PROJECTS OF THE INSTITUTE OF MATERIALS SCIENCE

Project title:	**Synergistic effect of final machining on the corrosion resistance of austenitic stainless steels**
Coordinator	prof. Ing. Mária Dománková, PhD.
Start Date	01/07/2023
End Date	31/12/2026
Program	APVV
Annotation	Austenitic stainless steels (ASSs) are important structural materials due to their suitable combination of mechanical, technological and physical properties. This combination ensures their wide application in various industries. They are also important construction materials in nuclear power plants, especially in the primary circuit. However, their properties, such as corrosion resistance can be very significantly degraded by the inappropriate state of the microstructure. It is a well-known fact that the precipitation of inappropriate phases, such as carbide M23C6, can cause loss of corrosion resistance and susceptibility to intergranular corrosion. As some experience from technical practice shows, corrosion cracking can also be initiated by the state of the steel surface. It turns out that the presence of deformation-induced martensite, a high degree of deformation, or high residual stresses on the surface of the manufactured components can create conditions for the initiation and propagation of corrosion cracking. As part of the project solution, it is expected to expand knowledge about the loss of corrosion resistance of ASSs caused by the machining process, especially in terms of microstructural changes in the machined layer. Determination of the causes of the violation of the passivation layer, which is responsible for the corrosion resistance of steels, or to find out the causes that cause the passivation layer on the machined surface not to be restored again.

Project title:	**Environmental friction coatings for extreme tribological applications**
Coordinator	Ing. Martin Sahul, PhD.
Start Date	01/07/2023
End Date	30/06/2027
Program	APVV
Annotation	The project is focused on the development of new carbon-based nanocomposite coatings, so-called "DLC coatings" with improved functional properties designed to protect materials working in extreme tribological conditions. In general, DLC coatings are characterized by a unique combination of mechanical (high hardness) and tribological (excellent wear resistance, low coefficient of friction) properties, which makes them a suitable candidate for coating gears and bearings. The use of DLC coatings in tribological systems leads to a reduction of energy losses caused by excessive friction, as well as to a reduction in the consumption of industrial oils and lubricants, which has a positive impact on the environment. From this point of view, it is therefore possible to consider these coatings as environmental. However, the wide application of DLC coatings is limited mainly by their insufficient adhesion caused by high internal stresses, as well as low thermal stability (up to 300°C), which results in the so-called "graphitization" accompanied by a decrease in hardness and wear resistance. However, these problems can be overcome by using suitable dopants as well as by suitable coating architecture. As part of the project, DLC coatings alloyed

with suitably selected metallic (e.g. Nb, V, Ta) and non-metallic elements (e.g. B) will be produced by the methods of cathode arc evaporation (ARC), magnetron sputtering (MS) and high-power impulse magnetron sputtering (HiPIMS). In addition, the selected DLC coatings will also be deposited in the form of multilayers. The influence of the used method, parameters and alloying elements on stoichiometry, structure, tribo-mechanical properties, thermal stability and oxidation resistance of DLC coatings will be investigated in detail. In addition, the effect of the multilayer design will be evaluated by comparing the properties of multilayers with the properties of single-layer coatings deposited under the same physico-technical conditions.

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Coordinator	Ing. Martin Sahul, PhD.
Start Date	01/07/2023
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Project title:	**Synthesis and characterisation of nonconventional oxide glasses and glass-ceramics for optoelectronics**
Coordinator	doc. Mgr. Ondrej Bošák, PhD.
Start Date	01/08/2024
End Date	31/07/2026
Program	APVV

Annotation

In recent years, electronics, informatics, and telecommunication technologies have been developing at an extremely rapid pace, which necessitates the synthesis and research of new functional materials. Optoelectronics, in turn, are an innovation engine for the development of almost all industrial sectors and fields of science, including medicine, mechanical engineering, electronics, information and communication technologies, nanotechnology, metrology, spectroscopy, etc. Glass materials have a special place in the development of optical and electrical materials science. Recently, interest in electron-conducting glasses has increased following the successful application of their switching properties in electronic devices or their photoconductive properties. A feature of most electron-conducting oxide glasses is that they can simultaneously exhibit ionic and electronic conductivity. In this way, they can incorporate foreign atoms electrochemically into their glassy structure by simultaneous incorporation of electrons and ions. The research set out in this project is fundamental, concerning the synthesis and study of the structure of novel, unconventional crystalline and amorphous materials, based on TeO2 and Bi2O3, study of their structure, electronic and dielectric behavior, the correlation between the studied parameters, and influence of the structural units on the properties. In this way, new scientific knowledge will be added, and light thrown into unexplored systems. The results of the instrumental spectral analyses, in parallel with the results of the dielectric properties will provide a complete and in-depth assessment of the structure, including the structural groups and the chemical relationships between them. Based on the mentioned above, results will be obtained for the areas of glass formation and structural models characterizing the respective system will be proposed.

Project title: **Electron beam weldability and properties of 316LSi stainless steel printed with laser metal deposition**

Coordinator Ing. Martin Sahul, PhD.

Start Date 01/07/2025

End Date 30/06/2027

Program APVV

Annotation

The given Danube strategy project focuses on the investigation of electron beam weldability (EBW) and the properties of 316LSi stainless steel components fabricated using laser metal deposition (LMD) technique. The base materials for EBW will be printed with LMD. The filler material (welding wire) used for the deposition process will be 316LSi austenitic stainless steel. The printed samples will be then machined to the form of the sheet. The research will aim to evaluate the effect of EBW on the microstructure and mechanical properties of the printed 316LSi sheets. Key objectives include assessing the integrity of welded joints, identifying proper welding conditions, and understanding the interplay between additive manufacturing process and state-of-the-art EBW method used for joining. Focus will be put on the analysis of the porosity in LMD part, EBW welded joint and the characteristics of different zones of welded joint, such as LMD base material, heat-affected zone (HAZ) of LMD base material, and EBW weld metal from the point of view of properties, and corrosion resistance as well. The findings are expected to contribute valuable insights into the performance and reliability of 316LSi stainless steel in demanding applications, particularly in industries such as aerospace, marine, automotive, and chemical processing.

Project title: **Design of new glasses and glass-ceramics with Na-ions electric conductivity**

Coordinator doc. Mgr. Ondrej Bošák, PhD.

Start Date 01/07/2025

End Date 30/06/2027

Program APVV

Annotation Lithium-ion (Li-ion) batteries have become an indispensable part of our daily lives. However, new systems are needed to meet the increasing energy demand, with higher and safer energy densities. In this perspective, solid-state batteries (SSBs) are attracting increasing interest, as the problems of electrolyte leakage and flammability can be eliminated in these devices. Inorganic sodium (Na)-based SSBs offer an alternative to Li technologies for various applications due to their low cost, Na availability, increased safety, and high energy density. Solid electrolyte with Na - ionic conductivity is a key component of SSBs. This project will focus on sulfide-based solid electrolytes (SSEs), due to their mechanical properties, which provide good contact at the electrolyte/electrode interfaces, low grain boundary resistance and higher ionic conductivity compared to their oxidized counterparts. The research set out in this project is fundamental, concerning the synthesis and study of the structure of novel, unconventional crystalline and amorphous materials for sulfide-based solid electrolytes (SSEs). The initial compositions tested in this project are [Na2S]1-x[(In2S3)1-y(Sb2S3)y]x, then we will work on materials with less heavy elements, notably in the system [Na2S]1-x [Al2S3]x. We will be focused on their preparation, structural characterisation, study the conductivity of sodium ions, as well as evaluation the performances of these new materials as solid electrolytes in all-solid-state Na-ion batteries.

Project title: **Research on arc-based 3D printing of corrosion-resistant aluminium alloy**

Coordinator Ing. Martin Sahul, PhD.

Start Date 01/01/2026

End Date 31/12/2027

Program APVV

Annotation Additive manufacturing is a highly popular and widely used concept for producing complex metal components in a “layer-by-layer” manner. These methods include Wire and Arc Additive Manufacturing (WAAM), which offers unique advantages in terms of deposition efficiency and production costs. It is ideal for producing dimensional components with a surface condition nearly identical to that immediately after the WAAM process. The presented project focuses on the additive manufacturing of components using WAAM technology and the subsequent evaluation of their structure, mechanical properties, and corrosion resistance. The AA5087 aluminium alloy will be used as the welding material. The project is divided into three research areas: (1) investigation of WAAM technology itself (including programming suitable welding torch movement strategies, testing WAAM parameters, shielding atmosphere, etc.), (2) detailed characterisation of the structure and mechanical properties of the components, and (3) examination of their corrosion resistance. During the WAAM process, arc welding parameters will be monitored, and temperature fields measured using thermocouples. Light microscopy and mechanical testing will be employed to characterise the properties of the components. More advanced analytical techniques (SEM, EBSD, and X-ray diffraction) will be used for

detailed microstructure analysis. An important stage will involve corrosion testing of the components not only in laboratory conditions but also within the environment of the Adriatic Sea, which is particularly significant in the development of alloys for the marine industry. The project aims to assess the influence of WAAM process parameters on porosity, microstructure, mechanical properties, and corrosion resistance of the fabricated 3D components.

Project title:	**Research of precipitation in Cu-Sn alloys due to cryogenic processing and aging**
Coordinator	Ing. Jana Ptačinová, PhD.
Start Date	01/01/2025
End Date	31/12/2028
Program	VEGA
Annotation	The main goal of the project is to determine the opportunity to vary the microstructure and mechanical properties of tin bronzes with different tin contents, by combination of solution annealing, cryogenic treatments and artificial ageing. Tin bronzes with tin contents in the range of 6-20 wt.% will be solution annealed at temperatures 700-800 °C and for different durations, cryogenically treated in liquid nitrogen (for 24 - 168 h) and artificially aged at 300-400 °C for different durations (up to 1000 h). The obtained microstructures will be studied by light- scanning electron- and transmission electron microscopy and microanalysis, X-ray diffraction and electrical conductivity measurements. The impact of microstructural changes on mechanical properties will be examined by measurements of hardness, tensile properties, Charpy impact toughness and fracture toughness. As the principal outcome of the project, the systematic study on the heat treatability of tin bronzes will be elaborated.

PROJECTS OF THE INSTITUTE OF PRODUCTION TECHNOLOGIES

Project title:	**Research of unique unconventional methods of preparation of cutting edge microgeometry to increase cutting tool performance and machining productivity**
Coordinator	Ing. František Jurina, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	If we want to machine with powerful tools, preparation of the microgeometry of the cutting tool is a necessary condition for productive machining. The presented project is focused on the research of completely new and unique methods of microgeometry preparation of cutting edges of cutting tools by progressive methods, namely: plasma discharge in electrolyte (PDE), high-speed vibratory drag-finishing and rotary ultrasonic machining. Extensive research has shown that by properly setting the technological conditions of the PVE process, it is possible to remove material from sintered carbide and form the shape of the microgeometry of the cutting edges of the cutting tool in a few tens of seconds. To adjust the microgeometry of the cutting edges of sintered carbide tools, highspeed vibratory drag-finishing uses an order of

magnitude higher rotational frequency with the assistance of vibrations of the grinding medium in order to compact the grinding mixture. High-speed vibratory drag-finishing will take place on our own designed prototype device. The DMG Ultrasonic 20 machine will be used to form the microgeometry of the cutting edges of CBN milling cutter plates by rotary ultrasonic machining. The appropriate size of the cutting edge radius is related to the type and properties of the material being machined. The proposed project will be focused on research of tool microgeometry modification in machining of difficult-to-machine materials, namely: hardened tool steel X37CrMoV5-1 and superalloy based on nickel NiCr19FeNbMo in order to bring new knowledge for these groups of materials. During long-term tool life tests, the measurement of selected surface roughness parameters and monitoring of the development of cutting forces during machining will also take place. The DMG CTX alpha 500 multi-axis turning center will be used to test turning inserts. The 5-axis CNC milling center DMG DMU 85 monoBlock will be used for testing monolithic milling cutters made of SK and milling.

Project title:	**Experimental research of new active solder alloys for higher application temperatures of power semiconductor modules in electromobility applications**
Coordinator	prof. Ing. Roman Koleňák, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	The submitted project is oriented to research of the new active lead-free solders destined for electro-mobility applications at higher service temperatures. The new active solders will be destined mainly for the production of modern packaged power semiconductor parts used in electronic industry, where it is necessary to join the metallic, ceramic and composite materials. Concept of the new soldering alloys is based on alloying the solders with a small amount of active elements. The solders containing these metals exert a high affinity to one or more elements of the ceramic or semiconductor materials and are thus capable to wet their surfaces directly. The supposed solution fully corresponds with the present requirements for environmental suitability and recycle ability of consumables, regarding versatility of their application for the metallic, ceramic and composite materials. The new lead-free soldering alloys will be used for progressive and hybrid fluxless soldering technologies. The developed solders and fabricated soldered joints will be subjected to extensive structural and thermic analyses and analysis of mechanical properties as well. Their technological solderability in application with progressive and hybrid technologies will be determined and the optimum procedures for fabrication of soldered joints will be defined. Project solution is divided to five stages, whereas each stage correlates with the demands laid for fulfilment of the set aims. The proposed methodics of project solution is from the global aspect comparable with the present methodics applied in the research and development workplaces in the world. The adequacy of proposed methodics is supported by an extensive analysis of the current status in this field. Besides the applicant's organisation, also the co -solving organisation - The First Welding Company Inc. will cooperate in solving the project objectives.

Project title:	**Research of friction stir welding of aluminum alloys with regard to spindle load and tool life**
Coordinator	doc. Ing. Jozef Bárta, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	The project is focused on friction stir welding (FSW) of selected aluminum alloys. Aluminum alloys are the most commonly used material after steel in the engineering industry. Their weldability is often problematic because of their physical properties and structural changes in the materials after welding process. Friction stir welding in Slovakia is not as developed as abroad. On the other hand, the use of FSW in the production of light alloy components due to the reduction of emissions in the automotive industry is very advantageous. The reason is the elimination of fusion welding methods, which bring with them a numerous problems, such as hot cracking and the porosity of the welded joint. The key element in FSW are tools and optimal technological parameters. From the principle point of view, the production of tools does not differ from the production of machining tools, where one of these leading positions is held by the Slovak company Masam s.r.o. The current cooperation of this company with MTF STU makes it possible to assume that the results of submitted project will create competitive tools and apply FSW technology in Slovakia to a much greater extent. The main goals of the project are to define the geometry of tools to minimise the load applied to the device spindle, to solve the weldability of particular aluminium alloys, to find suitable welding parameters for these alloys and to define boundary conditions for the use of machining devices for friction stir welding. By defining the boundary conditions for the application of FSW in standard production, it is possible to contribute to increasing the competitiveness of enterprises in the form of flexibleproduction, i.e. use of machining devices also for friction stir welding (FSW).

Project title:	**Investigation of the dual laser beam energy distribution on the microstructure and properties of duplex steels welded joints**
Coordinator	Ing. Beáta Šimeková, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	Duplex stainless steels (DSS) usable in the chemical, petrochemical and food industries are two-phase alloys consisting of equal ratio of austenite and ferrite phases in their microstructure. Such composition provides the best compromise between mechanical properties and corrosion resistance in aggressive environments. However, welding of DSS by conventional methods leads to several disadvantages, such as residual strains in the weld, the formation of different precipitates, not equal ferrite/austenite ratio in microstructure resulting in degradation of welded joints properties. The DSS crystallize as fully ferritic or ferritic–austenite, with austenite precipitation resulting from solid solution reactions during further cooling. Therefore, it is very important to control the weld microstructure directly during the welding process, while no detrimental phases (nitrides, carbides, intermetallic phases) are formed. Laser welding using a dual beam offers the innovative way of solution. By distributing the energy of laser beam in two spots,

additional heat is introduced into the weld, which ensures a slowing down the cooling of DSS and ensures the required ferrite/austenite ratio in the weld microstructure. However, there is not enough information in this topic. Therefore, the aim of the project is the comprehensive study of the influence of dual laser beam energy distribution on the resulting microstructure, mechanical and corrosive properties of welded joints. The simulation of the process using experimental data will be included in order to obtain a model of DSS heating and welding with the possibility of verifying the mechanical and corrosion properties. The results will be directly applied in practice through the project partner PRVÁ ZVÁRAČSKÁ, JSC, which has been engaged in welding for a long time and would like to expand through this topic. The company Nerezinox, Ltd., offers stainless steel profiles of various sizes, has showed an interest in project results.

Project title:	**Robotic-Based Hybrid Manufacturing of Workpiece for the Concept of Smart Production**
Coordinator	doc. Ing. Radovan Holubek, PhD.
Start Date	01/07/2024
End Date	30/06/2027
Program	APVV
Annotation	The kinematic robotic structure is a game changer for commercializing advanced manufacturing technologies as the key player for the 4th industrial revolution considering the environmental issues. The aim of the presented project is research in the field of hybrid additive manufacturing using a robotic kinematic structure. The presented project reflects new trends in the engineering industry, as well as the research and innovation strategy of the Slovak Republic RIS3 SK. The strategic goal of the presented project is research, development and optimization of hybrid additive manufacturing technology. The project is focused on the implementation of a robotic kinematic structure for the needs of the production of engineering workpieces. Hybrid additive manufacturing combines additive manufacturing with CNC machining. The intention is to use these 2 technologies and implement them on a robotic structure that provides us with more degrees of freedom and thus kinematic movements. As a result, it is possible to manufacture parts with complex shapes, and the final adjustment of the shape and surface of the part can be achieved by machining. The robotic additive manufacturing workplace will be designed for layer-by layer digital production of complex workpiece by multi-axis additive manufacturing, and for finalisation by machining. The CAM procedure will be developed for simulation of HAM using topology optimization. The research on the technological parameters of the machining process effect on production accuracy, structure stiffness and surface roughness will be executed, and obtained information can be implemented into the adaptive control system. These experiments may give essential novel insights into optimizing the processing parameters and toolpath planning using computer-aided subtractive manufacturing software using controllable mathematical models. Such a system can be used for independent adjusting the technological parameters of the machining process.

Project title:	**Research on wire laser additive manufacturing of aerospace superalloys**
Coordinator	Ing. Barbora Ludrovcová, PhD.
Start Date	01/02/2025

End Date	31/12/2028
Program	APVV
Annotation	Wire Laser Additive Manufacturing (WLAM) is a relatively new concept applied to producing complex metal parts using the "layer by layer" principle. This technology has unique advantages in terms of deposition efficiency, production costs, as well as environmental impact. It is ideal for producing shape-complex components with a surface condition almost identical to the final one after the process. The project is focused on extensive and detailed research into the additive manufacturing of parts from the Inconel 718 nickel superalloy using the WLAM method. From a research point of view, the project is focused on reducing the total heat input of laser cladding process through several options, namely research into the deposition technology itself, including the design of suitable strategies for the movement of the laser head, as well as testing and optimisation of selected parameters of the WLAM process, by analysing the thermal history of the samples after different interlayer dwell times between deposition of individual beads and application of additional cooling in the form of a copper pad. The detailed characterisation of the structure and mechanical properties of the components is related to the mentioned strategies for reducing the heat input. During the WLAM process, the parameters of the laser deposition process will be monitored, the molten pool will be analysed in situ with a high-speed camera, and the temperature fields will be measured using thermocouples. Light microscopy and mechanical tests of printed parts will be used to characterise the properties of the components. The most modern analytical techniques (SEM, TEM, EBSD and XRD) will be used for a more detailed microstructure analysis. An important stage will be applying heat treatment of components to improve their mechanical properties. To achieve a successful project solution, not only an experimental approach but also numerical simulations will be applied.

Project title:	**Monitoring of production and logistic systems supported by the use of IoT technologies**
Coordinator	doc. Ing. Daynier Rolando Delgado Sobrino, PhD.
Start Date	01/07/2025
End Date	30/06/2027
Program	APVV
Annotation	IoT devices now permeate nearly all aspects of daily life, managing our homes, vehicles, factories, and more. Modern production and logistic tools, devices, and machines often include built-in sensors, though these are usually inaccessible to users, designed primarily for maintenance, and are not very adaptable. Additionally, many of the older equipment lack modern sensors. This situation is present through most of the instances of a production facility. This project aims to explore how affordable IoT sensors, like MPU6050 modular sensors, PVDF - Piezoelectric Film vibration sensors, MAX6675 thermal modules, etc., can be utilized for the monitoring of machines and/or material handling equipment. For these purposes, the project team plans to conduct extensive testing with various sensors and equipment in both the Hungarian and Slovak universities. It is a goal of the project to connect these sensors to WiFi-enabled controllers for real-time/online data processing, transmission and the subsequent monitoring of the equipment. This data, alongside suitable data processing and simulation tools, will help develop Digital Twins, mostly individual equipment or devices in this phase, potentially leading to their optimization.

Given the significance, novelty, and complexity of this topic for Europe and both of the V4 countries, the project will focus on creating the concept, the methodological apparatus, executing the necessary experiments, and implementing both the hardware and software components of the sensory systems into a prototype. It is also a future goal of the project team to expand into a larger international consortium to fully develop and realize the entire system. The project will also provide a clear research path and opportunity to young researchers, specially female, in both of the partner organizations.

Project title:	**Sustainable Cutting Tools Design through Generative Design Research**
Coordinator	doc. Ing. Ivan Buranský, PhD.
Start Date	01/07/2025
End Date	30/06/2027
Program	APVV
Annotation	The project focuses on an innovative and comprehensive approach to the design of cutting tools for machining processes such as turning and milling. These processes are crucial in the engineering industry, requiring cutting tools with high strength, precision, and resistance to wear. The research aims to develop cutting tools that meet these demands while simultaneously supporting sustainability and technological advancement. By utilizing generative design, the project facilitates the development of cutting tools with optimized properties. These designs address requirements for low weight, increased rigidity, and high strength, leading to more efficient and precise machining. Reducing material and energy consumption during tool production brings significant environmental benefits, supporting the creation of environmentally friendly manufacturing solutions. An essential part of the project is the application of modern additive manufacturing technologies, which are integral to the Industry 4.0 concept. Additive manufacturing enables the production of lighter, environmentally sustainable, and longer-lasting tools. Optimization of cutting tool designs and manufacturing processes improves reliability, lifespan, and maintenance costs, while reducing the ecological footprint associated with their use. The project encompasses the development of monolithic cutting tools and cutting insert holders that align with the needs of modern industry. This technological advancement has the potential to transform machining processes, achieving a level of efficiency, precision, and sustainability previously unattainable. The project's contribution lies in advancing and applying innovative manufacturing technologies that enhance productivity and promote ecological responsibility in the industry.

Project title:	**Prototype development of an industrial equipment for a unique plasma polishing technology**
Coordinator	doc. Ing. Štefan Podhorský, CSc.
Start Date	01/09/2025
End Date	31/08/2029
Program	APVV
Annotation	The presented project is focused on the development of a production device for surface treatment of metals by plasma discharge in the electrolyte. The relatively new and unique technology of plasma discharge in the electrolyte is an ecologically, hygienically, but also technologically advantageous alternative to the technology of

the electrochemical (galvanic) method of polishing, which is currently commonly used in industrial production. Unlike the electrochemical method of polishing, it is not necessary to use corrosive, toxic or otherwise dangerous chemicals in the case of plasma surface treatment technology. The benefit of the introduction of this new technology into industrial practice will primarily be the reduction of the ecological burden caused by currently used technologies. In addition to environmental and hygienic benefits, the plasma discharge technology in the electrolyte is also characterized by many technological advantages, as well as a significant increase in the quality of the treated surface and also an increase in productivity. The research team has been developing this progressive technology for a longer time, but the key obstacle to its introduction into industrial practice is the lack of industrial technological equipment that can be directly used in the mass production process. The aim of the presented project is the devolopement of the prototype, its building and also the development of other necessary equipment for the workplace of plasma treatment of metal surfaces so that these as a whole can be used directly in the mass production process. There are only a few companies in the world that offer similar devices, however, these are of a simple concept, without stabilization of process parameters and are not suitable for use in mass production.

Project title:	**Research of welding of heterogeneous materials used in fusion reactors by beam methods**
Coordinator	prof. Ing. Milan Marônek, CSc.
Start Date	01/09/2025
End Date	31/08/2029
Program	APVV
Annotation	The project focuses on welding research of heterogeneous materials used in Tokamak fusion reactors using beam technologies such as laser and electron beam welding. Materials such as tungsten, copper, graphite or molybdenum are nowadays used to manufacture HHF components (High Heat Flux) in the divertor space, due to their good heat resistance and high thermal conductivity. Often, they are exposed to temperatures of more than 100 million °C. HHF components made of these materials must necessarily be connected to a cooling system made of stainless steels, and various transition materials are used to connect them to the cooling system. The aim of the project is basic research in welding of stainless steel with copper alloys, which can be used to connect the above-mentioned difficult-to-weld materials. The project includes experimental production of weld joints, characterization of their structure, analysis of their mechanical properties and quality control. The project results will contribute to expand knowledge in materials science and welding technologies, which will support the safe and efficient development of fusion reactors for sustainable energy production.

Project title:	**Research of cadmium-free hard brazing filler metals for multilayer material systems in fusion reactors, manufactured and repaired under high-vacuum conditions.**
Coordinator	prof. Ing. Roman Koleňák, PhD.
Start Date	01/09/2026
End Date	31/08/2030

Program	APVV
Annotation	The project is focused on fundamental research into the brazing of multilayer material systems intended for components exposed to high heat flux and cyclic loading of fusion devices. The core of the project lies in the research, design, and experimental verification of cadmium-free, environmentally compatible hard brazing fillers based on Cu-In, Cu-Ag, and related alloy systems modified with Mn, Ni, and Sn. The originality of the project consists in alloying the brazing fillers with small additions of active elements (Zr, Hf, Cr, Ce) in order to improve wettability, chemical reactivity, and the formation of reaction layers at the interface. Brazing will be primarily focused on multilayer combinations such as W/Cu/CuCrZr, Mo/Cu/CuCrZr, and Ta/Cu/CuCrZr, as well as joints of W, Mo, Ta, Al_2O_3, and AlN with high-purity copper (4N). The experiments will be carried out using electron-beam heating under vacuum and brazing in an vacuum furnace. The project outputs will include new knowledge on joint formation mechanisms, diffusion processes, and the growth of reaction layers in the investigated systems. One of the outputs will be a database of relationships between brazing filler composition, process parameters, interfacial microstructure, mechanical integrity of the joints, and recommendations for the design of brazing fillers and technological procedures for vacuum brazing of multilayer systems. The project will be carried out in close cooperation with the industrial partner FIRST WELDING COMPANY, Inc., which will provide technological know-how, fixture design, and conditions for validating selected procedures in an environment close to industrial practice.

Project title:	**Research on the Application of Plasma Discharges for Cutting Edge Preparation of Cutting Tools and the Implementation of an Original Edge Preparation Device**
Coordinator	Ing. Tomáš Vopát, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	The project focuses on applied research and development of a method for cutting edge microgeometry preparation using plasma discharges in an electrolyte. It builds upon the results of fundamental research and represents a systematic extension of existing knowledge toward practical application. The main objective is to verify the tool life of cutting tools through extensive testing, with emphasis on statistical relevance and confirmation of result repeatability. The project also includes the design, construction, and validation of an original edge preparation device based on a plasma method, which is unique compared to existing technologies. The device will be tested in a relevant environment close to industrial practice to support technology transfer into industrial applications. The expected outcome is a technological solution with high application potential, contributing to increased efficiency and competitiveness of manufacturing processes in the mechanical engineering industry.

Project title:	**Implementation of progressive methods of education in professional subjects in the field of mechanical engineering and industrial robotics**
Coordinator	doc. Ing. Augustín Görög, PhD.

Start Date	01/01/2024
End Date	31/12/2026
Program	KEGA
Annotation	The Faculty of Technology of the Technical University in Zvolen and the Faculty of Materials Technology of the Slovak University of Technology in Trnava currently provide teaching at all three levels of higher education. The project is aimed at supporting and improving the quality of education in professional subjects taught at the faculties as well as at building and upgrading laboratories at the faculties, with the aim of making the latest research results available to students and teachers, and is also aimed at increasing the employability of graduates of the study programmes on the labour market. The solution will be aimed at systematically introducing progressive educational methods in order to increase interest in studying subjects in the field of engineering and industrial robotics and at the same time to raise the level of knowledge of graduates in the field.

Project title:	**New methods and forms of higher education by supporting distance forms of online access and multimedia support for selected subjects of the study programme Computer Aided Design and Production and Computer Aided Manufacturing Technologies.**
Coordinator	prof. Dr. Ing. Jozef Peterka
Start Date	01/01/2025
End Date	31/12/2027
Program	KEGA
Annotation	The submitted project proposal is focused on the use of two technologies of the distance form of education, namely: online access and multimedia (MM) support. The goal of the project is to make available to students not only study materials for online education and self-study, but also an online practicum in CNC programming to a greater extent and intensity.

Project title:	**Development of modern methods of teaching technical subjects in the university environment - creation of a multimedia textbook**
Coordinator	prof. Ing. Peter Košťál, PhD.
Start Date	01/01/2025
End Date	31/12/2027
Program	KEGA
Annotation	The project "Development of Modern Methods of Teaching Technical Subjects in the University Environment - Creation of a Multimedia Textbook" aims to innovate and increase the efficiency of teaching technical disciplines at the university level through the integration of the latest technologies and didactic methods in the creation of a multimedia textbook. This project aims to increase the availability and quality of learning materials for all learning modalities such as face-to-face learning, online learning, and student self-study. The multimedia textbook will include videos, animations, simulations and interactive tests to promote better understanding and increase student engagement in the learning process. In addition, the project includes training sessions for university teaching staff to equip them with the necessary knowledge and skills for the effective use of new technological tools in the educational

process. This approach not only modernizes the teaching of technical subjects but at the same time supports the development of teachers' pedagogical competencies. The overall result will be to increase the quality of technical education at the university and provide students with better tools for their future professional employment in technical fields.

Project title:	**Heuristic and competence-oriented university education in manufacturing engineering**
Coordinator	doc. Ing. Jana Šugárová, PhD.
Start Date	01/01/2026
End Date	31/08/2028
Program	KEGA
Annotation	The project is aimed at developing innovative forms of university education, extending existing standard learning methods with experiential and competency-based learning activities in the newly designed engineering study programme Manufacturing Engineering. In cooperation with industrial and foreign partners, various forms of formal and informal, practice-orientated, personalised education and training will be developed and validated to support the balanced development of graduates' technical and key competencies in order to meet the requirements for their successful application in contemporary engineering practice at both national and supranational levels. The expected outcome of the project solution will be a conceptually and content-adapted model of education with a strengthened share of heuristic, inquiry-orientated educational strategies supporting students' independence, activity and creative thinking.

Project title:	**Investigation of the dual laser beam energy distribution on the microstructure and properties of duplex steels welded joints**
Coordinator	Ing. Beáta Šimeková, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	VEGA
Annotation	Duplex stainless steels (DSS) usable in the chemical, petrochemical and food industries are two-phase alloys consisting of equal ratio of austenite and ferrite phases in their microstructure. Such composition provides the best compromise between mechanical properties and corrosion resistance in aggressive environments. However, welding of DSS by conventional methods leads to several disadvantages, such as residual strains in the weld, the formation of different precipitates, not equal ferrite/austenite ratio in microstructure resulting in degradation of welded joints properties. The DSS crystallize as fully ferritic or ferritic–austenite, with austenite precipitation resulting from solid solution reactions during further cooling. Therefore, it is very important to control the weld microstructure directly during the welding process, while no detrimental phases (nitrides, carbides, intermetallic phases) are formed. Laser welding using a dual beam offers the innovative way of solution. By distributing the energy of laser beam in two spots, additional heat is introduced into the weld, which ensures a slowing down the cooling of DSS and ensures the required ferrite/austenite ratio in the weld microstructure.

However, there is not enough information in this topic. Therefore, the aim of the project is the comprehensive study of the influence of dual laser beam energy distribution on the resulting microstructure, mechanical and corrosive properties of welded joints. The simulation of the process using experimental data will be included in order to obtain a model of DSS heating and welding with the possibility of verifying the mechanical and corrosion properties. The results will be directly applied in practice through the project partner PRVÁ ZVÁRAČSKÁ, JSC, which has been engaged in welding for a long time and would like to expand through this topic. The company Nerezinox, Ltd., offers stainless steel profiles of various sizes, has showed an interest in project results.

Project title:	**Research into the innovative unconventional methods of preparation of cutting edge microgeometry to increase the tool life of cutting tools**
Coordinator	doc. Ing. Vladimír Šimna, PhD.
Start Date	01/01/2023
End Date	31/12/2026
Program	VEGA
Annotation	Cutting edge preparation of cutting tools is currently one of the most modern ways to increase the tool life of cutting tools. By edge preparation in the field of cutting tools production we mean the modification of the cutting edge microgeometry of manufactured or newly sharpened cutting tools. The aim of the project is to create cutting edge rounding with new and unique edge preparation methods by plasma discharge in electrolyte, high-speed vibratory drag finishing and rotary ultrasonic machining (RUM), which have not been used for this purpose elsewhere in the world in practice and research. Cutting edge preparation is performed on prototype devices, which were originally developed at the Faculty of Materials Science and Technology STU (in the case of RUM on a machine tool with ultrasound assistance). One of the benefits will be the development of advanced edge preparation methods that can for the required cutting edge radius in an extremely short time and in the required quality.

Project title:	**Modification of the structure and mechanical properties of solder alloys to increase the reliability of soldered joints in advanced electronic applications**
Coordinator	Ing. Tomáš Meluš, PhD.
Start Date	01/01/2023
End Date	31/12/2026
Program	VEGA
Annotation	Presented project is focused on the research of the modification of soft solder alloys to achieving higher joint reliability in modern and advanced electronic applications. Modified solder alloys will be directed primarily to the production of modern high-performance semiconductor packaged components in the electronics industry, where it is necessary to join metal, ceramic and composite materials. The concept of the project is based on the alloying of solders with active and stabilizing element. Solders containing an active element have a high affinity for one or more elements of ceramic materials and are able to directly wet their surfaces. The stabilizing element will serve to improve the structure and increase the integrity and functionality of the joint after demanding reliability tests. The concept of the project corresponds to the current

requirements for environmental suitability and recyclability, taking into account the versatility of the use of solders for metallic, composite and ceramic materials.

Project title:	**Research of active soldering alloys filled with nanoparticles of ceramic materials**
Coordinator	prof. Ing. Roman Koleňák, PhD.
Start Date	01/01/2024
End Date	31/12/2027
Program	VEGA
Annotation	The presented project is oriented to research of active lead-free soldering alloys, filled with the nanoparticles of ceramic materials with the aim to reduce the silver content in these alloys. The new active soldering alloys will bemoriented mainly to the production field of modern power semiconductor parts servicing at higher operating temperatures, applied for example in electromobility. During their production in electronic industry it is necessary to join the metallic, ceramic and composite materials. The new concept of soldering alloys is based on their filling with the ceramic nanoparticles and alloying with a small amount of active elements. The proposed solution fully corresponds with the present requirements for environmental suitability and recyclability of consumables, considering the versatility of their application for the metallic and ceramic materials. The new lead-free soldering alloys will be destined for the progressive and hybrid flux-free soldering technologies.

Project title:	**Research and development of sensor calibration methodology for diagnostic equipment for automated and robotic systems**
Coordinator	prof. Dr. Ing. Jozef Peterka
Start Date	01/01/2024
End Date	31/12/2027
Program	VEGA
Annotation	The project includes the development of an automated diagnostic device, research into its control and operation, as well as detailed studies of the results and their analysis. The application outputs will be applied for determining the contact forces in material handling in the field of robotization of assembly, automation of machining and in determining ergonomic conditions in production. The diagnostic device can be applied in the field of sensor calibration and recalibration. The diagnostic algorithm will be a diagram of logical decisions based on previously studied rules. This will create a comprehensive sensor calibration methodology for the diagnostic system. The methodology will be developed in the research for selected sensor types and for the application of automated diagnosis, monitoring and operation of sensor systems, especially in the process of machining automation and robotic assembly.

PROJECTS OF THE INSTITUTE OF INTEGRATED SAFETY

Project title:	**Progressive methods of testing dust and dust-air mixtures for the needs of the manufacturing industry in Slovakia**
Coordinator	doc. Ing. Richard Kuracina, Ph.D.

Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	A safe working environment is important in all industries, especially where dangerous situations such as fires ornexplosions can often occur. Explosions and fires in industrial dusts are still relatively common. More than 70% of materials and wastes in the form of dust processed and occurring in indust ry are flammable. This means that in most industrial plants where such materials are present, the risk of fire and dust explosion is real. Fire and explosion characteristics are an important indicator of the properties of combustible dusts. From the point of view of fire safety, these indicators are very important, whether they are explosive limits, initiation energies or flammability characteristics, while the value of individual characteristics depends mainly on the test conditions, which should be close to real conditions in practice. Their creation and simulation is not easy, therefore it is necessary to take into account various external influences and parameters. The project will be primarily focused on the study of the characteristics of dusts with emphasis on their flammability and explosiveness. In order for the measurement of characteristics to correspond to the conditions of practice, the research will be carried out both on unique devices used in fire engineering and after modification of commonly used measurement procedures. The project will accredit a laboratory (as the first in Slovakia) to study the fire and explosion parameters of dusts. A database of fire and explosion parameters of dusts will also be created, which will be publicly available for all industries in the Slovak Republic and for the general professional public. The result of the project solution will be the possibility of increasing the level of safety and explosion prevention in industry in Slovakia.

Project title:	**An insulating panel for wooden buildings with properties at the level of scientific and technological possibilities, prepared in laboratory conditions by utilizing waste wood**
Coordinator	prof. Ing. Jozef Martinka, PhD.
Start Date	01/09/2025
End Date	31/12/2028
Program	APVV
Annotation	Wooden buildings represent a healthy way of living. They are made of biologically renewable materials and have the lowest impact (compared to other buildings) on climate change (due to minimal CO2 emissions during production and high thermal resistance and resulting energy savings). Wooden buildings currently have only a few significant disadvantages resulting from the properties of their building components, namely: flammability and limited resistance to moisture and biological factors (wood-boring insects, fungi and molds). These are practically the only factors that limit their wider use. The increase in the number of wooden buildings will significantly contribute to solving many current economic problems at both the national and European levels (especially energy saving). The requirements set by Directive (EU) 2012/27/EU as amended by Directive (EU) 2018/2002 will probably not be achieved in the Slovak Republic by 2030 without increasing the number of wooden buildings (and the associated energy savings). The problem is that the shortcomings of wooden buildings (flammability and low resistance to water and biological factors) are often addressed separately in Slovakia, but also in the world (it is known that improving

one parameter often negatively affects another). A significant opportunity in the construction of wooden buildings is the use of waste wood, which would significantly contribute to reducing CO2 emissions (if carbon remains bound in waste wood, it will not be released in the form of CO2 during its energy recovery). The world-class and at the same time excellence of the project results from the fact that the aim of the project is to create an insulation panel for wooden buildings that solves all of today's problems of wooden buildings (a diffusion-open insulation panel with reduced flammability - at the level of fire reaction class B, with high resistance to water and biological factors, made from waste wood).

Project title:	**Research and development of transparent photovoltaic cells suitable for windows and skylights in buildings**
Coordinator	prof. Ing. Jozef Martinka, PhD.
Start Date	01/01/2025
End Date	31/12/2028
Program	VEGA
Annotation	The aim of the project is research and development of solar cells, made by vaporizing thin layers of semiconductors on transparent wood. Transparent wood is a renewable material with zero carbon balance and greater thermal resistance than glass. By vaporizing semiconductor layers onto transparent wood, functional solar cells will be created that retain varying levels of transparency/translucency. The possibility to produce such a cell will represent a key advance, as it will allow mounting solar cells on windows and skylights of buildings. In the warm months, such cells will reflect part of the sunlight, turn part into electrical energy and release part into the building. This will enable optimal lighting of the building without excessive overheating and at the same time produce electricity. In the winter months, they also let some of the sunlight into the building and turn some of it into electricity. In addition, high thermal resistance (compared to glass) will contribute to energy savings for heating.

PROJECTS OF THE ADVANCED TECHNOLOGIES RESEARCH INSTITUTE

Project title:	**Reduction of AC losses in a cable model made of striated high-temperature superconductors**
Coordinator	Mgr. Michal Skarba, PhD.
Start Date	01/09/2025
End Date	31/08/2029
Program	APVV
Annotation	High-temperature superconductors based on REBCO (Rare Earth Barium Copper Oxide) are used in magnet windings for devices with high magnetic fields (>10 T) such as particle accelerators or nuclear fusion reactors. During the operation of these devices, alternating current (AC) losses occur and REBCO tapes are affected by cyclic electromagnetic forces, arising during the time change of the magnetic field, which can cause failure of the device. The aim of this project will be the development of a striated REBCO tapes and a TORT (Tapes on Round Tube) type cable with low AC losses and high mechanical toughness (for example fatigue strength). We plan to achieve the reduction of AC losses by striating the REBCO tape and altering the

material of the cable former. However, after such process, it is necessary to protect the striated REBCO layers with an additional (multi)layer for the purpose of chemical and thermal stabilization. The former of the cable will be 3D printed from a composite material based on PETG CF (polyethylene terephthalate glycol reinforced with carbon fiber), with much lower electrical conductivity than previously used formers. By altering the material of the former in the TORT cable, we can reduce the total magnetization losses by decreasing the eddy currents, which were contributed by the copper former. According to numerical calculations (ANSYS, COMSOL), we apply the corresponding mechanical load to REBCO tapes (untreated/striated) and cables from these REBCO tapes. Afterwards, we determine the mechanical toughness of the cables, which will be optimized by studying the REBCO tape damage using SEM, FIB, XPS and ERDA methods. A successful production of a short TORT cable with a stabilization (multi)layer wound on a composite former will be a confirmation of the suitability of this cable concept. By combining the above materials, we can create an innovative superconducting cable with significantly reduced AC losses and high mechanical toughness.

Project title:	**Nuclear magnetic dipole moments from NMR spectra for future nuclear and atomic physics experiments: computational chemistry meets nuclear physics**
Coordinator	RNDr. Andrej Antušek, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	Nuclear magnetic dipole moments are fundamental nuclear properties that underpin a wide range of modern experiments in nuclear physics, atomic physics, and magnetic resonance spectroscopy. In recent years, advances in hyperfine spectroscopy and beta-detected nuclear magnetic resonance (beta-NMR) have created an urgent demand for reference magnetic dipole moments with unprecedented accuracy and rigorously quantified uncertainties. This project aims to deliver a new generation of highly accurate nuclear magnetic dipole moments by combining selected NMR experiments with state-of-the-art ab initio calculations of NMR shielding constants. The core methodology integrates advanced electronic-structure theory accounting for electron correlation and relativistic effects with realistic modeling of molecular (solvent) environments using ab initio molecular dynamics enhanced by machine-learning force fields. The project addresses (1) key unresolved inconsistencies in magnetic moments derived from liquid-phase NMR, (2) establishes validated computational protocols for beta-NMR probe nuclei in room-temperature ionic liquids, and (3) refines reference moments of heavy nuclei critical for tests of quantum electrodynamics in extreme magnetic fields. A particular emphasis is placed on uncertainty quantification and the consolidation of NMR-based magnetic moments into a unified, reference-grade data set. The anticipated outcomes include several high-impact publications, direct support for ongoing and planned experiments at CERN-ISOLDE, and the preparation of evaluated nuclear magnetic dipole moments for inclusion in the next update of the IAEA Table of Recommended Nuclear Magnetic Dipole Moments. Beyond nuclear physics, the developed computational protocols will be broadly applicable to the prediction of NMR properties in complex liquid environments relevant to materials science and chemistry, ensuring long-term scientific impact.

Project title:	**Micromechanical and microstructural response of helium-irradiated nuclear materials**
Coordinator	Mgr. Zoltán Száraz, Ph.D.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	Understanding the effects of radiation damage and helium accumulation on the mechanical performance of structural materials is a key challenge for the safe and reliable operation of current and future nuclear energy systems. While neutron irradiation provides the most representative conditions, its practical limitations necessitate complementary experimental approaches. Ion-beam irradiation combined with micromechanical testing has emerged as a powerful tool for accelerated materials screening, however, the interpretation and transferability of micromechanical data from ion-irradiated layers remain insufficiently understood. The MICRO-HELIOS project aims to establish a robust experimental and methodological framework for assessing helium effects on the micromechanical behavior of nuclear structural steels. Building on the results and experimental capabilities developed in the predecessor ARTHEMIS project, MICRO-HELIOS will systematically investigate the influence of helium-todamage ratio, irradiation temperature, and irradiated layer thickness on mechanical response and microstructural evolution. The project will extend the scope from a single material to a comparative study of ferritic/martensitic, austenitic, and oxide-dispersion-strengthened steels. By combining advanced multi-energy ion irradiation, state-of-the-art micromechanical testing, and complementary microstructural characterization techniques, MICRO-HELIOS will identify key thresholds and size effects governing the representativeness of micromechanical measurements. The expected outcomes will improve the reliability of ionirradiation-based testing methodologies and provide experimentally grounded insights into helium-induced degradation mechanisms. These results will contribute to the advancement of radiation tolerance assessment methods and support the development and qualification of materials for nuclear energy applications.

Project title:	**Establishing a Unified Structural Evolution Theory for Late Transition Metal Oxides and Halides: Theoretical Conceptualization and Experimental Validation**
Coordinator	doc. Mgr. Mariana Derzsi, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	Despite the technological ubiquity of late transition metals ((Pd,Ni,Cu,Ag)), significant regions of their binary phase diagrams remain unexplored "white spots." This project addresses this critical structural void by transitioning from descriptive crystallography toward a predictive, concept-driven science. We aim to establish a Unified Structural Evolution Theory that treats the entire compositional gradient as a continuous life-cycle, from metallic lattice fragmentation to the formation of complex ionocovalent frameworks and polyanionic species. The methodology utilizes a "Tandem Modeling- Diagnostic Engine" that bridges an existing ab initio Big Data

reservoir of over 50,000 models with a robust in-house physical library. We employ Periodic Graph Theory (PGT) and advanced bonding analytics (ELF, QTAIM, COOP) to identify the "architectural hallmarks" of metastable phases. These theoretical blueprints are then definitively validated through a forensic diagnostic framework utilizing co-localized AFM-Raman, XPS depth profiling, and T-EBSD mapping. The final outcome will be a Structural-Electronic Phase Atlas, a functional roadmap that enables the rational, theory-guided design of functional inorganic solids. By bridging the traditional divide between theory and experiment, the project establishes a new conceptual grammar for understanding and navigating the structural complexity of the late (d)-block.

Project title:	**Non-equillibrium synthesis routes for novel metastable transition metal oxides**
Coordinator	Ing. Pavol Noga, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	This project aims to synthesize and characterize new metastable oxide phases of copper, palladium, and nickel predicted by DFT+EA calculations but experimentally unrealized. Using a newly commissioned Petrik P3k system integrating HIPIMS, conventional sputtering, thermal evaporation, and plasma immersion ion implantation in ultra-high vacuum, the project enables precise control over film composition and hydrogen content with immediate characterization before phase degradation. The approach uniquely combines comprehensive theoretical databases, purpose-built non-equilibrium synthesis capabilities, hydrogen quantification via ToF-ERDA, and dual synthesis pathways including epitaxial nanoparticle growth on crystalline substrates. Target phases include oxygen-rich palladium oxides (Pd2O3, PdO2), metastable copper oxides (Cu3O2, Cu2O3), and nickel oxo-superoxide/peroxide architectures. Expected outcomes provide experimental confirmation of predicted phases, viable physical synthesis routes for advanced oxide semiconductors, systematic understanding of hydrogen's role in phase formation, and contamination-free epitaxial nanoparticle synthesis methods with applications in catalysis, sensing, transparent electronics, and energy conversion technologies.

Project title:	**Moving beyond deeply rooted approximations in theoretical chemistry and materials modelling**
Coordinator	RNDr. Martin Šulka, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	Some of the simple approximations frequently used in ab initio computer simulations of molecules and condensed matter were introduced decades ago to allow for calculations of physical properties with the limited computer power available at the time. Given the computer power available today and recent algorithmic developments, especially in the field of machine learning (ML), more accurate simulation methods have become feasible, rendering the use of many popular approximations unjustified. In this project, we plan to identify some of those

approximations and critically assess their modern alternatives. We will, for instance, investigate the use of ab initio molecular dynamics in combination with ML to perform rate constant calculations of catalytic reactions beyond the transition state theory, and vibrational spectra beyond the harmonic approximation. In the field of in silico drug design, we will develop and evaluate ML-based methods beyond conventional inhibitor-protein affinity predictions by incorporating ligand conformational flexibility, and enhance proteinligand affinity predictions by targeting individual components of the binding free energy for a more detailed and accurate assessment. Using an original methodology based on fixed-node diffusion Monte Carlo, developed by some of us, we will investigate the strong correlation in catalytic clusters and examine the connection between local charges, ionization potential, and CO2 activation. In the realm of relativistic chemistry, we will reach beyond scalar relativity proposing new efficient calculation protocols for spin-orbit corrections relevant in heavy-element systems. We will suggest novel materials based on polyethylene chains cross-linked by metal atoms and predict their properties.

Project title:	**Thermal stability and radiation response testing of structural materials for nuclear applications**
Coordinator	Mgr. Zoltán Száraz, Ph.D.
Start Date	01/01/2024
End Date	31/12/2027
Program	VEGA
Annotation	The proposed project aims to study the effects of elevated temperature and ion irradiation on the stability, microstructure evolution, and micromechanical properties of prospective structural materials for GEN IV fission reactors, Small Modular Reactors as well as fusion applications. Materials in these innovative systems need to withstand harsh environments in terms of high temperature, corrosive coolants, and high radiation doses. The demanding requirements are not met by current structural materials. Screening of thermal stability and radiation resistance of materials with superior corrosion resistance in heavy liquid metals will support their development and qualification for nuclear applications. The proposed work will contribute to a better understanding of the damage evolution, hardening phenomena, and underlying mechanisms. Some of the selected AFA steels and ODS Fe-Cr-Al alloys have the potential to be applied as accident tolerant fuel cladding in current reactor fleets and concentrated solar power.

PROJECTS OF THE CENTRE FOR NANODIAGNOSTICS OF MATERIALS

Project title:	**Photochemically Versatile Materials for Water Treatment**
Coordinator	Ing. Mário Kotlár, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	This fundamental research project is based on photochemically versatile (PCV) materials which are simultaneously combined photocatalysis and photo-Fenton with additional synergy. Indeed, by looking at the literature, the photocatalytic and Fenton

processes are intensively documented with tens of thousands of publications during last years without significant advancement for real applications. Therefore, the idea of this project is to provide a breakthrough in photochemical science. The PCV materials will be prepared in the form of composites (composed photocatalytic and photo-Fenton materials e.g. TiO2 and Fe2O3) and as single-phase materials (semiconductor photocatalyst composed of element active in photo-Fenton process e.g. CuFe2O4). The optical and structural properties of PCV materials are extensively investigated using a wide range of techniques (XRD, SEM, TEM, DRS, XPS, UPS, etc.). The photochemical process triggered by PCV materials are fully resolved. To this end, photocatalytic and photo-Fenton processes are studied as a whole by analyzing the oxidative power of PCV materials i.e. by quantifying the reactive species using both fluorescence and EPR techniques. To investigate the synergy in PCV materials, the photocatalysis and photo-Fenton are subsequently quenched, thus allowing to determine the contribution of each photochemical processes along with the synergy effect. Finally, the PCV materials are tested in the degradation of different organic pollutants in both synthetic and real wastewater. Such tests highlight the relevance of this project based on the innovative concept of photochemical vers atility for applications in sustainable water treatment in the frame of the circular economy of water.

Project title:	**Towards Superior Perovskite-based Solar Cells via Optimized Passivation and Structure**
Coordinator	Ing. Mário Kotlár, PhD.
Start Date	01/07/2022
End Date	30/06/2026
Program	APVV
Annotation	Solar cells (SCs) are one of the highly promising options for environmentally clean electricity production. Their role in our future energy mix depends on further reduction in system costs, and device efficiency is of key importance. Hybrid organic-inorganic perovskites seem to be suitable candidates for next -generation photovoltaics, either in tandem with crystalline silicon solar cells or as a cheap/flexible thin-film alternative. Over the last few years, the power conversion efficiency of perovskite SCs has surpassed 25 %. However, its further increase is conditioned by the effective passivation of the detrimental defects at the perovskite interface and grain boundaries. This project is dedicated to understanding the role of defects in limiting photovoltaic performance and developing effective passivation routes to achieve further performance advances. Its innovation potential lies in increasing the efficiency of future SCs via targeting the defect-related nonradiative traps at the surfaces and interfaces and their efficient passivation. The project combines the different expertise and various experimental techniques of three partners intending to translate the acquired new scientific knowledge of defect passivation in hybrid perovskites into technological advances.

Project title:	**Colour centres in diamond – correlation between atomic structure and opto-electronic properties**
Coordinator	Ing. Viliam Vretenár, PhD.
Start Date	01/07/2024
End Date	31/12/2027

Program	APVV
Annotation	The subject of the project is in the field of quantum technologies. We will prepare and characterize optically-active defects in diamonds and correlate the atomic structures with optical properties to be used for quantum applications. For a wide range of dopant concentrations, we will identify the dopant distributions and study the evolution of dopants' configuration in-situ, during thermal annealing, using atomic-resolution microscopy and spectroscopy techniques. We will further study the effect of annealing on the opto-electronic properties by measuring photoluminescence, photocurrent and electroluminescence for the same set of samples. Graphene transparent electrodes on a diamond surface will be fabricated for phototransport measurements. Diamond-based hybrid p-i-n diodes will be prepared for electroluminescence measurements. We will focus on finding a correlation between the atomic structure and the opto-electronic properties of differently doped diamonds. This will contribute to the understanding of the fundamental relationship needed to efficiently design optically-active elements for diamond quantum devices.

Project title:	**CMOS-compatible synthesis and integration of TMD materials**
Coordinator	Ing. Viliam Vretenár, PhD.
Start Date	01/09/2026
End Date	31/08/2030
Program	APVV
Annotation	The project focuses on the development of scalable and CMOS-compatible technologies for fabricating field-effect transistors (FETs) based on transition metal dichalcogenide (TMD) materials. Due to their atomically thin nature and tunable electronic properties, TMDs represent promising channel materials for next-generation FET devices beyond conventional silicon technology. However, their practical implementation is limited by challenges related to large-area synthesis, contact engineering, and compatibility with standard CMOS processes. The primary objective of this project is to realize both p-type and n-type TMD-based FETs integrated on a single technological platform, enabling complementary transistor operation analogous to CMOS logic. The project will focus on controlled synthesis of high-quality TMD thin films using CMOS-compatible deposition and chalcogenization techniques, followed by their direct integration into back-gated and top-gated FET architectures. Special emphasis will be placed on channel thickness control, interface and contact engineering, and doping strategies to achieve stable and reproducible p-type and n-type transport characteristics. Comprehensive electrical characterization of the fabricated FETs will be combined with advanced structural and chemical analyses to establish clear correlations between material properties, device architecture, and transistor performance metrics such as mobility, threshold voltage, subthreshold swing, and on/off current ratio. The expected outcome of the project is the demonstration of scalable, complementary TMD-based FET devices fully compatible with CMOS processing, providing a technological foundation for future low-power, high-density electronic circuits.

PROJECTS OF THE INSTITUTE OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Project title:	**Novel Trends and Sustainability in Logistics**

Coordinator	doc. Ing. Helena Fidlerová, PhD.
Start Date	01/01/2026
End Date	31/12/2027
Program	APVV
Annotation	The presented scientific bilateral cooperation project between the Slovak University of Technology in Bratislava (STU) and the University of Montenegro (UoM) aims to increase awareness and understanding of sustainable and innovative trends in logistics among university students, early career researchers and academics through a combination of educational activities and hands-on experience. The aim of the project is to contribute to the development of resilient and environmentally sustainable solutions in the field of logistics, transport and related technologies in the Slovak Republic and Montenegro through interdisciplinary cooperation between STU and UoM experts and students.. The content focus of the project responds to current EU priorities such as the European Green Deal, digital transformation and the integration of the circular economy, applying an interdisciplinary approach linking logistics, transport systems, environmental, economic and social sustainability of solutions and risk identification. Key activities include the organisation of a joint international student scientific conference and workshop, professional visits to laboratories at and excursions to industrial enterprises applying sustainable logistics principles. The project foresees joint publication outputs, creation of educational materials in English and strengthening of research and intercultural competences of the participants. The practical part includes professional visits to laboratories at STU and UoM and excursions to industrial enterprises applying the principles of sustainable logistics in practice. Young researchers and PhD students will be actively involved in all stages of the project, thus strengthening their research, organisational, communication and intercultural competences. The project creates the prerequisites for future joint project initiatives and long-term partnerships in research, education and knowledge transfer into practice.

Project title:	**Creation of a laboratory for the systematic knowledge transfer from the research of personnel aspects of human technology interaction into selected subjects of industrial engineering**
Coordinator	doc. Ing. Zdenka Gyurák Babeľová, PhD.
Start Date	01/01/2024
End Date	31/12/2026
Program	KEGA
Annotation	The purpose of the project is to create a laboratory with its own database of research tools and data collected through them, which will be aimed at identifying and developing complex skills necessary for practical application in industrial engineering and management of industrial enterprises. The implementation of research tools will make it possible to ensure the systematic transfer of information from the investigation of personnel aspects of the interaction of people and technologies to the study of industrial engineering. The created database of research tools will make it possible to determine the prerequisites (individual characteristics, abilities, skills) for their work among current and future industrial engineers and managers. Research tools will also be aimed at investigating the prerequisites for effective human-

technology interaction and the successful adaptation of employees to new technologies. The use of valid and reliable research tools will ensure the collection of data necessary for the identification of prerequisites and necessary skills for effective work in industrial engineering and management of industrial enterprises. The data collected as part of the research will be used for publication in order to build an excellent workplace. The built laboratory will also provide training for industrial engineers and managers in the form of an assessment and development centre and a training course focused on work in the field of human resource management and employee performance management.

Project title:	**Transformation of education focused on innovative didactic tools for the digital enterprise, artificial intelligence, and assessment of digital maturity**
Coordinator	Ing. Vanessa Prajová, PhD.
Start Date	01/01/2026
End Date	31/12/2028
Program	KEGA
Annotation	The purpose of the project is to create a laboratory with its own database of research tools and data collected through them, which will be aimed at identifying and developing complex skills necessary for practical application in industrial engineering and management of industrial enterprises. The implementation of research tools will make it possible to ensure the systematic transfer of information from the investigation of personnel aspects of the interaction of people and technologies to the study of industrial engineering. The created database of research tools will make it possible to determine the prerequisites (individual characteristics, abilities, skills) for their work among current and future industrial engineers and managers. Research tools will also be aimed at investigating the prerequisites for effective human-technology interaction and the successful adaptation of employees to new technologies. The use of valid and reliable research tools will ensure the collection of data necessary for the identification of prerequisites and necessary skills for effective work in industrial engineering and management of industrial enterprises. The data collected as part of the research will be used for publication in order to build an excellent workplace. The built laboratory will also provide training for industrial engineers and managers in the form of an assessment and development centre and a training course focused on work in the field of human resource management and employee performance management.

Project title:	**Acceptance and use of Innovations 4.0 in relation to cognitive gains and load in the context of sustainable development goals**
Coordinator	doc. Ing. Helena Fidlerová, PhD.
Start Date	01/01/2024
End Date	31/12/2026
Program	VEGA
Annotation	The project is based on the previous findings of the UTAUT model of acceptance and use of technological innovations, according to which effort and load expectations are among the main determinants of Innovations 4.0 acceptance and us. By verifying the acceptance and use of Innovations 4.0 in Construction sector, the project aims to identify an extended model of acceptance of technological Innovations 4.0 with an

emphasis on achieving selected sustainable development goals in a triple bottom line perspective. The project experimentally verifies the impact of selected Virtual learning environments 4.0 a) in the area of cognitive load and cognitive benefits in the frame of ARCS motivation model, b) with regard to the effect of the time factor and the type of virtual educational environment 4.0. The technology of Virtual Reality, the use of which the project verifies, can be applied in the training of workers from practice.

PROJECTS OF THE INSTITUTE OF APPLIED INFORMATICS, AUTOMATION AND MECHATRONICS

Project title:	**The development of teaching aids for subjects focused on mechatronic systems and experimental**
Coordinator	Ing. Rastislav Ďuriš, PhD.
Start Date	01/01/2024
End Date	31/12/2026
Program	KEGA
Annotation	The main aim of the project is to create the new teaching aids and study supports for subjects Mechatronic Systems, Modeling of Mechatronic Systems and Experimental Methods and Technical Diagnostics. Part of the created teaching aids and study materials will also be used in the subjects Hydraulic and pneumatic systems and Reliability and safety of technical systems. The created devicesand modules will primarily be used as part of exercises for practical verification of acquired theoretical knowledge.

Project title:	**Teaching and development of methodology for the use of microcontrollers in automation using practical examples and laboratory exercises for engineering students**
Coordinator	prof. Ing. Juraj Ďuďák, PhD.
Start Date	01/01/2024
End Date	31/12/2026
Program	KEGA
Annotation	The project is focused on building a microcontroller laboratory and creation of course materials for teaching the subject "Microcontrollers for use in industry" focused on the design and implementation of elementary modules based on currently used microcontrollers at the Faculty of Materials Science STU in Trnava in the study field "Automation and Informatization of Processes in Industry" (AIPP) in the second level of university study. The course provides students with the basics of design and implementation of embedded devices based on modern microcontrollers for use in Industry 4.0 and Internet of Things networks. The course consists of the necessary theoretical foundations of microcontrollers, communication interfaces, standard and special sensors, methods of low-level communication, mutual communication of several modules and design solutions based on the principle of using a real-time operating system (RTOS). The content of the course will be primarily focused on the integration of sensors of physical quantities and currently used microcontrollers into functional units with a focus on the use of these modules in the environment of

industrial networks and communication protocols used in Industry 4.0 and also in the environment of IoT networks. Emphasis will be placed on the basic parameters of development such as minimization of consumption and computing time, best-practices in creating trouble-free firmware in terms of the overall implementation of the solution and the implementation of secure communication at the lowest level of communication. The course builds on existing courses Programming languages (programming in C language), Fundamentals of automated control (basic algorithms with process control methods), Electrical engineering and electronics (basic electrical connections, electronic circuits) and Technical means of the course will also form the basis for the solution of new bachelor's and master's theses, as the possibilities of application of microcontrollers in the field of automation are rather wide.

Project title:	**Aggregation function, fusion function, uncertainty modeling, Choquet integral, neural network, machine learning**
Coordinator	prof. RNDr. Zdenko Takáč, PhD.
Start Date	01/01/2025
End Date	31/12/2027
Program	VEGA
Annotation	The success of most of the algorithms and methods used in artificialb intelligence strongly depends on the fusion of data. The project aims to develop new aggregation functions for data represented by intervals and vectors, taking into account the specific requirements resulting from their application in neural networks. The following three aspects of data will be taken into account: order, internal interaction and symmetry/asymmetry. In connection with the order, the project will focus on admissible orders and different degrees of relaxation of monotonicity. In connection with interaction, the project will focus on the investigation of fuzzy integrals, especially Choquet and Sugeno integrals. From non-symmetric functions, the project will focus on functions based on penalties and on overlap and grouping functions. An essential part of the project will be the analysis of the use of the developed aggregation tools in the implementation of neural networks in various areas, above all image and text recognition.

Project title:	**Research on the transformation of current SME companies to the level of sustainable and resilient smart companies using advanced exponential technologies in the context of Industry 4.0 and 5.0**
Coordinator	prof. Ing. Pavol Tanuška, PhD.
Start Date	01/01/2025
End Date	31/12/2028
Program	VEGA
Annotation	The main idea of the project is to provide enterprises with a systematic and holistic solution enabling the transformation of SME companies to the level of modern European companies, giving them increased competitiveness, emphasis on the humans, production resilience and overall sustainability. The goal of the project is to investigate the possibilities of deploying exponential technologies, mainly including artificial intelligence, edge computing, IIoT, and Big Data with regard to technological complexity, economic flexibility, and synergy with the objectives of Industry 5.0. In order to obtain new and practically usable knowledge a methodology for the

transformation of current companies will be proposed. This methodology will enable the digitisation of production processes, the optimisation of key KPIs, the implementation of predictive maintenance, and technological information in real time, which will significantly contribute to the effective operation of modern sustainable and resilient companies.

Project title:	**Study and numerical simulation of hybrid technologies for material welding and cladding supported by ultrasound**
Coordinator	doc. RNDr. Mária Behúlová, CSc.
Start Date	01/01/2025
End Date	31/12/2028
Program	VEGA
Annotation	The main scientific goal of the project is the research, development and implementation of new physical principles and solutions based on the application of ultrasound to increase the performance and efficiency of selected technological processes of metallurgical joining and cladding and obtaining high-quality final products. The material-technological area will be focused on the production of combined weld joints of various types of steel and light metal alloys and products, prepared by additive technologies with the support of ultrasound, as well as the optimization of parameters of these processes using numerical simulation. For the development of innovative ultrasound assisted welding and cladding technologies, new elements, technological devices and systems will be designed. The implemented mechatronic systems will enable the analysis of current state of the process in real-time, facilitating online modification of parameters to achieve optimal operating conditions for the hybrid technological process.