Study programme P4F13A Physics of Nanostructures and Nanomaterials

Board of the doctoral programme

Members of the board: http://mff.cuni.cz/phd/or/p4f13 .

Cooperating institutes

- Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8
  http://www.fzu.cz/

- Institute of Photonics and Electronics, CAS
  Chaberská 57, 182 51 Praha 8
  http://www.ufe.cz/

- J. Heyrovsky Institute of Physical Chemistry, CAS
  Dolejškova 2155/3, 182 23 Praha 8
  http://www.jh-inst.cas.cz/

Available topics of the dissertation

Topics are listed in SIS at http://mff.cuni.cz/phd/temata/p4f13 .

Courses

Compulsory courses

Code	Subject	Winter	Summer
NEVF534	**Physics of Low-dimensional Structures**	2/0 Ex	2/0 Ex
NFPL199	**Physical Methods in Nanostructure Studies**	—	2/0 Ex
NEVF535	**Nanomaterials I**	2/0 Ex	2/0 Ex
NEVF533	**Physical Methods of Nanostructure Technology**	2/0 Ex	2/0 Ex
NFPL187	**Seminar on Nanomaterials: Physics, Technology, Applications I**	0/2 C	—
NFPL188	**Seminar on Nanomaterials: Physics, Technology, Applications II**	—	0/2 C

Other lecture courses and seminars from related fields, elective in respect to the dissertation topic, e.g.:

Code	Subject	Winter	Summer
NOOE070	**Optics of Nanomaterials and Nanostructures**	—	2/0 Ex
NOOE121	**Methods of Laser Spectroscopy in Semiconductor Spintronics**	2/0 Ex	2/0 Ex

NBCM101	**Detection and Spectroscopy of Single Molecules**	2/0 Ex	—
NEVF515	**Methods of Physics of Surfaces and Thin Films I**	—	2/0 Ex
NEVF516	**Methods of Physics of Surfaces and Thin Films II**	2/0 Ex	—
MC240P58	**Nanomaterials II**	—	2/0 Ex
MC240P92	**Methods for the study of solid-state materials and surfaces**	2/0 Ex	—
NOOE003	**Materials and Technology in Optoelectronics**	2/0 Ex	—
NOOE009	**Optoelectronics and Optical Properties of Solids**	—	2/0 Ex
NFPL013	**X-ray Scattering on Thin Films**	2/0 Ex	—
NFPL173	**Electron Transport in Quantum Systems**	—	3/0 Ex
NFPL085	**Electronic Theory of Solids**	—	2/0 Ex

Requirements for the state doctoral exam

During the examination, the student will receive three questions from the areas defined below: I. Broad base, II. Important physical and technological aspects of nanostructures, and III. A question related to the topic of the theses (a list of up to five questions will be provided by the supervisor, e.g., via email to the student at the study school's chair at least two weeks before the date of the examination).

I. Broad base

I.1. I.1. Structural properties and dynamics of the nanoscale systems

General symmetry in solids; crystallography of 3D, 2D, and 1D nanomaterials. Relaxation and reconstruction of surfaces.

Vibrational properties of the lattice - phonons in nanostructures and surface phonon states.

Mechanical properties of nanostructures; plastic, and elastic deformation.

I.2. Electronic structure, optical and magnetic properties

Electrons in the periodic medium, band structure, chemical bonding. Consequences of the reduced dimensions to electronic states of solids (size effect, quantum confinement).

Surface electronic states, electronic states in low-dimensional systems. Linear response theory, optical transitions.

Transport properties - transport equations, scattering mechanisms, quantum Hall effect.

Magnetic properties of low-dimensional structures.

II. Important physical and technological aspects of nanostructures

II.1. Preparation methods

Physical and chemical methods of growth of thin films, nanoparticles, and other important classes of nanomaterials.

The classical theory of nucleation, theory of thin-film growth, processes of self-assembly.

Methods of preparation of nanostructures used in the dissertation.

II.2. Characterization methods

Diffraction methods (X-ray and electron diffraction, neutron scattering).

Electron microscopy, ion microscopy, AFM, STM, and other scanning methods.

Methods of surface electron and ion spectroscopy (UPS, XPS, AR PES, AES, etc.).

Optical methods of studying nanostructures (UV / VIS, FTIR spectroscopy, ellipsometry, Raman scattering, nonlinear optical spectroscopy).

Transport methods (electrical conductivity, magnetoresistance, and Hall effect).

Electrochemical methods and other special experimental techniques according to the focus of the doctoral thesis.

III. Selected parts of the problem solved within the topic of the dissertation thesis.

Reccomended literature

Aoki, H., Dresselhaus, M.S.(eds): **Physics of graphene.** *Springer, 2014.*

Bhushan, B. (ed.): **Springer Handbook of Nanotechnology.** *2nd ed. Springer, 2007.*

Bimberg, D. et al.: **Quantum Dot Heterostructures.** *J. Wiley, 1999.*

Delerue, C., Lannoo, M.: **Nanostructures, theory and modeling.** *Springer, 2004.*

Edelstein, A. S., Cammarata, R.: **Nanomaterials, Synthesis, Properties and Application.** *Inst. of Physics Publishing, 1996.*

Gabrys, B. J. (ed.): **Applications of Neutron Scattering to Soft Condensed Matter.** *Gordon and Breach Science Publisher, 2000.*

Grundmann, M.: **Nano–optoelectronics.** *Springer, 2002.*

Guozhong, C.: **Nanostructures and Nanomaterials.** *Imp. Coll. Press, 2004.*

Herman, M. A., Richter, W., Sitter, H.: **Epitaxy: Physical Principles and Technical Implementation.** *Springer, 2004.*

Hirsch, P.: **Electron Microscopy of Thin Crystals.** *R. E. Krieger Publishing, 1977.*

Lowe, T. C., Valiev, R. Z. (eds.) **Investigations and Applications of Severe Plastic Deformation.** *NATO Science Series 80, Kluwer Academic Publishers, Dordrecht, 2000.*

Lu, G. Q., Zhao, X. S.: **Nanoporous Materials Science and Engineering.** *Imperial College Press, 2004.*

Michely, T., Krug, J.: **Atoms, Mounds and Atoms, Patterns and Processes in Crystal Growth Far from Equilibrium.** *Springer, 2004.*

Mills, D. J., Bland, J. A. C. (eds): **Nanomagnetism.** *Elsevier, 2006.*

Ozin, G. A., Arsenault, A. C.: **Nanochemistry.** *RSC Publ., 2005.*

Pietsch, U. et al.: **High–resolution x–ray scattering from thin films and nanostructures.** *Springer, 2004.*

Reich, S., Thomsen, C., Maultzsch, J.: **Carbon Nanotubes.** *J. Wiley, 2003.*

Roe, R.–J.: **Methods of x–ray and Neutron Scattering in Polymer Science.** *Oxford University Press, Oxford, 2000.*

Shchukin, V. A., Ledentsov, N. N., Bimberg, D.: **Epitaxy of Nanostructures.** *Springer, 2004.*

Venables, J. A.: **Introduction to Surface and Thin Film Processes.** *Cambridge University Press, Cambridge, 2000.*
Vollath, D., **Nanomaterials.** *Wiley, 2010.*
Williams, D. B., Carter, C. B.: **Transmission Electron Microscopy, a Textbook for Material Science.** *Plenum Press, New York, 1996.*
Wolf, E. L.: **Nanophysics and Nanotechnology, An Introduction to Modern Concepts in Nanoscience.** *Wiley–VCH, Berlin, 2006.*
Xu, Y., David, D., Nitta, J. (eds): **Handbook of Spintronics** *Springer, 2015.*

A lecturer and supervisor may expand the list of suggested literature by publications and review articles related to the topic of the dissertation.