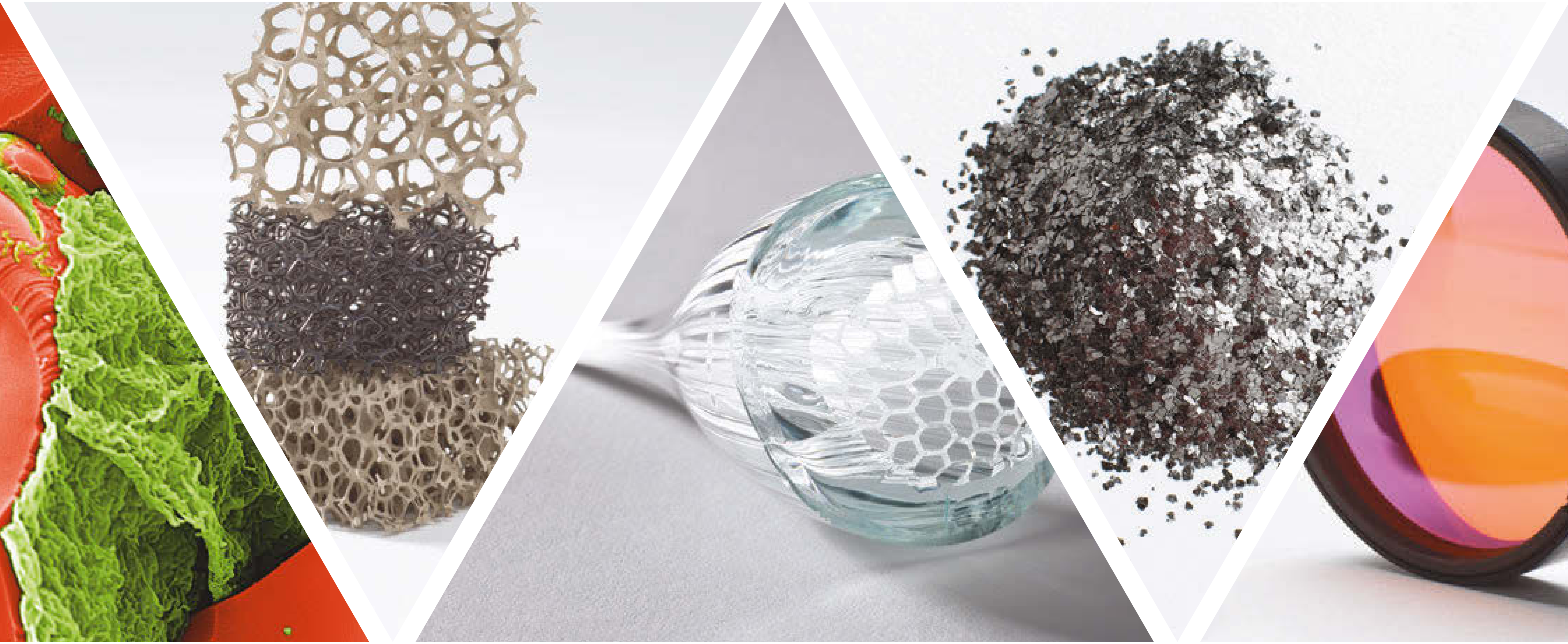
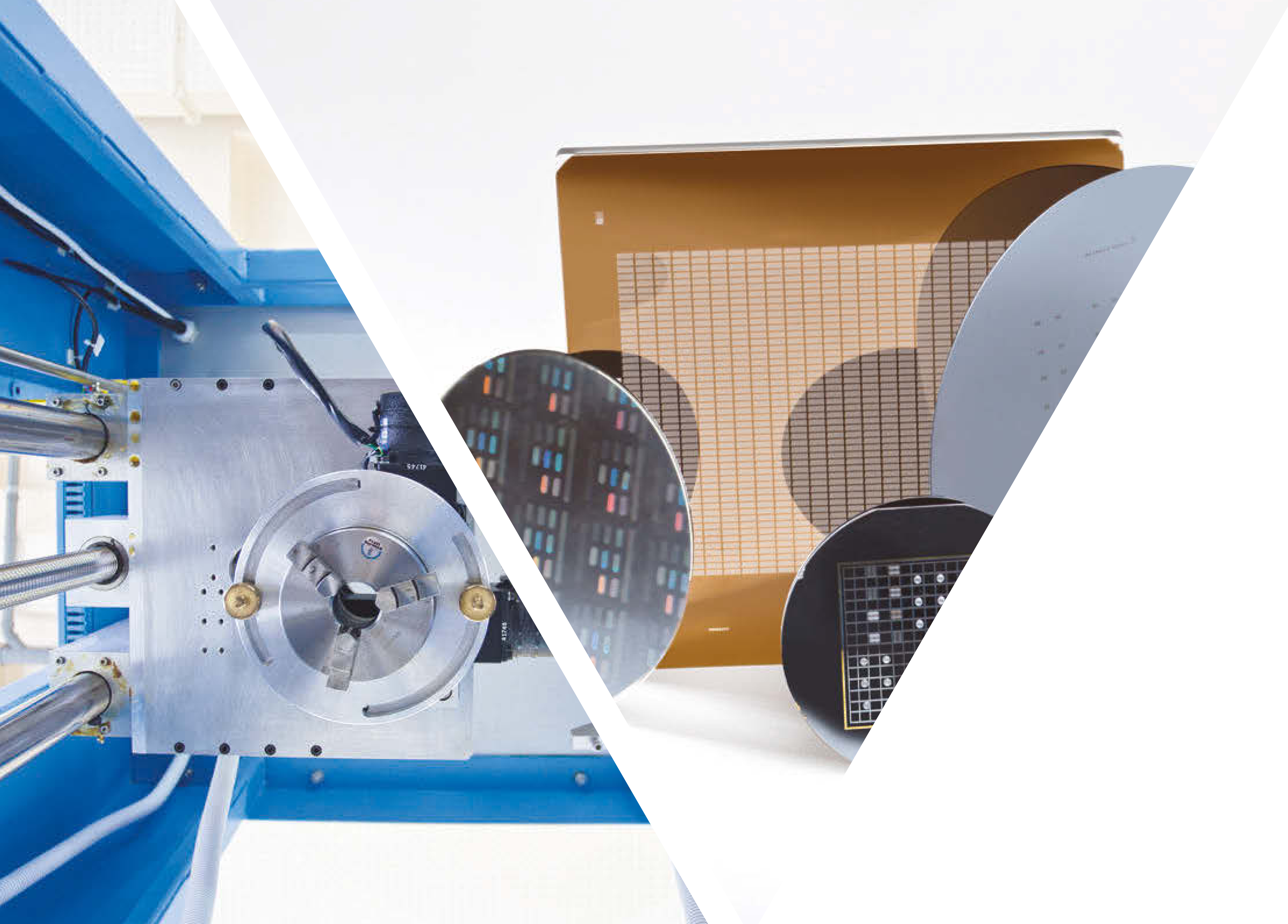
Institute of Electronic Materials Technology





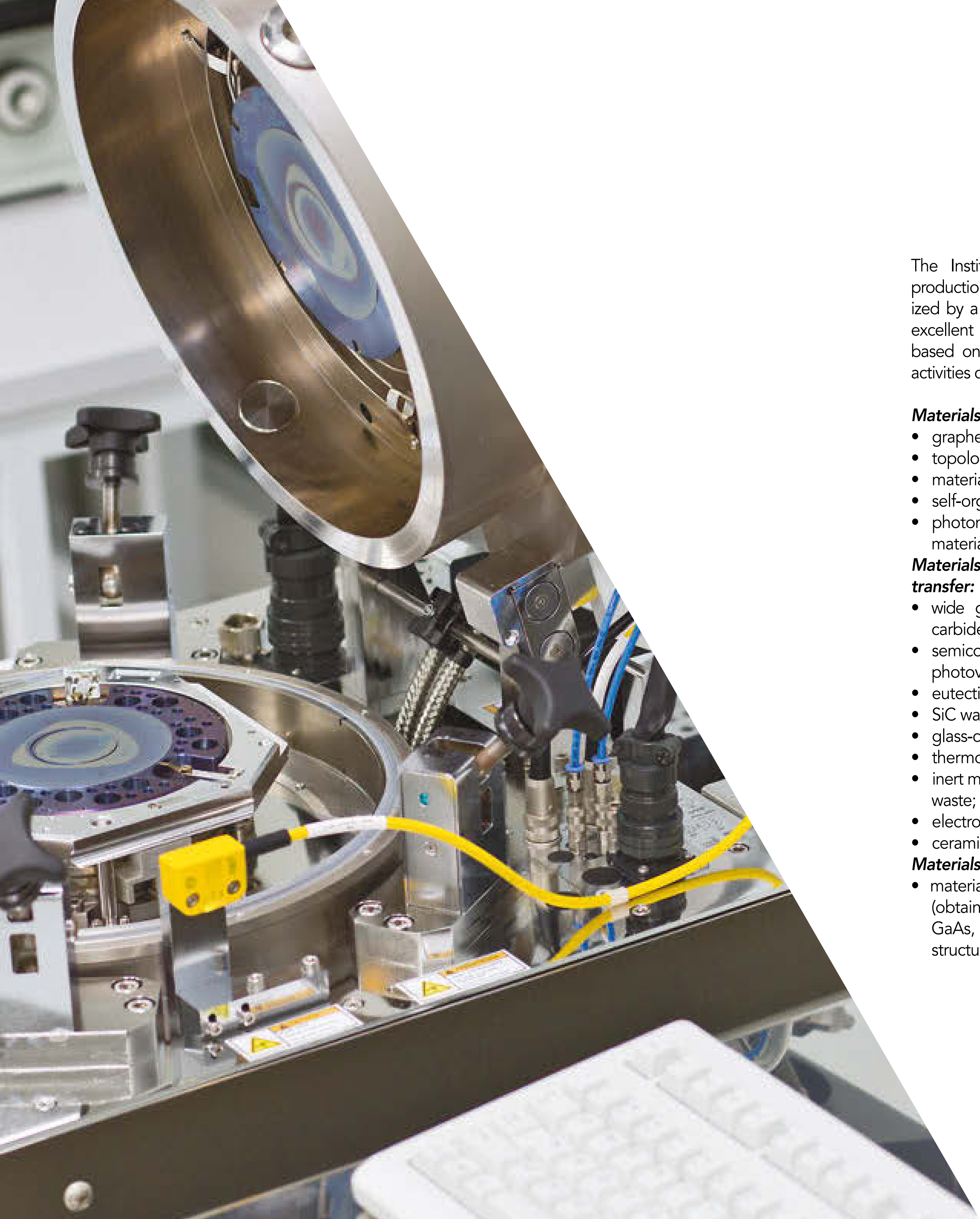
Institute of Electronic Materials Technology

Founded in the early seventies of the twentieth century, the Institute of Electronic Materials Technology (ITME) with about 300 employees is a research, development and consultative institution offering a unique combination of scientific and technological capabilities. The Institute of Electronic Materials Technology is recognized for its comprehensive and interdisciplinary research in the field of materials engineering, electronics, photonics, optoelectronics, environmental engineering, chemical technology and nanotechnology.

Our research in the field of materials engineering is carried out on advanced and innovative new generation materials, including two-dimensional materials such as graphene. Technologies for producing new materials are being developed and properties of the materials are being tested, as well as their applications in power industry, electronics, photonics, aerospace, automotive and other sectors.

The ITME achievements place it among the best research and development institutions that successfully carry out innovative research in many fields related to new technology. Scientists cooperate with a great number of national and foreign universities, institutes, research and development centres and major electronic industries all over the globe. The Institute provides its research and technological services to industries and other scientific institutions.

Please visit our website for more information: www.itme.edu.pl



The Institute develops advanced innovative production technologies of materials characterized by a perfect crystallographic structure and excellent properties, as well as components based on these materials. The scope of R&D activities carried out covers the following areas:

Materials for next-generation components:

- graphene;
- topological insulators;
- materials for spintronics;
- self-organising materials;
- photonic crystals, including plasmonic materials and metamaterials.

Materials for energy generation, storage and transfer:

- wide gap semiconductors, including silicon carbide for GaN HEMT transistors;
- semiconductor-doped glass optical fibres for photovoltaics;
- eutectic materials for photovoltaics;
- SiC wafers and SiC epitaxial layers;
- glass-ceramic seals for fuel cells;
- thermoelectric materials;
- inert matrices for a safe storage of radioactive waste;
- electrode materials for lithium ion batteries;
- ceramic-metal composites and FGMs.

Materials for photonics:

- materials for III-V based semiconductor lasers (obtained using GaAsP, InGaP, AlGaAs, GaAs, GaSb and InP), wafers, epitaxial structures;
- GaN-based epitaxial structures;
- materials for solid state lasers, produced using strontium-calcium niobate;
- infrared photodetectors and UV photodetectors;
- oxide crystals for lasers, passive Q modulators, scintillators, electro-optical and piezoelectric devices, substrates for superconducting HTSc layers;
- glass and ceramics with carefully designed spectral characteristics, including transparent ceramics;
- diffractive optical elements and microlenses;
- nanostructured thin layers;
- luminescent nanopowders and nanocrystals;
- optical fibres and waveguides, including active and photonic fibres.

Materials for electronics:

- silicon monocrystals (standard Si wafers and Si wafers with special properties);
- porous silicon;
- silicon foils;
- epitaxial layers on silicon;
- SiC wafers and SiC epitaxial layers;
- nanopowders and polymer-based powders, pastes and inks for printed electronics;
- photosensitive pastes;
- piezoelectric crystals;
- ceramic-metal composites;
- super-pure metals.

Components:
ITME has elaborated a great number of innovative electronic components based on the manufactured materials, for instance:

- optical fibres (active and photonic), filters, diffractive lenses, two-dimensional photonic microstructures;
- passive elements on membranes (sensors);
- filters, resonators, sensors and actuators based on surface acoustic waves;
- semiconductor devices (lasers, transistors, photodetectors, Schottky diodes);
- solid state lasers and microlasers.

The manufacture of state of the art components is possible at ITME due to high-tech equipment enabling:

- design and manufacture of masks;
- deposition of dielectric thin films (SiO_2, Si_3N_4, AlN);
- multilayer metallization;
- use of lithography: contact printing using deep UV, electron beam pattern generation;
- application of various etching techniques, including reactive ion etching and controlled sidewall etching.

Advanced m thods of material properties investigation:
The characterization of materials is performed at ITME by the following methods:

- standard chemical analysis and spectral instrumental methods (flame atomic emission spectrometry, atomic absorption spectroscopy, ultraviolet to far-infrared spectroscopy);
- Mössbauer spectroscopy (conventional, conversion electron method, X radiation method and unique "rfMössbauer" method developed at ITME);
- X-ray powder diffraction using the Rietveld method, High Resolution X-ray diffraction, X-ray reflectometry and X-ray diffraction topography;
- scanning electron microscopy and a method based on synchrotron radiation;
- electron paramagnetic resonance;
- atomic force microscopy;
- standard thermal methods (high-temperature microscopy, thermogravimetry, differential thermal analysis, dilatometry, etc.) and X-ray methods;
- mechanical methods (testing resistance, friction, hardness, etc.);
- optical methods (microscopy, absorption, reflectometry).

Methods of electronic and photonic components investigation:
ITME tests optoelectronic, microelectronic and piezoelectric devices, using special techniques enabling the characterization of components, including:

- I-V and C-V measurements;
- deep level transient spectroscopy;
- impedance measurements and the measurements of scattering matrix elements up to the frequency of 20 GHz;
- noise measurements;
- analysis of operational parametres of lasers and photodetectors.


ELEKTRONICZNYCH

ITME Departments	*Telephone number:*
Laboratory of High-Purity Materials Characterization	(+48 22) 639-55-40
Department of Microstructural Research	(+48 22) 639-55-15
Department of Ceramic-Metal Composites and Joints	(+48 22) 639-58-15
Department of Ceramics	(+48 22) 639-55-54
Department of Silicon Technology	(+48 22) 639-55-11
Department of Optoelectronics	(+48 22) 639-55-04
Department of Chemical Technologies	(+48 22) 639-58-52
Department of Glass	(+48 22) 639-59-05
Department of Epitaxy	(+48 22) 639-55-88
Department of Epitaxy and Characterization	(+48 22) 639-58-36
Department of Thick-Film Materials	(+48 22) 639-58-57
Department of Functional Materials	(+48 22) 639-56-02
Department of Applications of $A^{III}B^{V}$ Materials	(+48 22) 639-58-17
Department of Piezoelectronics	(+48 22) 639-55-13

Laboratory of Characterization of High-Purity Materials

The Laboratory provides the following services:

- trace analysis of high-purity materials (metals, oxides, nitrides),
- analysis of rare earth elements,
- analysis of:
  - ✓ materials for piezoelectronics: $LiNbO_3$, $LiTaO_3$, $LiB4O_7$, quartz; $GdCa_4O(BO_3)_3$: Nd,Yb,Eu,Pr,Tm; $NdCa_4O(BO_3)_3$; $LaCa_4O(BO_3)$,
  - ✓ materials for optoelectronics: $LiNbO_3$, BaB_2O_4, $Y_4Al_2O_9$ (YAM),
  - ✓ materials for laser techniques: YAG: Nd,Er,Ho,Tm,Pr,Cr,Mg,Yb; $Yb_3Al_5O_{12}$ (YbAG):Er; YVO_4:Ho,Yb,Er,Tm; $La_3Lu_2Ga_3O_{12}$:Cr; $Sr_3Y(BO)_3$ (BOYS):Yb; $Sr_xBa_{1-x}Nb_2O_6$ (SBN):Ce; $Ca_xBa_{1-x}Nb_2O_6$ (CBN),
  - ✓ materials for aluminate scintillators: $LuAlO_3$ (LuAP):Pr,Cr,Mo; $PrLaAlO_3$; $LaAlO_3$,
  - ✓ superconductivity materials: $SrLaAlO_4$, $SrLaGaO_4$, $SrLaGa_3O_7$:Ho; $NdGaO_3$:Y,
  - ✓ materials for epitaxial substrates: GaN, GaAs, GaSb, InP,
  - ✓ materials for nuclear waste immobilisation: $CaMoO_4$:RE,
  - ✓ different kinds of optical and technical glasses,
  - ✓ materials for optics: CaF_2, BaF_2, LiF, $LiYF_4$: Pr,Ho,Tm,Pr,
  - ✓ complex alloys such as: $AgCu_{28}$; AgCuZn, $AgSnO_2$; WCu_{25}; WCuSb; WCuAgNi; WAgSb; WAg_{25}; AgCuNi; CuZn; SnIn; AgNi; PbSnAg; AgCuPd; SnP; AgPt; $AuGe_{12}$; AuIn; AuSb,
- analysis of ceramics, spinels such as $MgAl_2O_4$,
- analysis of water and wastewater, environmental materials, air,
- analysis of Cr VI in passivated zinc coatings.

The Laboratory designs and elaborates analytical methods which are well-suited to environment protection needs.

The Laboratory operates in conformance with the PN-EN ISO/IEC 17025 standard.

The Laboratory was accredited by the Polish Centre for Accreditation (CERTIFICATE OF ACCREDITATION No AB267).

The Laboratory carries out all analyses using classical chemistry and the following modern instrumental techniques: ICP-OES, UV-VIS, FAAS, GFAAS

Scope of accreditation

Material	Trace elements
Water and wastewater	Cr, Cu, Pb, Zn, Cd, Fe, Na, K, As, Mn, Ni, Mg (0,10 ÷ 1000 mg/l)
Air in the workplace	HCl (1,25 ÷ 12,5 mg/m³) PH_3 (0,05 ÷ 0,92 mg/m³) NO_2 (0,2÷ 2,8 mg/m³)
Passivated zinc coatings	Cr (VI) (0,02 ÷ 0,20 µg/cm²)


POLSKIE CENTRUM AKREDYTACJI
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PCA
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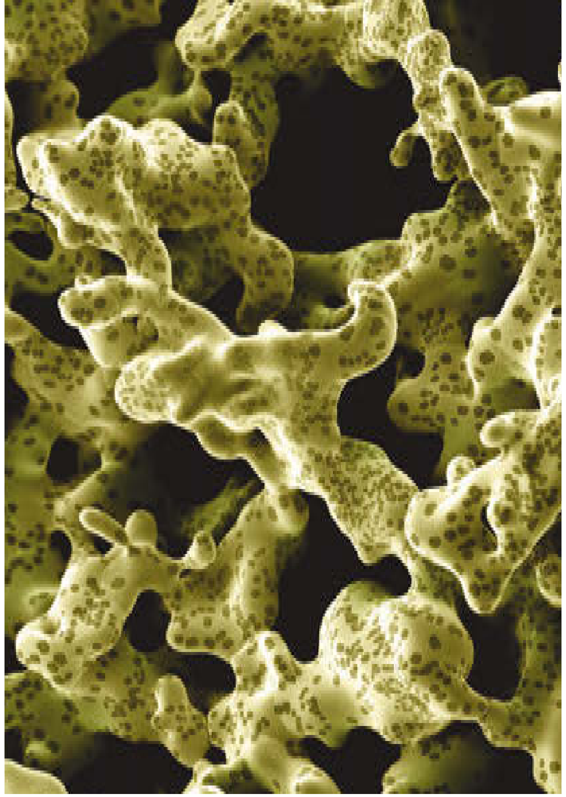
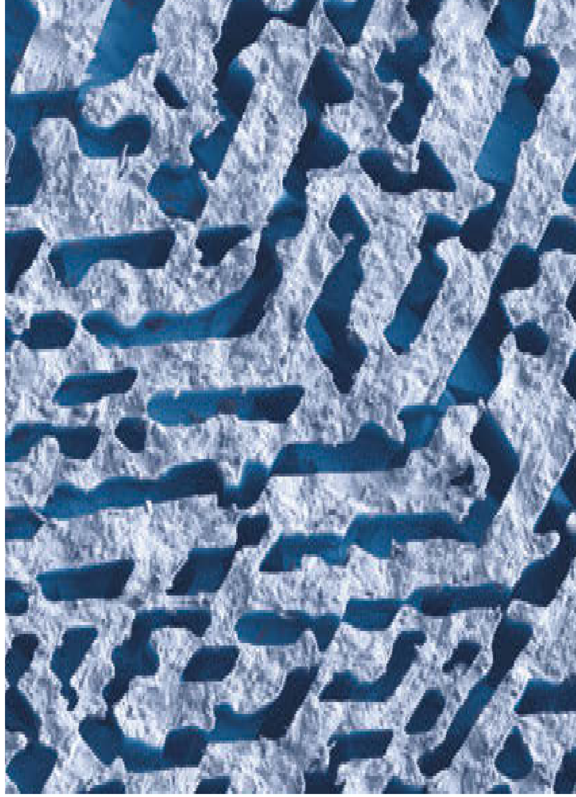
CERTYFIKAT AKREDYTACJI
LABORATORIUM BADAWCZEGO
ACCREDITATION CERTIFICATE OF TESTING LABORATORY
Nr AB 267
Potwierdza się, że: / This is to confirm that:
INSTYTUT TECHNOLOGII MATERIAŁÓW ELEKTRONICZNYCH
LABORATORIUM CHARAKTERYZACJI MATERIAŁÓW WYSOKIEJ CZYSTOŚCI
ul. Wólczyńska 133, 01-919 Warszawa
spełnia wymagania normy PN-EN ISO/IEC 17025:2005
Akredytowana działalność jest określona w Zakresie Akredytacji Nr AB 267
Akredytacja pozostaje w mocy pod warunkiem przestrzegania wymagań jednostki akredytującej określonych w kontrakcie Nr AB 267
Certyfikat akredytacji ważny do dnia 10.03.2019 r.
Akredytacji udzielono dnia 31.12.1999 r.
DYREKTOR POLSKIEGO CENTRUM AKREDYTACJI
Warszawa, 22 stycznia 2015 roku

Department of Microstructural Research

The Department carries out basic and applied research in the field of materials science.
Currently, we focus on the development of new analytical methods of materials and modification of these materials using ion beam techniques for improvement of their structural and functional properties.

In particular, we specialize in:

- analysis of materials surface using Scanning Electron Microscopy including: EDS, EBSD, CL, FIB,
- materials research using advanced X-ray diffraction characterization methods including:
  - ✓ phase analysis using X-ray powder diffraction methods, structure analysis using the Rietveld method,
  - ✓ X-ray diffraction topography,
  - ✓ HRXRD analysis of crystalline layers and structures,
- development of numerical methods for analysis of X-ray diffraction data,
- development of methods of ion beam modification of materials,
- analysis of accumulation of radiation defects in materials used in nuclear engineering,
- studies of functional properties of irradiated polymers,
- analysis of friction and wear properties of surface layers of various materias.

The Department also offers services in the field of:

- study of material microstructures,
- ion implantation in materials.

The research work of our Department has gained worldwide recognition. Its researchers participate in different EU programs and realize numerous NCN and NCBiR projects.

Department of Ceramic-Metal Composites and Joints

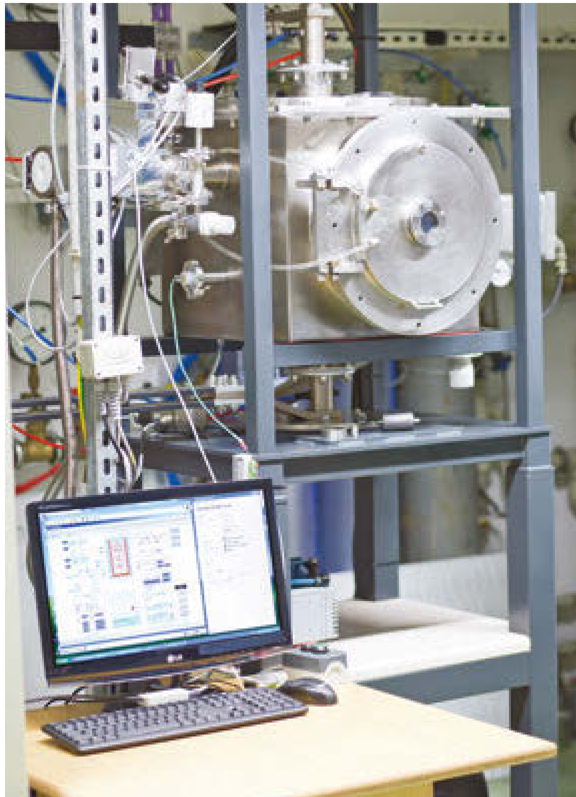
The main research field of the Department of Ceramic-Metal Composites and Joints is the development of the technology of composite materials, functionally graded materials (FGMs) and the joints of advanced materials. The research work carried out at the Department includes both the fabrication and characterization of composite materials, with a particular focus on physical and chemical phenomena that accompany the processes of their fabrication.

Our research focuses on the following materials:

- metal-metal composites (metallic matrix + metal fibres, metallic matrix + metal particles e.g. Cu-W, Ag-W),
- metal-ceramic composites (metallic matrix reinforced with ceramic or carbon fibres, metallic matrix reinforced with ceramic particles - $Cu\text{-}C_f$, Cu-SiC, Cu-AlN, $Cr\text{-}Re\text{-}Al_2O_3$, $Mo\text{-}Al_2O_3$, $NiAl\text{-}Al_2O_3$, $Cu\text{-}Al_2O_3$),
- gradient-type ceramic-metal composites.

Another area of the Department's activity are materials for energy conversion (TE – thermoelectric materials). The research is focused on the following two basic groups of materials: skutterudites and tellurides (antimony and bismuth).
Our additional area of focus is development of technology of joining composite materials with other materials.
The Department also carries out research works concentrated on joining various electro-insulating materials (corundum-, nitride- and carbide ceramics, glasses) with metals (copper, molybdenum, FeNi alloys, steels); the outcome joints are intended for vacuum, electronic, nuclear and power applications.
In our technology, the vacuum-tight electro-insulating current and voltage bushings are brazed using low-temperature and high-temperature brazing alloys chiefly made of silver and copper depending on the installation and exploitation conditions of the joints.
We also produce metallic layers on various ceramic substrates or special layered substrates of the copper-alumina-copper type using the Copper Direct Bonding (CDB) technique, and materials intended for surface assemblage.

The Department of Ceramic-Metal Composites and Joints also offers research, implementation and service works concerning the fabrication of alloys and metal sinters, including those designed for electric contacts. The composite materials intended for electric contacts are fabricated using the classical powder metallurgy methods or an original infiltration technology (W-Ag, W-Cu and W-CuSb composites). The metallic alloys are fabricated by the vacuum melt method.
The Department is a member of the European Virtual Institute on Knowledge-based Multifunctional Materials AISBL (KMM-VIN) (www.kmm-vin.eu).



Department of Ceramics

One of the main research areas of the Department of Ceramics is the preparation of ceramic powders with complex, controlled morphological and optical parameters. The following wet chemical methods are mainly used: co-precipitation, hydrothermal synthesis or sol-gel processes and subsequent consolidation of materials which represent specific microstructural, optical and mechanical properties.

Currently, our research is focused on developing the production processes of ceramics (including the optimization of powder fabrication, ceramics shaping and finally sintering) for optical applications. The studies concern yttria, yttrium aluminum garnet and magnesium aluminate spinel ceramics which are either undoped or doped with rare earth and/or transition metals ions. Our attention is devoted to the understanding of the relationship between processing conditions, ceramics microstructure and the final mechanical and optical properties. Due to the possibility of using ceramics in extreme conditions, we also study their mechanical, thermal and radiation resistance properties. In the Department of Ceramics we also conduct research on the preparation of ceramic materials with a controlled porosity size, the doctor-blade tape casting of ceramic foils, and the preparation and characterization of TiO_2 thin films with self-cleaning and photocatalytic properties.

Over the years a number of fabrication technologies of the following ceramics have been developed:

- luminescent powders,
- transparent ceram,
- highly porous ceramics and metal with controlled porosity size and level,
- glass and ceramic foils produced by the doctor-blade method,
- multifunctional TiO_2 thin films.

We are open to cooperation in the abovementioned areas, offering potential technology transfer and small scale production of materials designed on customer request.

Moreover, we are also able to provide the following research and technology services:

- formation and sintering of ceramic, metallic and composite materials,
- cryogenic granulation of micro- and nanopowders,
- preparation of ceramic, glass and composite foils by the doctor-blade method from aqueous and non-aqueous suspensions.

Department of Silicon Technology

Various manufacturing technologies of silicon crystals have been developed in the laboratories of the Department of Silicon Technology, including CZ (the Czochralski method) and FZ (the floating zone method). We offer silicon single crystals and silicon wafers (of different types) with diameters from 1" to 4" – with standard and above standard thicknesses, from 50 μm up to 40000 μm and beyond. Silicon wafers provided by us are processed as cut, lapped, etched, one-side-polished and both-sides-polished, depending on the customer needs.

Simultaneously, the Department conducts quality assessment of the surface of wafers and the quality of the layers under the surface, and experimental research on silicon wafer technology, such as the use of liquid wax, adhesive methods, choice of mixtures for silicon etching, elimination of surface defects of polished plates of "haze" or improving the quality of the polished silicon plates to reach world standards. Levels of haze, OSF and S-pits defects, and the usefulness of various materials for internal gettering processes can be examined.

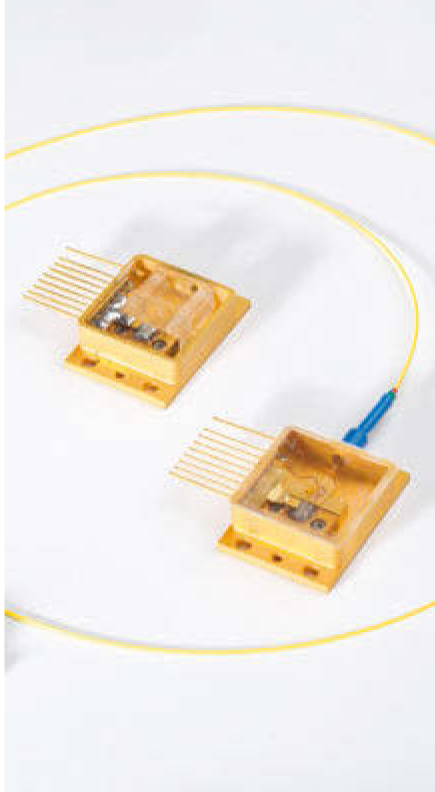
The Department has developed silicon manufacturing processes, in which:

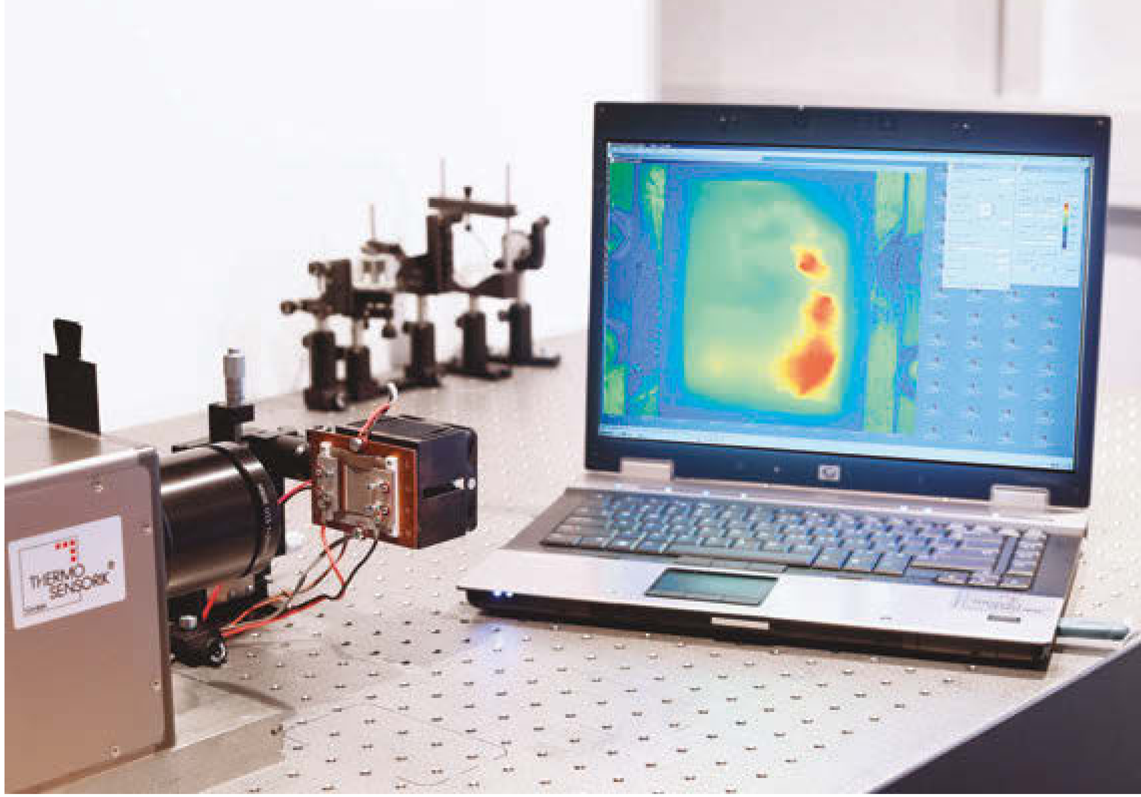
- controlled level of oxygen in silicon single crystals of 5.5 ÷ 10 x1017 atoms per cm^3 was reached, and software for an automated crystal growth process control was implemented;
- controlling the conditions of melting and the flow of argon significantly reduced the impact of migration of carbon in silicon during crystal growth (standard carbon content of the produced single crystals of silicon is lower than 2 x1016 atoms per cm^3);
- 1", 2", 3" and 4" single crystals were obtained with unusual orientations of (<110>, <112>, <113>, <133>, <210>, <310>, <510>, <511>, <711>, <221> , <321>);
- we produce wafers with standard orientation (<100>,<111>) and disorientation up to 15°;
- polished silicon plates with diameters up to 100 mm and thicknesses > 2000 μm are characterized by tolerance of thickness, flatness and TTV <5 μm and surface roughness of <5 Å;
- we obtained an ultra-thin double-sided polished silicon wafer (thickness 50 μm) with 2" diameter, tolerance of thickness ± 0.5 μm and close to the spherical shape of its distribution, the orientation of the plate with an accuracy of <0.05° and primary flat better than <20', with a roughness of the surface <5 Å (working within the European grant Imaging with Neutral Atoms framework).

We developed:

- a thermal control system for the growth of single crystals of silicon to ensure the thermal stability of crystals (nucleation time of a typical precipitation is above 100 hours);
- methods to obtain single crystals of silicon with standard properties using conventional doping techniques.

The Department also offers measurement and research services and is open to cooperation in the field of silicon technology.





Department of Optoelectronics

The activities of the Department of Optoelectronics cover a wide range of areas such as the development of new semiconductor laser sources, various solid-state laser components, heat removal techniques, packaging and integrating of optoelectronic devices, as well as optical and thermal characterization of innovative materials and devices. Our extensive experience allowed the development of many state-of-the-art optoelectronic devices such as low-beam divergence high power diode lasers, integrated with diffraction optics windows or pigtailed fibres, mounted on microchannel coolers. The infrastructure of the department consists of complete technological lines (processing line for contact photolithography, line for chemical processing, equipment for evaporation and sputter coating, automatic disk saws for precise cutting, equipment for rapid thermal processing, equipment for precise thinning of substrates for semiconductor, dielectric and metal substrates, line for semiconductor chip assembly). Characterization techniques are developed in specialized laboratories for diode laser and solid-state laser characterizations as well as spectroscopic and thermal analyses.

Our team can provide custom-specific solutions for tailor-made laser sources, integration of electronic devices, packaging services to transfer research into applications. We are open to cooperation in the area of design, prototyping and tests of laser diodes and diode pumped laser systems based on active materials such as transparent ceramics, oxide crystals, glasses and oxide crystal epitaxial layers.

Our technological group cooperates with industrial partners in the area of specialized cutting, coating and packaging processes.

The range of services offered by the group covers a wide spectrum from bilateral industrial projects to various practical solutions and customized technological services. The long-term experience of the team enables realization of innovative products based on advanced methods and processes.

We are open to cooperation in the field of optical characterizations (photoluminescence and micro-photoluminescence, measurements of absorption, determination of excited state lifetimes) of optical materials in various states and forms. Our team has considerable experience in characterization of materials for passive Q-switches (investigations of ceramic, single-crystal and glass materials doped with transition metals, characterization of modulators based on graphene and graphene oxide, determination of spectroscopic parameters). Another area of our expertise are thermographic measurements (investigations of heat flow in the micro-scale, thermal profiling, studies of transient thermal phenomena).

Department of Chemical Technologies

The Department specializes in chemical synthesis of advanced materials intended to be used in electronics, optoelectronics and energy storage devices. The Department has experience in the manufacture of nanomaterials and nanostructures. Apart from scientific research, implementation services for practical applications of new technologies are developed.
The abovementioned activities are carried out by scientists assigned to two research teams.

Laboratory of Chemical Graphene
Scientific research is carried out in the field of chemical preparation methods of flake graphene and its derivatives:

- intercalated graphite, thermally expanded graphite, graphite oxide, graphene oxide, reduced graphene oxide,
- graphene paper,
- graphene obtained by direct exfoliation of graphite in solvents.

Optimization procedures are applied at various stages of graphite processing to obtain the abovementioned products. There is an ongoing cooperation with other institutions, both in the study of the properties and the applications of graphene materials developed at our department.

Laboratory of Bio- and Nanomaterials
We work on the chemical synthesis of nanocrystalline materials and nanostructures with different techniques including the sol-gel process, co-precipitation, hydrothermal and combustion synthesis, reverse microemulsion, electrochemical and solid phase method. The obtained materials are applied to:

Optoelectronics:

- as starting materials to produce laser ceramics,
- as luminescent composites with organic and inorganic matrices, for example as optical fibers or waveguides,
- as luminophores which can emit radiation in various wave regions depending on ion doping.

Devices for producing and storing energy:

- as electrode materials for lithium ion batteries and supercapacitors.

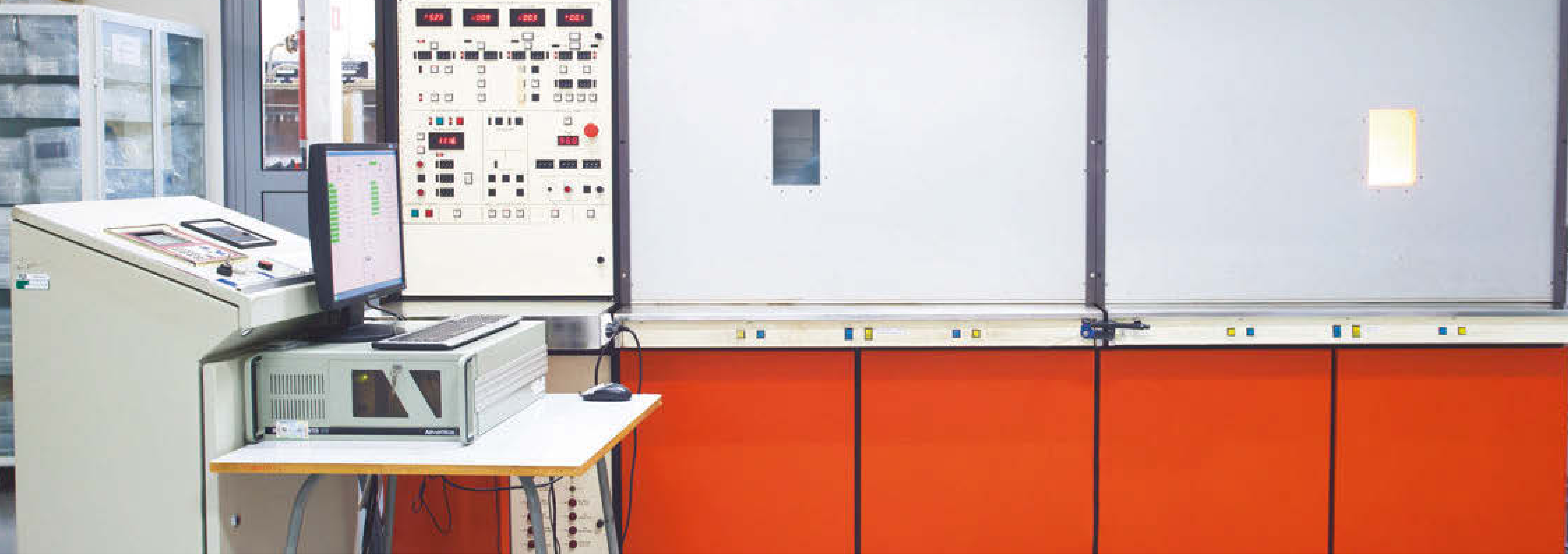


Department of Glass

The Department of Glass has over 30 years of experience in the design and fabrication of various types of multicomponent glasses and fiber optics elements. These include fluoride, tellurite, silicate and phosphate compositions of optical quality, "fiber-grade" glasses, synthesized from oxides or non-oxide compounds of heavy metal ions, and compositions doped with rare-earth ions for fiber lasers. Our Glass Studio is equipped with a lineup of resistance and induction furnaces, a glove box with an advanced air-purification system and with miniature furnaces for melting and annealing glasses under stringent control of the process atmosphere. The post-processing capabilities include high precision cutting, rounding, grinding and polishing. The fabrication capabilities include custom glass blocks, rods and tubes, and specific components such as substrates or filters. Micro- and miniature glass lenses, either refractive or diffractive, can also be fabricated using our hot-embossing press. A fully equipped characterization laboratory assures accurate measurements of temperature, rheological and optical properties of the glasses and optical elements.

Our three-storey fiber drawing lab is equipped with four large drawing towers and two smaller calibration towers, as well as clean-room cabinets and precision tools for preparation of fiber preforms. We have 25+ years expertise in fiber optics and more specifically fabrication of image guides and classic optical fibers, including rare-earth doped active fibers, as well as 15+ years of experience with photonic crystal fibers (passive or active) and more recently unique nanostructured optical fibers. The drawing equipment is compatible with either soft glass or silica glass preforms. Combined with our own fiber design and simulation software, we are able to deliver custom micro- and nanostructured optical fibers and fiber optics components for the visible, near-IR and mid-IR wavelengths up to about 5 μm, for applications ranging from nonlinear optics (supercontinuum generation), through polarization or wavefront manipulation, beam delivery to micro-optofluidics. Our optical fiber post-processing and characterization lab is equipped with a highly advanced microstructured fiber fusion splicer, as well as optical setups for measurements of attenuation, bending loss or chromatic dispersion. In-house scanning electron microscopy imaging of the fabricated structures is also available.

Our flagship products include hot embossed micro-lenses for the mid-IR, fiber-optics compatible nanostructured microlenses and micro-axicons and the all-normal dispersion ("ANDi"), as well as all-solid glass (fusion-splicing compatible) nonlinear photonic crystal fibers for coherent supercontinuum generation.



Department of Epitaxy

The main activities of the Department of Epitaxy are focused on research and development of silicon epitaxial layers deposited by the CVD method, epitaxial layers characterization and the development of experimental techniques for characterization of electronic properties of a defect in semiconducting materials.
We manufacture many different types of epitaxial wafers and structures such as single epitaxial layers, multilayer epitaxial structures (e.g. p/n/n+, n/p/p+) and thick, high-resistivity epitaxial layers for charged particle detectors production. Our offer includes silicon epitaxial layers with thickness and resistivity in the range of 2-180 mm and 0.003-5000 respectively. For the characterization of epitaxial wafers the following electrical and optical measurements are performed: epitaxial layers thickness determination by IR interferometry; majority carrier concentration profile by the capacitance-voltage method with a Hg probe; resistivity profile versus depth by the spreading resistance method on a beveled sample and average resistivity with a 4-point probe (on a p/n junction wafer).
The techniques of Deep Level Transient Spectroscopy (DLTS) and High-Resolution Photo-Induced Transient Spectroscopy (HR PITS) were developed in our Department to control impurities and electrically active defects concentration in silicon and other semiconductors. The properties of both the shallow and deep defect centres are investigated in various materials including silicon, GaAs and InP as well as GaN and SiC. The main activity is aimed at characterization of defect centres in high-resistivity semiconductors using the HRPITS technique, especially at irradiation-induced defects in silicon. We are able to provide our services or collaboration also in these sophisticated measurements.
As part of our commitment to research we are involved in international collaboration on radiation hardening of silicon detectors within the framework of the CERN-RD50 project, „Radiation hard semiconductor devices for very high luminosity collider". Our department is also working on a project entitled "High-resistivity nitrogen-enriched silicon as a new material for manufacturing high energy particle detectors". The Project has two objectives: the first is to develop the production technology of new silicon wafers with the nitrogen concentration exceeding 1×1015 cm^{-3} and the resistivity ~ 2000 Ωcm and the second is to determine the radiation resistance of the new wafers compared to those made without the nitrogen-enrichment.
Our Department is open to various forms of collaboration including quality assessment of semiconductor materials, common research projects, exchange of Ph.D. students and exchange of experience.

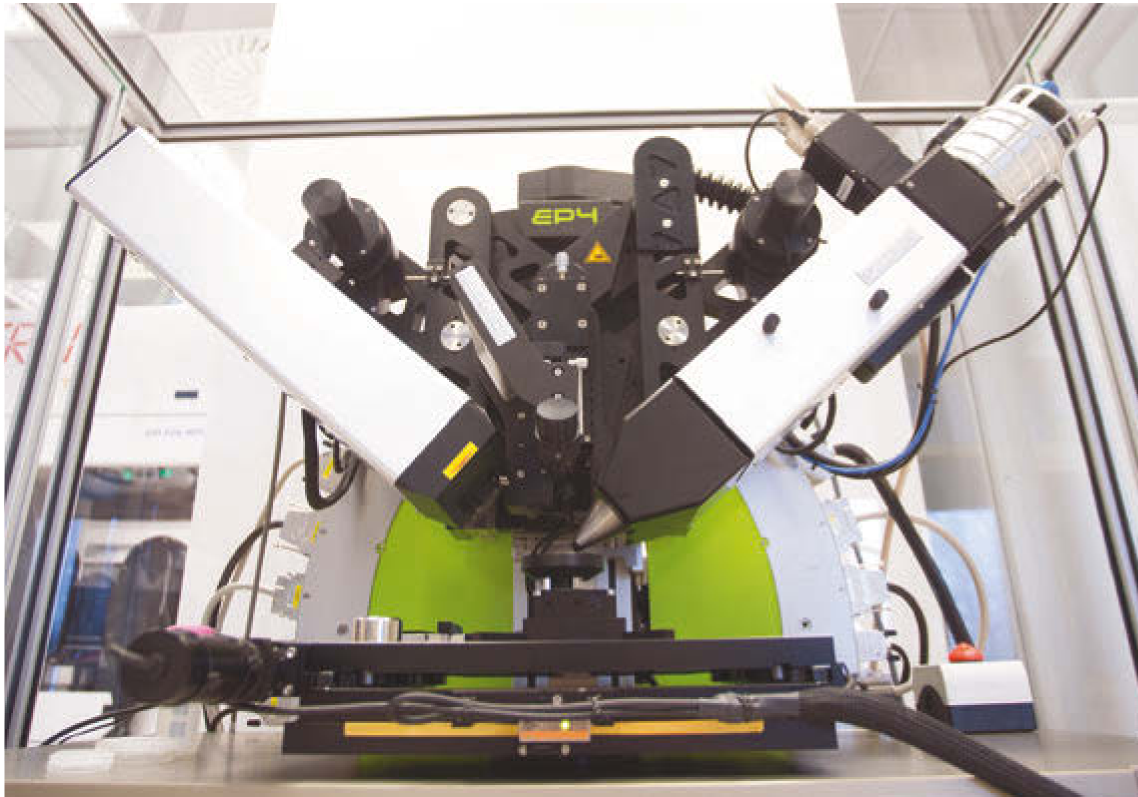
Department of Epitaxy and Characterization

The Department of Epitaxy and Characterization is one of ITME's leading branches focused on III-V and IV-IV epitaxial materials research and production for advanced electronics as well as on research and industrial applications of graphene on SiC, Ge and metallic substrates. The department's 25-strong team of professionals offer in-depth knowledge of and wide experience in physics of semiconductors, epitaxy of semiconductor compounds and their characterization. Our professors, postdocs, PhD students and technologists are actively involved in a number of long-term research programmes, such as EU's Graphenics, Graphica, Graphene Flagship, aimed at boosting the commercialization of most innovative ideas.

Using AIXTRON's Metal Organic Chemical Vapour Deposition (MOCVD) and Chemical Vapour Deposition (CVD) systems, we produce exceptionally high-quality GaAs-, InP-, GaN-, GaSb- and SiC-related epitaxial structures.

We test all products comprehensively using standard and advanced characterization methods, including optical microscopy, optical profilometry, electron microscopy, atomic force microscopy, photoluminescence spectroscopy, ellipsometry, Raman spectroscopy, secondary ions mass spectroscopy, Hall effect, ECV, X-ray and microwave measurements. We interact regularly with prominent national and international R&D centres and commercial entities in the area of solid-state physics, electron technology, electronics and materials engineering.

The Department of Epitaxy and Characterization is undertaking its semiconductor and graphene manufacturing business through its commercial partners.



Department of Thick-Film Materials

The Department of Thick-Film Materials is the main Polish producer of electronic pastes used in thick film technology.

We offer:

Pastes on ceramic substrates for firing
The following wide range of standard screen printing materials is offered to be applied on different ceramic substrates, mostly on an alumina substrate, fired at 500 -1100°C:

- conductive (Ag, PtAg, PdAg),
- resistive (RuO_2 based, 10-100 kΩ/□),
- dielectric,
- high resolution photoimageable conductive pastes (Ag, Au, Pt – line/space 30/40 μm wide) that are ideal for low loss microwave planar passive devices like filters, couplers and resonators.

All of the abovementioned materials comply with the RoHS directive (lead free).

Pastes for flexible electronics
The Department carries out research on materials used in organic electronics that can be cured at temperatures below 300°C and can be applied by: screen printing, spray coating and ink-jet printing.
We are involved in preparing and tailoring of organic/inorganic composites with carbon nano-tubes, graphene nanoplatelets, graphene oxides which can form antennas, transparent electrodes and many more on rigid and flexible substrates.
Screen printed pastes are applied onto organic substrates (silver and protective graphite) cured at low temperatures (below 150°C).

Nano-silver based pastes sinterable below 300°C
Nano-silver based pastes are applied and sintered on a wide range of substrates including ceramic, aluminium, copper, gold, glass, polyimide foil. They reach thermal and electrical performance close to bulk silver. They can replace the galvanic methods for silvering aluminium connectors used in power lines.
We also offer nano-silver based pastes intended for low temperature joining that can be sintered at 250°C under pressure starting from 2.5 MPa and once sintered can withstand temperatures above 350°C, providing thermal conductivity above 250 W/mK. They are ideal for power semiconductor devices die attached.

New thick-film compositions, tailored to individual customer's requirements can be offered.

The Department possesses equipment suitable for executing thick film technology (modern screen printers, IR and UV driers, conveyor belt furnaces, etc.) and may offer thick film devices. Assistance in the design of a thick film circuit lay-out can be provided as well.

Department of Functional Materials

The work of the Department of Functional Materials is devoted to developing and manufacturing crystalline materials. Our mission is to carry out basic and applied research in the field of crystal growth, novel composite materials and characterization. We have developed growth technologies of single crystals of oxides, $A^{III}B^{V}$ compounds and 4H- and 6H-SiC. We have also investigated growth of metamaterials, plasmonic materials and eutectic materials by the micro-pulling-down method. We are open to collaboration within the framework of scientific projects as well as with industrial partners.

Materials

- $A^{III}B^{V}$ compounds (GaAs, InAs, GaP, InP, GaSb) grown by the Czochralski method.
- Oxide crystals (YAG, YAP, GdCOB, SBN, YVO, NGO and other available on-demand) grown by the Czochralski method.
- Calcium fluoride and barium fluoride crystals grown by the Bridgman method.
- Silicon carbide crystals (4H and 6H) grown by the PVT method.
- Other special optical and electronic materials of high purity (made on customer request).
- Novel materials in small quantities grown by the micro-pulling down method.

Processing

- Processing of quartz substrates with thickness of 0.3 mm and diameter of up to 75 mm or thickness of 0.5 mm and diameter of up to 100 mm.
- Processing of silicon carbide boules and wafers.
- Processing of optical elements made of oxide and fluoride crystals.

Characterization

- Optical microscopy.
- Dilatometry.
- Simultaneous thermal analysis (differential calorimetry, differential thermal analysis, thermogravimetric analysis).
- Spectrophotometry.

Based on our specialist knowledge and facilities we are also capable of offering services in the field of crystal growth technology development (know-how) and mechanical processing.

Department of Applications of $A^{III}B^{V}$ Materials

The Department develops semiconductor devices on single crystal substrates and epi-layers grown at ITME and provides feedback information on the material quality. Our commercialized products are GaN/AlGaN Schottky and pin ultraviolet detectors, high precision chromium masks and diffractive optical elements for UV,VIS, IR and THz spectral range.

Products and developed technologies:

- GaAs MESFET technology comprising direct ion implantation into the semi-insulating single crystal,
- simple GaAs integrated circuits in the BFL arrangement,
- GaAs detectors of X, α and γ radiation,
- GaAs/InGaAs/AlGaAs HEMT and RTD (resonant tunneling diode),
- InP/InGaAs/InAlAs HEMT and RTD (resonant tunneling diode),
- silicon micromachined bolometer and thermopile,
- GaN/AlGaN Schottky and p-i-n ultraviolet detectors,
- GaN/AlGaN HEMT,
- SiC high-voltage Schottky diodes,
- processing technology of SCH lasers.

The Mask Laboratory in our Department has used electron-beam lithography since 1991 and has a long tradition of advanced photomask production and direct pattern writing of semiconductor structures with a submicrometer feature size. Project Micro and Nano Technology Center MINOS carried out in 2011-2014 allowed us to equip the Laboratory with a new, much more advanced e-beam pattern generator Vistec SB251. This professional, high productivity variable shaped e-beam system enables writing high resolution patterns (better than 50 nm) over a large area (200x200 mm^2) with extremely dense addressing grid (1 nm). In addition to the e-beam lithography, UV and hot embossing nano imprint lithography systems are used for binary patterns transfer and 3D structures replicating with a feature size even below 50 nm (e.g. multi-phase-level diffractive optical elements). Combining modern, unique equipment with long experience, the Mask Laboratory is able to provide leading edge technology solutions for all areas of micro and nanolithography applications, including microelectronics, photonics, integrated optics, microoptics and micromechanics.

Department of Piezoelectronics

The Department of Piezoelectronics carries out research in the following areas:

- Characterization of new piezoelectric crystals. Measurement of elastic, piezoelectric and dielectric permittivity tensors.
- Calculations and measurements of surface acoustic waves (SAW), pseudo-surface acoustic waves (PSAW), surface transverse waves (STW), acoustic plate modes (APM) and Lamb modes in piezoelectric crystals.

  The Department possesses computer programs for parameter calculations of the aforementioned wave types and proper measurement equipment.
- Design and fabrication of devices with various acoustic wave types for application to telecommunication and piezoelectric sensors. Catalogue data of the offered devices are available on our website.
- Investigations into nondestructive structural health monitoring (SHM).
- Investigations into piezoelectric sensors of viscosity, temperature and pressure.

Recent achievements:

Elastic, piezoelectric and dielectric constants of GaN crystals were determined based on surface acoustic wave measurements. SAW delay lines and resonators on bulk-GaN were developed. The grant was funded by the United States Army Research Office. Resonators with SAW on GaN were constructed and measured. AMP properties of Z-cut GaN plates were investigated.

Elastic, piezoelectric and dielectric constants of neodymium calcium oxoborate, $NdCa_4O(BO_3)_3$ monocrystals were determined on the basis of surface acoustic wave measurements. Temperature SAW properties in the crystal were also investigated. The grant was funded by the Polish National Science Centre.

SAW and APM properties in $SrLaGa_3O_7$ monocrystals were investigated for the temperature of up to 500°C.

A two-port SAW synchronous resonator was designed and fabricated on gadolinium calcium oxoborate $GdCa_4O(BO_3)_3$. Its parameters were measured for the temperature of up to 500°C.

A laboratory system for wireless temperature measurement (0–100°C) based on the STW quartz resonator was designed and fabricated.

A laboratory system for viscosity measurement using APM in quartz was designed and fabricated.

Properties of chosen Lamb modes were investigated in YX $LiNbO_3$ crystals.

Properties of SAW on ZX°45 $Ca_2Al_2SiO_7$ crystals grown by the Czochralski method were investigated.

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