Current subject area:
Physics of nanoparticles

Status	Course code / number in the book: *PHYSICS OF CLUSTERS, NANOPARTICLES AND NANOSYSTEMS* Taught by: Stepan Mudry			
Acad. cycle	**ECTS credits**	**Duration**	**Semester**	**Contact hours**
Barchelor	4	1 semester	Winter, spring	64
Year of study	**Weekly lectures/seminars**		**Prerequisites**	
4	32/ 32		**Structure of bulk solids, physical properties of crystalline and amorphous materials, Material science**	
Languages	**Examination**		**Assessment**	
English	Written exam		100 point scale	

Aims and objectives: Provide with knowledge concerning the dependence of physical properties on size of solids in the nanometer regime and explain, using the understanding the main laws of physics and chemistry why these dependences occur. The objective of the course is also to describe the quantum size effect and how it changes the properties of properties, which are important for nanotechnologies.

Description: Introducing part of part of Physics of Clusters, Nanoparticles and Nanosystems consists the basics of physics and chemistry of clusters, their features in comparison with atoms and bulk solids. Significant part of lectures and seminars offers the knowledge on fractal structure of cluster systems and the relation between structure and physical- chemical properties. Large part of course is based on the considering of behavior of electrons in nanoclusters and nanoparticles. Structure, properties and synthesis of carbon- based clusters, fullerenes and carbon nanotubes as well as their application are considered in relation with other nanoparticles. Quantum size effect and its influence on physical properties of quantum wells, wires and dots is discussed using the basics of quantum mechanics.

Reading list:
1.Frank J. Owens, Charles P. Poole Jr. The Physics and Chemistry of Nanosolids Wiley-Interscience, New Jersey, 2008
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Physics of Clusters, Nanoparticles and Nanosystems

Education program

(Prof. Stepan Mudry)

1. Introduction. Aim and content of the course. Interelation between physics of nanosystems and other subjects (solid-state physics, chemistry, material science, quantum theory, biology, engineering). Basics of nanotechnology.
2. Transition from atomic to bulk structures. Clucters, nanoparticles and nanosystems. Size dependence of structure and properties. Size and dimensionality effects. Kinds of nanoparticlers.
3. Individual clusters and clusters in nanosystems. Cluster-cluster interaction. Clusters as superatoms. Kinds of clusters. Atomic and electronic structure of clusters. Structural magic numbers and electronic magic numbers. Change in valence energy band levels with size.
4. Metallic nanoclusters, their structure and properties. Magnetic clusters, gaseous and molecular clusters. Super fluid clusters of helium. Colloidal clusters. Semiconducting nanoclusters. Photo fragmentation and Coulomb explosion in clusters.
5. Clusters in disordered systems. Cluster structure of liquid metals and amorphous solids. Obtaining the cluster structure parameters from X-ray, neutron and electron diffraction measurements..
6. Carbon-based nanoclusters. Fullerene, its structure and physical properties. Fullerenes of other atoms. Fullerenes of different size. Doped fullerenes. Fullerene-based crystalline nanoclusters.
7. Carbon nanotubes. Kinds of nanotubes. Atomic and electronic structure of nanotubes. Improving the mechanical properties of carbon nanotubes. Electronic properties .Metallic and semiconducting nanotubes. Properties variation at doping of nanotubes with other atoms . Capillary phenomena in nanotubes
8. Clusters of water and ice. Structure and properties. Planar and spatial clusters. Dependence of cluster structure on number of atoms and thermodynamic parameters.
9. Vibrational properties of nanoclusters. Effect of dimension on atomic vibrations density of states and Debye frequency. Phonon confirment.
10. Thermodynamics and phase transitions in clusters. Melting of clusters. The self – organization process in clusters formation processes.
11. Methods of nanoclusters producing. Synthesis of fullerenes and nanotubes. Arc method, laser evaporation, chemical methods and thermolysis. Application of fullerenes and nanotubes.
12. Cluster systems and nanoparticles.Porous cluster systems Aerogels, their structure and properties. Carbon-based nanoporous materials for supercapacitors. Porous silicon, its structure and properties. Cluster assemblies in zeolite pores. Structure and physical properties of zeolites, doped with small clusters
13. Nanoparticles in colloidal suspensions. Magnetic l;iquids, structure and properties.Cluster-cluster, nanopowder-nanopowder and cluster (nanopowder) interactions in magnetic liquids.
14. Cluster systems with fractal structure. Fractal structure features, fractal dimension and their estimation by means of small angle X-ray and neutron scattering.Crystallization and aggregation processes. Limited atomic diffusion at formation of fractal nanosystems.
15. Mechanical properties of nanomaterials. Dependence of mechanical properties of metals on grain size. Strengthening the metallic alloys.
16. Nanocrystals in amorphous matrix. Process of controlled nanocrystalization. Amorphous-crystalline nanocomposites with improved mechanical and magnetic properties.
17. Conduction electrons in clusters and nanostructured materials. Size effects and density of states. Quantum wells, wires and dots. Relation between density of states and properties. Size effect and thermoelectric properties. Nanostructured thermoelectric

materials.Electroconductivity of nanosystems. Single electron tunneling. Ballistic conductivity.

18. Optical properties of nanoparticles and nanosystems. Absorption and luminescence properties. Nanosystems with metallic and semiconducting clusters.. Plasmon and exciton absorptions.
19. Magnetic properties of nanostructured systems. Superparamagnetism. Magnetic phase transitions.Magnetic quantum mechanic tunneling.
20. Hall effect in two-dimensional electron systems.Quantum Hall effect. Landau levels. Integer and fractional Hall effects. Quantum Hall effect in graphene.