MATERIALS SCIENCE MSc
ITEMS FOR FINAL EXAMINATION

1. Characterization methods of crystalline structure (ideal and real structure, structure-dependent and structure-independent physical properties, simple structures, symmetry in crystals, direct and reciprocal lattice, X-ray, electron and neutron diffraction)
2. Lattice defects and their influence on materials' properties. Point defects (equilibrium lattice defects, mixing and formation entropy and enthalpy, quenched-in and thermally annealed processes), dislocations (topological properties, continuum theory, forces on dislocations, partial dislocations), internal surfaces (type of grain boundaries and phase boundaries, energy of boundaries, nanostructural materials)
3. Diffusion in solid materials (macroscopic and microscopic description, concentration-dependent diffusion coefficient, Kirkendall-effect, Darken equations, up-hill diffusion)
4. Mechanical properties (plastic deformation, strain hardening, solid state hardening, precipitation hardening)
5. Lattice vibrations (classical and quantum mechanical description, aqustic and optical phonons, experimental determination of the phonon spectrum). Thermodynamic properties of crystals (thermodynamics of phonon-gas, specific heat, anharmonicity and thermal expansion, transport properties of phonons, heat conduction). Superfluidity
6. Electronic states in periodic potential (band structure, simple methods to determine the band structure, metals, semiconductors, insulators)
7. Conduction (relaxation-time approximation and its limitations, Boltzmann-equation, general transport coefficients of scattering on impurities, phonons and electrons in metals and semi-conductors)
8. Basic s of magnetism (Hund's rules, splitting of degeneracy in crystal field, dia- and paramagnetism of atoms and ions, paramagnetic resonance, Pauli-paramagnetism, exchange interaction, direct exchange, super exchange, RKKY interaction). Ordered magnetic systems. (mean field theory and spinwave theory of ferromagnetism and antiferromagnetism, magnetic anisotropy, domains), disordered magnetic systems (spinglasses)
9. Solid solutions (thermodynamics of multicomponent systems, quasi-chemical model, ideal and regular solid solutions, factors determining the solid solubility)
10. Phase diagrams (equilibrium and non-equilibrium diagrams, construction of phase diagrams from free energy vs. concentration functions). Solidification (homogeneous and heterogeneous nucleation, crystal growth, synthesis of single crystals, temperature and concentration driven solidification, zone refining, non-equilibrium solidification)
11. Phase transformations in solid state (precipitation, spinodal decomposition, diffusion-free transformations).
12. Particle and wave-detectors, X-ray, electron and neutron detectors, active material of detectors, basic principles of detectors, resolution of detectors.
13. Microscopes studying microstructural and nanostructural systems: transmission and scanning electronmicroscopes, scanning tunnelling and atomic force microscopes (STM, AFM), their operation modes, operational background, resolution and their application in materials science.

14. Mechanical properties of nanostructured materials. X-ray reflection and magnetic properties of multilayers exhibiting nanometric layer thickness.
15. Properties of carbon-based nanostructures (graphene, fullerene, nanotubes). Bonding properties of carbon. Structure, mechanical and electric properties of graphene, fullerene and nanotubes. Preparation methods. Applications.
16. Preparation of nanoparticles by chemical route: co-precipitation technique, sol-gel synthesis, microemulsion and hydrothermal processes.
17. Preparation and stability of nanodisperse systems. Spontaneously formed nanostructures. Formation of nanoparticles by homogeneous nucleation. Preparation of monodisperse polymer latex dispersions by emulsion polymerization. Theories of electrostatic and steric stability of colloidal dispersions. Self-organizing nanosystems. Spontaneous formation of micelles and vesicles.
18. Polyelectrolyte / surfactant nanocomplexes and nanoparticles. Impact of polymer structure and charge density on the properties of polyelectrolyte/ionic surfactant complexes and on the mechanism of macromolecule / surfactant interaction. Transition between polyelectrolyte / surfactant solution and colloidal dispersion of polyelectrolyte / surfactant nanoparticles.
19. Preparation of highly porous systems: synthesis of aerogels and cryogels, their structure and application.
20. Synthesis of precursors: organic, inorganic, and metalorganic starting materials.
21. Classification of ceramic fibers, their properties, and preparation techniques.
22. Classification of bioceramics, their introduction with examples and applications.
23. Optical properties of metal and semiconducting nanoparticles. Properties of excitons in semiconductors. The effects of quantum confinement on the properties of excitons. Optical applications of semiconducting nanoparticles. Fluorescence in metal nanoparticles. Comparison of optical behaviours of metal and semiconducting nanoparticles. Application of metal nanoparticles.
24. Preparation of surface layers I: chemical vapor deposition (CVD), physical vapor deposition (PVD), sol-gel method, electrochemical deposition.
25. Preparation of surface layers II: ordered molecular nanolayers, self-assembling Langmuir and Langmuir-Blodgett films.
26. Synthesis and properties of functional polymers: dendrimer polymers, polymer gels, conducting polymers. Preparation of conducting polymers by chemical synthesis and electric polymerization. The characteristic properties of conducting polymers. Applications.
27. Preparation of responsive nanostructures in bulk phases and at interfaces. Types of polymers sensitive to environmental parameters. The external "stimuli" that determine the physical state of the polymers and their response to the "stimuli". Principles of behavior of environmentally sensitive polymers and the corresponding basic physical interactions.