Entrance exam program in training of highly qualified personnel (Ph.D. programme) 2.6. "CHEMICAL TECHNOLOGIES, MATERIAL SCIENCES, METALLURGY"

Program of the entrance examination for postgraduate study in the direction of training of higher qualification 2.6. Chemical technologies, material sciences, metallurgy; by scientific specialty 2.6.17. Materials Science contains sections:

THEORETICAL FUNDAMENTALS OF MATERIALS SCIENCE. Basic concepts of crystal chemistry. Factors determining the structure of inorganic compounds: stoichiometry, the nature of the chemical bond and the size of atoms (ions). Types of chemical bonds in a solid. Methods of valence efforts and valence bonds. The densest packages and types of voids. Defects of crystalline solids: types of defects, interaction of defects. Anisotropy of crystal properties. The zone structure of crystals, the formation of zones as a result of overlapping orbitals. The population of zones, its influence on the electrophysical properties of crystals. Phase diagrams, phase transitions. The main types of condensed T-phase diagrams of two-component systems (with simple eutectic, with the formation of intermediate compounds of constant and variable composition, with unlimited and limited solid solutions, with polymorphism of components and compounds). The main non-invariant equilibria of the eutectic type (eutectic, eutectoid, monotectic, monotectoid). Non-invariant equilibria of the peritectic type (peritectic, peritectoid, synthectic). Thermodynamic classification of phase transitions. Stable and metastable phases. Condensed systems. Kinetics of phase transitions. Embryo formation, critical embryo size, embryo growth. Temperature-time-transformation diagrams. Martensitic transformations. Transitions of the order-disorder type. Methods of synthesis of solids. Direct synthesis of compounds from simple substances. Solid-phase synthesis and its features. The use of mechanochemical activation. Chemical methods of homogenization. Sol-gel method. Reactions in the gas phase, aqueous and non-aqueous solutions, melts. Method of chemical deposition from the gas phase. Chemical transport reactions for the synthesis and purification of substances. Hydrothermal synthesis. Synthesis using supercritical solvents. Self-propagating high-temperature synthesis. The use of vacuum, high pressures in synthesis. Electrochemical methods of synthesis. Methods for obtaining solid amorphous substances and glasses. Methods for obtaining solid phases in the nanoscale state. Functional materials. Ceramics. The main patterns, mechanisms and methods of sintering. Methods for obtaining dense and porous ceramics. Properties determined by the microstructure and structure of ceramic grain boundaries. Metals and dielectrics. General properties of metals. The concept of alloy. Proprietary and impurity semiconductors. Ionic conductivity and solid electrolytes. Superionic conductors with cationic, oxygen-ion and halide-ion conductivity. Mixed ion-electronic conductors. Application of solid electrolytes and mixed conductors in electrochemical devices (current sources, fuel cells, chemical sensors, selective membranes). Magnetic properties of solids and magnetic materials. Fundamental and functional parameters. Structural sensitivity of magnetic properties. Classification of magnetic materials, basic structures and properties. Superconductors. The concept of critical temperature, critical current, critical magnetic field. Superconductors of the I and II kind. Low-temperature and high-temperature superconductors, their critical characteristics, fields of application. Monocrystalline materials, their role in science and technology. Methods of obtaining single crystals. Amorphous materials and glasses. Factors affecting glass formation. Oxide and chalcogenide glasses. Electrically conductive glass. Metal glasses. Glass ceramics. Sitalls, the ability to control their structure and properties. Various applications of glasses.

Recommended literature:

1. Gruzdev V.S. Material science: Textbook / V.S. Gruzdev. - M.: Academia, 2019. - 432 p.

2. Adaskin, A.M. Material science and technology of metallic, nonmetallic, and composite materials: Textbook / A.M. Adaskin, A.N. Krasnovsky. - M.: Forum, 2018. - 592 p.

METHODS OF STUDYING THE COMPOSITION AND STRUCTURE OF SOLIDS. Methods of studying the structure and phase composition. Metallographic and fractographic research methods, optical and electronic, including diffraction microscopy (transmission and scanning electron microscopes). X-ray research methods: structural and spectral analysis methods. Methods of investigation of physical properties and phase transformations in metals and alloys. Magnetic and electric methods of analysis of phase and structural transformations. The thermo-EMF method. The method of nuclear magnetic resonance. The nuclear gamma resonance method. Physical methods of non-destructive testing of material defects Ultrasonic flaw detection. X-ray and gamma-ray flaw detection. The method of eddy currents. Magnetic and thermal flaw detection. Mechanical properties of materials and methods of their determination. Schemes of the stressed and deformed state of materials Planar and volumetric stress states. Flat deformation. Stress concentration. Residual stresses, definition, classification. Elastic properties of materials Modulus of elasticity and its dependence on the crystal structure of the material. Elastic consequence, elastic hysteresis, internal friction. Plastic deformation and deformation hardening Processes of sliding and twinning. Edge, screw and mixed dislocations. Sliding and crawling of dislocations. The interaction of dislocations with each other and with impurities. Features of deformation of mono- and polycrystals. Effect of grain boundaries on plastic deformation of polycrystals. Disclaimer. Superplasticity. The effect of plastic deformation on the structure and properties of materials. The hardening mechanism. Deformation hardening. Hardening of solid solutions during the interaction of dislocations with impurities of the introduction. Dispersion hardening. Destruction of materials Types of destruction of materials. Mechanisms of crack generation. Force, deformation and energy criteria of local destruction. Crack resistance. Approaches of fracture mechanics to the selection of structural materials, the calculation of the size of the permissible defect and the prediction of durability. Mechanical properties of materials and methods of their determination Classification of methods of mechanical tests. The importance of mechanical characteristics in materials science. Mechanical properties determined under static loading. Tensile, compression, bending, torsion, crack resistance tests. The influence of alloying, the structure of stress concentrators and the scale factor on the characteristics of mechanical properties. Mechanical properties determined under dynamic loading. Influence of the deformation rate on the strength and ductility characteristics.

Recommended literature:

1. Bondarenko G.G. Fundamentals of materials science: textbook / G.G. Bondarenko, T.A. Kabanova, V.V. Rybalko. — 3rd ed. — Moscow: Laboratory of Knowledge, 2020. — 763 p.
2. Matyunin V.M. Mechanical and technological tests of structural materials: a textbook for universities / V.M. Matyunin, A.Yu. Marchenkov, M.A. Karimbekov. – M.: Publishing House of MEI, 2018. – 192 p.