doctoral study program at FEE CTU - P0533D110030

Applied physics

topics of the state doctoral examination (SDZ)

A) Physical properties, characterization methods, modeling and application of materials

1. Inorganic and organic semiconductors, elementary and compound. Concept of donor and acceptor in semiconductors. Materials for photovoltaic cells. Transport phenomena in semiconductors, transport equations, drift, diffusion, collision mechanisms, mobility, generation mechanisms and recombination.

2. Classification of materials according to electrical properties: insulator, metal, semiconductor. Surfaces and interfaces in semiconductors, their practical technical applications. PN junction in semiconductors, their properties, examples of PN junctions in electronics. Schottky transition and usage examples.

3. Optical phenomena in semiconductors, their technical and technological use. Photonic and plasmon structures, their technical utilization.

4. Description of interaction of materials with electromagnetic and particle radiation.

5. Photovoltaic systems. Overview of types and principles of photovoltaic systems. Basic functions of a photovoltaic system, from light capture to the formation of output voltage and current.

6. Sensor systems. Sensor concepts. Overview of physical principles of sensors, technical realization of sensors, examples of use in practice. Sensor system components, from principles to communication.

7. Description of interaction of materials with biological environment. Influence of materials, their structure and properties on the structure and function of biomolecules, cells and microorganisms. The role of zeta potential, pH. Debye's length in solution.

8. Structure of basic types of carbon materials. Relationship between structure and properties of graphite, soot, fullerenes, nanotubes, diamond. Electronic applications of carbon materials.

9. Modern 2D materials and quantum dots. Features, functions, engineering applications.

10. Materials diagnostics. Basic methods of chemical and structural analysis, overview of methods for determining material properties. Electrical conductivity measurement methods. Methods of optical and electron spectroscopy.

11. Microscopic methods in material physics. Optical microscopy, near field microscopy. Atomic force microscopy and its derived methods. Nanomechanical and nanoelectronic measurements. Electron microscopy. Infrared and Raman micro-spectroscopy.

12. Bundling technologies for material processing for electronics and production of electronic components. Laser, electron, ion and molecular beams.

13. Plasma technologies for preparation and treatment of materials, application of discharges. ICP, RF, MW plasma, magnetron sputtering. CVD plasma and thermal technology. Non-thermal atmospheric discharges. Direct and indirect exposure to discharge, utilization of discharge products.

B) Physical principles, properties, diagnostics and modeling of plasma

14. Basics of plasma physics. Cyclotronic frequency, plasma frequency, collision frequency, mean free path, Debye shielding, magnetic pressure, beta parameter. Dielectric constant of plasma. Polarization, plasma magnetization. Polarizability Tensor. Permittivity tensor. Sah's equation, plasma classification by concentration and temperature. Basic properties of individual types of plasma. Collisions in plasma. Effective cross-section.

Coulomb collisions. Coulomb's logarithm. Runaway solution (passing electrons), Chandrasekhar function. Basic equations of magnetohydrodynamics. Continuity equation, equation of motion, equation for magnetic field. Frozen and diffuse magnetic field. Waves in plasma. Alfvén's magnetoacoustic complex. Electromagnetic waves in plasma (O, X, R, L waves). CMA diagram. Overview of plasma instabilities. Kelvin-Helmholtz, Rayleigh-Taylor, islet instability. Two-beam instability, plasma fiber instability. Silent configuration. Helical structures, law of conservation of helicity, examples of helical structures in nature.

15. Plasma diagnostics and simulations. Overview of plasma methods and parameters. Methods of measurement of current and potential in plasma, Langmuir probe, Rogowski ring. Plasma resistivity. Fundamentals of spectroscopy. Spectrum acquisition, spectral lines, determination of temperature, concentration, plasma composition, rotational and vibrational spectra, determination of other plasma characteristics. Thermal capacity of vibration and rotational states. Magnetic field measurements. Faraday rotation, Zeeman effect, direct measurements, magnetometers. Visualization diagnostic methods. Interferometric and cyclic methods of density gradient measurement, image reconstruction. Overview of basic methods of plasma density measurement, density determination of electromagnetic waves, importance of plasma frequency. X-ray diagnostics of hot plasma. Microwave and corpuscular diagnostics. Detection of neutrons.

16. Classification of electrical discharges. Dependent and independent discharges. Voltamper characteristics of the discharge under reduced pressure, silent discharge, glow, arc, spark. Townsend theory and ignition voltage. Paschen's law. Thermoemission, secondary emission, cold emission, explosive emission, photoemission. Excitation, dissociation and ionization, formation of radicals. Thermal and non-thermal plasma, drift regions, afterglow. High frequency and microwave discharge. Elementary processes on electrodes and discharge volume.

17. Discharges at atmospheric pressure. Examples of atmospheric pressure discharges. Positive, negative, and bipolar corona. Trichel's pulses. Warburg's law. Dielectric barrier discharge. Sliding discharge. Methods of stabilization and homogenization of discharges at atmospheric pressure.

18. Z-Pinscher. Bennett equilibrium, pressure p(r), Bennett equation for pinch temperature. Modes of instability. Reverse pinch, Kruskal's stability conditions. Electromagnetic collapse. Self-organization of magnetic structures in discharge.

19. Thermonuclear fusion. Basic fusion reactions. History, present and future, Lawson's criterion. The principle of tokamak and stellarator. Inertial fusion.

C) General physical basics, calculations and modeling

20. Transport events. Ohm, Fick and Fourier law, Onsager relations of reciprocity. Diffusion, mobility, ambipolar diffusion. Diffusion across the magnetic field, the effect of collisions on diffusion in the magnetic field. Movements of charged particles. Equation of motion, adiabatic invariants, drifts. Movement in a magnetic field.

21. Statistical physics. Boltzmann equation, Fokker-Planck equation. Moment theorem, moments of the Boltzmann equation.

22. Modeling and simulation as a tool for analysis of physical systems. Methods for physical simulation of properties and phenomena from atomic to macroscopic level. Simulation in equilibrium and non-equilibrium states. Monte Carlo simulation. Equivalence of models of different physical systems. Software tools for computer simulation, application areas, comparison.

23. Numerical solutions of equations. Methods of solving ordinary and partial differential equations. Convergence and stability, networks, finite elements. Example of difference scheme. Hybrid methods. Methods for solving motion equations (Boris-Buneman, Leap-frog scheme).