MaMaSELF: AMU, Faculty of Physics, 3rd semester:

7 ECTS are earned during the summer school at Montpelier. Therefore 23 ECST points have to be collected at AMU during 3rd semester in order to complete 30 ECTS in total. Student seminar is mandatory (2 ECTS points) and three practical courses should be chosen (6 ECTS in total). Additionally 15 ECTS points have to be collected choosing 5 lectures. Two lectures are mandatory (see below) while 3 others lectures must be chosen from the list given below. In the case of questions please contact Jacek Kubicki (jacek.kubicki@amu.edu.pl).

code	Name of activity	No. of hours	Selection	Form of passing	ECTS points
SS	**Lecture Group 1 – Solid State (1 or 2 lectures to be chosen by students, total 15 ECTS points must be collected from Lecture Group 1 and Group 2):**				**6-9**
SS1	Introduction to neutron scattering	30	mandatory	exam	3
SS2	Conducting nanostructures. Methods of fabrication and analysis	30	☐	exam	3
SS3	Signal and energy processing in nanopatterned materials	30	☐	exam	3
SS4	Magnetism, magnetic materials and magnetization dynamics	30	☐	exam	3
SS5	Physical properties of 1D and 2D materials and their application in low energy consuming electronic devices.	30	☐	exam	3
SS6	Electric and thermoelectric transport at the nanoscale	30	☐	exam	3
SM	**Lecture Group 2 – Soft Matter and Organic-Inorganic Hybrids (1 or 2 lectures to be chosen by students, total 15 ECTS points must be collected from Lecture Group 1 and Group 2):**				**6-9**
SM1	Sunlight energy conversion	30	mandatory	exam	3
SM2	Biophotovoltaic materials	30	☐	exam	3
SM3	Thermodynamics of electrolyte solutions	30	☐	exam	3
SM4	Introduction to computational studies of electronic structure of nanosystems	30	☐	exam	3
SM5	Confined effects of liquids in nanoporous matrices.	30	☐	exam	3
SM6	Functional Nanomaterials and Photocatalysis	30	☐	exam	3

SE	**Students' seminars**				**2**
SE	**Students' seminars** **(2-3 seminars will be given by each students from the topics related to the chosen lectures from group 1 and group 2)**	**30**	**mandatory**	**delivered seminars**	**2**
PC	**Practical Courses (3 courses have to be chosen)**				**6**
PC1	Fabrication and analysis of surface nanostructures	15	☐	written report	2
PC2	Coarse-grained Monte Carlo simulations of polymers	15	☐	written report	2
PC3	Time-resolved absorption measurements	15	☐	written report	2
PC4	Electron microscopy	15	☐	written report	2
PC5	Molecular dynamics simulations – part I	15	☐	written report	2
PC6	Liquids in confinement; the novel phases in nanopores	15	☐	written report	2
PC7	Preparation and characterization of solar cells	15	☐	written report	2
				Total:	**23 +7***

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Lectures description (red – delivered by experimentalists, blue - by theoreticians**)**

Students must attend to at least 5 lectures, 2 of them are mandatory

Lecture group 1 - Solid State

SS1. Aleksandra Pajzderska: **Introduction to neutron scattering**

The lecture will include:

1. Theory of neutron scattering
2. Elastic and inelastic neutron scattering
3. Neutron scattering facilities and productions of neutrons
4. Neutron detection, instrumentations and instrument components (spectrometers, diffractometers and reflectometers)
5. Methodology of measurement and access to neutron facilities
6. Examples of the use of neutron methods in condensed matter research, in particular: in materials for energy conversion and energy storage, ionic and conducting systems, fuel cell, thin films, nanocomposites, porous systems and photovoltaic systems.

SS2. Mateusz Kempiński: **Conducting nanostructures. Methods of fabrication and analysis**.

Lecture will involve the following topics:

1) Basic issues concerning the physics of conductors (free electron gas, Fermi level, band structure, electron scattering mechanisms, etc.).
2) Methods of nanostructure preparation (thin layer deposition: PVD, CVD, ALD, MBE; surface nanostructurization: IBS, GLAD, thermal reconstruction; lithographic methods).
3) Surface Analysis Techniques (overview of vacuum technologies; imaging: STM, AFM, SEM; spectroscopy: XPS, EDS, Raman, STS; structure: XRD, XRR, RHEED, LEED; adhesion and wetting: contact angle).
4) Charge carrier and spin transport in nanostructures (measurement techniques: AC/DC four probe conductivity, EPR, Hall effect; localization: granular systems and metal-insulator transitions, tunneling and hopping conduction, Coulomb blockade, quantum dots, single electron devices).
5) Carbon-based nanostructures (graphene, nanotubes, fullerenes, active carbons, etc.).
6) Application of conducting nanostructures (sensors, energy generation and storage, nanoelectronics, spintronics, etc.).

SS3. Jarosław W. Kłos: **Signal and energy processing in nanopatterned materials**

The aim of the course is to make students familiar with the physics of excitation (electromagnetic waves, electronic excitation and spin-waves) in various types of periodic, two-component structures and to present the basic computational methods dedicated to such systems (e.g. plane wave method). The lecture and the tutorial will be devoted to the selected categories of periodic composites such as: phontonic crystals, semiconductor superlattices and magnonic crystals, which manifest the presence of energy gaps in the spectrum of excitations. The knowledge about the wave excitations in such systems is important for designing of new materials and devices for signal processing.

SS4. Maciej Krawczyk: **Magnetism, magnetic materials and magnetization dynamics**

The first part of the lecture is dedicated to introduction to magnetism. Starting from basic low of the electrodynamics, magnetic and electromagnetic fields, the magnetization and magnetic moment, with susceptibilities of ferromagnetic, antiferromagnetic and ferrimagnetic materials will be discussed. Advanced concepts of electron-electron interaction will be introduced in order to give a general overview and explains basic fundamental concepts in magnetism and microscopic origin of the magnetism in solids. The second part concerns magnetic properties of ferromagnetic materials with explaining role of different type of energy terms determining magnetic properties. The detailed description of hysteresis and related properties will be provided, including magnetic domain formation, domain walls theory and complex magnetization textures with its possible applications in future magnetic memories. The physics of thin films, multilayers, giant magneto-resistance, and nanoscale patterned ferromagnetic materials will be presented with emphasizing prospects for controlling and using heat dissipation. Last part will be devoted to the spin wave dynamics and principles of the magnonics, an emerging field of physics with its potential to be used in electronic, radio-frequency and spintronic devices offering up to two orders of magnitude decrease of the energy consumption as compared to the currently used CMOS and RF devices

SS5. Maciej Wiesner: **Physical properties of 1D and 2D materials and their application in low energy consuming electronic devices.**

Reduction of dimensions of a material from 3D to 2D or 1D results in confinement of charge carriers and phonons spreading in the material. Consequently classical approach is not satisfactory, because quantum phenomena have to be taken into account to describe properties of the above mentioned particles and quasi-particles. Graphene, silicene, topological insulators are examples of the 2D materials considered as the best candidates for application in nanoelectronics for lossless energy transfer of high frequency signals.

The NanoBioMedical Centre offers impressing facilities allowing for samples fabrication and their characterisation. An electron beam lithography, focus ion beam and photolithography will be used for sample fabrication. Characterisation of the samples will be performed using four-probe station, AFM, SEM and microRaman spectroscopy.

SS6. Ireneusz Weymann: **Electric and thermoelectric transport at the nanoscale.**

In this lecture we will give an overview of basic theoretical methods used for studies of electric and thermoelectric transport properties of various nanostructures, including quantum dots, molecules and nanowires. We will discuss new effects emerging in transport through such systems in the context of low-energy consuming devices for future memory cells and information processing. Special attention will be paid to the discussion of thermoelectric properties, such as the Seebeck and spin-Seebeck effects. We will present the relevant theoretical framework to analyze these effects in nanostructures and discuss the differences compared to conventional bulk materials. Large enhancement of thermopower in nanoscale structures resulting from size quantization and quantum interference makes these systems very promising for energy harvesting devices.

Lecture group 2 - Soft Matter and Organic-Inorganic Hybrids

SM1. Marcin Ziółek: **Sunlight energy conversion**

The lecture will be devoted to the principles of photovoltaics and the systems used for solar fuels (mainly water splitting). The operation of solar cells of the first, second and third generation will be presented, the efficiency limits of various devices will be discussed, and the emerging branches of photovoltaics will be highlighted. Large part will be devoted to the recently widely studied sunlight conversion systems using nanomaterials and hybrid organic-inorganic composites. This lecture will be also accompanied with the presentations how to prepare simple low-cost solar cells (e. d. dye-sensitized solar cells) and how to characterize them using basic photovoltaic and spectroscopic measurements. The use of modern ultrafast laser spectroscopy tools used to study dye-sensitized and perovskite systems will be also emphasized.

SM2. Krzysztof Gibasiewicz: **Biophotovoltaic materials**

In the first part of the lecture natural photosynthetic light conversion will be introduced and selected light-converting proteins will be presented in more details. Then theories of intermolecular energy and electron transport will be introduced followed by presentation of basic optical and electrochemical techniques used to track excitation energy and electron transport. In the second part of the lecture selected biohybrid materials composed of photosynthetic proteins and inorganic components (conducting glass, semiconductors, conducting gels) will be described. Basic spectral and electrochemical properties of photovoltaic cells containing these materials will be demonstrated in the lab.

SM3. Jarosław S. Kłos: Thermodynamics of Electrolyte Solutions

Part One: Introductory Statistical Mechanics (statistical postulates, statistical description of many-particle systems, microcanonical ensembles, canonical ensembles, grand canonical ensembles).

Part Two: Introduction to phenomenological thermodynamics (basic notions and the zeroth law of thermodynamics, the internal energy and the first law of thermodynamics, the entropy and the second law of thermodynamics, the thermodynamic potentials).

Part Three: Electrolyte Solutions (introduction to thermodynamics of solutions, perfect solutions, real solutions, chemical reactions, galvanic and electrolytic cells, the Nernst Equation, The Gouy-Chapman Theory, The Stern Layer, The Debye-Hueckel Theory).

SM4. Tomasz Kostyrko: Introduction to Computational Studies of Electronic Structure of Nanosystems

Nanoscience deals with phenomena that appear on interface of solids and atomic or molecular world. The problems that emerge need applications of methods coming from various research fields: atomic, molecular and solid state physics, quantum chemistry and computer science. The ensuing computational tasks are very demanding since a large number of electrons are involved in forming main features of electronic structure of the nanosystems. Therefore one needs methods that provide a trade-off between the accuracy and feasibility of computation procedures.

The lecture will provide an introduction to the computational chemical methods used in studies of electron properties of solids and nanostructures. The foundations of the density functional theory will be presented and a review of its implementations in several freely accessible (GPL licensed) computer codes will be given. The application of the method will be exemplified by discussing various case studies. Emphasis will be put on selected nanosystems important for the energy processing and applications. In particular, carbon-based systems like nanotubes and graphene, both free-standing as well as forming composite systems with inorganic crystals will be analyzed.

SM5. Małgorzata Śliwińska-Bartkowiak: Liquids in Confinement; Quasi-high pressure effects in nanopores

Phenomena that occur only at very high pressures in the bulk phase are often observed to occur in the confined phase at normal pressures (the pressure of the bulk phase equilibrium with the confined phase) in abundant experimental evidence suggests that adsorbates confined in nanoporous carbons exhibit high pressures, such as high pressure crystal structures, high pressure chemical reactions, and the deformation of pore walls due to the adsorbate. Also molecular simulation studies of the pressure tensor for simple adsorbates in carbon nanopores of slit, cylindrical and spherical geometries show that for modest bulk phase pressures the pressures parallel to the pore walls (tangential pressure) is of the order of GPa , while the pressure normal to the wall is of the order of about hundreds of MPa, and can be positive or negative depending on the pore size.

SM6. Igor Iatsunskyi: **Functional Nanomaterials and Photocatalysis**

The course will be devoted to the main principles of photocatalysis and the photocatalytic materials. The mechanism and kinetic analysis of photocatalytic reactions; evaluation methods of photocatalytic activity; typical fabrication methods of common photocatalysts and the factors for improving photocatalytic activity will be studied. Examples of various practical applications of the photocatalysis and the photocatalysts will be presented.

Practical Courses

(red – experiments, blue - theoretical calculations)

(choose 3 courses)

PC1. Fabrication and analysis of surface nanostructures (M. Kempiński) more info

PC2. Coarse-grained Monte Carlo simulations of polymers (J. S. Kłos) more info

PC3. Time-resolved absorption measurements (G. Burdziński) more info

PC4. Electron microscopy (NanoBioMedical Centre) more info

PC5. Molecular dynamics simulations (A. Pajzderska) more info

PC6. Liquids in confinement; the novel phases in nanopores (M. Śliwińska-Bartkowiak) more info

PC7. Preparation and characterization of solar cells (M. Ziółek) more info

Additional information:

- **link to syllabuses for all lectures and practical courses and**
- **link to some additional information about English program at AMU in Poznan.**