UNIVERSITY OF LJUBLJANA
Faculty of Mechanical Engineering

Nanotechnologies (6028-M) 5 ECTS

Lecturer: **M. Kalin**

Lectures: 30h | Tutorials: 12h | Labs: 18h | Project: 0h | Lang. :

Objectives

1. To understand basic scientific and applied problems at the nano scale and enable creative ability to tackle them.
2. To learn about different nanotechnologies and their application and limitations.
3. Understand the fundamental physical principles at the nano level.
4. To learn and understand the basic principles and application of nanostructures and nanomaterials.

Programme

Lectures:

1. Introduction: definitions, examples, field of work, history.
2. Characteristics of nanotechnologies and specifics of nano scale phenomena: differences between nano and macro technology. Minituarization, physical laws, fundamentals of quantum mechanics, electromagnetic waves, quantization of energy, duality of energy and matter, the principle of indeterminacy.
3. Bonds and surface forces: classification and properties of bonds, intramolecular bonds, Lennard-Jones potential, van der Waals bonds. Surface forces between bodies - key equations. Forces in fluids: electrostatic, zeta potential, DLVO theory, structural forces (solvation, hydration, hydrophobic).
4. Free surface energy and wettability: surface energy, surface tension. Wettability, Young's equation, types of wettability, influences (Cassie, Wenzel, homogeneity, chemical). Capillary effect and condensation, meniscus.
5. Adhesion and adsorption: adhesion work, adhesion between solids and in moisture. Adsorption, adsorption types, isotherms. Surface film growth.
6. Characterization of nanostructures: optical methods, electron microscopy, scanning probe methods, spectroscopic methods, diffraction, combined methods.
7. Nanomaterials production: types, fabrication, bottom-up growth (ALD, sol-gel, SAM, chemical, ...) and top-down (crushing, multiple types of lithography).
8. Types of nanomaterials: basic differences and characteristics, types: nanoparticles, nanofilms, nanograins, nanoporous, nanowires, nanotubes, fullerenes, graphene ...
9. Nanoscience: health dangers in nanotechnology, measurements, legislation, protection.
10. Surface effects and nanotubes: nano surface Properties, real surface, nanotubes, models, nanocontacts. Super-low friction with solids.
11. Thin-film lubrication: nanotubes, thin-film lubrication, thin-film lubrication concepts. Super-low friction with liquids.
    Nanotribology in engineering systems: examples of nanotribology application. Boundry lubrication in engines, in cutting and forming processes. Boundary slip, slip length, calculation models.
12. Nano-scale modeling: application of nano-scale modeling: first principles and molecular dynamics.
13. Nanotechnology for tribological solutions (Brainstorming): system analysis, possibilities, concepts, measurements, implementation, solutions, application. Example.
14. Application of nanotechnologies in technology: nanotechnology, nanobiotechnology, nanosensors, nanomechanics, nanotechnologies in batteries, healthcare, automotive, MEMS/NEMS, optics, textiles.

Prerequisites

In order to successfully achieve this course, the students must have:

- Meeting the enrolment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Learning outcomes

Knowledge:

In-depth theoretical, methodological and analytical knowledge with elements of research and application in nanotechnology.

Skills:

- Understanding the procedures and applications of nanotechnologies.
- Independent evaluation and analysis of nanostructures and nanomaterials.
- Ability to perform basic physical nano-level modelling and experimental techniques with rigorous analyses of results.

Assessment

Theoretical subject (lectures): 50%, Independent work in tutorials: 20%, Laboratory work in tutorials (including reports): 20%, Seminar: 10%.

Literature

1. L.Theodore: Nanotechnology - Basic Calculatuions for Engineers and Scientists, Wiley-Interscience, 2006.
2. B. Rogers, J. Adams, S. Pennathur: Nanotechnology - Understanding small systems, CRC Press, 2008.
3. B. Bhushan (Ed): Handbook of Nanotechnology, Springer, 2007.