Federal State Autonomous Educational Institution of Higher Education "Moscow Institute of Physics and Technology (National Research University)"

APPROVED
Head of the Phystech School of Aerospace Technology
S.S. Negodyaev

Work program of the course (training module)

course:	Beam-Plasma Technologies. Part 1. Biomedical Applications/Пучково-плазменные технологии. Часть 1. Медико-биологические приложения
major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии
	Phystech School of Aerospace Technology
	Chair of Logistics Systems and Technologies
term:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Grading test

Academic hours: 30 AH in total, including:
- lectures: 15 AH.
- seminars: 15 AH.
- laboratory practical: 0 AH.

Independent work: 15 AH.

In total: 45 AH, credits in total: 1

Author of the program: T.M. Vasileva, doctor of technical sciences, associate professor

The program was discussed at the Chair of Logistics Systems and Technologies 09.02.2022

Annotation

Known applications of electron beams and electron-beam generated plasma for biology and medicine are the course subject. Among them:

- Production of bioactive compounds and materials.
- Sterilization of various surfaces and living tissues.
- Applications in hematology.
- Applications in dentistry and orthopedics.
- Applications in therapy of skin diseases and surgery.
- Plasma in pharmacology.
- Plasma in agriculture and veterinary medicine.

The basic concepts of plasma physics and plasma chemistry are given in the context of “Plasma medicine”, “Plasma pharmacology” and “Plasma agriculture” for techniques and equipment. All applications of the electron beams and electron-beam generated plasma are considered from both the point of view of scientific fundamentals and practical realizations.

1. Study objective

Purpose of the course

To present students the basic concepts of plasma physics and plasma chemistry in the context of “Plasma medicine”, “Plasma pharmacology” and “Plasma agriculture”; to acquaint students with beam-plasma techniques and equipment for bioactive compounds production and their biomedical applications.

Tasks of the course

• Familiarization of students with known applications of non-equilibrium plasmas in technologies of:
- production of bioactive compounds for use as active agents of drugs;
- production of materials with increased biocompatibility;
- direct therapeutic effect on the human body;
- sterilization of various surfaces and tissues of the human body.

• Demonstration to students of beam-plasma systems that directly affect plasma on the tissues of the human body;

• Demonstration to students of the operation of beam-plasma systems in solving scientific problems related to technologies for production of bioactive compounds and medical materials;

• Developing students' skills in analyzing beam-plasma systems for their subsequent use in “Plasma medicine”, “Plasma pharmacology” and “Plasma agriculture”.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.2 Assess the relevance and practical importance of research in professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)

different solution methods	Gen.Pro.C-3.3 Gain knowledge of analytical and computational methods of problem-solving, understand the limitations of the implementation of the obtained solutions in practice

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- principles of operation and design of beam-plasma systems intended for the known and advanced biomedical technologies;
- methods of work on beam-plasma setups for technological purposes, features of their operation and maintenance;
- methods for measuring the main parameters characterizing the operation modes of beam-plasma setups;
- parameters and target characteristics of beam-plasma systems for biomedical purposes.

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems for biomedical applications;
- perform calculations of the main parameters characterizing the operating modes of beam-plasma setups in solving practical biomedical problems;
- carry out preliminary design of beam-plasma setups designed to solve biomedical problems;
- perform physical and computer modeling of work processes in beam-plasma plasma-chemical reactors and setups for non-vacuum electron-beam processing of materials;
- master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of beam-plasma systems for biomedical purposes.

master:

- the skills of mastering a large amount of interdisciplinary and special information;
- a culture of setting goals in the design and application of beam-plasma systems for biomedical application;
- skills of working on beam-plasma setups, ensuring their reliable and safe operation.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Fundamentals and applied aspects of nonequilibrium plasma usage for biology, pharmacology and medicine.	1	1		
2	Selected principles of biology and medicine that underlie biomedical applications of non-equilibrium low-temperature plasmas.	2	2		
3	Non-equilibrium plasma generators used in plasma medicine and for production of bioactive compounds and materials.	2	2		
4	Electron-beam and plasma technologies for sterilization of various surfaces and living tissues.	2	2		
5	Beam-plasma technologies for hematology.	2	2		

6	Beam-plasma technologies for dentistry and orthopedics.	1	1		
7	Beam-plasma technologies for the treatment of skin diseases and surgery.	1	1		
8	Beam-plasma technologies for pharmacology.	2	2		
9	Beam-plasma technologies for agriculture and veterinary medicine.	2	2		15
AH in total		15	15		15
Exam preparation		0 AH.			
Total complexity		45 AH., credits in total 1			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 3 (Fall)

1. Fundamentals and applied aspects of nonequilibrium plasma usage for biology, pharmacology and medicine.

Introduction. Subject, goals and objectives of the course. Review of well-known fundamental and applied research on the subject of the course. Basic schematic solutions for low-temperature plasma generators and beam-plasma setups for biomedical technologies.

2. Selected principles of biology and medicine that underlie biomedical applications of non-equilibrium low-temperature plasmas.

Molecular bases of the organization of living systems. bioorganic molecules. Terminology used to describe biological objects and their functioning. Cells: organization and functions. Mechanisms of interaction between plasma and cells in vitro and in vivo.

3. Non-equilibrium plasma generators used in plasma medicine and for production of bioactive compounds and materials.

Gas-discharge plasma technical systems: glow discharges of various frequency ranges, discharges at atmospheric pressure. Dielectric barrier discharge. Electron-beam plasma generators. Hybrid plasma generators. Generators of flows of low-temperature non-equilibrium plasma.

4. Electron-beam and plasma technologies for sterilization of various surfaces and living tissues.

Plasma technologies as an alternative to traditional sterilization technologies. Non-thermal low-pressure plasma in the problems of surface sterilization. Inactivation of microorganisms in atmospheric pressure plasma. Factors determining the sterilizing effect of plasma exposure. Sterilization of living tissues of animals and humans. The problem of destruction of living tissues under plasma exposure. Sterilization of biological objects by fast electron flows. Prospects for the use of beam-plasma systems for the sterilization of biological objects.

5. Beam-plasma technologies for hematology.

Mechanisms of the effect of non-equilibrium plasma on the blood. Coagulation of blood under the influence of non-thermal plasmas. Plasma wound healing. Practical designs of plasma coagulators.

6. Beam-plasma technologies for dentistry and orthopedics.

Plasma modification of the biological properties of polymeric materials used in dentistry and orthopedics. Increasing the biocompatibility of polymeric and metallic materials. Plasma-stimulated processes to control cell and tissue regeneration. Plasma therapy of dental diseases. Beam-plasma technologies in the production of dental and bone implants.

7. Beam-plasma technologies for the treatment of skin diseases and surgery.

Inactivation of bacteria and fungi under the action of non-thermal plasma. Creation of ions directly on living tissue. Plasma therapy of skin ulcers. Treatment of oncological skin diseases. Plasma scalpel.

8. Beam-plasma technologies for pharmacology.

Beam-plasma technologies for obtaining inhibitors of human blood platelet aggregation. Manufacture of hemostatic agents. Obtaining bioactive complexes for targeted delivery of drugs to the area of therapeutic effect. Creation of plasma mixtures with "targeted delivery" to the cellular level. Hybrid materials based on plasma-modified peptides and polysaccharides. Bioactive complexes based on graphene.

9. Beam-plasma technologies for agriculture and veterinary medicine.

Methods for beam-plasma processing of natural organic raw materials (wood, chitin, chitosan) as a basis for obtaining bioactive materials for agriculture: plant growth stimulants, alternative herbicides, animal protection products, sorbents and enterosorbents. Technologies for improving the safety of agricultural products based on low-temperature plasma and electron beam processing.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

Experimental complex "Beam-plasma systems and technologies" as part of the ELU-1 and ELU-2 installations, diagnostic equipment, auxiliary and special technological equipment (room 222 of the UPM building). Personal computers of the required performance.
Necessary equipment for lectures and practical exercises: computer and multimedia equipment (projector, marker board, Internet connection).

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

1) Plasma Medicine. Applications of Low-Temperature Gas Plasmas in Medicine and Biology. Editors: M. Laroussi, M. G. Kong, G. Morfill, May, 2012.
2) Alexander Fridman, Gary Friedman. Plasma Medicine. Wiley, 2013.
3) M G Kong1, G Kroesen2, G Morfill3,5, T Nosenko3,4, T Shimizu3, J van Dijk2 and J L Zimmermann Plasma medicine: an introductory review. New Journal of Physics, Volume 11, November 2009.
4) M. Vasiliev, T. Vasilieva. Materials production with Beam Plasmas. In Encyclopedia of Plasma Technology (Ed. J.L. Shohet, Taylor & Francis), 2017. P. 152-166. Additional literature

Additional literature

1) Encyclopedia of Plasma Technology (Ed. J.L. Shohet, Taylor & Francis), 2017.
2) Fridman G., Vasilets V., Gutsol A., Friedman G., Shekhter A.B., Fridman A., Plasma Processes and Polymers, 2008, V. 5, P. 503-533.
3) Fridman G., Shereshevsky A., Jost M.M., Brooks A.D., Fridman A., Gutsol A., Vasilets V., Friedman G., Plasma Chemistry and Plasma Processes, 2007, V. 27, P. 163–176.
4) Kalghatgi S.U., Fridman G., Cooper M., Nagaraj G., Peddinghaus M., Balasubramanian M., Vasilets V.N., Gutsol A.F., Fridman A., Friedman G., IEEE Transactions on plasma science, 2007, V. 35, P. 1559-1556.

7. List of web resources that are necessary for the course (training module) mastering

Not used

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

Microsoft Office. Internet access.

9. Guidelines for students to master the course

Successful mastering of the course “Beam-Plasma Technologies. Part 1. Biomedical Applications” requires significant self tuition of the student. Self tuition includes:

- reading and taking notes of the recommended literature;
- study of educational material (based on lecture notes, educational and scientific literature);
- solving problems offered to students at lectures;
- preparing to self tuition and tests.

The guidance and control over the student self tuition is carried out by the analysis of the self tuition results, tests, and individual consultations.

SUPPLEMENT

Assessment funds for course (training module)

major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии Phystech School of Aerospace Technology Chair of Logistics Systems and Technologies
term:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Grading test

Author: T.M. Vasileva, doctor of technical sciences, associate professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
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	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)
	Gen.Pro.C-3.3 Gain knowledge of analytical and computational methods of problem-solving, understand the limitations of the implementation of the obtained solutions in practice

2. Competency assessment indicators

As a result of studying the course the student should:

know:

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master:

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3. List of typical control tasks used to evaluate knowledge and skills

Current control is carried out in the form of independent work or written tests on each topic.

The management and control of the student's independent work is carried out as a result of the analysis of the results of control, independent work, as well as individual consultations.

4. Evaluation criteria

1. Features of beam-plasma installations designed for fundamental and applied research in the field of biomedical applications of nonequilibrium low-temperature plasma.
2. Methods for generating active particles of nonequilibrium plasma in laboratory and technological installations.
3. Transport of active plasma particles to the object of plasma exposure.
4. Processes occurring on the surface of a solid body in contact with a nonequilibrium plasma.
5. Mechanisms of action of thermal and non-thermal plasma on polymers and biopolymers.
6. Mechanisms of action of thermal and non-thermal plasma on cells and living tissues.
7. Kinetic schemes describing the generation of ozone and nitrogen oxides in plasma sterilization units.
8. Processes that determine the plasma-stimulated synthesis of oxide and nitride coatings with increased biocompatibility.
9. Processes that determine the destruction of macromolecular compounds in nonequilibrium plasma.
10. Generation of UV radiation using plasma systems.
11. X-ray generation in beam-plasma systems.
12. Action of fast electrons on macromolecular compounds and biological objects.

The mark is excellent 10 points - given to a student who has shown comprehensive, systematized, deep knowledge of the curriculum of the discipline, who is interested in this subject area, who has demonstrated the ability to confidently and creatively apply them in practice in solving specific problems, free and correct justification of the decisions made.

An excellent mark of 9 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, free and correct justification of decisions made.

An excellent grade of 8 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, the correct justification of the decisions made, with some drawbacks.

A good score of 7 points is given to a student if he firmly knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but does not adequately substantiate the results obtained.

A good score of 6 points is given to a student if he firmly knows the material, expounds it competently and to the point, knows how to apply the knowledge gained in practice, but makes some inaccuracies in the answer or in solving problems.

A good score of 5 points is given to a student if he basically knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but makes a large number of inaccuracies in the answer or in solving problems.

The mark is satisfactory 4 points - given to a student who has shown a fragmentary, scattered nature of knowledge, insufficiently correct formulations of basic concepts, a violation of the logical sequence in the presentation of the program material, but at the same time he has mastered the main sections of the curriculum necessary for further education and can apply the acquired knowledge in sample in a standard situation.

The mark is satisfactory 3 points - given to a student who has shown a fragmented, scattered nature of knowledge, makes mistakes in the formulation of basic concepts, disruptions in the logical sequence in the presentation of program material, poorly knows the main sections of the curriculum necessary for further education and hardly applies the acquired knowledge even in standard situations.

The score is unsatisfactory 2 points - given to a student who does not know most of the main content of the curriculum of the discipline, makes gross errors in the formulation of basic principles and does not know how to use the knowledge gained when solving typical problems.

The mark is unsatisfactory 1 point - given to a student who does not know the main content of the curriculum of the discipline, makes gross errors in the formulation of the basic concepts of the discipline and generally does not have the skills to solve typical practical problems.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

To pass an oral differential test the student is given 60 minutes for preparing and 15 minutes for presentation. The discussion on the student presentation should not exceed 15 minutes.

When preparing differential testing, students can use the discipline program, lecture notes and any other information excluding on-line Internet resources.