs. Electroplating elements. Polymeric batteries.
13. Nano-devices, nanomachines, nanosystems. Features of mechanics in nanoscale. Hydrodynamics of nanoridines. Nanotribology. (Dry friction on an atomic scale. Friction under liquid lubrication). Technologies for the production of micro / nano devices and machines. Nanos-sori. (Membrane sensors. Tactile sensors. Sensors for detecting acceleration, vibration, shock. Contactless optical sensors. Stringent sensors. Console-beam sensors.). Actuators, manipulators, engines. Nanomotors are the muscles of a nanorobot. Elements of microhydraulics.
14. Integrated systems. Inertial devices. Optomechanical MEMS. MEMS radio engineering. Microanalytical laboratories on a single chip. The Millipede Project. Medical nanotechnology. Inter-lectual nanosystems and nanobots.
15. Molecular devices. Molecular tweezers. Rotaxanes and cathenies. Rotational motion. Reciprocal movement. Harvesting schemes by stringing ring molecular struc- tures into linear ones.
16. Nanobiology Nanobiotechnology The main objects of nanobiotechnology. Self-assembly and self-organization. Artificial membranes Nano-technology of nature. Storage, recording and processing of information in live systems. Genetic engineering. Transgenic animals and plants. Genodified products: pros and cons. Lotus Effect. Geckos, mussels and superglue. Biocomputers. Nanocontainers, nanoreactors, micelles.
17. Nanomedicine. The use of DNA for drug synthesis. Nanotechnology against viruses and bacteria. Targeted delivery of drugs packaged in nanocapsules to diseased cells. Nanotechnology in the fight against cancer. Nanotechnology in diagnostic junction. The risks of using nanomaterials are possible.

18. Prospects for nanotechnology development and possible socio-economic consequences of the nanotechnology revolution. Nanotechnology around us. Examples of products created with nanotechnology matching and reasons for their unique properties. Non-wettable surfaces. Bactericidal surfaces based on nanoparticles of titanium oxide and silver. Nanocomposite materials. Nanotechnology in various fields of production. Nanotechnology in energy engineering and ecology. Nanotechnology in Forensics and Cosmetics. Dihint of nanotechnology development in our country and in the world. Prospects of the world nanoeconomics.

5 Individual work

Independent work of the student (full-time form) includes preparation for practical and laboratory classes; Independent study of additional literature and questions for self-control of mastering the content of educational material, as well as solving homework for each content module.

5.1 List of topics for self-study 3rd semester

1. History of nanotechnology. Works by R. Feinman and E. Drexler.
2. Zone diagram of the tunnel contact of two conductors. The equation for tunneling current.
3. Volt-ampere characteristic of tunnel contact.
4. STM in different environments (vacuum, gases, liquids).
5. Interaction of AFM probe with solid surface, Van der Waals force.
6. Application of BSOM for the study of nanostructures, elements of fiber and integral optics, in chemistry and molecular biology.
7. The use of STM for the study and modification of the surface of solids.

5.2 Розрахунок часу для самостійної роботи студента за видами

№ s / n	Types of work	Number of hours
1	Development of program material, which is taught at lectures and topics of self-study	15
3	Preparation for practical classes	12

4	Performing individual tasks	15
	Together	**42**

Independent work is performed in accordance with the methodological guidelines for independent work of students.

6 Individual tasks

Students complete individual assignments in the form of a abstract and defend it with an MSPowerPoint presentation.

7 Learning methods

Illustrative-illustrative or informative-receptive method, reproductive method and method of problematic presentation. On another classification: verbal (lectures, explanations at practical classes, instruction - at laboratory); practical methods (solving physical problems) and visual.

8 Control methods

Control written surveys on practical topics. Modular material controls for content modules.

EXAMINATION QUESTIONS

1. Statistical analysis of SPM data. Construction and processing of histograms of altitude distribution.
2. Methods for digital filtering of SPM images.
3. Polymeric, biological and biocompatible materials
4. Medical nanotechnology. Intelligent Nanosystems and Nanobots.
5. Genodified products: pros and cons.
6. Lotus Effect. Geckos, mussels and superglue
7. Examples of products created with nanotechnology matching and reasons for their unique properties.
8. Nanotechnology in Forensics and Cosmetics.

9. History of nanotechnology. Works by R. Feinman and E. Drexler.
10. Zone diagram of the tunnel contact of two conductors. The equation for tunneling current.
11. Volt-ampere characteristic of tunnel contact.
12. STM in different environments (vacuum, gases, liquids).
13. The interaction of the AFM probe with the solid surface, the van der Waals force.
14. Application of BSOM for the study of nanostructures, elements of cellular and integral optics, in chemistry and molecular biology.
15. The use of STM for the study and modification of the surface of solids.

9 Distribution of points that students receive

From training or control over the course	Points for one class or control measure	For the semester		Before the 1st certification	
		number of lessons or check-ups	the sum of points	number of lessons or check-ups	the sum of points
Control works	3	8	24	4	12
Control modules	13	2	26	1	12
Protection of individual tasks	10	1	10	-	-
The amount of current control			60		24
Passing the exam			40		
Total			100		

Rating scale

Sum of points for all kinds of educational activity	Score on a national scale	
	for exam, course project (work), practice	to offset
90 – 100	perfectly	counted
82-89	good	
74-81		
64-73	satisfactorily	

60-63		
35-59	unsatisfactory with the possibility of reassembly	not reassigned
0-34	unsatisfactory with the compulsory re-study of the discipline	not included in the compulsory re-study of the discipline

10 Recommended information sources

Basic

1. Golovin, Yu. I. Introduction to Nanotechnology [Text] / Yu. I. Golovin. - M.: Mechanical Engineering, 2007. - 496 p. : il.
2. Andrievskiy, R.A., and Ragul, A.V., Nanostructured Materials. M .: Academy, 2005.
3. Kobayashi N. Introduction to Nanotechnology. M .: BINOM. Laboratory of Knowledge, 2005.
4. Poole C., Owens F. Nanotechnology: Textbook. allowance. M .: Technosphere, 2005.
5. Nanotechnology in the next decade. Forecast of the direction of research. Ed. Roko MK, Williams RS, Alivisatosa PM: The World, 2002.
6. Zolotukhin IV, Kalinin Yu. E., Stogney OV New directions of physical material science. Voronezh: Publishing House of Voronezh State University, 2000.
7. Shik A. Ya., Bakuyeva LG, Musikhin SF, Rykov SA Physics of low-dimensional systems. St. Petersburg: Science, 2001.
8. Harris P. Carbon nanotubes and related structures. New materials of the 21st century. M .: Technosphere, 2003.
9. Ratner M., Ratner D. Nanotechnology: a simple explanation of another brilliant idea. M .: Williams Williams, 2004.
10. Moreau W. Microlithography: principles, methods, materials: In 2 h. M.: Mir, 1990.
11. Andrievsky RA Fundamentals of nanostructured material science. Opportunities and problems / RA Andrievsky. —M. : BINOM. La Knowledge Boratorium, 2011. - 186 p. : il. - (Nanotechnology).
12. Golovin, Yu.I. Nanomir without formulas / Yu.I. Golovin; ed. prof. LN Patrikeeva.- M.: BINOM. Laboratory of Knowledge, 2012. - 543 p.

Auxiliary

1. Scanning probe microscopy of biopolymers. Ed. Yaminsky IV M .: Scientific World, 1997.
2. Rykov SA Scanning probe microscopy of semiconductor materials and nanostructures: Textbook. manual for universities. General ed. Ilyina VI, Shika A. Ya., SPb: Nauka, 2001.
3. Grechikhin LI Physics of nanoparticles and nanotechnologies. General basics, mechanical, thermal and emission properties. Minsk: Technoprint, 2004.
4. Valiyev KA Physics of submicron lithography. M .: Science, 1990.

Information resources

Reference materials on the site:
http://nano.msu.ru/education/courses/basics
Reference materials on the site:
http://www.nanometer.ru
Reference materials on the site:
http://popular.rusnano.com/Section.aspx/Show/28164