

**APPROVED**  
**at a meeting of the**  
**Scientific Council**  
**NJSC «Al-Farabi KazNU».**  
**Minutes No.10 dated**  
**May 23, 2022.**

**The program of the entrance exam for applicants to the PhD**  
**for the group of educational programs**  
**D101 – «Materials Science and Technology of New Materials»**

**1. General provisions.**

1. The program was drawn up in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 600 “On Approval of the Model Rules for Admission to Education in Educational Organizations Implementing Educational Programs of Higher and Postgraduate Education” (hereinafter referred to as the Model Rules).

2. The entrance exam for doctoral studies consists of writing an essay, passing a test for readiness for doctoral studies (hereinafter referred to as TRDS), an exam in the profile of a group of educational programs and an interview.

<b>Block</b>	<b>Points</b>
1. Essay	10
2. Test for readiness for doctoral studies	30
3. Exam according to the profile of the group of the educational program	40
4. Interview	20
Total admission score	100/75

3. The duration of the entrance exam is 4 hours, during which the applicant writes an essay, passes a test for readiness for doctoral studies, and answers an electronic examination. The interview is conducted on the basis of the university separately.

**2. Procedure for the entrance examination.**

1. Applicants for doctoral studies in the group of educational programs D101 - «Materials Science and Technology of New Materials» write a problematic / thematic essay. The volume of the essay is at least 250-300 words.

2. The electronic examination card consists of 3 questions.

**Topics for exam preparation according to the profile of the group  
of the educational program.**

Discipline «**Modern materials science**»

**Topic 1. «Ultrafine or nanostructured materials. Areas of their application. Nanopowders, methods of their synthesis».**

Subtopics:

Method of deposition, gel method, method of recovery and thermal decomposition.

Physical methods of obtaining powders.

Mechanical methods of obtaining by grinding.

Chemical methods of synthesis.

**Topic 2. «Bulk nanostructured materials, methods for their production. Controlled crystallization of amorphous materials. Compaction of ultrafine powders».**

**Subtopics:**

Intense plastic deformation of materials with normal grain size.

Nanowires and nanofibers.

Technologies for obtaining, processing metal, ceramic, diamond materials (based on superfine powders, fibers and films).

Technologies for the production, processing of composite materials and coatings with nanostructure (based on superfine powders, fibers and films).

Methods for the study of structure and properties and their control.

**Topic 3. «Growing single crystals. Peculiarities of damage formation in dislocation-free and low-dislocation single crystals. Impact of contaminants».**

Subtopics:

Technology of making plates. Formation of instrument structures.

Growing an epitaxial structure.

Problems of silicon optoelectronics. Thin-film structures based on amorphous hydrogenated silicon and related materials.

Fullerenes - materials of the future.

**Topic 4. «Metallic composite materials. Composite materials with aluminum, magnesium, titanium matrix. Composite materials based on immiscible metal components. Copper based systems».**

Subtopics:

Laminated composite materials. Aluminum fiberglass (sials).

Development of thermally stable composites based on refractory metals.

Carbon-carbon composite materials. Reinforcing frames. CCCM matrices.

Ceramic-metal composite materials - cermets. Transformation-hardened ceramic ceramic materials.

**Topic 5. «Powder production. Operation, cleaning, mixing, degassing».**

Subtopics:

Obtaining, processing and application of modern inorganic powder materials.

Compaction of powders. Powder steel. Powder parts production.

Control of the structure and properties of powders, materials and products from them

**Topic 6. «Modern materials science of structural materials based on metals, intermetallic and non-metallic compounds, polymers and ceramics operating in extreme conditions».**

Subtopics:

Heat-resistant steels. Super steel. Areas of their application and conditions of service.

Nickel, iron-nickel, cobalt alloys.

Monocrystalline alloys directed to the eutectic. Permeable high-temperature alloys. Modern disc nickel alloys.

Intermetallic compounds. Titans and iron.

### **Topic 7. Structural steels and alloys of increased reliability. High strength steels.**

Subtopics:

Corrosion-resistant steels and alloys.

Alloys for special purposes.

Shape memory alloys. Shape memory and hyperelasticity effects.

Superferrites. Austenitic grade steels.

### **Topic 8. «Amorphous metal alloys. Receiving. Mechanical, magnetic and chemical properties».**

Subtopics:

Thermal stability of amorphous metal alloys.

Superplasticity of materials, its varieties. Superplastic materials. Structural superplasticity.

Structural superplasticity of ceramic materials. Superplasticity of amorphous alloys (metallic glasses). Superplasticity during phase transformations.

### **Topic 9. «Synthesis of high-strength polycrystals from graphite using complexly alloyed catalysts. Nickel-chromium, nickel-chromium-carbon systems».**

Subtopics:

Nickel-chromium-metal system. High-strength diamond polycrystals for tool making.

Growing large diamond single crystals.

The use of diamonds in high technology.

### **Topic 10. «New magnetic materials».**

Subtopics:

Magnetically hard materials based on the systems iron-nickel-aluminum-cobalt, iron-chromium-cobalt, manganese-aluminum, cobalt-platinum, iron-platinum.

Sintered permanent magnets. Film permanent magnets.

Soft magnetic materials. Electrical steel. Precision soft magnetic alloys based on iron-nickel and iron-cobalt. Amorphous and nanocrystalline alloys.

Ferrites. Spinel-structured soft magnetic ferrites.

Ferrites with a hexagonal structure. Ferrites with garnet structure.

### **Topic 11. «The phenomenon of superconductivity».**

Subtopics:

Superconducting state and main groups of superconducting materials.

Composite superconducting materials, the basic principles of their creation.

### **Topic 12. «Physical materials science of metallic and non-metallic inorganic and organic films, layers and multilayer systems».**

Subtopics:

Physicochemical bases of changing the properties of surfaces of materials by coating and modification.

Technology of application of inorganic coatings.

Modern analytical and structural methods of their research and control.

### **Topic 13. «Multicomponent nanostructured films».**

Subtopics:

Self-lubricating coatings for medicine. Research methods.

Heat-conducting coatings.  
Coatings with heat-corrosion resistance and high-temperature oxidation resistance.  
Optical coatings. Coatings for microelectronics.  
Multilayer coatings in optics.

#### **Topic 14. «Approaches to the classification of materials».**

Subtopics:

Structural and functional materials.  
Classification of materials by functional properties.

#### **Topic 15. «Semiconductor quantum dots as a replacement for traditional inorganic and organic phosphors».**

Subtopics:

Heterostructures and superlattices.  
Quantum dots in biological research.  
Thermoelectric materials.  
Ternary semiconductors and multilayer heterostructures based on them.  
Dye-sensitized solar cells (Grätzel cells), mesoporous oxide semiconductors.  
Semiconductor clathrates, skutterudites.

### **3. List of references.**

#### **Main:**

1. Karabasova Yu.S. New materials. - M.: Mrs., 2002.
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4. Tyalina L.N., Fedorova N.V., Korolev A.P. Materials science and technology of structural materials: Textbook / 5th ed., Rev. - Tambov: Publishing house of TSTU, 2009. - 100 p.
5. Tkachev A.G., Shubin I.N., Popov A.I. Industrial technology and innovation. Equipment for the nanoindustry and technology for its manufacture: Textbook. - Tambov: Publishing house of TSTU, 2010 .- 132 p.
6. Materials science: Textbook for universities / B.N. Arzamasov, V.I. Makarova, G.G. Mukhin and others; Under the general ed. B.N. Arzamasova, G.G. Mukhina. - M.: Publishing house of MSTU im. N.E. Bauman, 2004 .- 648 p.
7. Batiykov, V.T. Materials Science: Textbook / V.T. Batiykov, G.G. Seferov, G.G. Seferov et al. - M.: Infra-M, 2018 .- 415 p.
8. Kobelev, A.G. Materials Science. Composite materials technology: Textbook / A.G. Kobelev, M.A. Sharonov, O.A. Kobelev. - M.: KnoRus, 2016 .- 288 p.
9. Pozdnyakov, V.A. Physical material science of nanostructured materials / V.A. Pozdnyakov. - M.: MGIU, 2007 .- 424 p.
10. Nikulin, S.A. Materials science: special steels and alloys: Textbook / S.A. Nikulin, V.Yu. Turilin. - M.: MISiS, 2013 .-123 p.

#### **Additional:**

1. Baron Yu.M. (ed.). Construction materials technology. Textbook for universities. - SPb.: Peter, 2012 .- 512 p.
2. Bolton W. Structural materials: metals, alloys, polymers, ceramics, composites. Pocket guide. - DODEKA-XXI, 2004 .-- 320 p.

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4. Arzamasov, B.N. Materials science / B.N. Arzamasov. - M.: MG TU, 2008. - 648 p.
5. Technology of construction materials. Textbook for universities. / Dalsky A.M., Arutyunova I.A., Barsukova T.M. and others. Under total. Ed. A.M. Dalsky. 3rd ed. - M.: Mashinostroenie, 2011. - 447 p.
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7. Adaskin, A.M. Materials science (metalworking) / A.M. Adaskin. - M.: Academia, 2018. - 560 p.
8. Modern technologies for the production and processing of polymer and composite materials: textbook / V.E. Galygin, G.S. Baronin, V.P. Tarov, D.O. Zavrzhin. - Tambov: Publishing house of FGBOU VPO "TSTU", 2012. - 180 p.
9. Bogodukhov, S. Materials Science: Textbook / S. Bogodukhov. - M.: Mechanical Engineering, 2015. - 504 p.
10. Kapustin, V.I. Materials Science and Electronics Technology: Textbook / V.I. Kapustin, A.S. Sigov. - M.: Infra-M, 2018. - 224 p.
11. Vikhrov, S.P. Biomedical Materials Science: Textbook for Universities / S.P. Vikhrov, T.A. Holomina and others - M.: GLT, 2006. - 383 p.
12. Novikov, Yu.N. Electrotechnical materials science: Textbook / Yu.N. Novikov. - SPb.: Lan, 2016. - 200 p.
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17. Materials science and technology of metals / G.P. Fetisov, M.G. Karpman, V.M. Matyushin - M.: Higher school, 2001 - 638 p.
18. Materials Science / G. G. Seferov, V. T. Batienvkov, G.G.Seferov, A.L. Fomenk. - M.: INFRA-M, 2005. - 160 p.
19. Electronic Processes in Non-Crystalline Substances: Iz-stvo Mir. 1979 / N.F. Mott, E.A. Davis
20. P. V. Pavlov, A. F. Khokhlov Solid State Physics, Moscow: Vysshaya Shkola, 2000. 494 p.

### Discipline "Functional materials and coatings"

#### **Topic 16. «Substances, phases, defects. Zone structure of crystals. Dielectrics, semiconductors, metals».**

Subtopics:

Features of catalysts, glasses, dielectrics, semiconductors, superconductors.

Basic principles of obtaining materials. Forms of existence of materials. Phase transformations.

Crystal growth.

Crystals and methods of obtaining them.

Whiskers. Synthetic crystals of functional materials.

Growing crystals from solutions, melts and gas phase. Obtaining thin films.

#### **Topic 17. «The structure of dielectrics. The main types of polarization of dielectrics».**

Subtopics:

Ion-relaxation polarization.

Migration ion polarization.

Inhomogeneous and disordered dielectrics. Special states and types of dielectrics.  
Electrets. Piezoelectrics.  
Polycrystalline dielectrics.

**Topic 18. «Diamond-like semiconductors».**

Subtopics:

Semiconductors  $A^{III}B^V$  and  $A^{II}B^{VI}$ .

Chalcogenides of elements of the fourth and fifth groups.

High temperature semiconductors.

Crystallization methods of purification. Growing crystals from the gas phase. Sublimation-condensation method.

Semiconductor films. Alloying.

Oxide semiconductors, methods of obtaining them.

**Topic 19. «Film as a composite. Mutual influence of the film and the substrate».**

Subtopics:

Deposition conditions and film morphology. Epitaxy.

Methods of film deposition.

Spectrophotometry of films.

Application of thin-film nanomaterials.

**Topic 20. «The theory of nucleation and film formation».**

Subtopics:

Formation of defects during film growth.

Falling particles onto a substrate, adsorption and thermal accommodation, processes during the interaction of atoms, molecules and radicals with the surface.

Chemical etching (spraying), physical spraying of the surface.

Cathodic sputtering.

Properties of thin films. Adhesion. Wear resistance and coefficient of friction.

Elasticity, microhardness and strength. Conductivity of continuous films.

**Topic 21. «Features and capabilities of modern methods of materials research».**

Subtopics:

Principle of operation and capabilities of a scanning electron microscope.

Give the principle of operation and capabilities of the atomic force microscope.

Give the principle of operation and capabilities of the transmission microscope.

Raman scattering of light and X-ray structural analysis.

**Topic 22. «Ceramic materials».**

Subtopics:

Ceramic materials with dielectric, magnetic, optical, chemical and nuclear functions.

Promising ceramic composites.

Materials based on silicon nitride.

Solid-phase electrolytes and electrode materials.

High-temperature superconductors (HTSC).

**Topic 23. «Materials with colossal magnetoresistance».**

Subtopics:

New magnetoactive composites and materials for magnetic recording, spintronics.

Devices for recording and storing information based on ferroelectrics and ferromagnets.

Magnetic fluids.

**Topic 24. «Bioactive glass ceramics. Carbon as a material for implants».**

Subtopics:

Ceramic materials based on  $\text{Al}_2\text{O}_3$  and  $\text{ZrO}_2$ , hydroxyl and fluoroapatite.

Ferromagnetic and radioactive bioceramics for the treatment of malignant tumors.

Ultrafine manganites in thermal treatment of cancerous tumors and drug transport.

Carbon ceramic for heart valve.

**Topic 25. «Materials used for hydrogen purification».**

Subtopics:

Creation of composite membranes for hydrogen purification. Hydrogen storage.

Adsorption storage methods using carbon nanofibers, nanotubes, crystalline microporous organometallic frameworks.

Chemical methods of hydrogen storage - materials used.

Metal hydrides as a storage medium for hydrogen. Protonic electrolytes.

High-temperature and low-temperature proton electrolytes.

**Topic 26. «Nanomaterials for creating membranes».**

Subtopics:

Classification of membranes.

Membrane technologies.

Polymer membranes.

Porous filter elements.

**Topic 27. «Nanostructured crystals for photonics».**

Subtopics:

Photonic crystals, approaches to synthesis.

Areas of application.

**Topic 28. «Shape memory alloys (nitinol). Smart or smart polymers».**

Subtopics:

Conductive polymers.

Piezoelectric materials for creating sensors.

Magnetorheological, electrorheological fluids.

Thermo- and photosensitive polymers.

**Topic 29. «Classical superionics. Electronic ionic conductors».**

Subtopics:

Cathode and anode materials of lithium batteries.

Protonic conductors based on barium cerate.

The use of solid electrolytes.

**Topic 30. «Triple and multicomponent systems».**

Subtopics:

Konoda. Rules for use in phase diagrams.

Construction of cones in the concentration triangle.

Triple four-phase balance.

Gibbs phase rule.

### 3. List of references.

#### Main:

1. Functional nanomaterials: textbook. manual / A.A. Eliseev, A.V. Lukashin. - M.: Fizmatlit, 2010.- 452 p.
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11. Modern problems of nanotechnology: textbook. Part 2 (course of lectures) / B. M. Sinelnikov, S. E. Khoroshilova, V. A. Tarala, L. S. Lunin, I. A. Sysoev, L. A. Kasharina. - Stavropol: SevKavGTU, 2012. - 200 p.

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4. E.L. Ivchenko, G.E. Pikus. Superlattices and other heterostructures. Springer Ser. Solid State Science. Vol. 110. Springer. Berlin. 1997.
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10. Zhuravleva N.V., Lukin E.S. Ceramics based on silicon nitride // Ogneupory, 1993.1. from. 6-12.
11. Gurevich Yu.Ya. Solid electrolytes / Yu.Ya. Gurevich; Academy of Sciences of the USSR; Resp. ed. A.P. Levanyuk. - M.: Nauka, 1986. -- 171 p.
12. Dunyushkina L.A. Introduction to methods of obtaining film electrolytes for solid oxide fuel cells: monograph / L.A. Dunyushkin. - Yekaterinburg: URO RAN, 2015. - 126 p.
13. Brusentsov Yu. A., Minaev AM Fundamentals of physics and technology of oxide semiconductors: Textbook. Tambov: Publishing house of Tamb. state tech. University, 2002. 80 p.
14. Kekalo I.B., Samarin B.A. Physical metallurgy of precision alloys. Alloys with special magnetic properties. - M.: Metallurgy, 1989.
15. Gorbenko O.Yu., Bosak AA Magnetoresistance of manganites in weak magnetic fields and its application // Sensor. No. 2. 2002.S. 28–44.



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17. Alloys with shape memory effect / Otsuka K., Shimizu K., Suzuki Y. and others; Per. with jap. I. I. Druzhinin; Ed. A.M. Glezer. –M.: Metallurgy, –1990. - 224p.
18. = Membranes and membrane technologies / Publisher: Scientific World ISBN 978-5-91522-366-9
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