CEITEC | Central European Institute of Technology
BRNO | CZECH REPUBLIC

MATERIALS CHARACTERIZATION AND ADVANCED COATINGS RESEARCH GROUP

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
INVESTING IN YOUR FUTURE

2007–13
OP Research and Development for Innovation

CONTENT

MATERIALS CHARACTERIZATION AND ADVANCED COATINGS RESEARCH GROUP

RESEARCH AREAS

Basic and applied research in complementary fields of design and processing of advanced materials and coatings using several different technologies. Detailed characterization of advanced materials and coatings from macro down to nanoscale.

Development of novel approaches and instrumentation in materials design, testing and characterization. Combination of e.g. micro- and nanostructural studies, environmental degradation studies, metallography, optoelectronic characterization of micro and nanostructures, tribology, Laser-Induced Breakdown Spectroscopy (LIBS) and μCT.

MAIN OBJECTIVE

The research capabilities of the group have already been demonstrated and performing onwards in the international context. Our main objectives are to react to recent trends and R&D activities in a broad range of scientific fields including aerospace, automotive, power generation industry, biology and electronics. The existing national and worldwide scientific cooperation is and will be further enhanced. A well-balanced research group is created yielding quality of results in basic research and strong cooperation with industrial partners in applied research.

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INCLUDING SUB-GROUPS:

- Laser-Induced Breakdown Spectroscopy
- X–ray micro CT and nano CT
- Advanced Coatings
- Nano and micro Tribology
- Optoelectronic Characterization of Nanostructures

CONTENT OF RESEARCH

- Coatings for aerospace and automotive industries – diffusion coatings, thermal barrier coatings, etc.
- Coatings for power industry – cavitation resistant coatings, wear resistant coatings, hydrophobic and hydrophilic coatings, etc.
- Coatings for medical treatment applications – HA, CDHA and TCP protective coatings for bioinert and bioactive metallic material substrates, etc.
- Functional and/or decorative electro-chemical coatings.
- Research and development of advanced coatings manufacturing technologies, surface machining technologies, and surface interaction technologies.
- Specific environmental testing areas of coatings and bulk materials such as tribology, cavitation, corrosion, water immersion, isothermal and cyclic furnace oxidation, burner and steam gas corrosion-resistance on a rig, etc.
- Development and application of high resolution micro- and nanoradiography, and computed tomography (μCT, nanoCT) techniques in combination with other analytical approaches such as LIBS and high-resolution 3D metrology.
- Basic and applied science studies in molecular degradation of lubricants, roughness behavior within lubricated contacts, thin-film-lubrication under non-steady-state conditions and effect of proteins in biotribology applications.
- Advanced structural and compositional studies of bulk materials, ultra-fine grain materials, materials surface, environmental damage mechanisms and advanced coatings (especially using a combination of metallography, LIBS, μCT and tribology approaches).
- Non-destructive and destructive characterization of materials inhomogeneities and local discontinuities.
- Improvement of diagnostic methods used for testing semiconductor materials and other electronic components and structures.
- Determination of correlations between the properties, and the geometrical and structural parameters of nanostructures.
- Low-frequency noise analysis of bulk volume and interface defects, determining quality and reliability of electronic devices.
- Development of highly sensitive sensors for detection of chemical substances dissolved in gases or liquids.
- Experimental and theoretical research of stochastic processes and charge carrier transport as a basis for new advanced technologies.
- Electromagnetic emission in dielectrics for the monitoring of the generation and growth of cracks under mechanical load.
- Applied research for solutions of industrial problems.

Ongoing and planned participation in the other areas of the CEITEC research: aerospace, automotive, power generation, medical treatments, ecology and communication.

LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS)

CHARACTERISTIC

LIBS is a technique capable of fast and even *in-situ* and stand-off elemental analysis. In LIBS, high energy laser pulse is focused on sample surface to ablate small amount (few ng) and thus to generate luminous laser-induced plasma (LIP). Characteristic spectral lines detected in LIP radiation provide qualitative and quantitative information about chemical composition of investigated objects.

ADVANTAGES OF LIBS ANALYSIS

- real-time, contactless with no need for sample preparation,
- ability to provide chemical analysis of samples in solid, liquid or gaseous states,
- capability to identify wide spectrum of chemical elements, depending on the element and material matrix the detection limits could be in sub-ppm level (below µg/g level),
- mainly, capability of *in-situ* remote/stand-off sensing (up to 30 m) in inaccessible and/or hazardous environments.

LIBS APPLICATIONS

In general, LIBS can be utilized wherever the real-time chemical analysis of materials is demanded, with primary aim on investigation of elemental composition of solid samples. Applications:

- biological and environmental diagnostics (detection of heavy/toxic metal contamination),
- metallurgy (fast on-line quality control),
- civil engineering (detection of material degradation and corrosion),
- homeland security (detection of explosives and chemical residues, narcotics),
- mining and extraterrestrial research (rock identification, quantification of trace elements),
- medicine, archaeology, forensics (e.g. braking track detection), etc.

LIBS LABORATORY

Laboratory of Laser Spectroscopy has more than 17 years of experience with the development of LIBS methods. LIBS laboratory disposes of all necessary equipment for the implementation of single-pulse LIBS and also double-pulse LIBS (with increased detection limits), LIBS + LIFS (Laser-Induced Fluorescence Spectroscopy). Direct analysis of liquids using LIBS is possible owing to the custom in-house built module. *In-situ* analysis of samples employing remote LIBS (by optical fibre) and stand-off LIBS (via air) systems. In 2014 a CEITEC BUT LIBS spin-off company (AtomTrace – www.atomtrace.com) was established, dealing with stand-off/remote LIBS and table-top LIBS systems, their design and development. Also, the scope of this company is aimed on customization of LIBS systems for i.e. industrial applications.

THE KEY EQUIPMENT:

- Stand-off LIBS system (rLIBS) was specially designed for *in-situ* and real-time analysis of hard to reach and/or hazardous/toxic samples. This device is composed of high energy laser BigSky Ultra CFR 400, Newtonian telescope for the collection of LIP radiation, spectrometer Catalina EMU and EMCCD detector Raptor Falcon.
- Modular LIBS interaction chamber was developed in the frame of Czech national grant project in cooperation with Tescan company (Czech Republic, focusing on electron microscopy). This interaction chamber is a suitable expansion of conventional table-top LIBS system enabling precise positioning of the sample, measurement in vacuum conditions and atmospheres of He, Ar, N and CO_2, optimized collection optics and special software for analysis of detected spectra.
- Despite the LIBS interaction chamber, the table-top LIBS system at CEITEC consists of high energy Nd:YAG solid state lasers Quantell Brilliant B, Solar LQ-529a and tunable Ti:Sa laser Solar Carat LX-325 (utilized for LIFS analysis), spectrometers Andor Mechelle 5000 (echelle configuration) and Lot Oriel 260 (Czerny-Turner configuration), ICCD detector Andor iStar, ICCD detector Princeton Instruments Pi-MAX3 and ICCD Jobin Yvon Horiba.

In collaboration with laboratories at Department of Chemistry at Masaryk University (Brno, CZ), LIBS laboratory can also offer the comparative measurements of samples by the Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) technique. Complementary molecular analysis of samples using Raman spectroscopy can be provided in cooperation with Academy of Sciences of the Czech Republic (Brno, Czech Republic).

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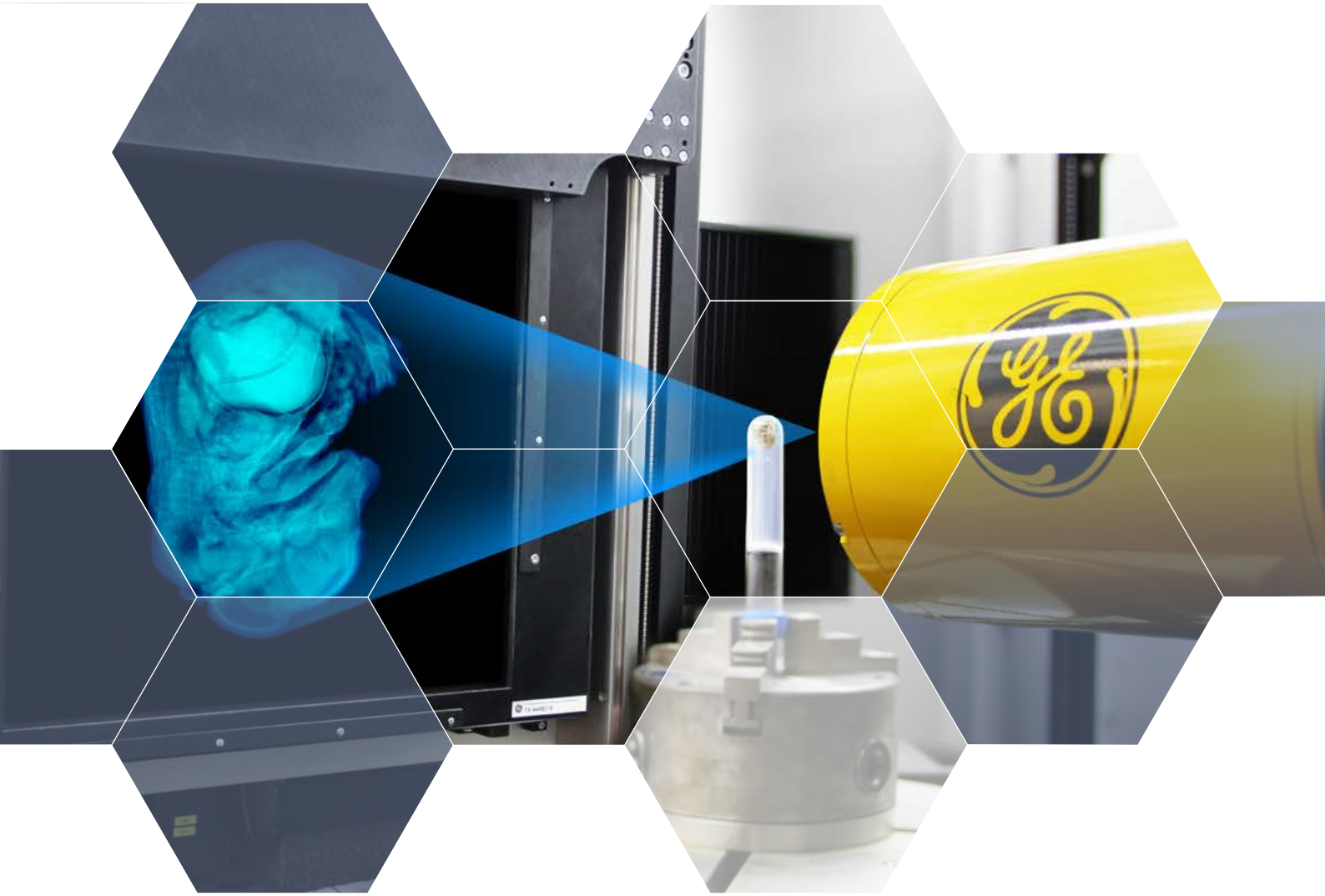
X-RAY MICRO CT AND NANO CT RESEARCH LAB

CHARACTERISTIC

The X-ray micro CT and nano CT research Laboratory of Materials Characterization and Advanced Coatings Research Group is a part of the Advanced Nanotechnologies and Microtechnologies Research Program at the Central European Institute of Technology (CEITEC) of the Brno University of Technology.

RESEARCH AREAS

- Development and application of micro- and nanoradiography and computed tomography (μCT, nanoCT) techniques in different scientific fields,
- High-resolution 3D metrology,
- Combination of micro- and nanoradiography and μCT, nanoCT techniques with other analytical approaches, e.g. with Laser-Induced Breakdown Spectroscopy (LIBS) for high-resolution elemental mapping, etc.



HISTORY OF THE LABORATORY

The basic impulse to investigate and apply μCT itself or accompanied by other related techniques came from the necessity to identify non-destructively a proper materials cross-section for elemental mapping preferably by LIBS. The development of μCT and nanoCT techniques in the research group started in 2005 with the collaboration with synchrotron Elettra, Trieste (Italy).

- Main fields of collaboration:
  - X-ray radiography and high resolution micro computed tomography (μCT),
  - Development of advanced techniques (dual-energy μCT, phase-contrast μCT, etc.),
  - Applications in various fields of basic and applied science.
- This cooperation resulted a number of scientific journal papers, per-reviewed articles for example in „Elettra Highlights", and a number of common conference contributions.

Based on the ongoing collaboration and active research projects realized at other synchrotrons in Europe, a brand-new X-ray computed tomography laboratory was established in the frame of CEITEC´s structure. The laboratory (www.ctlab.cz) is equipped with several state of the art μCT stations from GE and Rigaku.

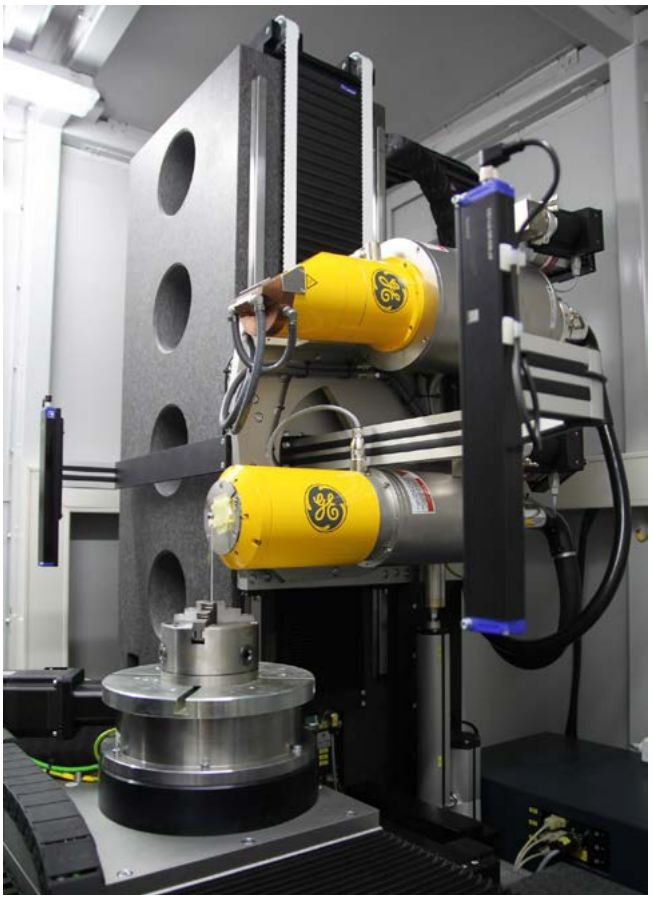
THE KEY EQUIPMENT

GE PHOENIX V|TOME|X L 240

- Maximum sample size – Ø500 x 800 mm, (i.e. size of the circumscribing cylinder),
- Maximum weight of the sample 50 kg,
- Achievable voxel resolution < 2 μm for 240 kV microfocus X-ray tube and ~ 1 μm for 180 kV nanofocus X-ray tube.

System:

- Granite-based 7-axes precision manipulation system,
- Open micro- (240 kV / 320 W) and nano- (180 kV / 15 W) focus X-ray tubes,
- Large active area (410 x 410 mm) 2048 x 2048 pixels (200 μm pixel pitch) GE DXR250 flat panel detector with a dynamic range 10 000 : 1,
- Built-in GPU cluster and software packages for real time and high-quality CT images reconstruction.



RIGAKU NANO3DX

- Tube voltage: 20 to 50 kV
- Tube current: up to 30 mA
- Target: Cr, Cu or Mo
- Detector: X-ray CCD camera
- Number of pixels: 3300 × 2500
- Pixel size: 0.27 µm or 2.2 µm
- Field of view: 0.9 × 0.7 mm or 7.2 × 5.4 mm
- Dynamic range: 16 bit
- Sample stage: automatic 5-axis stage
- Stage rotation axis accuracy: < 0.5 µm

GE PHOENIX V|TOME|X M

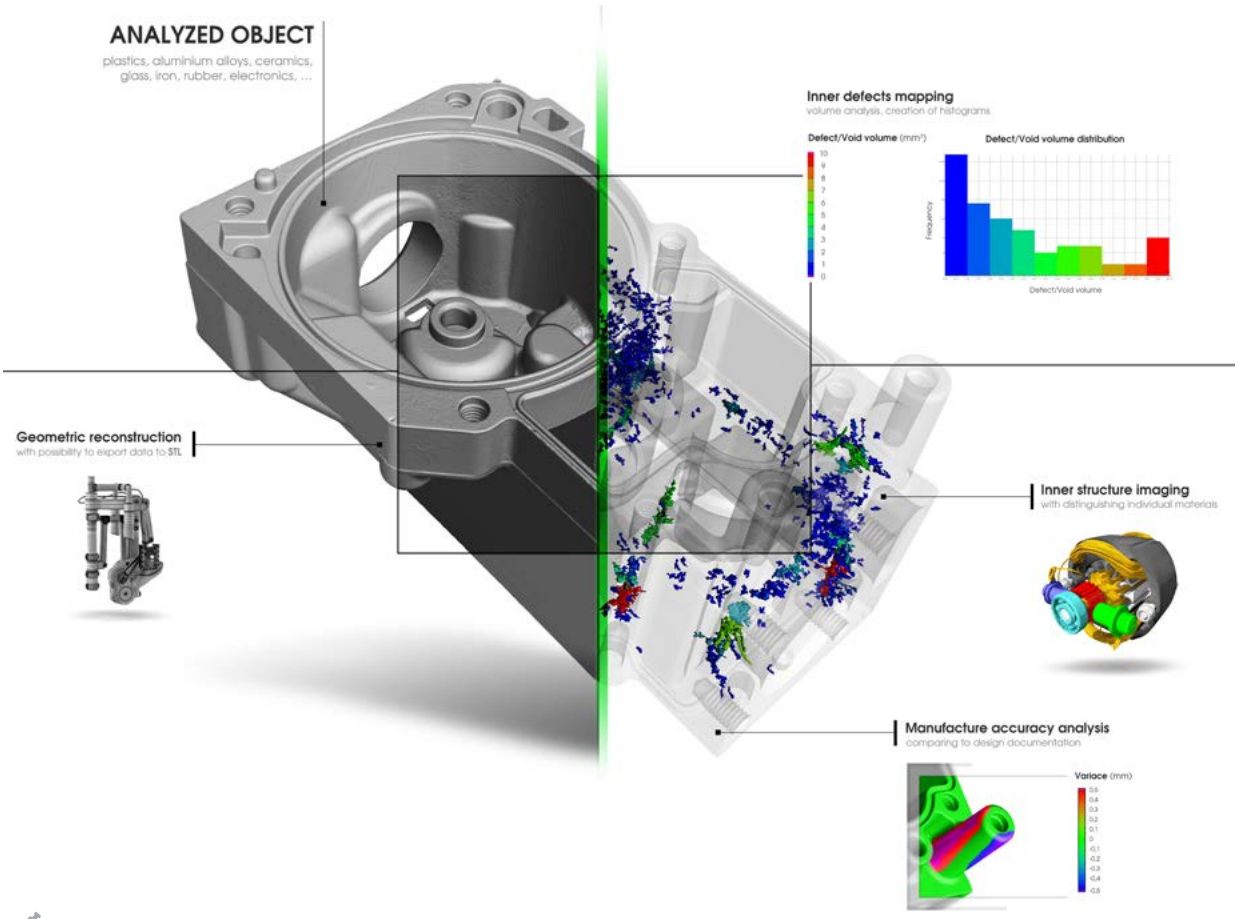
- Maximum sample size: Ø360 mm x 600 mm (i.e. size of the circumscribing cylinder),
- Maximum weight of the sample 50 kg,
- Achievable voxel resolution 1 µm
- Metrology edition with a measurement accuracy of 4+L / 100 µm referring to VDI 2630 guideline.

System:

- Granite-based 5-axes precision manipulation system
- Open microfocus X-ray tube 300 kV / 500 W
- GE DXR250 flat panel detector

DATA ANALYSIS

- 3D visualization software "Volume Graphics Studio MAX" with metrology packages
  - Coordinate measurement module,
  - Nominal / actual comparison module,
  - Wall thickness analysis module,
  - Porosity / inclusion analysis module.
  - Fiber composite material analysis module
  - Defect analysis according to specifications P 201 / VW 50097 and P 202 / VW 50093
- MAVI – Modular Algorithms for Volume Images with Particle features module, Point field statistics module, Mesh export and visualization module, Gray value mapping module
- GOM Inspect Professional – process-safe, parametric, traceable evaluation software for dimensional analysis of 3D point clouds
- Matlab – Numerical computing environment for data analysis, visualisation, programming and algorithm development
- Drishti – Volume exploration and presentation tool of the µCT data



APPLICATION EXAMPLES

- Mechanical-, Material-, Electrical- and Civil Engineering. Development, Trouble shooting & Reverse Engineering, Quality and inner/outer Shape Control of components from plastics, ceramics, light metal castings, wood, etc.
- Food industry (counting the number of bone fragments in meat products), medicine (study of bones or implants), archaeology (museum artefacts, ancient violins), anthropology, restoration etc.
- Forensic sciences and legal engineering, criminology, etc. (in a wide range of applications focused on non-destructive investigation of the inner / outer structure and damage of both materials & dimensions.
- Composites and nano-composites (carbon fibers reinforced materials or glass fibers reinforced plastics).
- Study of biological materials, bio-materials and soft tissue (biodegradable collagen scaffolds, cells, mouse embryos).

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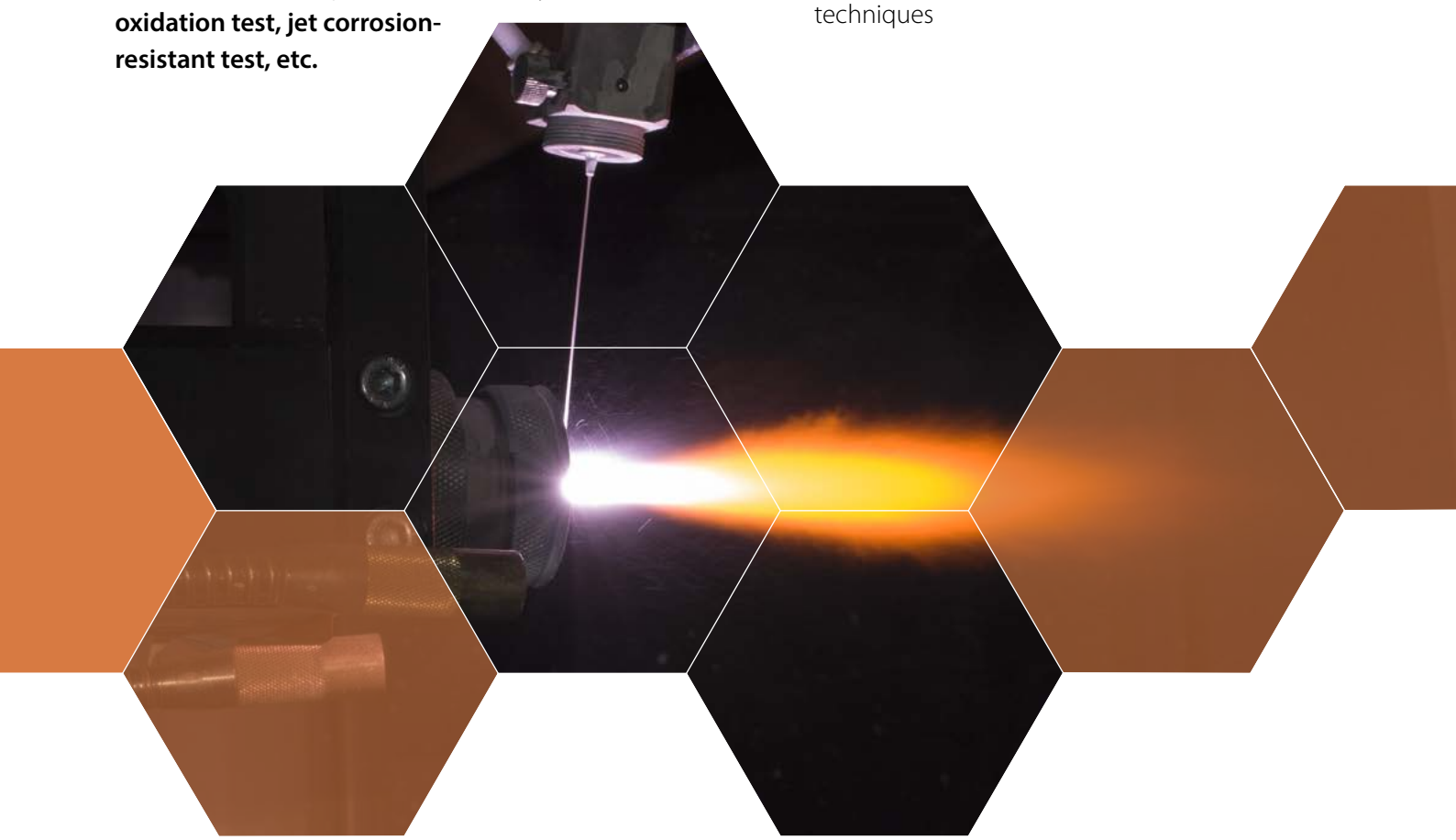
ADVANCED COATINGS

CHARACTERISTIC

Advanced Coatings (AC) as a part of the Research Group 1-06 is focusing on processing, research and development of high performance powders, materials and coatings for aerospace, automotive, power generation energetics and medical treatments. As an example the high temperature coatings, the cavitation resistant coatings and the wear resistant coatings produced by means of air spraying, thermal spraying or electro-chemical methods can be mentioned. The members of the research group coming from materials science and engineering, physics, chemistry and computational science branches also focus on research, development and failure analyses of bulk metallic alloys, surface and interface interactions, and powder processing in close collaboration with the Industry. AC is as well responsible for development of uncommon and unconventional testing techniques like cavitation resistance testing apparatus, cyclic furnace oxidation test, jet corrosion-resistant test, etc.

GENERAL AREAS OF AC PART OF RESEARCH GROUP INTEREST

- Coatings for aerospace and automotive high temperature applications (diffusion coatings, overlay coatings, thermal barrier coatings)
- Cavitation resistant coatings and wear resistant coatings for power generation energetics
- Functional and/or decorative electro-chemical coatings
- Biodegradable metallic materials and bioactive ceramic coatings for medical treatments
- Bulk metallic alloys surface interaction studies
- Solving industrial manufacturing problems in the knowledge-based link between materials structure and processing technologies
- Powder processing technologies
- Development of unique or uncommon testing techniques



AMONG OTHERS, MOST OF ACTIVITIES RUNNING UNDER THE PROJECTS SUPPORTED BY:

- Czech Science Foundation:
  - Plasma deposition, microstructure and thermomechanical stability of environmental barrier coatings
- Ministry of Industry and Trade:
  - Research and development of processing technology of non-toxic small caliber bullets
  - Research and development of roller bearing of mixer truck gearbox
- Technology Agency of the Czech Republic:
  - Research center of surface treatments
  - Research and development of high-speed surface machining technology for hard-surface coatings manufactured by means of thermal spraying
  - Research of advanced non-ferrous lightweight alloys for engineering applications

R&D ACTIVE AREAS OF AC PART OF RESEARCH GROUP:

- Thermal spraying (flame spray – powder / wire, twin wire arc spray, atmospheric plasma spray, vacuum/low pressure plasma spray and high velocity oxyfuel spray)
- Coatings for high temperature materials (diffusion coatings, overlay coatings, thermal barrier coatings, etc.)
- High and low temperature processing of HA, CDHA, α-TCP and β-TCP robocasted scaffolds and coatings for medical treatments
- Spraying and surface finishing of ceramic or cermet coatings
- High temperature materials (nickel, cobalt and molybdenum-based superalloys)
- Nickel-based aluminides and iron-based aluminides (intermetallics)
- Modification of aluminum alloys via surface treatments and additional heat treatment (Al, $AlSi_9Cu_3$, $AlMg_3$, etc. – element interaction studies, interfaces, diffusion)
- Non-ferrous alloys (aluminum, magnesium and zinc)

PLANNED ACTIVITIES:

- Detailed studies of thermal barrier coatings, CMAS resistant coatings, cavitation resistant coatings, hydrophobic coatings, abrasive and wear resistant coatings for aerospace and power generation energetics produced by means of solid and/or liquid feedstock
- Detailed investigation on hydro machine close circuits or stands for magnetically conductive ultrafine powders production
- More detailed studies on biodegradable bulk metallic materials and bioactive ceramic coatings
- Knowledge-based studies of advanced low temperature electro-chemical processing of coatings, decorative and/or hard anodizing

LABORATORIES

A) SPRAY TECHNOLOGIES LAB (BUILD AND WORK IN THE CLOSE COLLABORATION WITH S.A.M. – METALLIZING COMPANY)

Blasting Units
- OTECO set-up from 1 to 6 atm.

APS system
- Plasma GTV MF-P-1000
- gun METCO F4MB-XL
- powder feeder GTV MF-PF-2/2

HVOF system
- GLC HVOF 05
- gun HVOF GLC

TWAS system
- Oerlikon Metco 4R

Flame system (CMAS deposition)
- Powder / Wire – Oerlikon Metco

Thermal spray monitoring unit
- TECNAR Accuraspray G3C unit (to control and set -up thermal spray parameters)

Robot
- ABB IRB 2600 + IRC5 controller

Liquid solution / paints air spray
- Automatic air guns EST+
- Automatic pre-set up pressure tanks

Powder and liquids processing
- 3D printer BCN3D+ Extruder for suspension and sol-gel robocasting
- Semi-Micro analytical balances DISCOVERY DV314C
- Mechanical overhead stirrer HEIDOLPH RZR 2021
- Magnetic stirrer HEIDOLPH MR Hei-standard
- Ultrasonic homogenization bar SONOPLUS HD 3400
- Sieve shaker AS 200 digit

Testing
- Archimedes porosity method
- Ultrasonic testing according to ASTM standards
- Abrasion/wear tests: Sand rubber wheel test, Slurry Abrasion Resistance test

B) HEAT TREATMENT AND CHEMISTRY LAB

- Furnaces up to 1350 °C
- Programmable atypical two zone heated furnace for cyclic oxidation tests (heated zones: 1200 °C / 900 °C / other zones: Air forced cooling / Ambient cooling)
- Jet / Burner-Rig test
- Chemist laboratory and equipment
- Analytical microbalances
- Control climate chamber

C) MATERIALS SCIENCE LAB

- Metallography (STRUERS cutting machines, presses, grinding/polishing units)
- Microscope (OLYMPUS opto-digital microscope DSX 500i)

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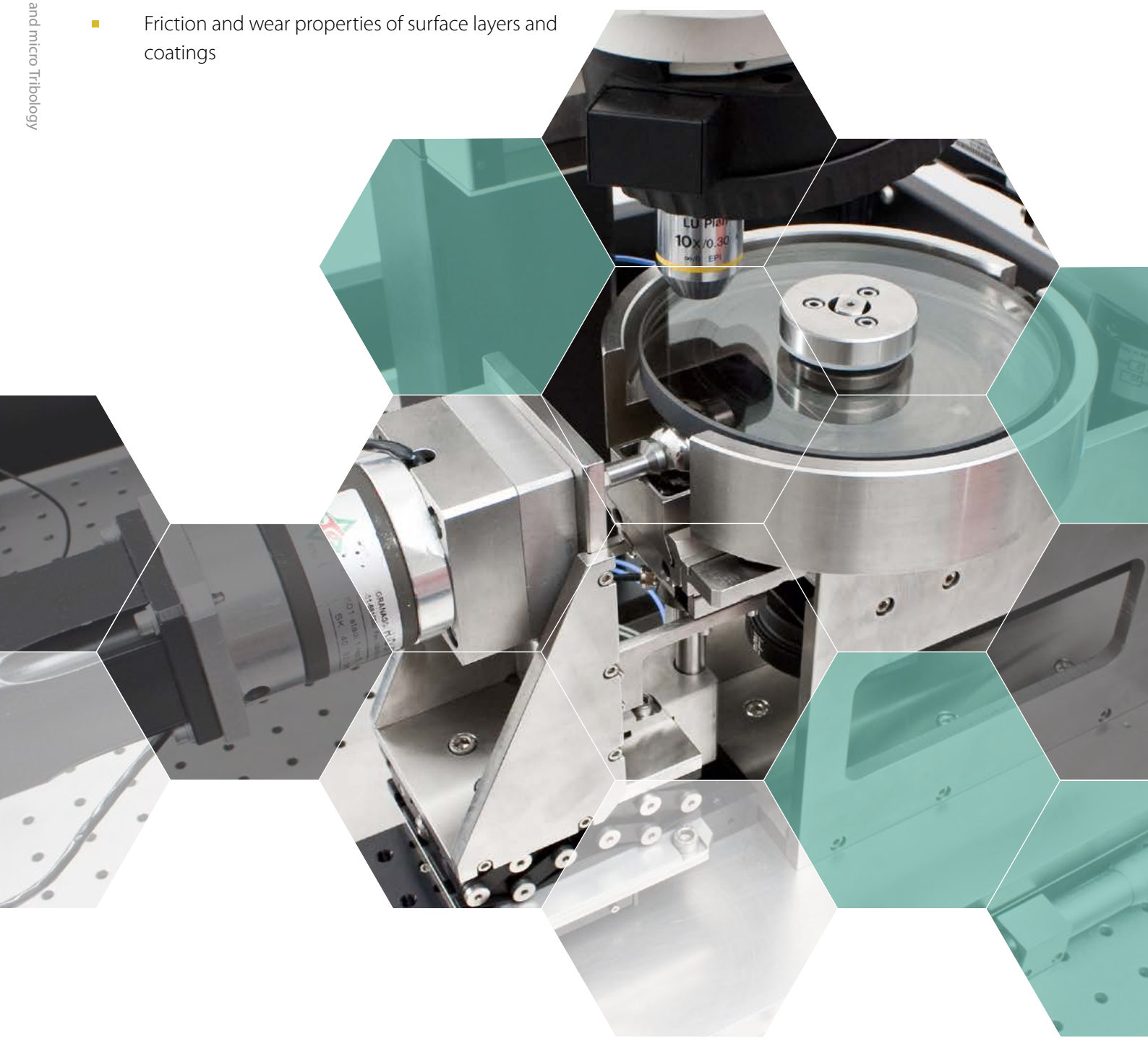
NANO AND MICRO TRIBOLOGY

RESEARCH AREAS

- Tribology – biotribology, nanotribology, surface texturing, starved lubrication, speed and load changes in elastohydrodynamic contact, oil degradation measurements, and transient behaviour of elastohydrodynamic contact
- Friction and wear properties of surface layers and coatings
- Experimental study of real roughness attenuation in rolling/sliding concentrated contacts
- Mechanical Degradation of the Liquid in an Operating EHL Contact



HISTORY OF THE LABORATORY

The Tribology Laboratory has history of more than 20 years and is recognized as a distinguished lab in specific field. A new experimental technique for the study of thin lubricant films by means of colorimetric interferometry has been developed here. This technique is able to provide real time data for thin lubricant film shape studies. The essential part of the lab is represented by an experimental apparatus for the study of elastohydrodynamic lubricant films based on a computer controlled dynamic Fizeau interferometer. Recently, a 3D optical profilometer based on phase shifting interferometry has been incorporated to measure in-situ initial undeformed real surface topography. Latest results published in scientific journals have proved the combination of thin film colorimetric interferometry with phase shifting interferometry to be one of the most powerful tools for the investigation of mixed lubrication of real surfaces in situ.

This laboratory enables practice verification experiments to be performed in precisely known conditions and ensure true and repeatable results. About 80 percent of machines are disabled as a result of the damage of thin surface layers caused, among other things, by the local breakdown of elastohydrodynamic lubrication films. It is in the close relation to the lubricant capability to create coherent protective film. It is mostly characterised by the film thickness dependence on operation conditions (speed, load, temperature etc.) and rubbing surfaces topography.

THE KEY EQUIPMENT

OPTICAL TRIBOMETER

Film thickness and friction measurements for highly loaded contacts between machine components. It can be used for the evaluation of lubricants and additives effects, effect of contamination, comparison of various types of lubricants etc.

Specifications:

- Contact load: 5 – 125 N
- Traction force: 0.05 – 30 N
- Rolling speed: 0.005 – 4 m/s
- Temperature: ambient to 150 °C ±1 °C

PHANTOM V710

High-Speed Camera

The high speed camera provides a record of the process or object that is moving very fast or when the process leads to very rapid changes.

Specifications:

- Max speed at full resolution of 1280 x 800 is 7530 fps
- Minimum exposure1 µs (optional 300 ns), 20 µm pixel size.

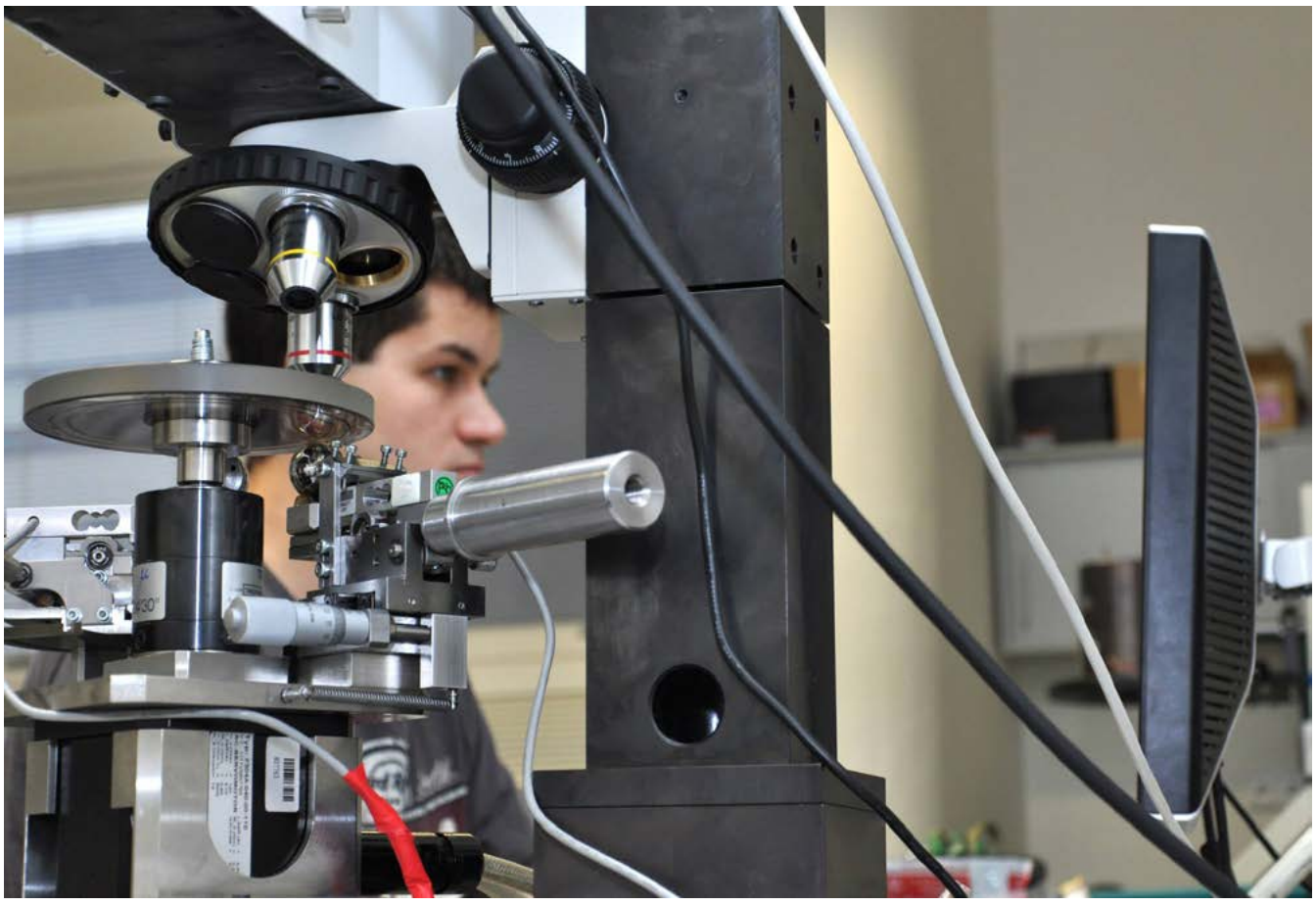
BRUKER CONTOURGT-X8

Non-Contact 3D Optical Profiler

The ContourGT-X8 provides the highest speed, accuracy, and range for 3D, non-contact surface measurement of ophthalmic lenses, medical devices and tools, high-brightness LEDs, semiconductor devices, through-silicon vias and trenches, solar cells, and precision machined parts.

Specifications:

- Magnifications from 0.5X to 200X enable characterization of a wide range of surface shapes and textures, sub-angstrom-to-millimeter vertical range.



MTM (MINI TRACTION MACHINE)

Mini Traction Machine

The Mini Traction Machine is a flexible general purpose instrument for measuring the frictional properties of lubricated and unlubricated contacts under a wide range of rolling and sliding conditions.

Specifications:

- Load from 0 to 75 N
- Contact pressure 0 – 3.1 GPa
- Velocity up to 4 m/s
- Slide-to-roll ratio from 0 to 100%
- The measuring temperature up to 150 °C
- The volume of test sample 35 ml (optionally 10 ml).

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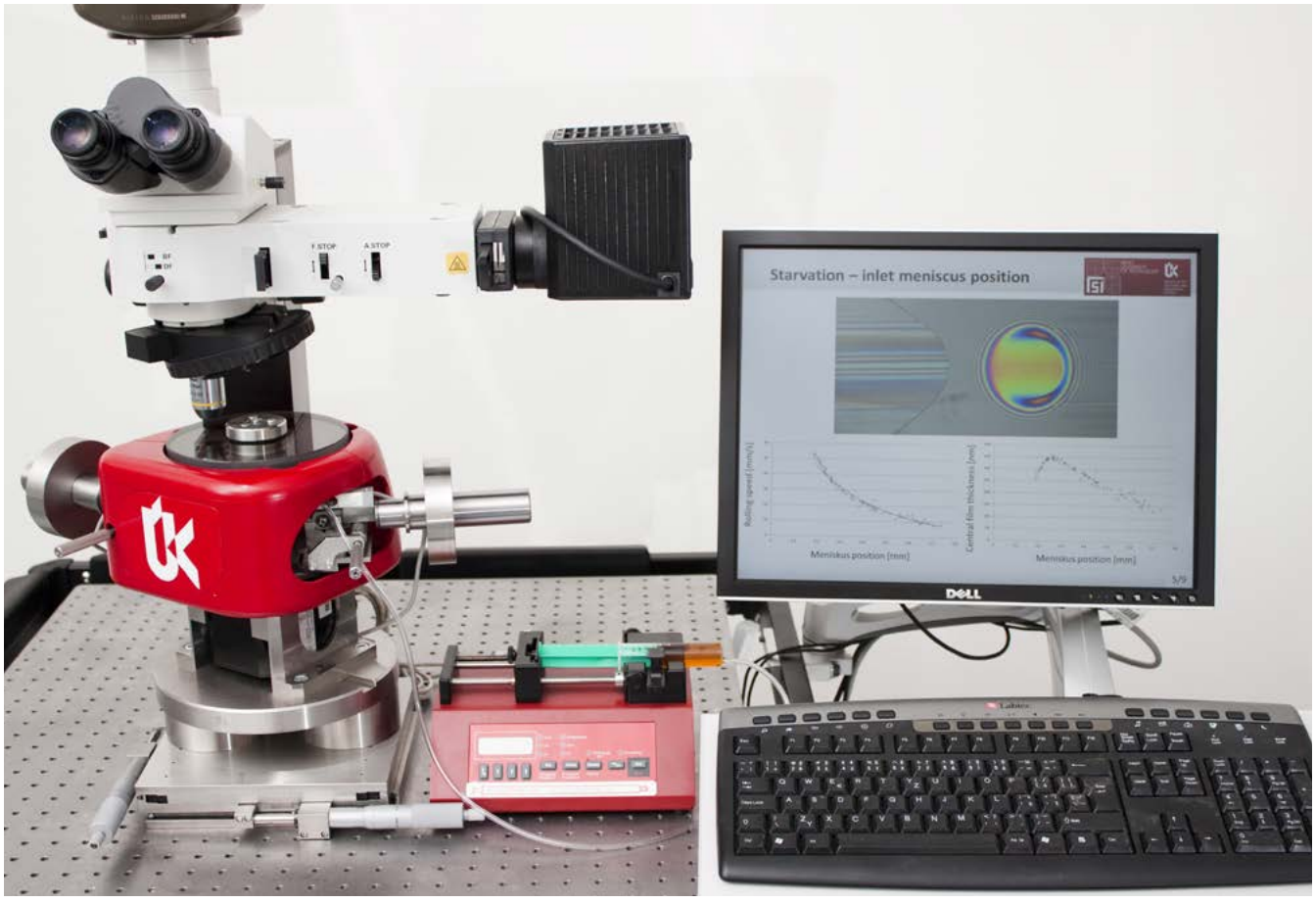
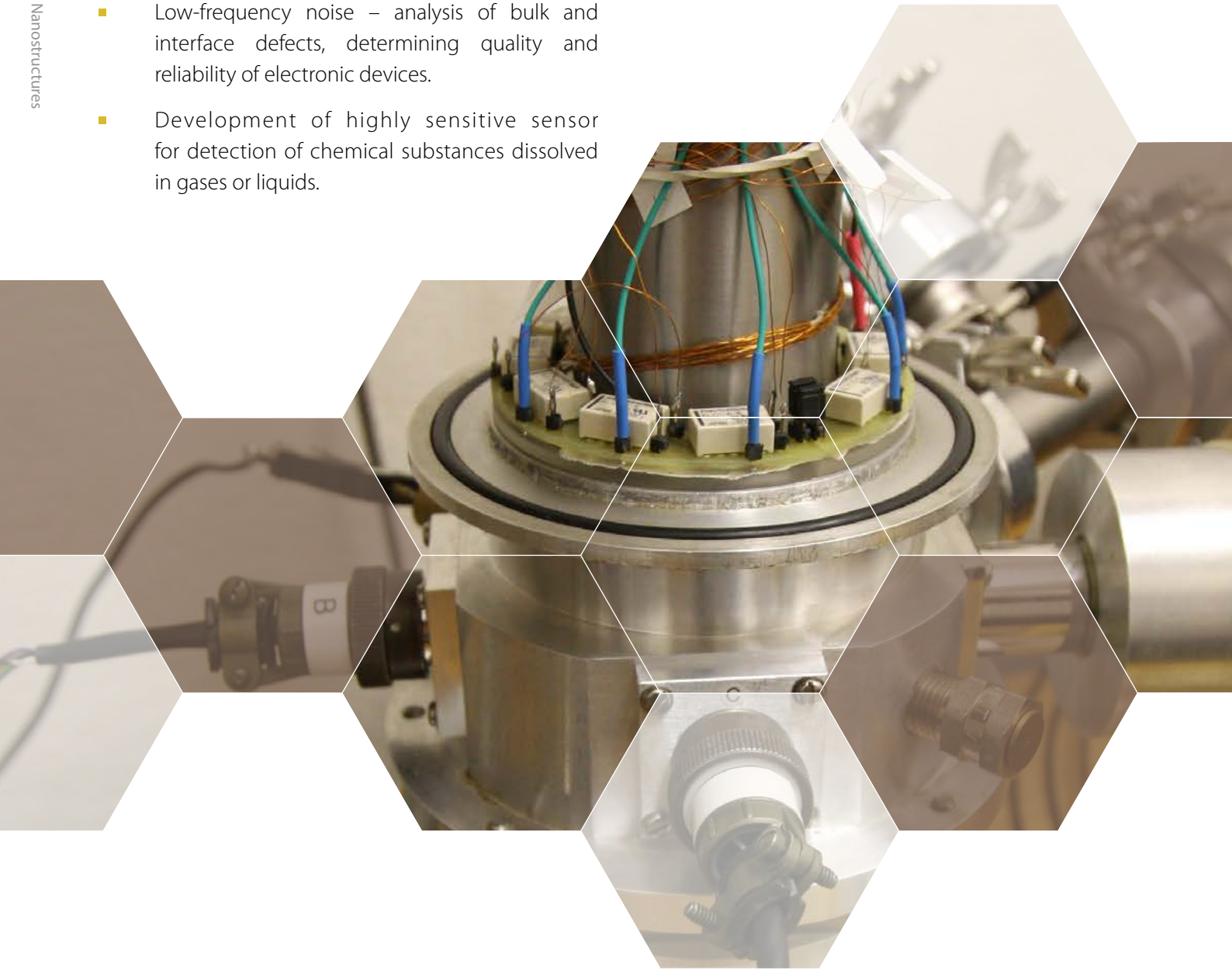


OPTOELECTRONIC CHARACTERIZATION OF NANOSTRUCTURES

AIMS OF RESEARCH

- Improvement of diagnostic methods used for testing semiconductor materials and electronic components and structures.
- Determination of the correlation between the properties and the geometrical and structural parameters of nanostructures.
- Low-frequency noise – analysis of bulk and interface defects, determining quality and reliability of electronic devices.
- Development of highly sensitive sensor for detection of chemical substances dissolved in gases or liquids.
- Application of novel diagnostic methods.
- Experimental and theoretical research of stochastic processes and charge carrier transport as a basis for new advanced technologies.



- Methods for non-destructive diagnostics of electronic components and structures.
- Investigation of material surfaces, characterization of local structure inhomogeneities.
- Electromagnetic emission in dielectrics for the monitoring of the generation and growth of cracks under mechanical load.

KEY RESEARCH EQUIPMENT

- Instruments for noise and dielectric measurements (Novocontrol Alpha-A analyzer, 10^{-5} – 10^{7} Hz)
- Scanning Electron Microscopy – Lyra FEG, FIB
- Scanning Microscope SNOM (< 40 nm) with AFM
- Optical He closed-circuit cryostat 10 K – 500 K
- Semiconductor characterization system Keithley
- Set of devices for EME and AE experiments, in particular low-noise preamplifiers and piezoelectric sensors and multichannel high-speed (10 MSPS) A/D converters
- FTIR – spectrometer Nicolet 8700
- Shared infrastructure within CEITEC core facilities Nanofabrication and Nanocharacterization

TOPICS STUDIED

ELECTRON TRANSPORT AND FLUCTUATIONS IN ELECTRONIC MATERIALS AND STRUCTURES, SUCH AS MOSFET STRUCTURE, SENSORS, SUPERCAPACITORS ETC.

- Experimental analysis of temperature dependences of the charge carrier transport and of current fluctuations will be carried out.
- Theoretical analysis of the charge capture and emission from the localized state and determination of trap parameters.
- Analysis of bulk and interface defects that determine the quality and reliability of electronic devices.

QUALITY AND RELIABILITY OF NANOSCALE OXIDE/POLYMER LAYERS FOR ELECTRONIC DEVICES

- Analysis of ion diffusion in external or internal electric fields, its impact on the quality and reliability of electronic devices as microchip sensors, electrochemical sensors, capacitors and cathode tips for autoemission of electrons into vacuum.
- Defects in oxide layers are mostly represented by oxide vacations; their concentration depends on the oxidation technology.
- Results conducted in this topic were partially used for the technology tuning in cooperation with AVX Czech Republic, Ltd., and Delong Instruments.

CARBON NANO-TUBES AND NANO-PARTICLES USED IN SUPER CAPACITORS

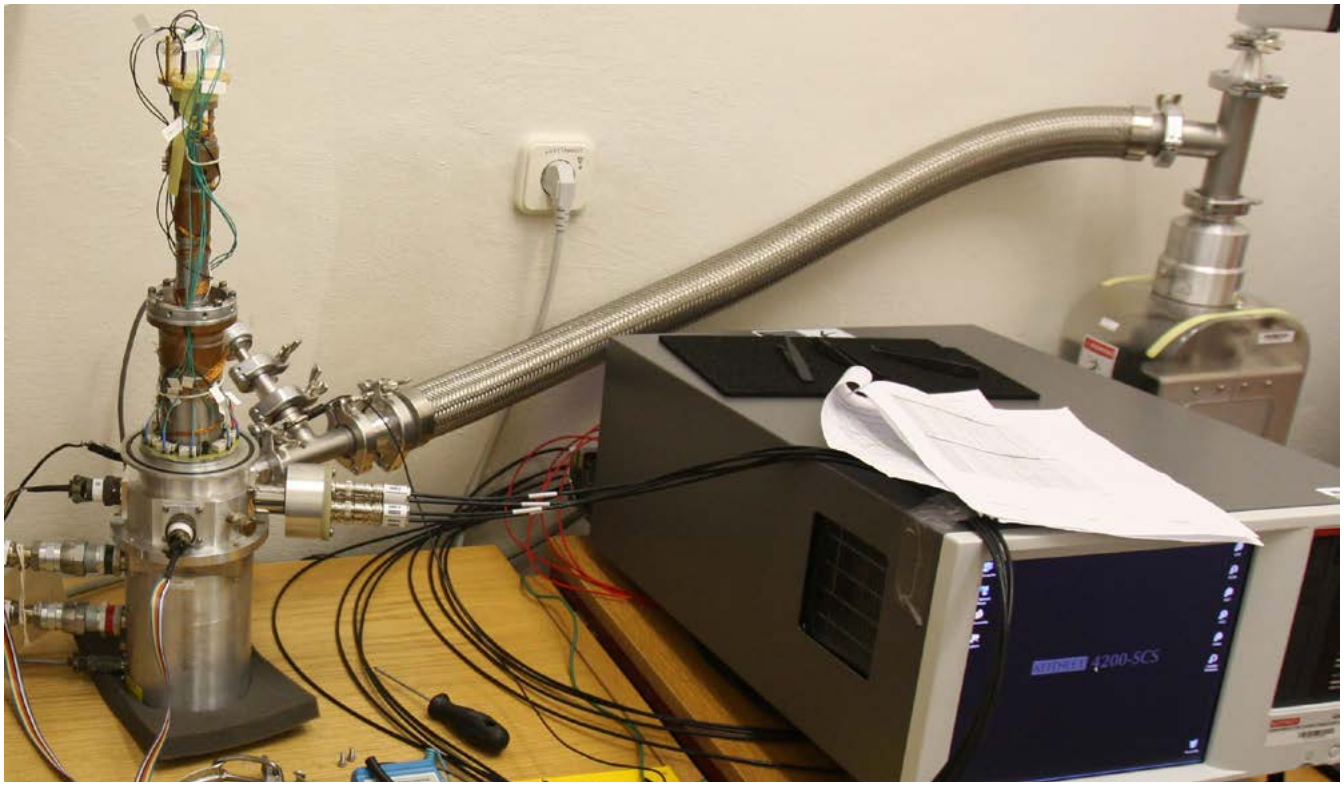
- Charge carrier storage on the electrodes and in deep localized states will be analyzed in order to show the correlation between energy stored in the capacitor and the dynamics of the super capacitor charging/discharging.
- Irreversible processes leading to the degradation.
- Optimization of the super capacitor energy density with respect to the maintenance of the quality and reliability.
- Research results were applied for evaluation of super capacitors within the research project of the European Space Agency (ESA) "ARTES 5.1" in 2014.

MICROSCOPIC CHARACTERIZATION AND OPTOELECTRONIC DEVICE TESTING

- Testing of optoelectronic devices using electroluminescence, noise spectroscopy and termography
- Nanometrology on bulk materials with nano-structures, nanomaterials and nano-composites. Microscopic characterization and contrast mapping of different physical quantities.
- Focused Ion Beam nanofabrication

DIELECTRIC SPECTROSCOPY OF MATERIALS IN ELECTRONICS

- Nanocomposites for electrical insulations.
- Addition of nanoparticles to epoxy resins increases their ability to withstand higher voltages and thus allows the reduction of insulation thickness.
- Giant-permittivity calcium copper titanates ($CaCu_3Ti_4O_{12}$, CCTOs) with pseudo-perovskite structure for high-C capacitors.
- Research of electrical properties of CCTO-based ceramics doped with transition metals and lanthanides, focused toward the identification of the mechanism leading to their high dielectric constant.



SUBGROUPS

DIELECTRIC RELAXATION SPECTROSCOPY

This method measures electric response of a material under study to electric fields with frequencies from 100μHz to 1 GHz under different temperatures, pressures, moisture levels, concentrations etc.

Dielectric relaxation spectroscopy yields information about the dielectric response of a material under study to electric fields with frequencies from 100μHz to 1 GHz under different temperatures, pressures, moisture levels, concentrations etc. The main information delivered by the DRS is both permittivity (dielectric constant) and dielectric losses (loss number and loss factor) as functions of frequency and temperature. From these parameters, further evidence can be obtained, as e.g. relaxation plot (activation diagram), characteristics of observed relaxations, their cooperativity, existing steric hindrances to the reorientation of molecules, associated activation energies and characteristic frequencies (eigenfrequencies). Generally, the information provided by DRS, is related to molecular dynamics of charges and dipoles within the structure under study.

The equipment currently available in the Department of Physics includes the helium closed-cycle CCS-400/204 cryostat by Janis Research with specifically designed cold head allowing the connection of various structures and devices with dimensions not exceeding 25 mm in diameter. This cryostat allows dielectric measurements in the temperature range 20 K – 500 K.

- Agilent (formerly Hewlett-Packard) impedance analyzers HP 4284A, HP 4285A, E 4991A and E 4980A with the necessary equipment,
- Novocontrol AT-A analyzer
- the total frequency range of the measuring equipment is 10^{-3} – 10^{9} Hz,
- Keithley 617 series electrometers with 10 – 17 A resolution,
- two cryostats – the ISI liquid nitrogen cryostat and the Janis closed-cycle CCS-400/ 204 helium cryostat, the total temperature range is 10 K – 450 K,
- a constant climate chamber Binder KMF 115 for stress testing with temperature range -10 °C/ 10 °C to 100 °C/90 °C (without/with humidity) and with humidity range 10 % to 90 %,
- muffle furnace/oven by BMT Brno with the temperature range 20 °C – 900 °C.
- FTIR spectroscopy (Nicolet 8700, 7800 – 350 cm^{-1}, optical resolution 0.09 cm^{-1}),

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NOISE AND ELECTRICAL CHARACTERIZATION OF ELECTRONIC MATERIALS AND STRUCTURES

Experimental and theoretical research of stochastic processes and charge carrier transport is a basis for new advanced technologies, for a further development of non-destructive diagnostics and advanced methods for the estimation of the lifetime of electronic components and structures.

The laboratory offers:

- Evaluation of quality and reliability of electronic materials and structures, such as supercapacitors, capacitors, electrochemical sensors, piezoresistive sensors, etc.
- Modelling of time and voltage characteristics, and temperature dependencies.
- Development of physical models or simplified equivalent-circuit models for end-users applications.
- Design of appropriate quality indicators for the manufacturing process.
- Development of new methods and new instruments for material characterizations.
- Accelerated aging (such as calendar tests, thermal ageing) and on-line evaluation of selected electrical characteristics of structures.

Experience and Equipment

The subgroup has long-term experiences in analyses of electronic components and estimation of their reliability. Our research team is based on mutual cooperation of perspective junior researchers and experienced senior scientists, who have been working in their research fields for decades. The laboratory is equipped by advance instrumentation available for noise spectroscopy, where key devices are

- Keithley 4200 – Semiconductor Characterization System for I-V measurements,
- HP/Agilent instruments for electrical impedance measurements,
- equipment for temperature measurement, such as temperature chambers, helium cryostat (Janis) and nitrogen cryostats, climatic chamber, and
- accessories, e.g. low-noise preamplifiers and amplifiers, digitizers, Faraday cages, etc.

The subgroup maintains a close cooperation with key European and Japanese laboratories; participates in EU programs and has its own PhD students. The laboratory is currently involved in several domestic and international research projects.

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OPTOELECTRONIC AND MICROSCOPIC CHARACTERIZATION OF STRUCTURES

Research of the subgroup is focused on the investigation and application of advanced characterization and diagnostic methods. These methods are based on the monitoring of transport and fluctuation processes in materials and electronic components, measuring of their optical response to external excitation, the use of Atomic force microscopy (AFM), Near-field scanning optical microscopy (SNOM) and Scanning electron microscopy (SEM).

Characteristics

- Basic characterization of semiconductor materials and electronic components in temperature range 10 K – 400 K by using wide spectrum of laboratory equipment (analyzer Agilent E4991, signal analyzer Agilent 35670A, semiconductor characterization system Keithley 4200, impedance analyzers, etc).
- Local optical and electrical characterization of optoelectronic structures with lateral resolution better than 250 nm (topography, local changes of material properties, local photocurrent, photoluminescence, electroluminescence).
- Characterization of passive electronic components in temperature range of 10 K – 400 K.
- Measurement of the surface potential distribution.
- Experimental evaluation of semiconductor devices parameters: charge carrier concentration, minority carrier lifetime, PN junction type, diffusion potential, width of the depletion zone, barrier capacity, etc.
- Diagnostics of structure quality (local and bulk defects, contacts) and study of structural parameters in room-temperature conditions and in extreme thermal conditions.
- Diagnostics of micro-cracks creation in non-conductive materials and electronic components in laboratory conditions (at predefined thermal or mechanical loading) or operational conditions by using of electromagnetic emission and acoustic emission.
- Formulation of physical models of electronic components or sensors to optimize their parameters.
- Development of new methods and new instruments for structures characterization.

Equipment

- Probe station Cascade Microtech M150 for micro-scale electrical measurement.
- Keithley 4200 parametric semiconductor analyzer (4 × SMU, CMU and PMU).
- National Instruments PXI system equipped for fine current-voltage characteristics measurement and real-time data acquisition.
- Noise spectrum analyzers: Dynamic FFT analyzer (DC – 100 kHz) Agilent 35670A, Base-band analyzer Rohde & Schwarz FMU36 (DC – 36 MHz) and high frequency analyzer Rhode & Schwarz FSV (100 kHz – 3.6 GHz).
- High sensitivity optical detector for near ultraviolet region (cooled PMT) for study of defects optical activity.
- Astronomy CCD camera cooled down to – 50 °C for visible optical region.
- Infra-red camera for study of samples thermal properties.
- Modular microscopes NT-MDT Solaris (SNOM, AFM) and Tescan SEM FIB.

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