OFFER SCIENTIFIC RESEARCH

FACULTY OF CHEMICAL TECHNOLOGY AND ENGINEERING

FOR INDUSTRY

UTP University of Science and Technology
in Bydgoszcz

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Faculty of Chemical Technology and Engineering

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The Faculty of Chemical Technology and Engineering is one of the oldest units of the University with its roots in the Faculty of Chemistry of the Evening School of Engineering established in 1951.
Department of Equipment and Food Technology

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HEAD OF DEPARTMENT
Marek Domoradzki, DSc. Eng.

Division of Food Analytics and Environment

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HEAD OF DIVISION
Grażyna Wejnerowska, DSc. Eng.

Research areas:

- analyses of environment, food and food products,
- technologies of environmental protection – physicochemical wastewater treatment, water purification, industrial waste treatment, utilisation of waste for energy purposes, recultivation of degraded areas.

Research offer

Analyses for environmental protection purposes and agri-food industry:

- physicochemical analysis of waste, water and wastewater,
- ecoanalytics – determination of pesticides, WWA, AOX, BTX and heavy metals in environmental samples,
- analysis of food and raw materials for food industry,
- trace and ultra trace analysis of food contamination,
- physicochemical evaluation of food products.

Waste treatment technologies:

- treatment methods of waste from the chemical and agri-food industries,
- management and treatment of wastewater sludge from processes of biological wastewater treatment,
- methods of energy-purpose waste utilisation.

Physicochemical methods of wastewater treatment:

- methods of pretreatment and treatment of wastewater from the chemical and agri-food industries,

Research areas:

- inorganic chemistry – properties, structure and durability of coordination compounds; selective metal dissolution, mathematical models and computer software for interpretation of mass-spectra, catalytic phenomena,
- physical chemistry – photochemistry of polymers and synthesis and photochemistry of dyes,
- organic chemistry – synthesis and physicochemical and biological, properties of sulphur and nitrogen organic compounds, search for new environmentally friendly organic technologies, treatment of waste and by-products of the chemical industry,
- structure and physical chemistry of surfaces – thermodynamic equilibrium states of adsorption systems, properties of homo- and heterogenous surfaces of adsorbents, adsorption of liquids and gasses,
- chemical technology – synthesis, modification and processing of polymers, unit operations performed on loose and granular materials,
- biotechnology and process engineering; technologies and agri-food processing equipment.
processes of coagulation, oxidation, flotation and membrane processes,
technological and optimisation research for wastewater treatment methods.

Evaluations of environmental impact and feasibility studies:
impact evaluations for investments of the chemical and agri-food industries,
feasibility studies for support funds applications.

Research equipment
- gas and liquid chromatographs,
- mass spectrometer,
- kits for liquid – liquid and liquid – solid body extractions,
- flow rate analyser,
- atomic absorption spectrometer,
- inversion voltamperometers,
- kits for comprehensive determination of components in waste, water, wastewater and gas samples,
- kits for comprehensive determination of components and contaminants in food and food product samples,
- research kits for physicochemical methods of industrial wastewater treatment.

Achievements
Granted and registered for protection patents mainly include new technologies of waste treatment, physicochemical methods of industrial wastewater treatment and instruments for wastewater treatment, such as:
- Development of the technology for degraded area recultivation. Patent P. 288162 (1990),
- Development of waste treatment technology.
- Development of fundamentals of physicochemical and process ecotechnologies,
- Treatment method of wastewater containing fat compounds. Patent P 353530 (2008),
- Pretreatment method of wastewater containing reducing compounds. Patent P 353531 (2008),
- Pretreatment method of wastewater containing organic compounds. Patent P 349696 (2008),
- Treatment plant for grease wastewater. Patent P 199963 (2008),
- Treatment plant for paint and varnish wastewater. Patent P 200131 (2008),
- Treatment plant for paint and varnish wastewater. Patent P 200131 (2008),

Division of Food Technology

HEAD OF DIVISION
Grażyna Gozdecka, DSc. Eng.

Research areas
- processes, operations and instruments for chemical and food industries, in particular:
  - non-pressure agglomeration of loose materials,
  - drying of loose and granular materials,
  - grinding of food products,
  - pelleting and coating of seeds,
  - production of compound fertilisers with extended period of nutrient release,
  - industrial dust treatment,
- research on the processes occurring during manufacturing of food product,
- designing instruments for food industry.
Research equipment
- Fritsch seed counter: Analysette 22,
- plate granulators,
- vibrating screen,
- standard equipment of a solid body laboratory (e.g. laboratory screens with a set of sieves, grinders, mills).

Achievements
- Scraper conveyor. Patent P. 125284 (1985),
- Universal vibrating screen. Patent P. 334105 (1999),
- Device of seed mechanical scarification. Patent P 387615 (2009),
- Gold Medal of the International Fairs in Brussels “Eureka 1998” for a horizontal conveyor of loose products,

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HEAD OF DEPARTMENT
Jacek Szymura, DSc. - Associate Professor

Research areas
- physicochemical profile of catalysers,
- monitoring systems in waste management,
- technologies on waste recovery and decontamination,
- physicochemical profile of waste and its toxicity,
- application of X-ray fluorescence and isotachophoresis,
- tribocatalysis evaluation of engine oil quality,
- computer-aided spectre analysis in mass spectrometry.

Research offer
- determination of active phase dispersion of metallic catalysts on relevant media,
- fast analyses of substance composition by means of X-ray fluorescence,
- separation and analysis of organic and inorganic ions in water solutions by means of isotachophoresis,
- development of comprehensive systems of waste management, in particular of hazardous waste,
- consulting in waste management and fulfillment of statutory obligations pursuant to regulations on waste and packaging.

Department of Inorganic Chemistry
research on properties of soil contaminated with heavy metals,
research on the toxicity profile of waste from paint based on lead compounds,
research on used oils and oil waste as hazardous waste,
used oils – treatment, regeneration and re-refining,
consulting in fuel and oil management in an enterprise,
consulting in interpretation of mass spectra of metal-organic compounds,
Offer Scientific Research Faculty of Chemical Technology and Engineering for Industry
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Training offer:
- Toxic waste and its treatment (implementation of legal regulations into practice),
- Systems of waste management in the light of legally binding regulations (presentation of current regulations and their interpretation),
- Preparation and keeping of documents regarding waste and packaging management (practical skills in terms of compulsory record-keeping and reporting),
- Oil and fuel management in an enterprise (adjustment to requirements of the European Union).

Research equipment
- Mini Pal device for X-ray fluorescence analysis,
- Labeco EA-100 device for capillary electrophoresis (isotachophoresis).

Achievements
- Expert of the Polish Chamber of Ecology in waste management. Certificate No. 65 (Włodzimierz Urbaniaik, DSc. - Associate Professor).
- Expert of the Polish Federation of Engineering Associations in; metallic catalysts on media (Jacek A. Szymura, DSc. - Associate Professor).

Department of Physical Chemistry and Technology of Organic Compounds

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HEAD OF DEPARTMENT
Andrzej Wrzyszczyński, DSc. - Associate Professor

Research areas
- modern photochemical technologies,
- synthesis and profiling of photochemical and photophysical properties of free radical polymerisation initiators, photoinitiated by ultraviolet and visible radiation,
- photochemistry and photophysics of dyers,
- spectroscopic probes,
- diamond electrodes.

Research offer
Synthesis of new, effective photoinitiators and co-initiators of free radical polymerisation and research on the process of polymerisation photoinitiation, including:
- synthesis and research on photoinitiators applicable in the technology of photochemically-hardened varnish coatings,
- synthesis and research on photoinitiators potentially applicable in dentistry,
- synthesis and research on photoinitiators applicable in the technology of photochemical manufacturing of prototypes (stereolithography).

Research works on photochemical and photophysical properties of dyers including:
- synthesis of new dyers,
- evaluation of their photochemical stability under conditions of photochemical reduction and photochemical oxidation,
- potential application in the processes of molecular spectroscopic microenvironment probing.

Research equipment
- FLS920 fluorometer for measuring the properties of excited singlet and triplet states (Edinburgh Instruments),
- Flash photolysis kit (Applied Photophysics LKS.60/S),
- Waters 1525 liquid chromatograph with UV-vis detector,
- UV-Vis spectrophotometers (Curry 3E Varian; MultiSpec-1501 Shimadzu),
- F-4500 Hitachi spectrofluorometer,
- lasers (Innova 90 Coherent; 543-500 MA Omnichrome),
- CS-1090 Cypress System electroanalyser,
- stereolithography kit.

Achievements
- 2004 Science Award of the President of Bydgoszcz,
- 3 medals on international invention fairs in 2008 and a diploma from the Minister of Science and Higher Education for the development of HF CVD production method of diamond electrodes for electrochemical purposes,
- Award of the Marshal of the Kujawsko-Pomorskie province for scientific research and technical progress in 2009.
Department of Chemical and Biochemical Engineering

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HEAD OF DEPARTMENT
Marek Wójcik, DSc. Eng. - Associate Professor

Research areas
- chemical and bioprocess engineering,
- enzymatic and microbiological bioprocesses.

Research offer
- research on biocatalysts and bioprocesses,
- microencapsulation of biologically active substances,
- enzyme deactivation and bioreactor optimisation,
- modelling of microorganism growth in bioreactor,
- technologies of obtaining immobilised biocatalysts.

Research equipment
- bioreactors for submerged cultures of microorganisms,
- bioreactors for surface cultures of microorganisms,
- UV-VIS spectrophotometer,
- Brookfield rotational viscometer,
- Alpha 1-2 freeze dryer,
- kit for determining nitrogen by means of the Kjeldahl method.

Achievements
- Device for sterile introduction of measuring elements into filled containers, especially bioreactors. Patent P. 156657 (1991),

Department of Organic Chemistry

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HEAD OF DEPARTMENT
Prof. Ryszard Gawinecki, DSc.

Research areas
- research on the structure of chemical compounds,
- spectroscopy of organic compounds,
- analysis of intra- and intermolecular interactions,
- synthesis and photochemistry of dyers,
- role of sensitisers in the processes of electron transfer (free radical polymerisation, conversion of solar radiation).

Research offer
- of organic compounds,
- effectiveness evaluation of organic compound synthesis methods,
- isolation and purification of organic compounds,
- spectroscopic identification of organic compounds,
- recording and interpretation of NMR, UV-vis and IR spectra,
- research on equilibria (especially tautomeric equilibria),
- measurement of physicochemical properties of organic compounds,
- solvent trials aimed at obtaining cocrystals for pharmaceutical purposes,
- measurements conducted for the purpose of confirming cocrystal obtaining,
- quantum-chemical calculations conducted for non-covalent complexes,
- quantum-chemical calculations conducted to determine: optimal compound structure, stereoscopic parameters, mechanisms and parameters of thermodynamic reactions,
- synthesis of new, effective photoinitiators and co-initiators of free radical polymerisation and research on the process of polymerisation photoinitiation,
- synthesis and research on photoinitiators applicable in the technology of photochemical-ly-hardened self-adhesive glues,
- research on photochemical and photophysical properties of dyers encompassing the prospects of their application as markers for determining bioparticles,
- training in:
  - synthesis, isolation and identification of organic compounds (mainly with spectroscopic methods);
choice of drying agents;
research on equilibria, especially tautometric equilibria;
scientific literature research for synthesis methods and properties of compounds;
spectroscopic measurements;
 intra- and intermolecular interactions, equilibrium processes;
conditions of conducting measurements of physicochemical parameters of organic compounds.

**Research equipment**
- NMR (Varian Gemini 200) spectrometer,
- equipment of reduced-pressure distillation,
- FLASH chromatography system,
- system for working in inert atmosphere,
- equipment enabling conduct of reactions at low temperatures,
- stereolitography kit.

**Achievements**
- 2004 Science Award of the President of Bydgoszcz.
- Award of the Polish Chemical Society for a series of scientific thesis.
- Science Scholarship of the President of Bydgoszcz for prominent young scientists in 2011.

**Research areas**
- research on the structure of chemical compounds,
spectroscopy of organic compounds,
analysis of intra- and intermolecular interactions.

**Research offer**
- synthesis of organic compounds,
effectiveness evaluation of organic compound synthesis methods,
isolation and purification of organic compounds,
spectroscopic identification of organic compounds,
recording and interpretation of NMR, UV-vis and IR spectra,
research on equilibria (especially tautometric equilibria),
measurement of physicochemical properties of organic compounds,
training in:
  - synthesis, isolation and identification of organic compounds (mainly with spectroscopic methods);
  - choice of drying agents;
  - research on equilibria, especially tautometric equilibria;
  - scientific literature research for synthesis methods and properties of organic compounds;
  - spectroscopic measurements;
  - intra- and intermolecular interactions, equilibrium processes;
  - conditions of conducting measurements of physicochemical parameters of organic compounds.

**Research equipment**
- NMR 400 Hz spectrometer,
equipment of reduced-pressure distillation.

**Division of Polymer Technology**
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**HEAD OF DIVISION**
Kazimierz Piszczek, DSc. Eng.- Associate Professor

**Research areas**
- research on the modification of processing and utility properties of thermoplastic polymers, including thermoplast composites with wood-based fillers and PVC nanocomposites with carbon nanotubes,
- research on the influence of mixture composition and processing conditions on the gelation of unplasticised PVC,
- occurrences taking place in PVC under gelation (rheological traits as a result of gelation, evaluation of physicochemical properties and structure of products, influence of process parameters and modifiers),
- modification of processing and utility properties of chlorofibre plastics,
- modification of polyolefin properties with the use of fillers and nucleating agents,
- polyolefin monocomposites,
- production of construction materials and composites of required properties,
- modification of processing and physicochemical properties of thermoplastic polymers, including: research on the correlation between processing parameters and the resulting polymer structure, evaluation of the influence of chemically active and inactive additives on polymer structure and properties,
- material recycling of polymer plastics, including: research on the utilisation of PE, PVC, PP, PS, PET, PBT recyclates and polyurethane rigid foams and on the impact of repeated processing,
- interpolymer compatibility of PP/PE, LDPE/HDPE blends and PET of various crystallinity degree, including: research on morphological structure and physicochemical properties.
Research offer
- research on the influence of physical modification on processing and functional properties in terms of new applications of polymer plastics or development of previously applied technological solutions,
- root cause analysis of fault occurrence in products made of polymer plastics and development of methods of fault elimination,
- development of new formulations of polymer mixtures with various modifiers and fillers, including wood-based fillers,
- development of new methods of testing polymer plastic products for various applications,
- assistance in managing problems in processing and application of polymer plastics,
- identification of polymers and polymer plastics by means of instrumental methods (FTIR, WAX, DSC, TGA spectrophotometry), evaluation of chemical and structural uniformity and properties of recirculated plastics,
- trainings in material science of polymer plastics, PVC processing, physical modification of polymers, production of WPC composites.

Research equipment
- WH 80 and Monomat 160 injection moulding machines,
- W32 single-screw extruder (equipped with an extrusion head for profiles, head for rheological measurements, rheological head for extruding plastics with wood-based fillers, lashing, worm dispensers),
- granulators, mixers,
- ultrasonic disintegrator (sonicator),
- Brabender plastographometer,
- PHM 63 hydraulic press and press for spectrophotometric films,
- roller press,
- capillary rheometers,
- polarising microscope with video tracking, interference microscopes, stereo microscopes, metallographic microscopes, microtomes,
- equipment for thermal research: dynamic scanning calorimeter (DSC), TGA device,
- gradient column for density determination,
- fractionation column for powder materials form fluidised beds,
- Tiratest 2000 fatigue testing machine,
- Vicat and Martens instrument,
- Charpy impact hammer,
- Rockwell and Shore hardness testers,
- a kit for determining thermomechanical curves with the use of Kargin method.

Achievements
- Development of production technology of PVC nanocomposites with carbon nanotubes with the use of the concentrate method (patent pending),
- Development of production technology of composites of thermoplastic polymers and wood-based fillers.

Division of Materials Chemistry and Polymer Protective Coatings

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HEAD OF DIVISION
Edwin Makarewicz, DSc. - Associate Professor

Research areas
Technology of producing metal and organic coatings applied on various metallic and non-metallic substrates, including:
- metallising and galvanic methods of alloy coating application,
- optimisation of coating application parameters in reference to their composition and wearing out of bath components,
- development of treatment and utilisation methods and composition analysis of sludge and wastewater from plating baths with the prospect of recovering metallic components as well as their alternative utilisation,
- production of water-dispersion paints from polymers or copolymers forming coatings of exceptionally high resistance to chemical environment and mechanical activity,
- research on the application of various painting materials in such ways as pneumatic spraying, electrophoretic painting with the use of the anaphoretic and cataphoretic method or by chemiphoresis,
- comprehensive research on the protective properties of obtained metal and organic coatings with the use of physicochemical and electrochemical methods, as well as accelerated tests in climate and salt chambers,
Research on the chemical resistance of coatings under varied corrosion aggressiveness environments,
research on sorption properties of artificial and natural materials,
development of economic methods of removing dissolved contaminants and suspensions from wastewater,
identification of the crystalline phase with the use of WAX method,
development of new methods for quantitative analysis of water-soluble polymers.

Research offer
- research on various methods of metal and organic coating application,
- research on the protective properties of metal and organic coatings with the use of invasive, noninvasive and electrochemical methods and carried out in environmental chambers,
- chemical analysis of plating baths, and post-plating wastewater and sludge, indication of means of their utilisation or management,
- chemical analysis and technical test of paint, varnishes and components of painting materials,
- design works and opinions regarding optimisation of technological calculations for plating and painting processes, wastewater treatment plants, etc.,
- technological support in launching plating plants, painting chambers and wastewater treatment plants,
- organisation of trainings, including: technology of anticorrosive protection for industrial facilities with the use of metal and organic coatings, evaluation of protective efficiency and coating quality,
- research on sorption properties of various materials,
- research on the utilisation of waste materials in wastewater treatment,
- identification of crystalline phase,

Research equipment
- laboratory equipment for the application of coatings with electrochemical methods, research and determination of parameters of plating baths, analysis of their composition,
- equipment and instruments for the application of organic coatings by means of the pneumatic, immersion, fluidised bed and electrophoretic methods, etc.,
- instrument for testing liquid painting materials, of varied textures (paints and putties) and powder paints,
- equipment for the research on physicochemical properties and chemical resistance of paint coatings in various environments and for electrochemical tests,
- UV-VIS spectrophotometers,
- X-ray diffractometer.

Achievements
Publications in national and international periodicals, conference lectures, patents, elaborations regarding water-based dispersion paints, ionic liquids and application techniques.
Institute of Mathematics and Physics

DIRECTOR
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The Institute of Mathematics and Physics has been a unit of the Faculty of Chemical Technology and Engineering since June 1998. The structure of the Institute of Mathematics and Physics includes 2 independent Divisions and Laboratories:

- Division of Mathematics,
- Division of Physics,
- Laboratory of Ellipsometry and Microstructure of Materials,
- Laboratory of Surface Engineering.

Division of Mathematics

HEAD OF DIVISION
Prof. Marek Lassak, DSc.

The Division of Mathematics has been established in result of merging three smaller units (the former Division of Mathematics, Division of Mathematics Application and Division of Methods of Mathematical Analysis along with Didactic Laboratory of Application of Mathematics and Programming).

The research conducted at the Division of Mathematics include:

- discrete geometry,
- geometry of convex bodies, covering convex bodies with polyhedra,
- initial-boundary problems for systems of partial equations
- problems of controlling,
- stochastic differential equations,
- mathematical methods for maintenance systems (infallibility issues).

Division of Physics

HEAD OF DIVISION
Antoni Bukaluk, DSc.

The research conducted at the Division of Physics regards issues of experimental physics, material and technology engineering and theoretical physics.

The main research areas of experimental physics include:

- optical and electron characteristics of metal and semiconductor surfaces,
- physicochemical processes occurring in the area near the surface,
- analysis of physical properties and chemical composition of surface and area near the surface of thin metallic and semiconductive layers and combined systems.

Experimental research on the properties of materials with the use of electron and optical methods are conducted in two laboratories of the Division of Physics:

- Laboratory of Surface Engineering,
- Laboratory of Ellipsometry and Microstructure of Materials.
Both of these laboratories cooperate with business entities in the field of material engineering, research and design of functional layers (anti-wear, tool, optical and decorative layers).

The research in respect of theoretical physics is conducted in three directions:

- processes of electromagnetic field impact on semiconductive nanostructures with particular focus on linear and non-linear optical characteristics,
- theory of model (bio)material formation,
- propagation, slowing and freezing of light impulse in atomic systems, under the conditions of electromagnetically induced transparency (EIT) variable in time.

Research offer

- design of software-controlled measuring systems for various physical quantities with digital recording of results,
- development and interpretation of measurement and observation results with the use of multivariate statistical analysis, consulting and cooperation in research planning,
- solution of problems in border areas between physics and chemistry as well as physics and biology occurring mainly in spatiotemporal scales, solution of problems in interaction energy, typical characteristic for the so-called soft matter systems, e.g. polymers, colloids, surfactants (such as lipid molecules), proteins and granular bodies,
- description and theoretical analysis of optical characteristics of semiconductors with particular focus on optical characteristics of semiconductive nanostructures,
- research on physical characteristics of cereal products,
- research on materials (including biological materials) with the use of UV-VIS-IR spectroscopy and modern methods of development and interpretation of measuring results – multivariate statistics and chemometrics.

Laboratory of Surface Engineering

HEAD OF LABORATORY
Marek Trzcinski, DSc.

The Laboratory of Surface Engineering is an interdisciplinary research laboratory for the field of surface science, surface engineering, material engineering and nanotechnology. The laboratory hosts research on the processes of formation and determination of structure and chemical composition of nanostructures, thin layers of metals and semiconductors and surface layer of metal alloys. The research also encompasses layers and structures utilised in nanotechnology - metallic, semiconductive and polymer, manufactured in other research laboratories by means of vacuum deposition, chemical epitaxy and methods of nanolayer application with the use of electron and ion beams.

The research conducted in the Laboratory of Surface Engineering concerns analysis of chemical composition and state of material surface and surface topography. At the same time, the Laboratory develops new materials and surface coatings.

The main experimental techniques are:

- diffraction of low-energy electrons,
- electron spectroscopy,
- photoelectron spectroscopy,
- scanning tunneling spectroscopy.

The research is conducted under the conditions of ultra high vacuum (UHV, pressure of the order of $10^{-10}$ mBar), while reactions on the surface of materials can be carried in a gas atmosphere, under high pressure of up to 20 Ba. The main research workstation is presented on figure 1.

The multi-chamber vacuum workstation consists of:

- a scanning tunneling scanning (STM) chamber,
- distributive chamber (operating the transfers of media between other chambers),
- lock chamber (enabling placement of samples in UHV without releasing air into the system),
- preparatory chamber (ensuring heating, cooling and ion-cleanse of samples, application of thin layers, recording of low-energy electron diffraction (LEED),
- analytical chamber (for recording photoemission spectra and preparation of composition profiles),
- high pressure reactor chamber (enabling local pressure increase in the surrounding of the sample and execution of reactions with chosen gasses).

Photoelectron spectroscopy (XPS)

Measuring data for the determination of composition are obtained in the form of spectra, on which characteristic peaks denote particular elements and their height is proportionate to the...
content of a particular element. On this basis it is possible to determine changes in the composition on the border of two materials.

A precise manipulator enables imaging of the surface chemical composition - i.e. representing the concentration of particular sample components in x and y variable function with accuracy to micrometres. The picture below presents a “map” of the surface with an “island” containing an admixture of copper of the order of 500 micrometers.

The photoelectron technique is a tool allowing to research not only the composition of the material, but also the chemical state. Depending on the type of bonds present on the surface the spectra present characteristic chemical shifts. Below you can see photoelectron spectra (XPS) of titanium oxide in various states of oxidation during ion etching.

**High pressure reactor**

When using a high pressure reactor under controlled conditions it is possible to produce and subsequently research new materials or material coatings, e.g. titanium oxides and nitrides, etc.
Scanning tunneling microscope (STM)

Surface imaging with the use of STM is based on the recording of the so-called tunneling current between the surface and the blade of a needle precisely moved over the surface of a tested material. After computer processing, atomic resolution maps of surface topography are obtained.

Research offer

- chemical composition analysis of solid bodies (both crystalline and amorphic) and preparation of chemical composition profiles of surfaces and the inside of the sample with spatial resolution of single nanometres,
- research on the chemical and electron characteristics of sample surface (such as identification of elements present on the sample surface, determination of chemical state of components - e.g. oxidation, type of bonds, occurrence in a chemical compound),
- research on the formation of chemical compounds, intermetallic compounds, surface alloys,
- research on the influence of admixture content on physicochemical properties of metals, semiconductive and combined systems,
- analysis of surface nanotopography of solid bodies - possibility of detecting crystalline structure of the body (basing on the LEED technique) and research on the topography of parts of certain samples in atomic resolution by means of the scanning tunneling microscopy (STM),
- possibility of producing and subsequent research of physicochemical characteristics of ultra thin and thin layers (coverage rate from fractions of a single atomic layer to hundreds of nm),
- conduct of sample reactions with chosen gasses (currently with oxygen and nitrogen) under the conditions of elevated pressure (up to 2 MPa) and temperature (up to 650°C).
- conduct of measurements by means of:
  - electron and photoelectron spectroscopy (AES, UPS, EELS),
  - low energy electron diffraction (LEED),
- conduct of deposition of thin layers of metals on various substrates under the conditions of ultra high vacuum,
- conduct of measurements with the use of vacuum deposition machine.

Equipment

Ultra high vacuum workstation, which includes a couple of research chambers:
- sample preparatory chamber for production of thin layers with a camera for imaging of low-energy electron diffraction (LEED), enabling preliminary determination of surface composition by means of the AES method,
- vacuum deposition machines with the ability to measure layer thickness with a quartz crystal balance,
- high pressure reactor,
- temperature-variable scanning tunneling microscope (STM) workstation along with software for surface imaging in atomic scale,
- spectrometer for photoelectrons excited with X-ray and ultraviolet radiation, equipped with hemispherical energy analyser (SCIENTA) with the ability of imaging surface composition of samples and the inside of samples, ion gun for the preparation of composition profile,
- device for sample transport under vacuum conditions (vacuum suitcase); enables exchange of samples between laboratories without contact with the air.

The laboratory also has ultra high vacuum workstations equipped with Auger electron spectrometers (AES), photoelectron spectrometers and electron energy loss spectrometers with cylindrical analysers (Staib Instrumente, Riber) and hemispherical analyser (Vacuum Generators).
The Laboratory of Ellipsometry and Microstructure of Materials is an interdisciplinary research laboratory for surface research with the use of optical and microscopic methods. The research allows to determine the properties of solid materials, thin layers, systems of heterostructural character, metals, semiconductors, dielectrics. It also enables to follow changes occurring in the course of aging, processing and operation and to evaluate the suitability of tested systems for various technologies, especially for nanotechnology, technology of solar absorbers and thermal radiation absorbers, photovoltaic panels, polymers, multicomponent crystals, decorative materials etc. Ellipsometric measurements (determination of \( \Psi \) and \( \Delta \) ellipsometric azimuths) are carried out for wavelengths from 193 nm to 25000 nm. Confocal microscopy and atomic force microscopy enable analysis of surface morphology and three-dimensional imaging of surface microstructure in a nanometre scale. The laboratory allows to determine micro-mechanical parameters of various materials: metals, alloys, polymers, composites (soft, hard, brittle and plastic materials) in real time and to alter these parameters in result of aging and fatigue processes. The laboratory also has the facilities for measuring electrical resistance of tested materials.

The Laboratory of Ellipsometry and Microstructure of Materials has also purchased:

- scanning laser confocal microscope along with an atomic force microscope (AFM),
- ellipsometer operating in the infra-red range,
- nano and micro scanning hardness tester.

**Research offer**

- imaging and analysis of 2D and 3D surface topography in a micro and nano scale, determination of linear profiles, analysis/counting of objects on the surface, determination of layer thickness,
- research on optical properties of low dimensional systems (heterostructures, LED, OLED and LD quantum well, plasmonic nanostructures), research on optical properties of effective centres, rough layers, composites, etc. and their parametrisation,
- research on optical anisotropy of materials,
- determination of roughness R and S parameters (PN-EN ISO 4287, PN-EN ISO 25178),
- determination of optical constants (combined dielectric function, combined refractive index, absorption coefficient, optical conductivity) and layer thickness of various materials basing on WVASE32, SpectraRay3 software and a database of own programs,
- determination of absorption band parameters,
- determination of transmission spectra within the wavelength range from 193 nm to 25000 nm,
- determination of hardness and elastic modulus (\( H \), \( E \)), and Young's modulus \( (E_y, E^*) \) of solid materials (metals, composites, polymers) and layers (e.g. paints, varnishes) in compliance with norm PN-EN ISO 14577,
- determination of surface resistance and specific resistance.

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**Equipment**

- UV-VIS-NIR V-Vase Ellipsometer (J.A.Woollam Co., Inc.),
- NIR-MIR Sendira Ellipsometer (Sentech GmbH),
- MIR Cary SPectrophotometer (Agilent),
- Lext OLS 4000 Confocal microscope (Olympus),
- Innova atomic force microscope (Bruker),
- MHT micro hardness tester (CSM Instruments, certified indenters: Vicker, Berkovich and Knoop, load range: from to 10 mN to 10 N, resolution up to 0.1 mN),
- Four point probe with a calibrated direct current source (Keithley).

The Institute of Mathematics and Physics also conducts research in the field of theoretical physics. Within the Division of Physics, there are three research groups conducting their work in various directions.

**Research Group of Modelling of Physico-Chemical Processes headed by Prof. Adam Gadomski, DSc.**

The main focus of research conducted by the members of the Group are the issues of the border areas between physics, chemistry and biology which are vital for modern material science. The main direction of research is the theory of model formation of (bio)material. The investigated phenomena include both self-formation to a native state basing on a folded particle (folded in the meaning of nanomechanics) obtaining a state of minimum energy (most often it is at the same time the state, which is most suitable for biological functionality) and a phenomenon of spontaneous or forced aggregation and/or crystallisation. Both processes are extremely important from the point of view of processes occurring in living organisms (mutations, neurodegenerative diseases such as Alzheimer’s and Parkinson’s diseases, Multiple Sclerosis and others). The research utilises both simplified (mesoscopic) models, where a single (bio) particle is represented by e.g. a small ball and the properties of a solvent are hidden in implemented potentials, as well as the so-called full-atom models, which incorporate all atoms constituting a macroparticle, a solvent and all other additives (pH Stabilisers, precipitants and others). An important role in modelled processes is also played by the temperature at which the investigated processes occur.

![Fig. 9. Modelling of protein formation.](image)

The other direction of research, vital from the point of view of the elderly, is a phenomenon of extremely low friction coefficient occurring on surfaces between joint elements, e.g. inside the
Research offer

- Modelling aggregation and transport phenomena in biopolymer and polymer systems basing on simplified and full-atom models,
- Modelling the influence of temperature, pH, chemical additives and changes in various physicochemical parameters on the dynamics and course of the above-mentioned phenomena,
- Simulations of combined systems (particle systems, social networks) with the use of Monte Carlo (MC) and Molecular Dynamics (MD) methods.

It is currently becoming increasingly common to use virtual social platforms for exchange of opinions, social meetings or playing network games. The virtual world becomes a venue of numerous interesting sociological phenomena, which can be investigated with the use of methods of statistical physics. Tracking information flow, creating/discontinuing contacts/alliances can be successfully simulated by means of computer methods utilised in simulations of physical systems and the obtained results, often highly interesting, can be utilised for further sociological research or marketing purposes.

Research Group of Quantum Optics and Quantum Informatics

The rapid development of quantum informatics motivates to search for new logical elements to be used in information processing. Quantum information processing is qualitatively different from classical methods. The main motive for research and quantum processing of information are the challenges facing modern computing technology. Fast-growing cryptography and quantum telecommunications necessitate the search for the possibilities to construct quantum computers with potential computing capabilities incomparably greater than those of classical methods. A representative comparison of their abilities is the example of decrypting the RSA protocol responsible for the safety of credit cards. With the use of currently available classical computers decrypting this protocol would require billions of years, while a quantum computer would need only a year to complete it.

The Research Group of Quantum Optics and Quantum Informatics is involved in theoretical research on light impulse propagation in atomic centres, its slowing, freezing, controlled processing and release. Such a process could be utilised for the construction of a universal set of logic gates and, consequently, for the construction of a quantum computer. Photons are highly durable and convenient information media, yet they are difficult to control. Processing of information carried by photons can be executed by means of an atomic centre they interact with.

The research of the Group particularly concerns the implementation of light frozen in an atomic system with a tripod configuration for the construction of one- and two-qubit logic gates of successful operation probability equal to 1. Another investigated issue was the Q factor of the described implementation processes, which currently constitutes a vital and broadly discussed problem of quantum information technology. Under appropriate conditions light excitement induces amplification caused by the fact that absorption for a certain range is partially negative.

In such a case there arise conditions for observation in a centre of impulses, the group velocity of which can be negative.

Another field investigated by the group is the propagation of electromagnetic radiation in centres with negative refraction index, i.e. in the so-called left-handed metamaterials (LHM). Meta-materials are artificially created structures built of many identical ‘meta-atoms’ of precisely defined electromagnetic properties. Meta-atoms are elementary cells of periodical structure of miniature resonant circuits. A crucial feature of metamaterials is the possibility of amending their parameters responsible for the propagation of electromagnetic radiation. Constructing a given metamaterial, one can amend its dispersion conditions “on demand”. In particular, it is possible to produce metamaterials of negative values of the refraction index, in which the occurring optical phenomena are “reversed”. The application of metamaterials enables to increase the resolving power of optical systems below the diffraction boundary (lower than the length of a wave).

The research conducted by the group is of model character, but the relevant environment of specialists shares a conviction that it is possible to utilise frozen light for the purpose of constructing optical switches and multiplexers. Also, the research on left-hand metamaterials is a thriving, modern and quickly developing field of many applications, e.g. in wave tunneling, transferring surface plasmons, directional antennae and absorbing layers.

KVAS HALUROWOWY

Offer Scientific Research Faculty of Chemical Technology and Engineering for Industry
Research Group of Semiconductors and Semiconductive Nanostructures
headed by Prof. Gerard Czajkowski, DSc.

The Group is involved in the development of theoretical description of optical characteristics of semiconductors and semiconductive nanostructures. The research work encompasses optical properties of excitons in structures of reduced number of dimensions (dots, discs, quantum wires) and properties of A'B' and A'B' semiconductive supernets. In particular, the group will investigate the optical properties of layers and semiconductive supernets in the area of exciton resonance. The aim of the theoretical analysis is to determine optical functions, such as combined dielectric function dependent on the electromagnetic wave frequency, electric susceptibility tensor, transmission and light refraction coefficients. The research also covers properties of semiconductive nanostructures, such as quantum wires, quantum dots and double quantum dots. The main aim of the research is to determine the energy levels and wave functions for electrons, holes and excitons captured inside the nanostructure, which can be placed in the external electric and/or magnetic field. Knowledge on wave functions enables determination of several properties of nanostructures, including optical properties, which are vital in designing optical and electronic elements.