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. Manufacturing Technologies/Пучково-плазменные технологии. Часть 1. Производственные технологии
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: M.N. Vasilev, doctor of technical sciences, full 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 in industrial technologies are the course subject. Among them:

- Thermal materials treatment
- Plasma chemical materials treatment
- Plasma-assisted coating deposition and synthesis.
- Treatment of natural and synthetic polymer materials treatment in cold plasmas
- Plasma-stimulated conversion of gases

The basic concepts of plasma physics and plasma chemistry are given in the context of engineering solutions for techniques and equipment for industrial technologies. Industrial 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 acquaint students with the applications of electron-beam plasma in modern industrial technologies and the development trends of scientific research related to the use of plasma in various fields of industry.

Tasks of the course

- Familiarization of students with known applications of electron-beam plasma in production technologies:
- Demonstration to students of the work of beam-plasma systems in solving problems of modifying materials and obtaining new materials by methods of beam-plasma impact on matter;
- Development of students' initial practical knowledge and skills when working with beam-plasma systems designed for materials processing technologies;
- Development of students' skills in designing beam-plasma systems in solving real technological problems, as well as in analyzing and optimizing workflows in such installations.

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 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

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 installations intended for the implementation of known and advanced production 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 industrial setups;
- parameters and target characteristics of beam-plasma systems for technological purposes.

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems in the development of technological setups;
- perform calculations of the main parameters characterizing the operating modes of beam-plasma setups in solving practical technological and engineering problems;
- carry out preliminary design of beam-plasma setups designed to solve problems of thermal, chemical-thermal and plasma-chemical processing of various materials;
- 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 technological 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 in industry;
- 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	Introduction to the subject. Basic schemes and technical solutions of beam-plasma setups for thermal, chemical-thermal and plasma-chemical processing of various materials.	2	2		
2	Control methods for installations that implement combined beam-plasma effects on matter.	2	2		
3	Methods for measuring physical quantities characterizing work processes in technological beam-plasma installations for various purposes	2	2		
4	Technological processes of thermal and chemical-thermal treatment of materials in electron-beam plasma.	2	2		
5	Technological processes of low-temperature plasma-stimulated synthesis of inorganic compounds.	2	2		
6	Technological processes of controlled destruction of macromolecular compounds in electron-beam plasma.	2	2		
7	Generation of hybrid plasmas and technological processes of coating deposition in hybrid plasmas.	3	3		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. Introduction to the subject. Basic schemes and technical solutions of beam-plasma setups for thermal, chemical-thermal and plasma-chemical processing of various materials.

Subject, goals and objectives of the course. Known industrial applications of electron-beam plasma. Basic schemes and technical solutions of beam-plasma setups for thermal, chemical-thermal and plasma-chemical processing of various materials. Ensuring the safety of industrial beam-plasma setups.

2. Control methods for installations that implement combined beam-plasma effects on matter.

Control of the accelerating voltage and current of the electron beam. Control of the energy release density in the working volume of beam-plasma installations. Control of pressure and component composition of the plasma-forming medium. Formation of the working zone in a beam-plasma installation during the processing of dispersed powders and liquids. Temperature control of materials when processing. Automatic maintenance of the specified modes during the materials processing.

3. Methods for measuring physical quantities characterizing work processes in technological beam-plasma installations for various purposes

Measurement of the temperature of materials during their beam-plasma processing. Measurement of heat flows in the working zone of the reactor, calorimetry of the reaction volume. Optical measurements as a source of information about the parameters of the reaction volume. Mass spectrometry of the reaction volume. Dosimetry of X-ray radiation in beam-plasma installations.

4. Technological processes of thermal and chemical-thermal treatment of materials in electron-beam plasma.

Heating of solids placed in an electron-beam plasma, phase transitions. Electron beam welding and cutting of materials outside of vacuum. Surface hardening of metals. Surface remelting and alloying. Thermal and chemical-thermal treatment of powders.

5. Technological processes of low-temperature plasma-stimulated synthesis of inorganic compounds.

Synthesis of nitrides and oxides of metals in electron-beam plasma. Mechanical and chemical properties of oxides and nitrides synthesized in electron-beam plasma. Biocompatibility of titanium oxides synthesized in electron-beam plasma. Synthesis of coatings on the surface of dispersed powders.

6. Technological processes of controlled destruction of macromolecular compounds in electron-beam plasma.

Obtaining low molecular weight compounds by controlled destruction of polysaccharides. Obtaining valuable water-soluble products from natural organic raw materials. Beam-plasma modification of proteins. Control of hydrophilic-hydrophobic properties of polymers and biopolymers by beam-plasma treatment. Technologies for the disposal of household and industrial waste based on the beam-plasma effect on the substance. Conversion of liquid and gaseous hydrocarbons in nonequilibrium plasma.

7. Generation of hybrid plasmas and technological processes of coating deposition in hybrid plasmas.

Obtaining single-layer and multilayer coatings in electron-beam plasma: various combinations of deposited materials and coating materials. Deposition of carbon coatings. Technique of hybrid plasma generation and features of the working processes organization in hybrid reactors. Deposition of coatings in hybrid plasma. 2D-coatings.

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) M. Vasiliev, T. Vasilieva. Materials production with Beam Plasmas. In Encyclopedia of Plasma Technology (Ed. J.L. Shohet, Taylor & Francis), 2017.
2) M. Vasiliev, Applications of Electron-Beam Plasmas in Plasmachemistry. Encyclopedia of low-temperature plasma. V. XI, P. 436-445. Chief editor V. Fortov. Moscow. Nauka, 2001.4)
3) M. Vasiliev, AungTunWin, I. Pobol. “New applications of the Beam-Plasma Systems for the materials production” Int. J. Nanotechnology. 2014, Vol. 11, Nos 5/6/7/8, P. 660-668

Additional literature

1) T. Vaislieva, S. Lysenko, D. Bayandina, M. Vasiliev. Electron beam transport in dusty plasma // Nuclear Instruments and Methods in Physics Research A – 2011. - V.645. – P. 90-95.
2) M.N. Vasiliev, A.H. Mahir. Electron–Beam Plasma Systems in Industrial and Aerospace Applications // Publications of the Astronomical Observatory of Belgrade, 2008, No. 84, P. 421-425.
3) Bychkov, V.; Vasiliev, M.; Koroteev, A. Electron-Beam Plasma: Generation, Properties, Applications; Moscow State Open University Publishers: Moscow, Russia, 1993.

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. Industrial Technologies" 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: M.N. Vasilev, doctor of technical sciences, full professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
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	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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- carry out preliminary design of beam-plasma setups designed to solve problems of thermal, chemical-thermal and plasma-chemical processing of various materials;
- perform physical and computer modeling of work processes in beam-plasma plasma-chemical reactors and setups for non-vacuum electron-beam processing of materials;
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master:

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- a culture of setting goals in the design and application of beam-plasma systems in industry;
- skills of working on beam-plasma setups, ensuring their reliable and safe operation.

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

The list of laboratory works, the performance and delivery of which is mandatory for obtaining an assessment on a differentiated test.

- Thermal and chemical-thermal structural steels in electron-beam plasma.
- Low-temperature plasma-stimulated synthesis of titanium oxides.

• Control of hydrophilic-hydrophobic properties of high-molecular compounds using nonequilibrium plasma.
• Generation of hybrid air plasma.

4. Evaluation criteria

1. The principle of operation of beam-plasma installations.
2. Formation of a plasma-forming medium in beam-plasma reactors..
3. Physical processes occurring in the gaseous reaction volume.
4. Processes occurring at the interface between beam plasma and solid body.
5. Beam-plasma reactors for technological purposes: main and auxiliary systems.
6. Diagnostic methods for electron-beam plasma
7. Methods for measuring the main parameters characterizing the mode of operation of a beam-plasma reactor.
8. Physico-chemical processes occurring during thermal and chemical-thermal treatment of materials in an electron-beam plasma.
9. Physical and chemical processes occurring during the synthesis of oxides and nitrides in an electron-beam plasma. Plasma-chemical model of electron-beam plasma of oxygen and nitrogen.
10. Physical and chemical processes leading to a change in the hydrophilic-hydrophobic properties of macromolecular compounds under the action of low-temperature plasma.
11. Mechanisms of loss of stability of the gaseous reaction volume in beam-plasma installations for technological purposes.
12. Mechanisms of loss of stability of the reaction volume containing a condensed dispersed phase, and methods for suppressing instabilities.

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.