Approved at the Academic Council meeting

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ENTRANCE EXAMINATION CONTENT
FOR THE MASTER'S DEGREE PROGRAM
IN NANOTECHNOLOGY AND MICROSYSTEM TECHNICS

CODE **«28.04.01 Nanotechnology and Materials for Micro- and Nanosystems/Нанотехнологии, материалы микро- и наносистемной техники»**

Moscow 2024

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I. Explanatory Note

The purpose of the entrance examination is to establish upon entering the master's programs the level of the candidate's knowledge of subject-related educational and scientific materials and compliance with the training requirements of the state educational standard of higher education in the Master's program "Nanotechnology and Micro and Nano Systems" in 28.04.01 "Nanotechnology and Micro and Nano Systems".

Entrance examinations are held in the form of an interview with use of remote technologies.

The duration of the entrance examination is not to exceed 40 minutes.

The maximum amount of points for the interview component is 100 points. 5 questions derived from program content comprise the interview component. Each question is scored from 0 to 20 points. The results of the evaluation interview are the sum of points earned for each question.

Candidate must earn a minimum of 40 points to be considered eligible for admission.

II. Examination Content Outline

Written exam on direction of preparation (For Russian citizens)
Interview in English on direction of preparation (for foreign citizens)

1. Basic concepts of solid state physics
   Electronic shells of atomic orbitals and types of chemical bonds in solids, strongest and weakest bonds, criteria of the bond strength. Amorphous and crystalline solids. Geometry of crystal lattices: symmetry of crystals, periodicity of crystal structures. The reciprocal lattice, lattice vibrations, phonons. Electron in a periodic field, the model of near-free electrons, tight binding approximation. Electric current in a Bloch state, concept of holes. Classification of materials. Anisotropy of solids.

2. Defects of crystalline lattices.
   Point defects. Equilibrium concentration of pint defects. Non equilibrium defects and their origin. Linear defects. Neutral and electrically active defects, their influence on conductivity and mobility. Dislocations, their types and parameters. Interaction between the dislocations. Internal phase boundaries and boundaries between phases. Interaction between internal defects, between defects and dislocations and dopants. Types of impurities, their electrical activity.

3. Normal metals and semiconductors.
   Classical dc transport, specific heat of crystal lattice and electron system. The Boltzmann equation for electrons. Conductivity and thermoelectric phenomena. Neutral and ionized impurities. Electron-Electron scattering, scattering by lattice vibrations. Electron-Phonon interaction in semiconductors. Generation and recombination of nonequilibrium charge carriers. Kinetic equation of recombination. Life time, diffusion free length.

4. Electrodynamics of Metals.
   Skin effect. Cyclotron resonance. Time and spatial dispersion. Waves in a magnetic field.

5. Optical Properties of Semiconductors.
   Photon-material interaction. Intraband transitions. Excitons, excitonic states in semiconductors, interband light absorption. Photo conductance. Radiation recombination.

6. Basics of phase transformation.
   Phase definition. Structure of pure elements and solid solutions. Classification of solid solutions. Phase equilibrium in multi component system. Gibbs' phase rule. Phase transitions of the I and II kinds. Basic types state diagrams of binary systems. Classification of phase transformation. Polymorphous transformation. Diffusive and martensitic transformations. Decay of oversaturated solid solution.

7. Diffusion. Phenomenological laws of diffusion.
   Self diffusion and hetero diffusion. Atomic mechanisms of diffusion. The role of vacancies, dislocations and grain boundaries. Diffusion in the gradient of concentration. Effects of temperature and duration in the process of diffusion. Reactive diffusion.

8. Methods for fabrication and modification of materials.
   Thermodynamics and kinetics of crystallization. Homogeneous and heterogeneous nucleation of crystals. Role of supercooling during the crystallization process. The mechanisms of crystal growth. Directional crystallization. The distribution coefficient of impurity during crystallization, crystallization cleaning material. Epitaxy. Mechanisms of growth of the epitaxial layer. Methods of growing bulk crystals of semiconductors and dielectrics, epitaxial layers and hetero-epitaxial multilayer heterostructures. The dependence of material properties on its composition and structure. Changing the properties by increasing temperature. Methods for controlling the properties of materials.

9. Nanocrystalline state and nanoparticles.
   Main types of materials in nanocrystalline state: structure, electron structure of nanocrystals, basics of physical-chemical theory of nanoparticle nucleation. Kinetic laws for modeling the processes of nanomaterial synthesis. Diffusion and kinetic processes of reactions of nanoparticle synthesis. Specifics of physical and chemical methods of obtaining nanoparticles. Kinetic rules for calculating the processes of nanoparticle synthesis. Determination of parameters of different stages for nanoparticle synthesis (quasi-equilibrium, diffusion, and kinetics).

10. Characterizations methods.
    Characterization methods of micro and nano scaled materials. Microscopic and probe characterization methods. X-ray diffraction in periodic structures. Evaluation of defect concentration.

III. Recommended Reading

1. Ковалев А.Н. Гетероструктурная наноэлектроника. - М.: Изд. Дом «МИСиС», 2009.
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6. Епифанов Г.И. Физика твердого тела. - М.: Лань, 2010
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10. Galperin Yuri M. Introduction to Modern Solid State Physics (http://folk.uio.no/yurig/fys448/f448pdf.pdf)
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12. Tjong S.C., Mai Y.-W. Physical Properties and Applications of Polymer Nanocomposites. — Elsevier, 2010.
13. Шалимова К.В. Физика полупроводников. - СПб.: Лань, 2010.-400 с.
14. Анфимов И.М., Кобелева С.П., Коновалов М.П., Осипов Ю.В., Орлова М.Н., Спицына Л.Г. Физика твердого тела. Сборник задач. - М.: МИСиС, 2011. - 70 с.
15. Webster John G., Eren Halit. Measurement, Instrumentation, and Sensors Handbook, Second Edition: Electromagnetic, Optical, Radiation, Chemical, and Biomedical Measurement. - CRC Press. 2014.
16. Johnson M. Magnetoelectronics. - Elsevier Academic press, 2004.
17. Piprek P. Optoelectronic Devices: Advanced simulation and analysis. - Springer, 2005.
18. Кузнецов Г.Д., Сергиенко А.А., Симакин С.Б., Курочка С.П., Курочка А.С. Элионная технология в микро- и наноиндустрии: неразрушающие методы контроля процессов осаждения и травления наноразмерных пленочных гетерокомпозиций. -М.: Изд. дом МИСиС, 2012.
19. Лозовский В.Н., Константинова Г.С. Нанотехнология в электронике. Введение в специальность. Уч. пособие. - СПб.: Издательство «Лань», 2008.
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