Centre For Research In The Field Of Semiconductor Materials And Technologies
The Centre has been established to provide for world-class educational and research activities in the field of physics and technology of semiconductors, technology of semiconductor materials and devices, and interdisciplinary research.

The Centre consists of 5 laboratories:

- Laboratory of Nanostructured Surfaces and Coatings
- Laboratory of Functional Electronics
- Laboratory of Nanoelectronics and Nanophotonics
- Laboratory of Organic Electronics at Siberian Institute of Physics and Technology
- Laboratory for Terahertz Research

These laboratories carry out research and development in such spheres as theory of condensed mediums and crystallization processes, spintronics and topological insulators, solid-state electronics and photonics, functional and organic electronics, microwave and terahertz electronics, nanosystem physics, materials science, computer simulation.

Laboratory researchers (including foreign specialists) are directly involved in the educational process at the Faculty of Physics and Faculty of Radiophysics: lecturing, conducting special trainings, acting as scientific advisors for Masters and post-graduate students.
Development of the research in the field of semiconductor materials and technologies in TSU

Development of the production technologies and research of the semiconductor materials properties as well as training of the specialists in semiconductor physics started in TSU in 1954 at the discretion of Victor Alexeevich Presnov, who became a Chair of Department of Physics of Semiconductors at that time. In the same year a scientific laboratory of semiconductors was created at Siberian Institute of Physics and Technology, TSU. Later V.A. Presnov became first director of Research Institute of Semiconductor Devices opened in Tomsk in 1964. This institute became one of the leading facilities of USSR Ministry of electronic industry. Works of TSU physicists of those decades became a founding stone for the formation of Tomsk school of physics of semiconductors. University graduates – employees of TSU and Siberian Institute of Physics and Technology became a skeleton staff of Research Institute of Semiconductor Devices.

In 1973 laboratory of semiconductors at Siberian Institute of Physics and Technology was reorganized into department of physics of semiconductors (headed by A.P. Vyatkin), which consisted of 7 laboratories:
- Laboratory of theoretical physics (headed by V.A. Chaldyshev),
- Laboratory of physics of semiconductors (headed by S.S. Khludkov),
- Laboratory of epitaxial structures (headed by L.G. Lavrentyeva),
- Laboratory of physics of semiconductor devices (headed by A.A. Vilisov),
- Laboratory of physics of dielectric structures (headed by V.M. Nesterov),
- Laboratory of luminescence of semiconductors (headed by P.E. Ramazanov),
- Chemical–technological laboratory (headed by V.A. Sannikov).

In 1991–2000s the conditions of drastic funding cuts and increasing role of market economy determined the structural adjustments of the organizational structure of the department and changes in manpower deployment. Nevertheless, TSU succeeded in preserving and developing the most important scientific areas connected with physics and technics of semiconductors.

Since 2005 development of the research on semiconductors in Tomsk was assisted by the increasing interest of the government to the education and science, creation of the Ministry of education and science, transition to the competitive financing of the science in the framework of Federal and sectorial target programs, and government regulations No 218, 219, and 220.

University was able to significantly improve material and technical support for educational and scientific processes in the framework of large projects, such as TSU Innovation educational program (2006–2007), Program of Tomsk State University development in its function as National Research University (2010–2019), TSU competitiveness improvement program (among leading world academic centers, 2013–2020).

Technological centers “Microelectronics” and “Organic electronics” were established that make it possible to carry out modern technological developments in the sphere of semiconductor materials, semiconductor detectors of electromagnetic emissions and gas sensors. Research equipment was acquired that renders it possible to conduct up-to-date research of structure, composition, electrophysical and optical properties of volume materials and epitaxial layers, including nanoheterostructures.

Currently several University department train specialists in semiconductors: department of physics of semiconductors, department of semiconductor electronics, department of quantum physics and photonics, department of analytical chemistry – on the Faculty of Physics, Faculty of Radiophysics, and Faculty of Chemistry.
Laboratory of Functional Electronics

Headed by Oleg Petrovich Tolbanov, Dr. Sc. (Physics and Mathematics), Professor, Director of Education and Scientific Information Center “Semiconductor sensors”

AIM OF CREATION

Development of the effective scientific, educational and innovative infrastructure for the increase in TSU competitiveness among the leading world academic centers in the sphere of semiconductor materials science, functional and quantum-sensitive sensor electronics.

MAIN TASKS

- Integration of education, research and innovation in the sphere of semiconductors in TSU; exercising “one-of-a-kind” training of highly qualified specialists, mostly post-graduate students – in total more than 20 trainees per year.
- Integration of TSU scientific schools along the priority directions; development of academic projects primarily at the confluence of sciences, formation of postdoc training system on the basis of the research being carried out.
- Integration into universal science along the competitive, “groundbreaking” research and technological areas. Development of the contacts with leading international scientific centers. Joint research and publications in foreign top-rated journals, bilingual training of post-graduate students.
- Development of original technologies, achievement of the results and production of outputs competitive in the world. Development and packing of hi-tech competitive production for the large industrial and spin-off companies and business structures in the sphere of high-end technologies.

MAIN LINES OF RESEARCH

- Development of applied and fundamental research, development of competitive high-end technologies of semiconductor materials, nanostructures and elements.
- Physical regularities in scientific research and competitive solutions in the spheres of semiconductor nanostructures and coordinate detectors for accelerative centers of particle physics, high energy physics and digital diagnostics systems of different purpose with properties exceeding world analogues.
- Regularities and laboratory technology of detector nanostructures production on the basis of GaAs, compensated by extrinsic nanoclusters with properties exceeding world analogues: diameter up to 4 inches (European standard), width up to 1.2 mm, electrical resistance more than 5x10^8 Ohm per cm, μτ ≥ 3x10^-4 cm^2/V for HEMT technology base plates, sensors, transformers and photoreceivers with wide spectral range.
- Regularities and laboratory technology of GaAs coordinate (microstrip and pixel) detectors production with useful area up to 50 cm^2, number of elements in microstrip detector up to 2048 and in pixel detector up to 1024 x 1024, using methods of integrated monolithic circuit (MIC).
- Simulation of physical processes and research of experimental regularities of charge transportation and aggregation as a function of structural and technological parameters of nanostructures and MIC GaAS coordinate detectors.
- Models of physical processes and experimental research of electrophysical properties of semiconductor complex crystals (CdTe, CdZnTe, TlBr, GaSe, ZnSe, AgGaSe, etc.) for establishing the possibility of their use as detectors of ionizing radiation and scintillating materials; development of the technology, manufacture and research of developmental prototypes of such detectors.
- Simulation of physical processes, development of structural and technological principles and research of the experimental regularities of laboratory prototypes of multielement detectors.
of ionizing emissions with inner reinforcement.

- Production and procurement of developmental prototypes of radiation-resistant multielement sensors and detectors of different constructive modifications with properties exceeding best world analogues to the spin-off companies for the different use in modern physical experiments and digital diagnostic medico–biological and technical equipment.

- Physical and technological aspects of research and utilization of diluted magnetic materials $A^3B^5$ and semiconductor nanostructures as a material for the creation of spintronics elements.

- Original methods of research of electro–physical properties and characteristics of super–fast processes in the semiconductor low dimensional structures and elements of electronic component base under optical excitation by ultrashort laser pulses.

- Development and research of semiconductor materials, structures and elements for the development of emission terahertz spectroscopy method, connected with coherent optical excitation and detection of temporary profiles of terahertz emission impulses.

- Regularities and development of highly sensitive sensors of different external effects and sensors of traces of biochemical processes on the basis of nanostructured metal–oxide films and structures formed on the semiconductor substrates.

**SOME RESEARCH RESULTS**

Laboratory researchers conducted and systematized a large volume of scientific research on the modification of GaAs properties under deep level impurity doping. They were able to create semiconductor semi–insulating structures, compensated by extrinsical nanocluster from transition group of the periodic table with properties exceeding world analogues.

On the basis of the structures laboratory developed a wide range of semiconductor devices for functional electronics of different purpose: UV photoreceivers, infrared transformer, pulse avalanche S–diodes of picosecond operating speed, and detectors of ionizing emissions. Laboratory researchers created and put on the world market unrivaled matrix detectors of ionizing emissions with number of pixels 768 x 512, used for the registration of synchrotron emission, in experimental high energy physics, in the system systems of digital chromatic images formation in x–ray and gamma–rays used in medicine, science and industry.
Laboratory staff conducted fundamental research of the compensation of GaAs conductivity by doping nanoclusters. Results enabled us to develop the technology of semiconductor high-ohmic structures production with properties exceeding world analogues (so called HR-GaAs<Cr> structures).

Consumers of the sensors and semiconductor detectors, developed and produced in TSU Laboratory of functional electronics, are significant amount of small and medium foreign firms developing digital radiographic diagnostic and informational systems of different functional purpose in the sphere of science, medicine, industry, ecology and security. The University of Freiburg (Germany) conducted independent tests of the semiconductor detectors prototypes. Picture shows the image of the head of the rat acquired with voltage applied to x-ray tube equals 25 kW using HR-GaAs<Cr>+Medipix3 detectors. German medical specialists evaluated the image as unrivaled in the terms of its quality.

Aggregation of matrix detectors (HPAD) into the line is a revolution in the spheres of registration of synchrotron emission photons and free electron emitters (XFEL). It is commonly accepted that they represent the detectors of the future having improved significantly in comparison with existing detectors on the basis of CCD cameras. TSU Laboratory of functional electronics develops constructions and technologies, manufactures and supplies matric sensors to the foreign partners for...
the Pilatus, Medipix and XPAD electronic chips created in different European research centers.

RUSSIAN AND FOREIGN PARTNERS
- DESY (Deutche Electronen Synchrotron) Hamburg, Germany
- RAL (Rutherford Appleton Laboratory), Oxford, UK
- ESRF (European Synchrotron Radiation Facility), Grenoble, France
- PSI (Paul Sherrer Institute), Villigen, Switzerland
- Stanford University, California, USA
- Joint Institute for Nuclear Research, Dubna, Russia
- Dectris Ltd., Baden, Switzerland
- XCounter Ltd, Stockholm, Sweden
- MARS Ltd, Christchurch, New Zealand
- Samsung, South Korea

Laboratory of Nanostructured Surfaces and Coatings

Headed by Vladimir Mikhailovich Kuznetsov, Candidate of Science (Physics and Mathematics), Associate Professor at Faculty of Physics, TSU
Head of research - Eugene Vladimirovich Chulkov, Dr. Sc. (Physics and Mathematics), Professor at National Research Tomsk State University, Professor at University of the Basque Country, Spain

MAIN RESEARCH AREAS
- Theoretical research of the electronic properties of topological insulators – new materials combining properties of a semiconductor (in volume) and metal (on the surface) using “ab initio” calculations.
- Development of the new conception of the multielement nanocomposite gradient coating formation in without sharp border between substrate and coating.
- Creation of the new types of vacuum ion plasma equipment.
- Construction of new topological insulators, based on the possibility to manipulate electronic properties of topological insulator through the change of their space and surface crystal structure.
- Variation of atomic composition, doping by impurity atoms and creation of heterostructures.
- Technology of vacuum–plasma equipment creation for treatment of particular items and achievement of particular desired properties, including determination of technological conditions of surface modification or coating for given details.
- Design of a vacuum unit for a given task (chamber volume, sources, holders).
- Manufacture and supply of vacuum unit to the plant with further servicing.

EXPECTED RESULTS

SPHERES OF RESULTS APPLICATION

Spintronics, quantum computers, superconductors, antifriction antiwear coating of car details and items used in aerospace industry, corrosion-resistance and chemically resis-
tant coatings of products, heat resistance coating, treatment of medical equipment and instruments.

RUSSIAN AND FOREIGN PARTNERS
- University of Zurich, Switzerland
- Forschungszentrum Jülich, Germany
- Donostia International Physics Center, San Sebastian, Spain
- Swiss Federal Institute of technology, Lausanne, Switzerland
- Marburg University, Philipps–Universität Marburg, Germany
- Maks–Plank Institute, Hale, Germany
- Hiroshima University, Japan
- Baku State University, Azerbaijan
- National Research Center “Kurchatov Institute”, Moscow, Russia
- Rzanov Institute of Semiconductor Physics, Siberian Branch of the Russian Academy of Sciences, Russia
- Sobolev Institute of Geology and Mineralogy, SB RAS, Russia
- Far Eastern Federal University, Vladivostok, Russia
- Institute of Strength Physics and Materials Science, SB RAS, Russia

Laboratory of Organic Electronics at Siberian Institute of Physics and Technology

Headed by Tatyana Nikolaevna Kopylova, Dr. Sc. (Physics and Mathematics), Professor

RESEARCH AREAS
Creation and research of organic optical materials for quantum and organic electronics: solid active mediums of tunable lasers and lasers based on them (including photoexcited organic semiconductor lasers); organic light emitting diodes, molecular sensors.

OBTAINED RESULTS
Laboratory created optical materials and quantum electronics appliances: small-sized, easy-to-use, cheap active mediums and solid lasers on the basis of organic compounds, emitting in wide spectral range – from blue to red glow; spheres of application – medicine, spectroscopy, derivation of new materials, and molecular sensorics.

Laboratory created organic semiconductor materials for construction of organic light emitting diodes and appliances based on them (small-sized indicators, full-color displays, and molecular sensors).
SPHERE OF RESULTS APPLICATION

Thin-film photoexcited lasers; organic light emitting diodes; indicators, displays, white-light sources; integrated molecular sensors.

RUSSIAN AND FOREIGN PARTNERS

- Institute of Macromolecular Compounds, RAS, Russia
- Novosibirsk Institute of Organic Chemistry, SB RAS, Russia
- Institute of Solid State Chemistry and Mechanochemistry, SB RAS, Russia
- Department of Physics and Astronomy, the University of Utah, Salt Lake City, USA
- Belarusian State University, Belarus
- Institute of Physics and Chemistry NAS of Ukraine

Laboratory is equipped with modern technological and research equipment for creation of organic light emitting diodes and appliances based on them (indicators, molecular sensors).

Laboratory for Terahertz Research

Heads by Valentin Ivanovich Suslyaev, Candidate of Science (Physics and Mathematics), Associate Professor at Faculty of Radiophysics, TSU

AIM OF CREATION

Familiarization with international and creation of own methodological and technical base for the research on physical phenomena, processes and properties of the matter in the understudied sphere of radio frequencies – terahertz diapason, which is located in the interval between extremely high frequency radio wave range and infrared range of the electromagnetic oscillations spectrum; conduction of research on electromagnetic response and electromagnetic parameters of natural and artificial materials in the wide range of electromagnetic emission frequencies. Low values of terahertz waves’ lengths open the new opportunities for studying the properties of living and nonliving matter, for revealing new scientific, industrial, biomedical, and ecological uses.

MAIN RESEARCH AREAS

- Research of the particularities of the interaction of terahertz waves with semiconductor, dielectric, composite materials, including nano-sized and metamaterials;
- Theoretical analysis and experimental research of the interaction between electromagnetic emission and multicomponent nanostructured composite mediums with an aim of creating the materials for passive elements effectively transforming emissions in terahertz and sub terahertz frequency bands;
- Research of the natural mediums (solid, liquid, gaseous) in the fields of terahertz frequency band;
- Research of the particularities of the interaction of terahertz waves with artificial and natural objects of different form and conductivity (ultra-fine filiform, film materials, small diffusers, anisotropic materials);
- Research of the possibility to create terahertz frequency band electronic base elements (emitters, detectors, multipliers, transformers, etc.);
- Research of the possibility to use terahertz frequency band radio waves in the contactless radio wave diagnostic equipment, non-destructing testing devices, and biomedical instrument engineering facilities.

EXPECTED RESEARCH RESULTS

- Development of the new highly sensitive methods of natural and artificial mediums research in quasi-optic beams;
- Development and creation of developmental prototypes of quasi-optic transformers for the measurement of electromagnetic parameters of semiconductor, dielectric, composite materials in terahertz frequency band;
- Creation of developmental prototypes of highly sensitive contactless high speed control devices using fluctuation of terahertz frequencies;
Development of the new composite materials with radiophysical properties prescribed in terahertz frequency band; 
Creation of experiment methodologies and prototypes of control devices for animated and unanimated nature objects in terahertz frequencies.

SPHERES OF RESULTS APPLICATION
- Development of physical bases of functional link of electromagnetic properties with content, morphology and structure of broad class materials;
- Creation of the new unique equipment and devices for research;
- Industrial contactless control for technical processes, materials and items;
- Creation of the new methods and means of control for natural objects and environment.

RUSSIAN AND FOREIGN PARTNERS
- “Tektronix”, Oregon, USA
- “Keysight Technologies”, California, USA
- “National Instrument”, Taxis, USA
- “Rohde & Schwarz”, Munich, Germany
- JSC VOTALI, Donetsk, Ukraine
- Research Institute of Nuclear Problem of Belarusian State University, Minsk, Belarus
- “Graphene materials”, Saint-Petersburg, Russia
- Institute of Material Science, SB RAS, Ulan–Ude, Russia
- Institute of Nuclear Physics SB RAS, Novosibirsk, Russia
- Khrustianovich Institute of Theoretical and Applied Mechanics SB RAS, Novosibirsk, Russia
- Institute of Solid State Chemistry and Mechanochemistry, SB RAS, Novosibirsk, Russia
- Boreskov Institute of Catalysis, SB RAS, Novosibirsk, Russia
- Nikolaev Institute of Inorganic Chemistry, SB RAS, Novosibirsk, Russia
- “Polus”, Tomsk, Russia
- “MIKRAN”, Tomsk, Russia
Laboratory of Nanoelectronics and Nanophotonics

Headed by Alexandr Vasilyevich Voitsekhovsky, Dr. Sc. (Physics and Mathematics), Professor at Faculty of Radiophysics, TSU

RESEARCH AREAS
- Research of epitaxial structures of different semiconductor compounds: cultivation, theory of growth, optical and electrophysical properties and their instrumental use;
- Design and research of the properties of semiconducting photoreceiving and emitting devices in infra-red and terahertz range on the basis of narrow-bandgap semiconductors;
- Research on electroneutrality, radiation hardness and structure defects in semiconducting compounds, ion-implant doping and ion etching;
- Research of the optical spectrums of quantum wells and quantum dots heterostructures;
- Design and research of the properties of the multilayer epitaxial light-emitting structures based on wide-gap semiconducting quantum well compounds.

EXPECTED RESULTS
- Development of the method of spectroscopy of the complex conductivity for the diagnostic of photo responsive and emissive semiconducting nanostructures including quantum wells and quantum dots, on the basis of A2B6 and A4B4 compounds;
- Development of the spectroscopic, mathematic and programming support for the remote diagnostics of the rocket engines and space vehicles using selective photoreceivers based on quantum well structures;
- Research of the physical bases of the development of solar batteries and thermal converters on the basis of quantum dots Ge/Si-nanostructures with built-in multilayered optical elements for the broadening of the spectrum into infra-red;
Development of the MIS devices (metal-insulator-semiconductor) based on heteroepitaxial cadmium-mercury-tellurium structures for the electronic component base of infra-red nanophotonics;

- Development of physical principles of photosensitive and light-emitting heterostructures on the basis of quantum well cadmium-mercury-tellurium structures cultivated by the molecular beam heteroepitaxy method;

- Development of radiation-resistant emitting sources in optical range on the basis of multilayered quantum well epitaxial structures GaN(GaAlN)/InGaN/GaN.

**SPHERES OF APPLICATION**

Materials science, development and modification of multilayered semiconducting nanostructures for optoelectronics devices: light-emitting diodes, photoreceivers, lasers, solar batteries.

**RUSSIAN AND FOREIGN PARTNERS**

- Fritz-Haber-Institut Berlin, Germany
- Microelectronics and Nanotechnology Centre of Rzeszow University Poland
- KARAT, Lviv, Ukraine
- Tohoku University, Sendai, Japan
- Rzanov Institute of Semiconductor Physics, SB RAS, Russia
- Polus, Moscow, Russia
- ORION, Moscow, Russia
- St Petersburg Academic University — Nanotechnology Research and Education Centre, RAS, Russia

**Small Innovative Enterprises**

Set up on the basis of the developments of the Centre for research in the field of semiconductor materials and technologies

**GALLIUM-ARSENIDE SENSORS**

**Types of activity**

- Research and development in the sphere of natural and engineering sciences
- Development and production of GaAs:Cr sensing material for the visualization of x-ray images

**Production/services:**

GaAs:Cr sensing material

**Spheres of product application**

- Microtomography;
- Nondestructive inspection aids.

**Technology features**

- Doping of GaAs by chrome atoms for attribution of unique properties to this material enabling its usage for the production of detectors and as integral part of tomography equipment.
Competitive strengths
- Twofold reduction of patient’s radiation dose in comparison with silicon detectors.
- Sevenfold reduction of exposure time.

Types of activity
- Research and development in the sphere of natural and engineering sciences;
- Metal working and coating;
- Production of devices and equipment for automatic regulation or control (automatic control centers or consoles).

Production/services
- Development of multicomponent nanocomposite and gradient-layered coating technologies for constructional and instrumental use with high physical and mechanical properties.
- Production of vacuum plasma equipment and devices for surface modification and coating synthesis.

Spheres of product application
- Antiwear coating of instruments;
- Antifrictional antiwear coating for automobile and aerospace industries;
- Anti-corrosive and chemically stable coating;
- Heat–resistance coating;
- Coating of insulating materials and devices;
- Treatment of medical equipment and instruments;
- Dentoprosthetic coating;
- Decorative coating;
- Development of transitional technologies from related industries: engineering, instrument engineering, semiconductor industry.

IKSDAIKON, LLC

Types of activity
Scientific research and manufacturing of innovative production – detector blocks for scanning x-ray machines on the basis of GaAs detectors with direct transformation of x-rays.

Production
Detection blocks and modules for scanning x-ray machines on the basis of GaAs detectors with direct transformation of x-rays.
Spheres of product application

- Production of hi-tech medical equipment and non-destructive inspection systems.
- Production consumers are companies producing x-ray technics. Offered detection blocks could be used in x-ray diagnostics for detection of carcinomas in early stages, when its successful pharmaceutical treatment is still possible.

Intellectual property

Know-how “Set of technical and construction documentation for detection block for scanning mammography units”

SEMIKON, LLC

Types of activity

Research and development in the sphere of natural and engineering sciences Production of control and measurement devices

Production

Device of non-destructive control of electrophysical parameters of high bandgap semiconductors “SemiCon-1”, designed for automated non-contact and express measurement of lifespan of non-equilibrium charge carriers (NCC), resistivity and conductivity type of semiconductors.

Sphere of production application:

Quality control of the derived semiconducting materials

Intellectual property

- Know-how “Design documentation for the device of non-destructive control of electrophysical parameters of high bandgap semiconductors”
- Know-how “Techniques of non-contact measurement on installation of ultra-high frequency at one point of simultaneously two parameters”.

![Photograph of a research facility with a scientist working on a high-tech device.](image)
Participation in exhibitions

Laureate diploma at 9th International exhibition of vacuum machines, equipment and technologies “VacuumTechExpo” 2014.
Production: Complex of vacuum plasma technologies and equipment for the improvement of surface properties of products of diverse spheres of industries”.
Authors: D.P. Borisov, A.D. Korotaev, V.M. Kuznetsov, E.V. Chulkov

Silver medal and diploma at 11th International exhibition of innovations «ARGA- 2013» (Zagreb, Croatia)
Competitive design “Effective technologies of vacuum plasma treatment of products in process settings with large vacuum units”.
Authors: D.P. Borisov, A.D. Korotaev, V.M. Kuznetsov, E.V. Chulkov, P.A. Terekhov, V.Y. Romanov, A.V. Kuznetsov

Big gold medal and diploma at 7th International biotechnological exhibition “RosBioTech-2013” (Moscow, Russia)
Production: “Technology and equipment for application of biocompatible calcium-phosphate coating on implants”.
Authors: D.P. Borisov, A.D. Korotaev, V.M. Kuznetsov, E.V. Chulkov, P.A. Terekhov

IX Moscow International Salon of Innovations and Investments.
Production: “Technology of semiconducting material synthesis on the basis of Ge–Si nanoheterostructures”
Head: A.B. Voitsekhovsky (Faculty of Radiophysics)
Co-authors: A.P. Kokhanenko (Faculty of Radiophysics), A.I. Nikiforov (Faculty of Radiophysics), O.P. Pchelyakov (Faculty of Physics)
Silver medal in the innovative developments and technologies competition

Production: Device of non-destructive control of electrophysical parameters of high bandgap semiconductors “SemiCon–1”
Head: L.G. Lapatin
1st degree diploma (with gold medal) in the competition “Best innovative project and best R&D project of the year”

Gold medal at International competition “National security”. XV International exhibition of means of state security provision «INTERPOLITEX-2011».
Development of complex security system on the basis of quantum-sensitive sensors
Head: O.P. Tolbanov