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| Ministry of Science and Higher Education of the Russian Federation |
| Federal State Budget Educational Institution of Higher Education **«MIREA – Russian Technological University»**  **RTU MIREA** |

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| **ADOPTED**  by the decision of the Academic Council of the Institute of Physics and Technology  «\_27\_» \_\_\_\_08\_\_\_\_\_ 20\_21\_ г.  Minutes of meeting №\_\_1\_\_\_ | **APPROVED**  Director of the Institute of Physics and Technology \_\_\_\_\_\_\_\_\_\_\_\_\_\_ R. Shamin  «\_\_27\_\_» \_\_\_08\_\_\_\_ 20\_21 г. |

**THE PROGRAM**

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| **OF THE FINAL (STATE FINAL) ATTESTATIONS** | | | | | |
| *(the name of the discipline (module) in accordance with the bachelor's training curriculum)* | | | | | |
| Direction of training | | | | | 11.04.04 “Electronics and nanoelectronics” |
|  | | | | | *(code and name)* |
| Profile | | Engineering of modern materials for information technology, renewable energy and sensing | | | |
|  | | *(code and name)* | | | |
| Institute | | Institute of Physics and Technology (PTI) | | | |
|  | | *(short and full name)* | | | |
| Form of training | | | full-time | | |
|  | | |  | | |
| Training program | | | | Magistracy | |
|  | | | |  | |
| Department | Nanoelectronics (NE) | | | | |
|  | *(short and full name of the department that developed the WP of the discipline (module) and implements it)* | | | | |

Moscow 2021

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| The Program has been developed | **Ph.D. Physics and Mathematics Fetisov L.Y.** |
|  | *(Academic degree and title, name of the developers)* |

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| The program has been reviewed and adopted | |
| at the meeting of the department | Nanoelectronics |
|  | *(name of the department)* |

Minutes of the department meeting from «\_\_\_» \_\_\_\_\_\_\_\_ 20 \_\_\_ г. № \_\_\_

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| Deputy head of the department |  | A.N. Yurasov |
|  | *(Signature)* | *(Full name)* |

**1. General provisions**

The program of the final (state final) attestations are made in accordance with:

The procedure for the state final certification of educational programs of higher education - bachelor's degree programs, specialty programs and master's degree programs (SMCO MIREA 7.5.1/03.P.30);

requirements of the Federal State Educational Standard No. 959 dated 21.09.2017 in the field of training 11.04.04 "Electronics and nanoelectronics", taking into account the specifics of the profile "Engineering of modern materials for information technology, renewable energy and sensing";

the curriculum and calendar curriculum in the field of training 11.04.04 "Electronics and nanoelectronics" and the profile "Engineering of modern materials for information technology, renewable energy and sensing".

The final (state final) certification in full refers to the basic part of the master's degree program and ends with the qualification "Master".

The final (state final) certification of graduates includes the defense of the final qualifying work (master's thesis), including preparation for the defense procedure and the defense procedure.

**2. Requirements for the final qualifying work and the procedure for its implementation**

The final qualifying work is considered as an independent final work of the student, in which the theoretical knowledge and practical skills acquired during the study of the cycles of disciplines provided for by the main educational program are systematized, consolidated and expanded.

The final qualifying work demonstrates the level of readiness of the graduate for independent professional activity.

The final qualification work is carried out in the form of a master's thesis.

Recommended topics of a master's thesis:

Method of formation of porous films of zirconate-titanate of pig for micro- and nanoelectronics devices;

Method of formation of ferroelectric nanostructures by femtosecond laser annealing;

Ion-beam etching as an intermediate stage in the removal of passivating layers of microcircuits within the framework of failure analysis technology;

Multilayer nanostructure ferromagnet-magnetoelectric;

Scanning near-field optical Microscope for Planar plasmon Nanomaterials Spectropolarimetry;

Local atomic and magnetic structure of amorphous, amorphous nanocrystalline and nanocrystalline alloys,

Nanostructures for perpendicular magnetic recording;

Ferroelectric properties of BSTIBNFO nanoscale layers and films;

Porous organosilicate films for IC metallization systems;

Self-assembly of bioorganic nanostructures based on diphenylalanine and their physical properties;

Piezoelectric resonant permanent magnetic field sensors based on Lead Zirconate-titanate;

Methods of diagnostics of luminescent micro- and nanostructures based on zinc oxide;

Device for filtering spatial noise of multi-element radiation receivers;

Method of control of ferroelectric memory elements;

Adaptive optics for diffusion media,

Integrated circuit of a device for reading and processing signals of a multi-element thermal radiation receiver;

Pyroelectric and electret phenomena in lead germanate crystals;

Magnetoelectric interactions in piezoelectric structures;

Two-phase shift CCD register with barriers;

Relaxation effects in polymer nanocomposites with magnetic nanoparticles;

Method of diagnostics of microcircuits for the presence of defects of elements;

Dielectric, conductive and magnetic properties of phase samples BiFeO;

Transport and optical properties of porous aluminum oxide membranes;

Sol-gel method for the formation of silicate layers with a porous microstructure

Gate structures for nanotransistors;

A model of a micromechanical mirror designed for matrix optoelectronic information transmission systems;

LL-type Vibration Microelectromechanical Gyroscope Model;

Application of methods of statistical analysis of the electrical scheme of the project in the design of submicron VLSI;

Simulation of a quantum ballistic nanotransistor.

The topics of master's theses are discussed at the meeting of the department and approved by the head of the department.

The topics of master's theses can be proposed by students upon their written application with justification of the expediency of developing a topic for practical application in the relevant field of professional activity.

The student must start working on the master's theses (MT) from the moment the assignment is issued. In the future, the work should be subject to a calendar schedule and be carried out continuously.

The MT consists of a calculation and explanatory note and graphic material. The Settlement and Explanatory Note (SEN) is the main document of the MT, which provides comprehensive information on the completed settlement, technological, design, research and organizational and economic developments carried out during the implementation of the MT. The volume of each of the sections is specified by the head of the relevant sections, while the total volume of the SEN is regulated only by the amount of information necessary and sufficient to fully disclose the calculations and developments performed.

The Settlement and Explanatory Note of the master's thesis should contain the following elements and sections:

- Title page;

- Assignment for the Master's thesis;

- Abstract (the main content of the MT and the main results are briefly reflected);

- Content (all sections, subsections and paragraphs of the SEN are indicated with the indication of pages);

- Introduction (the purpose of the work is indicated, the relevance of the chosen topic is justified, an assessment of the proposed solutions is given);

- Literature review (the results of the analysis of the state of the problem are given);

- The research section (the main section of the MT – contains all the stages of the master's thesis: theoretical introduction, details of the experiment, including a description of the experimental setup; results and discussion of research studies, theoretical calculations, computer modeling or other work carried out in the MT. The structure, subject matter and number of divisions into subsections are determined by the author of the work and agreed with the supervisor.);

- Conclusion (general conclusions on the work, analysis of the proposed solutions, recommendations on the application of the work in practice are given);

- List of sources used (list of literary and other information sources used in the performance of the work);

- Applications.

All materials on the MT (in the format .doc and .pdf) are handed over to the head of the work no later than a week before the defense to place them in the electronic library of the university. No later than 3 days before the defense, all materials are submitted for verification through the anti-plagiarism system for the amount of borrowings.

The final control of the completed MT is carried out by the head of the department in the presence of all the materials of the work, a positive result of checking through the anti-plagiarism system for the amount of borrowings and a positive review of the head for work. The purpose of the control is admission to the final state certification. The deadline is no later than 3 days before the final state certification. For final control, the head of the department is presented with a fully completed MT, signed by the head of the work. It is also mandatory to have a review of the head of work on the MT. The head of the department makes the final decision on the admission of the student to the defense.

For the defense of the master's thesis, the student submits the following materials:

- settlement and explanatory note with appendices;

- printout of the presentation to the report.

The graphic part of the work should be presented in a presentation that illustrates the report. To present the MT in the form of a presentation, the student must translate all the submitted materials (the graphic part of the work) into pdf format in advance.

The student is given 10 minutes to report on the completed MT. During the allotted time, the student should briefly highlight the content of the work performed by him with the justification of the decisions made. It is necessary to clearly highlight everything new that has been proposed and developed by the student himself, and to justify the technical and economic feasibility of these proposals. It is necessary to highlight in detail only the most important and interesting proposals and developments that distinguish the proposed variant from the basic or standard one.

The report should be illustrated with presentation slides. In the course of the report, you can use pre-written short theses or a plan. It is not allowed to read the report in full on paper.

**3. Criteria for evaluating the results of defending a master's thesis**

When completing a master's thesis, students should show their ability and ability, based on the acquired in-depth knowledge, skills and formed general cultural and professional competencies, independently solve the tasks of their professional activity at the modern level, professionally present special information, scientifically argue and defend their point of view. During the defense of the master's thesis, students must also demonstrate the level of their theoretical training. According to the results of the defense of the master's thesis, an assessment is made.

- the "excellent" rating is given if the work is in the nature of a completed scientific research or engineering solution, contains a competently stated theoretical basis, a critical review of literary and regulatory sources. The paper identifies problematic issues in the relevant area, analyzes them and offers variations of solutions. During the defense of the work, students demonstrated deep knowledge of the research topic, fluency in research data. High-quality demonstration material is used during the report. During the report and when answering additional questions, the student expounds exhaustively, consistently, clearly and logically, is able to closely link theory with practice, freely and fully answers the questions posed;

- the "good" rating is given if the work is in the nature of a completed scientific research or engineering solution, but contains an insufficiently in-depth presentation of the main theoretical positions and categories, a critical review of literary and regulatory sources. The paper identifies problematic issues in the relevant field, analyzes them and suggests solutions. During the defense of the work, students were given mainly knowledge of the research topic, demonstrated sufficient fluency in research data. During the report, demonstration material is used that does not contain gross errors. During the report and when answering additional questions, the student competently and substantially presents the material, avoiding significant inaccuracies in the answer to the question, correctly applies theoretical provisions in solving practical issues and tasks, possesses the necessary skills and techniques for their implementation;

- the "satisfactory" rating is given if the work as a whole has the character of a completed scientific research or engineering solution, but is characterized by an illogical and inconsistent presentation of theoretical material, contains an illiterate theoretical base, a superficial critical review of literary and normative sources. The paper identifies problematic issues on the research topic, but their analysis has not been carried out and solutions have not been proposed. During the report, demonstration material is used, which contains errors and inaccuracies. During the report and when answering additional questions, students demonstrated obvious difficulties in answering additional questions from members of the examination commission, knowledge of only the basic material, but no assimilation of its details, inaccuracies, insufficiently correct wording, violations of logical sequence;

- the "unsatisfactory" rating is given if the work does not bear the character of a completed scientific research or engineering solution, is characterized by an illogical and inconsistent presentation of theoretical material, contains an illiterate theoretical base, there is no critical review of literary and regulatory sources, has no practical significance. During the report and when answering additional questions, the student finds it difficult to answer the questions posed on the topic, does not know the theory of the question, makes significant mistakes, hesitantly, with great difficulty solves practical tasks or does not cope with them independently.

**4. Resource support of the State final certification**

Basic and additional educational literature recommended in preparation for the State final certification

a) basic literature:

1. Methodological guidelines for the implementation of the Master's final qualification work (Master's thesis) [Electronic resource]: Methodological guidelines / Sherstyuk N.E. Gladyshev I.V. Kuzne-tsov V.V. - M., MIREA - Russian Technological University, 2018 - 1 electron. opt. disc (CD-ROM)

2. Golovnin, V.A. Physical foundations, research methods and practical application of piezomaterials, Moscow: Technosphere, 2016. - 272 p.

3. Lurie M.S. - Microsystem converters (analytical review), 2015

4. Savitsky V.A. Microsystem technology and its components [Electronic resource]: textbook / V. A. Savitsky. - M.: MIREA, 2015. - Electron. opt. disk (ISO)

5. Golovnyuk, V.A. Physical foundations, research methods and practical application of piezomaterials, Moscow: Technosphere, 2016. - 272 p.

b) additional literature:

1. Savitsky V.A. Course of lectures on microsystem engineering and electronics Uch. pos. MSTU MIREA, electronic manual 2012

2. Golovin Yu.I. Fundamentals of nanotechnology.y. !v1.: Mechanical Engineering, 2012. 656 P.

3. Nano- and microsystem technology. From research to development : A collection of articles / Edited by P. P. Maltsev. - M.: Technosphere, 2005— - 590 p.

4. Chemical and biological sensors: Translated from English / B. Eggins. - M.: Technosphere, 2005— - 335 p.

5. HF MEMS and their application / V. Varadan, K. Vinoy, K. Joseph. - M.: Technosphere, 2004— - 525 p.

6. Micromechanical devices : Textbook for universities / V. Ya. Raspo-pov. - M.: Mechanical Engineering, 2007. - 400 p.

7. Golovin Yu.I. Fundamentals of nanotechnology. M.: Mechanical Engineering, 2012. - 656 P.

8. A.N. Ignatov Microcircuitry and nanoelectronics: Textbook. - St. Petersburg: Lan Publishing House, 2011. - 528 p.

9. Staroselsky V. I. Physics of semiconductor devices of microelectronics. Textbook for vu: se. / - 1\1.: IOrite, 2011.

10. Popov V.D., Belova G. F. Physical fundamentals of designing silicon digital integrated circuits in monolithic and hybrid design. Textbook./ - M.: Lan, 2013.

11. Vorotilov K.A., Mukhortov V.M., Sigov A.S. Integrated segneoelectric devices: rvronography / ed. chl.-corr. RAS A.S. Sigova. / - M.: Energoatomizdat, 2011.

12. Filachev A.M. Solid-state photoelectronics. Physical fundamentals of Studies. manual for universities / -M.: Fizmatkniga, 2007

13. Margolin V. I. Physical fundamentals of microelectronics Textbook for universities. / - M.: Academy, 2008.

14. Physico-chemical fundamentals of materials science: [Textbook] / G. Gott-stein. - M.: BINOM. Laboratory of Knowledge, 2009. - 400 p.: ill. Bib-liogr.: pp. 375-383

15. Materials science: Studies for technical universities/ B. N. Arzamasov, V. I. Makarova, G. G.·. Mukhin et al. --- Moscow: Bauman Moscow State Technical University, 2005. - 648 p.: ill. - Bibliogr.: pp. 630-631

16. Solid state physics. Crystal structure. Phonons: Studies. Manual / A.I. Morozov. - M.:MIREA. 2010. - 139 p.: ill. - Bibliogr.: pp. 136- 137 (11 titles) ISBN 978-5-7339-0813-7

17. Solid state physics: electrons in a crystal. Metals. Semiconductors. Dielectrics. Magnets. Superconductors: Studies. Manual/ A.I. Morozov. - Moscow: MIREA, 2008. - 183 p. Ill. - Bibliogr.: pp. 179-180 (13 titles) ISBN 978-5-7339-0680-5

18. Morozov A.I. Theory of elasticity (electronic textbook). FSUE STC "Informregister", state number.. registration 0321000074, 49s

19. Solid state physics: Textbook for universities/ P. V. Pavlov, A. F. Khokhlov M.: Higher School, 2000. 494 p.: il

20. Ashcroft, Mermin, Solid State Physics. Moscow: mir, 1979.

21. Theoretical physics: Textbook for universities: [in 1O t.] / L. D. Landau ,E. M. Lifshits. ----- M.: FIZiv1ATLIT, 2001-2004 ISBN 5-9221-0122-6

22. Galperin V.A., Danilkin E.V., Mochalov A.I. Plasma etching processes in micro- and nanotechnologies: textbook edited by Timoshenkov S.P." 1\1.B :VSH OM Laboratory of Knowledge 2010.

23. Ryzhonkov D.I. Nanomaterials.Moscow : BINOM, 2012.

24. E.D. Mishina. Methods of obtaining and studying nanomaterials and nanostructures. M. : BIIIO:Moscow:, 2,013.

25. Borisenko V.E., Vorobyova A.I., Utkina E.A. Nanoelectronics. - M.: BINOM. Laboratory of Knowledge, 2009.

c) Modern professional databases and information reference systems:

<http://www.microsystems.ru>

<http://www.electronics.ru>

<http://www.russianelectronics.ru>

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http://www .xilin,-x..comisearch/site-keyword-seaгc1.l1t111\?seaгcЬKeywo1·ds=vvebpack%20dovv111oad

http://[www.syпops vs.cor r1ITOOLS /SlLl CON /TCAD/Pages/c!efa ult.asp](http://www.syпopsvs.corr1ITOOLS/SlLlCON/TCAD/Pages/c!efault.asp)

Information and reference portal LIBRARY.RU – http:// www.library.ru

The working program of the State final certification is compiled in accordance with the requirements of the Federal State Educational Standard in the field of training **11.04.04** "Electronics and Nanoelectronics", taking into account the specifics of the profile « Engineering of modern materials for information technology, renewable energy and sensing ».