THE MINISTRY OF SCIENCE AND EDUCATION OF THE RUSSIAN FEDERATION Education
THE NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
«MISiS»

APPROVED:
Deputy Chair of the Admissions Committee

_____ / A.A. Volkov
«_22_» ____10____ 2020 г.

Approved at the Academic Council meeting of the college of New Materials and Nanotechnologies, №_07-20 from 22.10.2020
College Director

_____ / Professor Sergey Kaloshkin
«_22_» ____10____ 2020 г.

ENTRANCE EXAMINATION CONTENT FOR THE MASTER'S DEGREE PROGRAM IN NANOTECHNOLOGY AND MICROSYSTEM TECHNICS, CODE 28.04.01

Moscow 2020

CONTENTS

1. Explanatory Note

The purpose of the entrance examination is to establish upon entering the master's program 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 direction 28.04.01 "Nanotechnology and Micro and Nano Systems and the Master's program "Nanotechnology and Micro and Nano Systems".

The Master's degree program entrance exam in direction of preparation "Nanotechnology and Micro and Nano Systems" (28.04.01) is conducted in English: in written form for Russian citizens and in the form of an interview with the use of remote technology for foreign nationals.

Written exam on direction of preparation (for Russian citizens)

The examination lasts 90 minutes. There are 5 exam questions each carries maximum 20 marks. The examination mark is obtained by summing up the marks for all the questions. The minimum mark to continue the competition is 40.

The candidates can have on them the following items: pen, pencil, eraser, simple calculator (without programming).

Interview in English on direction of preparation (for foreign citizens)

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 score is 100 points.

Two questions derived from program content comprise the interview component. 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.

2. 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.

3. Recommended Reading

1. Ковалев А.Н. Гетероструктурная наноэлектроника. – М.: Изд. Дом «МИСиС», 2009.
2. Кожитов Л.В., Косушкин В.Г., Крапухин В.В., Пархоменко Ю.Н. Технология материалов микро- и наноэлектроники. Л.В. Кожитов. – М.: МИСиС, 2007. – 544 с.
3. Елисеев А.А., Лукашин А.В. Функциональные наноматериалы. – М.: Физматлит, 2010.
4. Вернер В.Д., Сауров А.Н. Нанотехнологии, наноматериалы, наносистемная техника. – М.: Техносфера, 2008.
5. Головин Ю.И. Основы нанотехнологий. – М.: Машиностроение, 2012.
6. Епифанов Г.И. Физика твердого тела. – М.: Лань, 2010
7. Ашкрофт Н., Мермин Н. Физика твердого тела (в 2х тт.). – М.: Мир, 1979. – 458+486 с. (Ashkroft N.W., Mermin N.D. Solid State Physics. – New York: Holt, Rinehart and Winston, 1976).
8. Киттель Ч. Введение в физику твердого тела. – М.: Наука, 1978. – 789 с. (Kittel C. Introduction to Solid State Physics (8th ed.). – New York: Wiley. 2004.
9. Kittel C. Quantum Theory of Solids. – New York: John Wiley and Sons, 1987.
10. Galperin Yuri M. Introduction to Modern Solid State Physics (http://folk.uio.no/yurig/fys448/f448pdf.pdf)
11. Shi D. Nanomaterials and Devices. – Elsevier. 2014.
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.
20. Щука А.А. Наноэлектроника (учебник). – М.: Бином. Лаборатория знаний, 2012.

21. Драгунов В.П., Неизвестный И.Г., Гридчин В.А. Основы наноэлектроники. – Новосибирск: изд. НГТУ, 2012.

22. Розеншер Э., Винтер Б. Оптоэлектроника. – М.: Техносфера, 2014.

23. Асеев А.Л. Наноматериалы и нанотехнологии для современной полупроводниковой электроники // Российские нанотехнологии, **1**, № 1-2, 2006. – С. 97-110.

24. Питер Ю., Мануэль Кордона. Основы физики полупроводников. – М.: Физматлит, 2002. – 560 с.

25. Гуртов В.И. Твердотельная электроника. – М.:Техносфера, 2008.

26. Матухин В.А., Ермаков В.А. Физика твердого тела. – М.: Лань, 2010.

27. Зегря Г.Г., Перель В.И. Основы физики полупроводников. – М.: Физматлит, 2009.

28. Пасынков В.В., Чиркин Л.К. Полупроводниковые приборы. – М.: Лань, 2006.

29. Лебедев А.В. Физика полупроводниковых приборов. – М.: Физматлит, 2008.

30. Киреев П.С. Физика полупроводников. – М.: Высш. шк., 1975.

31. Мотт Ю.И. Оптические свойства полупроводников. – М.: Наука, 1977.

32. Займан Дж. Принципы теории твердого тела. – М.: Мир, 1974.

33. Бонч-Бруевич В.Л., Калашников С.Г. Физика полупроводников. – М.: Наука, 1979.