PROJECTS OF THE INSTITUTE OF MATERIALS SCIENCE

Project Title	**Determination of optimal cryogenic treatment regime for tool steels**
Coordinator	prof. Ing. Peter Jurči, PhD.
Start Date	01/01/2020
End Date	31/12/2023
Program	VEGA
Annotation	The projekt is focused to in-depth investigation of phenomena that occur in selected chromium-vanadium ledeburitic tool steel as a result of different regimes of cryogenic treatmnent. Effects of important processing variables like the austenitizing temperature, temperature and duration of sub-zero treatment, and tempering regimes on the microstructure, hardness, flexural strength, fracture toughness, wear performance and corrosion resistance of examined steel will be determined within the project. This woiuld lead to better exploitation of the potential of cryogenic treatment for tool steels. A great number of experimental techniques will be used in the project, which enables to achieve the main scientific goal – to confirm the scientific hypothesis on possible simultaneous enhancement of normally conflicting properties like hardness and wear resistance on the one side, and the toughness on the other side, for selected Cr-V ledeburitic steel by using the cryogenic treatment.

Project Title	**Physical properties of heavy metal oxide glasses**
Coordinator	Mgr. Ondrej Bošák, PhD.
Start Date	01/01/2020
End Date	31/12/2022
Program	VEGA
Annotation	The project is focused on the study of special glasses designed for applications in photonics and optoelectronics including the central area of the infrared area of the spectrum. New ternary glasses based on TeO2 and Sb2O3 will be prepared on the basis of international cooperation. In the first part, selected physical properties of glasses will be characterized. In the framework of the project solution, effects of changes in the glass composition, observable changes in structure, and the possibilities of rare earth elements doping will be investigated by using electrical and dielectric methods. The next part will examine the influence of technological parameters of glass preparation, possibilities of diagnostics and prediction of achieved quality by monitoring of selected electrical parameters.

Project Title	**Thermal stabilization of high-temperature superconducting tapes for fault current limiters**
Coordinator	Dr.-Ing. Marcela Pekarčíková
Start Date	01/01/2021
End Date	31/12/2024
Program	VEGA
Annotation	Additional thermal stabilization is necessary for commercially available high-temperature superconducting tapes, in order to use the tapes in devices for fault current limiting in high-voltage grids. The proposed project is aimed at fabrication of thermally stabilizing composite coating (epoxy resin with ceramic filler), which will act as a sink and absorber of the heat produced in a limiting event. Various materials for

thermal stabilization will be tested, with regard to their thermal, physical, and mechanical properties, and their resistance against thermal shocks. Possibilities for improvement of mechanical properties will be investigated by additional reinforcement of the thermal stabilization. The effectivity of the thermal stabilization will be determined for superconducting tapes from various producers, by experimental limiting of fault current. Experiments will be complemented with numerical modelling.

Project Title	**Research on hybrid manufacturing of the components by means of progressive overlay welding methods**
Coordinator	Ing. Martin Sahul, PhD.
Start Date	01/01/2021
End Date	31/12/2024
Program	VEGA
Annotation	Additive manufacturing (AM) is a relatively new idea applied to the production of complex metal parts by "layer by layer" method. The project is focused on AM of components using Wire and Arc Additive Manufacturing (WAAM). MIG and CMT overlay welding methods will be used to produce 3D components. Proposed aluminium alloy and austenitic stainless steel will be used as welding materials. During the WAAM process, the parameters of overlay welding will be monitored, molten pool will be online analysed by means of a high-speed camera and the measurement of the temperature fields by thermocouples will be carried out. Light microscopy and mechanical testing will be used to characterize the deposited components. State-of-the-art analytical techniques (SEM, TEM, EBSD, and X-ray diffraction) will be used for more detailed analysis. The aim of the project is the evaluation of the influence of WAAM process parameters on the molten pool behaviour, porosity, microstructure and mechanical properties of produced 3D parts.

Project Title	**Investigation of structure, oxidation resistance and tribomechanical properties of nanocomposite multilayer transition element nitrides based coatings Key**
Coordinator	prof. Ing. Ľubomír Čaplovič, PhD.
Start Date	01/01/2022
End Date	31/12/2025
Program	VEGA
Annotation	The project is focused on the development of multilayer coatings for tool materials with improved tribomechanical properties, increased structural stability and oxidation resistance. By applying magnetron sputtering technology and combining the WNx coating with NbN, Ti-Si-N, MoN and Ti-Al-N coatings, four multilayers (WN / NbN, WN /Ti-Si-N, WN / MoN and WN / Ti- Al-N) will be deposited. The effect of process parameters (BIAS and bilayer period (?)) on the temperature and oxidation resistance of coatings and their structure, mechanical and tribological properties will be evaluated. Advanced analytical techniques HR-SEM, HR-TEM, EELS, FIB-SEM, EBSD, high temperature X-ray diffraction, GDOES, XPS, PIXE and RBS) as well as tribometric techniques will be used to characterize the multilayers. The aim is to create new progressive coatings with excellent tribological and thermal properties applicable to tool materials.

Project Title **Microstructure, phase stability and properties of multi-principal element alloys combining transition metals with post-transition metals**

Coordinator RNDr. Pavol Priputen, PhD.

Start Date 01/01/2022

End Date 31/12/2025

Program VEGA

Annotation The project is focused on searching for multi-principal element alloys that will combine properties not occurring in common alloys. Attention will be paid to alloy systems that combine transition metals with post-transition metals, such as aluminium or gallium. Alloys will be prepared by arc or induction melting. The prepared alloys will be analysed for their microstructure and phase composition by X-ray and electron diffraction, electron microscopy and energy dispersive spectroscopy. The alloys will be studied in the state after casting as well after heat treatment. In the study of alloy's properties, the attention will be focused mainly on mechanical properties, corrosion, oxidation and radiation resistance and thermodynamic stability. The project has the character of a basic research project with regard to the possible practical applicability of achieved results. The results obtained within the project will be published in peer-reviewed journals and presented at international scientific conferences.

Project Title **Effect of a stress state of Zn-based alloys on a mechanism and kinetics of their corrosion**

Coordinator prof. Ing. Martin Kusý, PhD.

Start Date 01/01/2022

End Date 31/12/2025

Program VEGA

Annotation The proposed project focuses on the narrow issue of corrosion of zinc and zinc alloys under residual and / or application stress. The available knowledge confirms that corrosion processes can take place in materials at elevated stress states even without significant surface corrosion. Their failure can be fatal without an obvious visual indication, similar to fatigue failure of materials. The aim of the project is to characterize the influence of residual and/or applied stress states on corrosion processes taking place in selected modern binary and multi-component Zn-based alloys, which are used in castings, corrosion protection (hot-dip coatings), soldering or in medicine in biodegradable implants based on Zn. Samples based on Zn will be prepared within the project by corresponding technologies containing residual stresses which will be determined. Subsequently, they will be tested in corrosive environments in order to identify the effect of residual as well as application stresses on corrosion.

Project Title **Analysis of microstructure formation and its influence on selected properties of lead-free solders**

Coordinator doc. Ing. Ivona Černičková, PhD.

Start Date 01/01/2022

End Date 31/12/2025

Program VEGA

Annotation The aim of the project is to study the Sn-Ag-Cu-X systems (X = Ni, Bi, Ga) suitable for lead-free solders, their thermodynamic description, modeling of microstructure formation and analysis of their mechanical, electrical and corrosion properties. For the experimental analysis, a scanning electron microscopy, energy-dispersive X-ray spectroscopy, X-ray diffraction and thermal analysis methods will be used. The creation of thermodynamic and kinetic models of microstructure formation will be realized by the CALPHAD method using the Thermo-Calc and Dictra software and using the phase-field method implemented in the MATLAB software. Furthermore, the mechanical, electrical and corrosion properties will be analyzed. The result will be a comprehensive description of the microstructure formation and its impact on properties of soldered joints, with the possibility of optimizing the microstructure using the composition and solidification conditions of these solders, also with the possible addition of nanoparticles.

Project Title	**E-learning and implementation of information technologies in teaching of materials-technology courses**
Coordinator	doc. Ing. Roman Moravčík, PhD.
Start Date	01/01/2020
End Date	31/12/2022
Program	KEGA
Annotation	The project is focused on the implementation of e-learning in the teaching and examination process in materials-oriented courses such as Materials Science I, Mechanical Testing and Defectoscopy of Materials, Heat Treatment and Surface Treatment of Materials and Thermodynamics and Kinetics, taught at the Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava (MTF STU).

Project Title	**Development of the Fe based PM components with increased fatigue strength.**
Coordinator	doc. Ing. Martin Kusý, PhD.
Start Date	01/07/2019
End Date	30/06/2022
Program	APVV
Annotation	The problem of the current serial production of PM-based Fe parts in the case of uniaxial single compression in combination with sintering, calibration and heat treatment for commercially used powder mixtures (in particular FeCu1.8C0.7 and FeMo0.5Ni0.5C0.6) is its density in range 6.9 -7.1 g.cm-3. In the case of the use of such components for the "high-performance" applications in engines and transmissions where resistance to dynamic load, high strength or fatigue properties is required, residual porosity is a limiting factor. The aim of the present project is therefore to develop PM-based Fe parts with a higher density > 7.4 g.cm-3 in series production to reduce porosity (mainly open and bonded pores) and its potential use in "high-performance" applications. With regard to the manufacturing infrastructure of Miba Sinter Slovakia Ltd. (subcontractor of the project), it is necessary to examine in detail the impact of the modification of the powder mixture (with respect to the amount of lubricant) and compression parameters (pressure and velocity) on residual porosity and fatigue strength. However, production technology must be designed with respect to the quality of the die, which is currently designed to working pressure up to 600 MPa.

Project Title **Study of non-conventional glasses modified by ion exchange or ion implantation**
Coordinator Mgr. Ondrej Bošák, PhD.
Start Date 01/02/2020
End Date 31/12/2022
Program APVV
Annotation The proposed project deals with the modification of surface of chalcogenide glasses by Na and K cations doping in order to modify their refractive index and/or their electrical conductivity. Glass samples will be prepared, modified by ion exchange or ion implantation and next they will be tested for their optimal functionality. Electrical and dielectrical properties will be used for characterization of ion content and transport in the investigated glasses. Analyses will be focused on the so-called phenomenon mixed-alkali effect. Surface of glasses prepared by ion implantation will be analyzed by RBS/ERDA and PIXE spectroscopy.

Project Title **Preparation and chracterisation of disordered materials for aplication in infrared spectra**
Coordinator doc. RNDr. Vladimír Labaš, PhD.
Start Date 01/03/2020
End Date 31/12/2022
Program APVV
Annotation Project is oriented on support of scientific cooperation of institutes from four contries and education of Ph.D. students in the field of special glasses. By using international cooperation, new glass systems based on chalcogenides and heavy metal oxides will be prepared. The thermal, optical, structural and electrical properties of prepared glass systems will be analysed using instrumentation of all partners. The influence of technological parameters on the chalcogenide glasses with gradient chemical composition influenced by gamma radiation as well as on selected glasses based on heavy metal oxides, will be studied. The possibilities of diagnostics of investigated glasses will be verified by monitoring of selected electrical parameters.

Project Title **Reseach on the electron beam weldability of hard to join dissimilar materials**
Coordinator Ing. Martin Sahul, PhD.
Start Date 01/04/2021
End Date 31/12/2023
Program APVV
Annotation The metallurgical joining of dissimilar materials (DM) is difficult, due to the different physical, chemical, and mechanical properties. Therefore, joining DM is a great challenge. One material is usually not able to ensure the complex properties required in demanding operating conditions. Prospective combinations include copper with austenitic stainless steel (ASS) and nickel with titanium. Challenges in terms of weldability of mentioned materials are obvious, high thermal conductivity of copper can cause problems with maintaining the weld temperature necessary to achieve full penetration, the crystal structure of Cu, Ni and ASS are prone to hot cracking. Titanium is characterized by a high affinity to oxygen. The most suitable procedure is to use a vacuum to protect the weld pool from contamination by gases from the environment, and thus to eliminate significant embrittlement. These issues are exacerbated when welding DM. While the formation of hard and brittle intermetallic

compounds (IMCs) is not observed in the first combination (Cu + ASS), the second combination of materials (Ti + Ni) forms 3 kinds of IMCs. In order to depress the formation of mentioned IMCs, highly concentrated electron beam welding (EBW) is proposed for research into the weldability of DMs. The equipment with the largest vacuum chamber for EBW in Slovakia will be used for the production of welded joints. The initial stage of experiments will be based on the design of experiment method to determine the influence of welding parameters on the responses. Butt and overlapped welded joints will be produced. Light microscopy and high-resolution scanning electron microscopy (including EDS analysis) will be used for detailed analysis of the microstructure of the welds. A detailed chemical analysis of the local areas of welded joints of dissimilar materials will be performed. The mechanical properties will be determined by automatic microhardness measurements and static tensile testing.

Project Title	**Novel multi-principal element alloys – design, characterization and properties**
Coordinator	doc. Mgr. Marián Palcut, PhD.
Start Date	01/07/2021
End Date	30/06/2025
Program	APVV
Annotation	To expand the alloy design space, recent efforts have shifted toward the development of alloys with several principal elements. These materials are referred to as multi-principle element alloys (MPEAs), complex concentrated alloys (CCAs), or high-entropy alloys (a subset of MPEAs). The aim of this project is to design and characterize a series of novel MPEAs. We shall prepare and study several ternary, quaternary and multiple element alloys with different chemical composition. We shall study the relationship between chemical composition, phase constitution and alloy microstructure. We will investigate the effects of processing conditions (annealing time, cooling rate) on the phase evolution. The materials will be characterized in terms of their thermodynamic stability. The major part of the project will be the electrochemical corrosion study of different alloys in aqueous electrolytes. We aim to investigate the electrochemical stability of the phases and explore the relationship between their corrosion activity and chemical composition. We aim to investigate the effects of various electrolytes. We shall study the corrosion mechanisms and identify the various corrosion products. The project will also include the study of MPEAs mechanical properties and reliability. Furthermore, we shall investigate the alloys mechanical properties at elevated temperatures (stress corrosion cracking) and under simulated atmospheric conditions (salt spray test). In the end, we aim to identify corrosion-resistant and mechanically stable materials for practical applications.

Project Title	**Optimization of round high-temperature supercnoducting cable for pulse magnetic field**
Coordinator	Dr.-Ing. Marcela Pekarčíková
Start Date	01/07/2021
End Date	30/06/2025
Program	APVV
Annotation	The project is focused on an optimization of a cable made of high temperature superconducting tapes wound on a core in form of a tube with the possibility of cooling the cable by the coolant flowing through the former. The purpose of the optimization

is a significant decrease of AC losses, which can be achieved through three modifications of the cable. The first one is to reduce the width of the 4 mm superconducting tape down to 1 mm with steps smaller than 0.2 mm. The tuning of the tape width should allow to prepare the cables with optimal packing of the cable layers and with greater flexibility. The second modification is an additional narrowing of the superconductor width by striation scribing the superconducting layer along the tape with already optimized width. Both processes require a development of a suitable method for the cutting and scribing process of the superconducting tapes with minimal impact on their mechanical, structural and electrical properties. The third modification is the innovation of the central former, which should fulfill requirement of significantly reduced electricalconductivity. Modified superconducting tapes and cables prepared from them will be characterized in terms of mechanical and electromagnetic properties. Most of the experiments will be supported by computer modeling.

Project Title	**Influence of stoichiometry and bias voltage on the microstructure and tribomechanical properties of nanolayer WN/TiSiN coatings with different bilayer thicknesses**
Coordinator	Ing. Martin Sahul, phD.
Start Date	01/01/2022
End Date	31/12/2023
Program	APVV
Annotation	The project is focused on the development of new nanoscale multilayer coatings with improved functional properties for the protection of materials working under extreme conditions. It is generally known that coatings with a multilayer architecture show improved physical and mechanical properties compared to those of individual layers forming the multilayer. For this reason, such a multilayer design is very advantageous since it allows combining different known coatings in a targeted manner and developing qualitatively new structures with desired characteristics. Within the project, WN and TiSiN coatings designed in the multilayer architecture will be deposited by magnetron sputtering. The effects of bias voltage and thickness of individual layers expressed by bilayer period (Λ) on the stoichiometry, structure, tribomechanical properties, thermal stability, and oxidation resistance of the multilayers will be comprehensively investigated. Moreover, the effect of the multilayer design will also be evaluated by comparing the properties of the multilayers with monolayers deposited at the same physical-technical regimes. Theoretical and experimental approaches will be used for successful project solution.

PROJECTS OF THE INSTITUTE OF PRODUCTION TECHNOLOGIES

Project Title	**Optimization of geometry of cutting tools produced by foundry technology and powder metallurgy to increase durability**
Coordinator	prof. Ing. Alexander Čaus, DrSc.
Start Date	01/01/2019
End Date	31/12/2022
Program	VEGA

Annotation Geometry of cutting edge has significant effect on wear resistance as well on durability of cutting tools. It is possible to produce near-net-shape cutting tools by both the foundry technology and the powder metallurgy and in the case of high speed steel (HSS) with significantly higher wear resistance compared to similar tools produced by conventional metallurgy using machining of wrought profiles. Optimization of cutting tool geometry will be carried out by numerical simulation of machining conditions and load for the tool in cutting process. Application of additive technologies, namely 3D printing of casting patterns from castable resin for investment casting into ceramic shell moulds, and cemented carbides (CC) from metal powder, provides flexible production of cutting tools with optimal shape without using very expensive and shape-complicated injection moulds for production of castable/burnout casting patterns as well as for forming dies for powder material compaction.

Project Title **Coating of powder metallurgical Titanium using electromagnetic radiation under working atmosphere, study of microstructure and coatings properties**
Coordinator prof. Ing. Peter Šugár, CSc.
Start Date 01/01/2020
End Date 31/12/2022
Program VEGA
Annotation The project deals with the possibility of surface treatment of titanium, which was prepared from titanium powder by low temperature methods of powder metallurgy. It is envisaged to use an energy beam of electromagnetic radiation incident on the surface of the PM titanium either in the form of laser beam or in the form of focused solar radiation. When heated under the working atmosphere, the reaction of titanium with oxygen or nitrogen molecules is assumed and coatings based on oxides, nitrides or their mixtures are expected to be formed. Subsequently,the microstructure and selected properties of the prepared coatings will be studied. The aim is to explore the possibilities of surface treatment of PM titanium, depending on future applications, to prevent surface damage during friction, to improve the surface for biocompatibility and to increase corrosion resistance of PM Ti, which are the most important reasons for surface treatment of usual titanium components.

Project Title **Accurate calculations, modeling and simulation of new surfaces based on physical causes of machined surfaces and additive technology surfaces in machinery and robotical machining conditions**
Coordinator prof. Dr. Ing. Jozef Peterka
Start Date 01/01/2020
End Date 31/12/2022
Program VEGA
Annotation The central idea of the project is to use accurate calculations based on analytical equations as a basis for predicting roughness characteristics of machined surfaces. At the center of interest are the physical causes of machined surfaces studied at the level of geometrical-kinematic, mechanical-physical and technological properties of members of the machining system. Our intention is to create mathematical models and simulation algorithms for individual physical causes of the machined surface. As study prototypes, we will consider type-defined and undefined cutting edge technologies and exception-additive technology. Another target group of research is

the inclusion of significant dynamic and stiffness characteristics. machines and machining robots. It is in robots that more time and emphasis will be placed on studying the effects of motion, kinematic bonds and trajectories. The inclusion of a robot technology and additive technology system is an important element of our research as a central project note.

Project Title	**Research of joining the metallic and ceramic materials in production of power semiconductor**
Coordinator	prof. Ing. Roman Koleňák, PhD.
Start Date	01/01/2020
End Date	31/12/2023
Program	VEGA
Annotation	The project is aimed to fundamental research of solderability of metallic, composite, non-metallic and ceramic materials applied in packaging of power semiconductor parts (chips, transistors, diodes etc.). The solution will be oriented to direct joining without application of coating for wettability assurance. Joining of semiconductor materials as Si, SiC and GaN is considered. Furthermore Al2O3, Si3N4, AlN and Cu/SiC composite material, which is applied mainly for the cooling of chips are also taken into account. Cu will be applied as an etalon material. New solder alloys alloyed with a small amount of active elements (Ti, La etc.) will be manufactured and also the solder alloys containing Bi and Zn, applicable for higher service temperatures. The solders will be designed with the aim to be suitable for direct soldering with application of power ultrasound. These new solders will be then tested for technological solderability. The interactions of solder alloys with the surface of substrates will be studied.

Project Title	**Research into the weldability and brazeability of materials with different melting temperatures joined with highly concentrated energy sources.**
Coordinator	doc. Ing. Erika Hodúlová, PhD.
Start Date	01/01/2021
End Date	31/12/2024
Program	VEGA
Annotation	The proposed project will be solved as a scientific research project focused on basic research in the field of welding and brazing of materials with different melting points by technologies utilizing high concentrated joining methods of materials. The Response surface method as the planning of the experiments will be used to determine the optimal parameters of high-productive joining methods (laser, electron beam, CMT, brazing of the two types of joints (butt and lap joint). Macro- and microstructural analysis of the joints will be used as experimental methods to evaluate the structural integrity of welded and brazed joints. EDX and XRD analysis and extended to high-resolution transmission electron microscopy will be used to determine the creation of different phases and change in chemical composition as well as the identification of excluded phases in joints. The mechanical properties of the joints will be evaluated by tensile strength and shear tests.

Project Title	**Progressive form of interdisciplinary education and support for the development of the study of vocational subjects in the university environment**
Coordinator	Dr. h. c. prof. Ing. Pavol Božek, CSc.

Start Date 01/01/2021
End Date 31/12/2023
Program KEGA
Annotation The main objective of the project is to increase the applicability of students in the labor market by expanding interdisciplinary cooperation of interested teachers and increasing the readiness of graduates to perform in international academic or professional space, which would contribute to the popularization of vocational subjects and their teaching at the Faculty of Materials Science and Technology of the Slovak University of Technology in Trnava and the Faculty of Technology of the Technical University in Zvolen in all three levels of higher education in the following specialized subjects: Design and operation of production systems, Digital Enterprise and Virtual Reality, Basics of Using CAD Systems, Informatics for Technicians, Algorithms and Programming, Programming Robots - Through Progressive Training Methods. The added value of the proposed project will also be the intensification of international cooperation in the field of education with several foreign universities with which cooperation agreements have been signed with the Faculty of Materials Science and Technology of the Slovak Technical University in Trnava and the Faculty Technology. The project will also include the transfer of research results into the pedagogical process and the improvement of the equipment of specialized laboratories, which will serve the needs of the project activities after implementation.

Project Title **Creation of new study materials including multimedia textbook in field of technical preparation of production in welding and joining**
Coordinator prof. Ing. Roman Koleňák, PhD.
Start Date 01/01/2020
End Date 31/12/2022
Program KEGA
Annotation The project is focused on the design and creation of a new modern university textbook and didactic tools for teaching the subject: "Technical preparation of production in welding and joining materials". The subject is part of a new study program at the MTF STU entitled "Welding and Joining Materials", to which there are no suitable teaching texts or other didactic tools in historical context. The proposed concept is aimed to creating a textbook and an electronic version of a textbook with multimedia content. The creation of new study materials will directly influence the understanding of the issue under consideration in order to prepare graduates for the profession of welding technician as well as technician in engineering. The textbook will contain the materials needed to understand the technical documentation of welding and bonding. Understanding the preparation and implementation of the documents needed before, during and after the release of the engineering product to production is very important in terms of time and quality. The accompanying product is the creation of multimedia content, which will include a chronological approach to creating technical and welding documentation with explanations of operations using graphical representations and practical examples. The aim of the course is to prepare a student who is able to prepare materials for the construction of connected structures from the breakdown of materials through their security, storage, labeling, distribution to individual workplaces for preparatory operations and their progress to the final workplace for joining parts to individual nodes and units.

Project Title	**Support of the distance form of education in the form of online access for selected subjects of computer aided study programs**
Coordinator	doc. Ing. Peter Košťál, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	KEGA
Annotation	The presented project proposal is related to the recent experience regarding the COVID situation and the implementation of the forced distance form of education. The project is focused on the use of two currently essential technologies: online access and multimedia (MM) support. The aim of the project is to make study materials for online education and self-study more accessible to students to a greater extent and intensity.

Project Title	**Creation of new study materials, including an interactive multimedia university textbook for computer-aided engineering activities**
Coordinator	doc. Ing. Peter Košťál, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	KEGA
Annotation	The presented project focuses on creating and integrating new study materials, including a multimedia university textbook to support the teaching of a further accredited subject Computer support of engineering activities in written and interactive multimedia universities. The support of better, more intensive and more effective perception of information from the written textbook in the professional subject "Computer support of engineering activities" (texts, pictures, graphs, speech, animations, video sequences) is made possible by multimedia presentations several forms. The information provided by the video sequences will professionally supplement the individual chapters and parts of the mentioned written university textbook. Multimedia options and hypertext are some of the right and practical tools to support professional study information. They allow easy search and easy orientation in professional texts. The basic principles of selected computer support systems will be implemented in workplaces using the prepared laboratory for a newly accredited subject. An interactive test will supplement the conclusion of each chapter.

Project Title	**Research of direct bonding of the ceramic and metallic materials by use of active soldering alloys**
Coordinator	prof. Ing. Roman Koleňák, PhD.
Start Date	01/07/2018
End Date	30/06/2022
Program	APVV
Annotation	The project deals with the study of direct bonding of ceramic and metallic materials by application of active soldering alloys. The active alloys will be based on tin or indium and alloyed with active metal, as for example Ti, La, Zr, Y etc. It is supposed that the active element will react with the substrate surface during soldering process and will thus assure the wetting of solder on a ceramic or other hard-to-solder material. The project is based on idea of direct fluxless bonding. Heating will be provided by the high-concentrated heat sources as the laser and electron beam. Power ultrasound will be

employed for activation of the new soldering alloys. Material solderability of the new developed solders will be studied. The following solderability criteria will be determined: wettability, spreadability, diffusion etc. Also interactions on the substrate/solder interface will be studied. Individual mechanisms of bond formation from the viewpoint of joint strength, speed of bond formation, life etc. will be compared.

Project Title	**Research of progressive methods of welding and soldering of corrosion-resistant steels and copper**
Coordinator	doc. Ing. Erika Hodúlová, PhD.
Start Date	01/07/2019
End Date	30/06/2023
Program	APVV
Annotation	The proposed project will be solved as a scientific research project focused on basic research in the field of welding and brazing/soldering of stainless steel with copper alloy by technologies utilizing progressive joining methods of materials. Several modern scientific methods will be used within the project in order to fill up the objectives set in particular stages of the project. In the early stages of the project, method of scientific analysis and planning of the experiments using Design Expert software package will be used to determine the optimal parameters of high-productive joining methods (laser beam, electron beam, CMT, brazing/soldering) of the two types of joints (butt joint and lap joint). To achieve the stated objectives working procedures will be developed based on the knowledge and gathered information. Macrostructural and microstructural analysis of the joints will be used as experimental methods to evaluate the structural integrity of welded and brazed joints. EDX analysis and extended to high-resolution transmission electron microscopy will be used to determine creation of different phases and change in chemical composition as well as the dentification of excluded phases in joints. For the determination of internal defects of welded joints the computer tomography will be involved. The mechanical properties of the joints will be evaluated by tensile strength test in case of butt welds, by shear strength in case of lap joints, micro-hardness and bend test.

Project Title	**Research of progressive methods of welding and soldering of corrosion-resistant steels and copper**
Coordinator	doc. Ing. Ladislav Morovič, PhD.
Start Date	01/07/2019
End Date	30/06/2023
Program	APVV
Annotation	The shape stability of the steel tubes has a major influence on the further technological process of the tube processing, i. e. on secondary production. It is a very important parameter in terms of functionality, for example, active and passive parts of a car, where the dimensional tolerance fields are one of the toughest in terms of prodution itself. It is important to pay attention to the research of the shape stability of the tubes by means of contact metrology systems (coordinate measuring machine with touch probe) and non-contact measuring systems (optical 3D scanner using active triangulation (structured light)). The resulting properties of the tubes depends on a number of factors, e.g. from the shape instability in the individual phases of the

production process in the process of production of tubes in Železiarne Podbrezová. The shape stability and the occurrence of geometric deviations are affected by the eccentricity that occurs primarily in the perforation process due to the off-centered punch, where there is uneven distortion due to the change in the original cross-sectional area of the blank on the radial removing of the material. In the process of producing tubes at the tensile reduction, a polygon is formed which results in uneven deformation caused by the stands in which the rolls are placed. Uneven distortion affects the internal structure of the material and hence the shape stability in the subsequent operation due to the anisotropy of properties. Experimental processes will be numerically simulated in the software DEFORM 3D. The aim is to identify, quantify and subsequently determine the effect of geometrical deviations on the instability of the tube dimensions and their technological inheritance, which is supposed to meet the most stringent technical and supplier conditions for the industry.

Project Title	**Research on properties of stainless alloys components made by additive manufacturing**
Coordinator	prof. Ing. Milan Marônek, CSc.
Start Date	01/07/2021
End Date	30/06/2025
Program	APVV
Annotation	The currently used additive manufacturing systems utilize a powder bed and for the remelting of the metal powder, the power laser or electron beam. Despite very high precision and low dimensional tolerances achieved with these techniques, the cost of the devices is high, the rate of component formation is low, resulting in longer production times and increased production costs. Among alternative methods of components fabrication by additive manufacturing, methods using additive material in the form of wire appear to be perspective. In the case of using an electric arc to melt wire, the acronym WAAM (Wire Arc Additive Manufacturing) is employed; using a laser beaminstead of an electric arc, the designation DMD (Direct Metal Deposition) is applied. Unlike specialized powder bed systems, WAAM and DMD can also be implemented on conventional 3-axis welding systems as well as robotic work cells.The originality and novelty of the project lies in its complexity. Its ambition is to bring a new, comprehensive knowledge in the field of component fabrication by progressive arc (CMT, TIG) and laser beam overlay welding of titanium, aluminium and nickel alloys. The project will focus on defining the key process parameters and strategies of torch and laser head movements, analysing the mechanical and structural properties of the producedcomponents, as well as acquiring new, original knowledge in the field of machining of the fabricated components. In this area, the attention of the team will be focused on the design and production of suitable cutting tools for machining the finished components, analysis of the impact of machining strategies on the characteristics of fabricated surfaces, deformations of components after machining as well as assessment of the lifetime of the used cutting tools.

Project Title	**Research of unique unconventional methods of preparation of cutting edge microgeometry to increase cutting tool performance and machining productivity**
Coordinator	Ing. Tomáš Vopát, 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.

PROJECTS OF THE INSTITUTE OF INDUSTRIAL ENGINEERING AND MANAGEMENT

Project Title	**Identification of priorities for sustainable human resources management with respect to disadvantaged employees in the context of Industry 4.0**
Coordinator	prof. Ing. Miloš Čambál, CSc.
Start Date	01/01/2020
End Date	31/12/2023
Program	VEGA
Annotation	The essence of the scientific project is to analyze the impact of changes in the performance of industrial enterprises on the priorities of sustainable HRM. Management approaches focus mainly on employee and business performance. Changes in the performance of industrial enterprises, related to the digitization increase, the reduction of live work in production, processes improvement, technologies are aimed at organization's efficiency and effectiveness increase. Implementation of new approaches can have an impact on employees of different generations, while the potential negative effect of these risks is not sufficiently analyzed. The aim of the project is to identify risks in the emergence of new practices, critical impact areas on employees, and explore mechanisms to eliminate these risks. The purpose of the project is to explore the potential of employing disadvantaged groups of employees in the context of changing conditions for enterprises, respecting the uniqueness of different generations of employees.

Project Title	**Implementation of integrated management systems with value-oriented requirements for the construction of modular collaborative workplaces**
Coordinator	doc. Ing. Alena Pauliková, PhD.

Start Date	01/01/2022
End Date	31/12/2025
Program	VEGA
Annotation	In collaborative operations of production or providing services, it is necessary to analyze the requirements placed on the working environment of employees, and it is necessary to orient them correctly in terms of value. This orientation considers employees who meet collaborative facilities (hereinafter - cobots) and share their workspace with them. These are divided into: 1. Users (cobot is a work assistant), 2. Operators (cobot is set up, serviced/maintained) and 3. Educational programmers (cobot is programmed). The solution should implement and maintain integrated management systems (MS) with an emphasis on strengthening the acceptance of cobot in a common workplace, "friendship" the cobot and humans, find a sustainable modus vivendi so that their shared space is safe and environmentally friendly (MS according to ISO 45001 and 14001), the processes performed were performed efficiently (ISO 9001 and 10007) within the win-win strategy (ISO 10014, 10015 and 10018).

Project Title	**Network visualization of common and specific elements and documented information of integrated management systems with respect to relevant ISO standards**
Coordinator	doc. Ing. Alena Pauliková, PhD.
Start Date	01/01/2020
End Date	31/12/2022
Program	KEGA
Annotation	The subject of this project is to elaborate a comprehensive overview used on a global scale and subsequent coordination of individual areas of management systems as part of a comprehensive integration for industrial operations including quality management, environment, OSH, energy, information security, transport, corporate social responsibility, business continuity and more. The set of selected areas will include the organization's connections with industrial operations, key customer requirements, leadership, planning, operational support, operations, performance evaluation, and improvement. Co-ordination will be performed using hierarchical organizational diagrams and final visualized by small world networks - Small World Networks and Scale-Free Networks.

Project Title	**The implementation of innovative educational methods and MM guide for decisionmaking area and application of analytical methods in the teaching process of selected subjects in the field of Industrial engineering**
Coordinator	doc. Ing. Henrieta Hrablik Chovanová, PhD.
Start Date	01/01/2021
End Date	31/12/2023
Program	KEGA
Annotation	The project is focused on creating an interactive multimedia educational application (portal) in order to increase the level of the pedagogical (educational) process with the necessary video sequences, images, and other multimedia conditions by innovating educational methods of the selected key subjects in the field of Industrial Engineering (Operational Research, Statistical Methods, Business Logistics). It will serve full-time

(combined) and external students of colleges/universities with a technical and economic focus, as well as for the professional public and those interested in the field. The submitted project will be a pilot project for other subjects in the field of Industrial Engineering. The use of multimedia in several forms will support the more intensive, effective, and rational perception of information in the selected subjects (texts, diagrams, photographs, speech, animations, video sequences, e-tests). Nowadays, it is important for students and graduates to be able to orientate themselves in a huge amount of information, to analyze and interpret the available information, and to be able to find an essential idea and focus on the goal. Interactive multimedia and hypertext, which the student (interested in the field) can access at any time and individually, are a suitable tool to support study information, easy search, testing, and easy orientation in them.

PROJECTS OF THE INSTITUTE OF INTEGRATED SAFETY

Project Title	**Progressive methods of polymer waste recovery for graphene production**
Coordinator	doc. Ing. Peter Rantuch, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	VEGA
Annotation	The worldwide production of plastics is more than 350 million tons per year. After taking into account the waste from the wood processing industry, this amount will be further increased. Recycling of waste polymeric materials is currently at a very low level. The main goal of the presented project is therefore their use for graphene production. This material was first prepared in 2004 and the Nobel Prize in Physics was awarded in 2010 for its discovery. Its properties predetermine it for various areas of use. Its popularity has risen sharply in the last decade and this trend is expected to continue in the future. The project is focused on two multidisciplinary proposals for its practical use: • formation of graphene-based flame retardants and • creation of graphene-based sorption materials for the removal of contaminants from water.

Project Title	**Implementation of progressive technologies, methods and forms to education in the study branch Safety and Security Science**
Coordinator	prof. Ing. Jozef Martinka, PhD.
Start Date	01/01/2020
End Date	31/12/2022
Program	KEGA
Annotation	The project is aimed at improving the quality of the educational process of students of the 1st and 2nd degree of university study in the study branch Safety and Security Science (Rescue Services) at the Technical University in Zvolen (Fire Protection and Safety Study Programme) and at the Faculty of Materials Science and Technology in Trnava (Integrated Safety Study Programme) based on application of advanced technologies, methods and forms of education. For selected coursed and core thematic areas of the study branch the innovative electronic learning materials and video tutorials will be created, as well as new modern teaching aids using 3D and large-format printing technology. Teaching materials will be prepared for practical exercises

based on direct interaction of teacher – student, using modern ICT devices and with Microsoft Education Tools (part of Microsoft Office 365). The level of knowledge will be verified by on-line tests. In addition to creating new multimedia interactive learning materials and improving the competences of students and graduates, online access and the availability of up-to-date learning materials will also be a benefit for students at other universities and practitioners.

Project Title	**Building an innovative teaching laboratory for practical and dynamic education of students in the field of occupational safety and health**
Coordinator	doc. Ing. Richard Kuracina, PhD.
Start Date	01/01/2021
End Date	31/12/2023
Program	KEGA
Annotation	The project is focused on building an innovative teaching laboratory for practical education of students of the Faculty of Materials Science and Technology in Trnava in the field of integrated safety. The teaching laboratory will provide students and other interested persons with dynamic education in the form of practical exercises carried out on unique devices enabling the study not only fire - explosion characteristics of dusts, but also measurement and evaluation of workplace parameters closely related to occupational safety and health. These exercises will be dynamic, mainly due to the possibility of transferring information from exercises taking place in real time to other places. The aim of this project is to increase the interest of high school students to study at technical universities and also as a response to the situation resulting from the global pandemic which significantly reduced or completely eliminated the contact method of teaching. The innovative teaching laboratory together with software and hardware support will enable university students of full-time and part-time study to acquire knowledge and skills that are currently required by professional practice. By applying the acquired knowledge in simple examples and practical demonstrations, they will gain an overview of the basics of safety engineering, risk analysis and risk management methods, dangerous substances, theory of fires and explosions, safety of working environment. All teaching materials(texts, presentations, multimedia videos, sample examples) will be published on a website created for this purpose.

Project Title	**New forms of education for crisis management (e.g. COVID-19) using artificial intelligence**
Coordinator	prof. Ing. Jozef Martinka, PhD.
Start Date	01/01/2021
End Date	31/12/2023
Program	KEGA
Annotation	The aim of the project is to create e-learning focused on innovative education (rapid transfer of information) of professionals in the field of crisis management, other professions directly or indirectly involved in crisis management, university students (directly or indirectly involved in crisis management) and the general public. E-learning will consist of three levels. The first level, intended for the general public, will be freely accessible. The second level, intended for teachers, university students, occupational safety and health technicians and occupational health service staff, will be accessible after registration - a university or specified e-mail address will be required for

registration. The third level, intended for crisis management specialists, will be accessible after registration(registration will only be allowed to specified persons). For professionals (students, occupational safety and health technicians, occupational health workers and crisis management specialists), elearning will focus mainly on providing the latest information in the field - focused mainly on the application and use of artificial intelligence, neural networks and data mining. Basic information will be provided to the public (the system will be prepared in the event of an unexpected crisis situation for the very fast publication of currently necessary information).

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, PhD.
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.

PROJECTS OF THE INSTITUTE OF APPLIED INFORMATICS, AUTOMATION AND MECHATRONICS

Project Title	**Development of advanced models for design and optimization of heat treatment and joining processes of newly developed high-strength steels**
Coordinator	doc. RNDr. Mária Behúlová, CSc.
Start Date	01/01/2020
End Date	31/12/2023
Program	VEGA

Annotation	The project is focused on the design and preparation of the new types of high-strength steels (AHSS) for automotive industry, including the technologies of their heat treatment and thermo-mechanical treatment, to obtain the optimal combination of specific properties of these materials (weight/strength/elongation). The next step is the investigation of the possibilities of metallurgical joining of newly designed AHSS and the analysis of development of dissimilar weld joints of AHSS and light-metal alloys (Al, Mg, Ti). The chemical compositions of steels will be proposed using the ThermoCalc software and JMatPro. The influence of technological parameters of heat treatment and material joining processes on the phase composition, microstructure and the final properties of AHSS will be predicted using advanced materials models and simulation models, using which the numerical simulations of investigated processes will be performed in ANSYS, DEFORM and SYSWELD software.

Project Title	**Proposal of identification and monitoring of production equipment parameters for the needs of predictive maintenance in accordance with the concept of Industry 4.0 using Industrial IoT technologies**
Coordinator	prof. Mgr. Róbert Vrábeľ, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	VEGA
Annotation	The main goal is to create intelligent system with capability, based on parameters of real production devices and thanks to including of modern modern data processing methods, such a neural network or expert system, to recognize state before failure and to generate a preliminary plan of device maintenance. Firstly, is important to identify key parameters of production units and process and to identify key physical values of environment of production process and important for state prediction. Secondly, will be designed methodological proposal of entire system, while final implementation will be verified in real environment. The output of the project is unique and universally usable solution able to generate predictive maintenance plan and thus avoid failures of production devices in production. In addition, the solution offers maximum flexibility thanks to the implementation of intelligent sensors and their wireless communication via IIoT standards.

Project Title	**Proactive control of hybrid production systems using simulation-based digital twin**
Coordinator	prof. Ing. Pavel Važan, PhD.
Start Date	01/01/2022
End Date	31/12/2025
Program	VEGA
Annotation	The project goal is to use the concept of a simulation-based digital twin and to design a proactive way of hybrid production system control at the MES level. Proactive way is a procedure in anticipation of future problems, needs or changes. The project will also include a solution for data acquisition from the hybrid production process, which will be used in the simulation to verify the achievement of the production plan objectives. Simulation results allow to revise the method of control and the necessary data are sent back to the MES to update the production process. From the point of view of the

control operational level, this can be considered as the use of online simulation in control. The result of the project will be the concept of using DT with online simulation utilisation in order to proactively support the production system control. The researchers plan to create a functional pilot solution on the model hybrid production system using the hardware and software available at the institute.

Project Title	**Innovation and new learning opportunities in industrial process management with PLC**
Coordinator	Ing. Andrea Némethová, PhD.
Start Date	01/01/2020
End Date	31/12/2022
Program	KEGA
Annotation	The presented project, entitled "Innovation and New Learning Opportunities in Industrial Process Control with PLC", aims to innovate an existing laboratory focused on industrial processes control by PLC. The laboratory currently contains 8 workplaces containing physical models enabling the simulation of selected processes. The aim of this project is to innovate the laboratory to simulate Inovácia a nové možnosti vzdelávania v oblasti riadenia priemyselných procesov pomocou PLC 3/21 Identifikátor: 20190425141260810 the realization of full-fledged workplaces with complex distributed control systems. The aim of this project is to innovate the laboratory so that all workplaces can be fully utilized and even more complex distributed systems can be simulated. This modernized laboratory will also allow the extension of the subject "Programmable Logic Controllers". Another benefit is the possibility of solving bachelor, master and dissertation theses. After implementing new workplaces and elements in the laboratory, this can be used to carry out workshops, create teaching materials and sample enclosures from individual workplaces.

Project Title	**Innovations of teaching process of technical subjects by implementation of augmented and virtual reality**
Coordinator	Ing. Ladislav Rolník, PhD.
Start Date	01/01/2021
End Date	31/12/2023
Program	KEGA
Annotation	The project is focused on the innovation of teaching technical subjects using augmented reality and virtual reality. The project also envisages equipping the laboratory with new types of machine parts and assemblies created by 3D printing, to improve students' technical imagination and skills in the field of construction and creation of technical documentation. In this project will be created a mobile application using augmented reality and virtual reality technologies and a web interface, where students will be able to view in an interactive way models of 3D components created in the CAD / CAM / CAE system CATIA V5. The prepared parametric models can then be printed on a 3D printer and will be used in exercises as study aids that will significantly help students understand the principle of orthographic projection of components. Really made functional models of kinematic systems will allow students to intuitively understand the functionality of mechanisms used in practice. In the following subjects (Finite element method, Parts and mechanisms of machines) it will be possible to analyze the created parts using the finite element

method in terms of thermal and mechanical stress in the CATIA V5 and ANSYS systems. The aim of the project is to increase the attractiveness of technical directions through an innovative approach to teaching subjects related to the construction of machinery. Another goal is to create macros in the Visual Basic for Automation VBA environment to support the automated process of constructing machine parts in CATIA V5.

Project Title	**Model of online teaching with an emphasis on increasing the quality of education of engineers in a period of a possible pandemic**
Coordinator	doc. RNDr. Mária Mišútová, PhD.
Start Date	01/01/2022
End Date	31/12/2023
Program	KEGA
Annotation	In the last two years, educational institutions have faced the enormous challenge of shifting teaching from classrooms to online. If such forms and methods used in full-time teaching are also used in distance teaching, their effectiveness may be lost. Therefore, it is necessary to develop innovative models of online teaching. The project aims to design, verify, and implement innovative models of teaching informatics and mathematics courses, emphasising improving the quality of learning through digital technologies. The target group is students of study programs of technical and economic universities. In addressing the project, we will identify desired learning outcomes to the design of a model of teaching that uses digital technology. The e-learning courses will enhance the model of teaching, as well.

Project Title	**Integration of the requirements of practice in the automotive industry with the teaching of subjects within the study programs Process Automation and Informatization in Industry and Industrial Management**
Coordinator	prof. Ing. Pavel Važan, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	KEGA
Annotation	The main goal of the project is the innovation of study programs at universities and the specific implementation of the online system in the teaching process of vocational subjects in the university environment and their connection with practice in accordance with the principles of Industry 4.0. The project aims to increase the employability of university students in the labour market by increasing the technical knowledge base and practical skills with an emphasis on innovation with a link to practice in the automotive industry. The presented project supports and creates new opportunities for connecting companies operating in the automotive industry and university education, using knowledge from research and knowledge from the relevant study programs guaranteed at the university. Due to the ever-increasing need to reflect on the requirements of practice for graduating students and graduates of our university, the project is a great opportunity to innovate the content of professional subjects. Graduates will gain a competitive advantage in the form of technical knowledge and practical skills in financial management, customer relationship management, project management, supply chain management, operational management as well as reporting and analytics. The concept of ERP is one of the decisive tools for the company´s success in the market and is currently a very topical

issue in the environment of manufacturing companies. The aim of the project is to support new approaches, modern teaching aids, and creative solutions in education.

Project Title	**Modernization and new possibilities of online education in the field of logical control systems and process visualization**
Coordinator	Ing. Martin Németh, PhD.
Start Date	01/01/2022
End Date	31/12/2024
Program	KEGA
Annotation	The presented project entitled "Modernization and new possibilities of online education in the field of logical systems of process control and visualization" is focused on the innovation of subjects, which are key subjects at the engineering level dealing with automation and control of industrial processes. The current state of the laboratory does not provide a sufficient number of workstations for a larger number of students. The aim of the presented project is to innovate the laboratory so that it is possible to simulate the implementation of full-fledged workplaces with complex distributed control systems. Virtual models can fully replace complex workplaces and provide students with fully programmed and simulated the production process. Such a modernized laboratory will also enable the extension of the subject "Process Visualization", as this subject is directly linked to the content part of the programming of production processes. Another benefit of the project is the possibility of solving bachelor's, diploma and dissertation theses. After the implementation of new virtual workplaces in the laboratory, this solution can be used for the implementation of workshops, the creation of teaching materials and sample examples from individual workplaces.

PROJECTS OF THE ADVANCED TECHNOLOGIES RESEARCH INSTITUTE

Project Title	**Computational design of novel functional materials**
Coordinator	doc. Mgr. Mariana Derzsi, PhD.
Start Date	01/01/2019
End Date	31/12/2022
Program	VEGA
Annotation	The project focuses on broadening the vistas of the technologically important systems with transition metals and lanthanides by predicting and targeted design of new as-yet unknown phases using theoretical approaches based on atomic-scale quantum-mechanical modelling, evolutionary algorithms and direct phonon method. The studied systems will encompass new electronic materials for spintronics, multiferroics and superconductors. This study will allow for designing of the most effective and technologically attractive structural forms of the newly predicted phases with metallic elements particularly tuned for the functionality in question in accessible pressure and temperature ranges.

Project Title	**Searching for multicomponent character of the flickering in accreting systems**
Coordinator	Mgr. Andrej Dobrotka, PhD.
Start Date	01/01/2020

End Date 31/12/2022
Program VEGA
Annotation: The aim of the project is to study fast stochastic variability generated by mass accretion in cosmic objects, where the main drive mechanism is disc driven accretion, i.e. (for our current focus) cataclysmic interacting binary stars with a white dwarf, X-ray binaries with black holes, or active galactic nuclei with a supermassive black hole in the center. This stochastic flickering do not originate only from one source and has a complicated morphology. The proposed project aims to study the frequency spectrum of variability in order to identify the source. Since all mentioned objects have the same physical process as the main engine, the flickering morphology must also have common features. Our goal is to look for these common features and to create a complex concept of flickering for all objects. For this purpose, we will use high-quality, extensive and multi-frequency data from space missions such as Kepler and XMM-Newton.

Project Title **Quest for novel inorganic compounds with nickel, palladium, copper and silver by DFT modelling and ion beam synthesis**
Coordinator Ing. Pavol Noga, PhD.
Start Date 01/07/2019
End Date 30/06/2023
Program APVV
Annotation The current project aims at a thorough theoretical and experimental study of all important stoichiometries, which are currently missing from the structure map of binary oxides and halides of Group 10 (Ni, Pd) and 11 (Cu, Ag) metals. Absence of these simple chemical stoichiometries is disturbing and calls for an explanation. What are the reasons for these white spots on the huge seas of chemical stability? Are these compounds truly unstable? Or, maybe, they could be stable but not enough attention was paid to them? Answers to these and related questions will be given within the project using state-of-the-art approaches for search of new materials that will rely on combination of computational modelling at the atomic level and experimental physicochemical techniques, reactive magnetron sputtering deposition and ion implantation. Our strategy meets the urgent need of the modern world for highly effective screening of the unknown potential of available natural resources and the most economic use of available research infrastructures.

Project Title **Quantum Monte Carlo for strongly correlated electronic systems**
Coordinator Ing. Matúš Dubecký, PhD.
Start Date 01/07/2019
End Date 30/06/2023
Program APVV
Annotation In recent years, single-determinant fixed-node diffusion Monte Carlo (FNDMC) reached high-standard accuracy in a number of diverse systems (where mean-field methods like DFT do not suffice) ranging from weakly bound noncovalent complexes to strongly correlated systems like solid transition-metal oxides at high pressures. Thanks to its favourable CPU cost scaling, parallelism, and direct access to periodicity, FNDMC gains popularity as an unprecedented benchmark tool for large realistic complex many-electron systems. Recent results however suggest, that the expected

accuracy is not always accessible, sometimes the results are overvalued, or they depend on the parameters that have been ignored to date. The reason being incomplete understanding of FN approximation (FNA) and its interplay with other possible biases. Our goal is identification and development of deep conceptual understanding of the key FNDMC error sources in strong interaction limit. We plan to uncover the currently unknown links between generic nodal (position-space) properties (e.g.,topology) of fermionic wave functions, and, their connection to the structure of many-determinant expansions and 1-particle reduced density matrix occupation numbers, as well as separation of electron correlation energy to dynamic and nondynamic (strong, multireference) component, which will enable fundamental understanding of FNA limits and decoupling of FN-bias from other bias sources of FNDMC. We also plan screening of FNDMC accuracy in strongly interacting model systems and unprecedented method developments that go beyond FN approximation. In addition to deep physical insights to the strong correlation effects in complex many-electron systems and limits of FNDMC methodology, the results of the project will enable rational usage and fine bias control of this method valuable for large systems.

Project Title	**Modern electronic devices based on ultrawide bandgap semiconducting Ga2O3 for future high-voltage applications**
Coordinator	Ing. Pavol Noga, PhD.
Start Date	01/07/2021
End Date	30/06/2025
Program	APVV
Annotation	Wide bandgap (WBG) semiconductor devices represent one of the key technologies in development of high power and high frequency systems for electric power conversion and telecommunications owing to their fundamental benefit of higher breakdown electric fields, in some cases increased electron mobility, and possibility to form heterostructures and 2D electron gas. GaN and SiC, two typical WBG examples also benefit from moderate values of thermal conductivity allowing for more efficient sinking of generated waste heat, lower channel temperatures, and enhanced device reliability. New emerging semiconductor materials with even higher bandgap energies Eg>3.4eV) referred to as ultrawide bandgap materials allow for further improvements in high power and high voltage handling solid-state electronic devices. Currently, semiconducting gallium oxide (Ga2O3) is under extensive study and expected to provide base material for rectifying Schottky-gate diodes and field-effect transistors for applications operating in kV range thanks to its good scalability, relatively simple synthesis, availability of native melt-grown substrates, and wide range of achievable n-type doping levels. The main aim of the proposed project constitutes material research and development of technology for epitaxial growth of epitaxial α-, β-, and ε-Ga2O3 layers and for processing of basic unipolar and bipolar electronic devices based on prepared Ga2O3 layers for future high voltage/power applications. Ga2O3 layers will be grown using liquid injection metalorganic chemical vapour deposition on sapphire, and higher thermal conductivity SiC substrates. We also aim to prepare Schottky diodes, FETs, and all-oxide Ga2O3 PN diodes using naturally p-type oxides (e.g. NiO, In2O3, CuO2). Comprehensive structural, electrical, optical, and thermal study of prepared epitaxial layers and devices will be conducted and numerous original, high-impact results are expected to be obtained.

Project Title	**Perovskite-based Films with Superior Passivation and Structure**
Coordinator	RNDr. Kamil Tokár, PhD.
Start Date	01/07/2022
End Date	30/06/2025
Program	APVV
Annotation	The growing global demand for electricity makes it essential to develop alternatives to fossil fuels. Not only to divert the upcoming energy supply shortage but also to reduce the effects of climate change. In this perspective, renewable energies from inexhaustible natural sources are the key to this industry's future, and solar energy, in particular, is one of the most promising. Solar cells (SCs) are one of the up-and-coming options for environmentally clean electricity production. Among several state-of-the-art generations, perovskite SCs, with the perovskite active light-harvesting material, are currently the most encouraging and promising hotspots of research. In order to make perovskite-based SCs available in the future, several issues need to be resolved, such as their lower efficiency compared to the most commonly used silicon. It was found that charge recombination plays a significant role in restricting the performance of potential perovskite-based applications, which usually happens in the presence of defect states. It is generally accepted that the perovskite defects are responsible for most of the issues that hinder the further commercial usage of perovskite-based devices. This indicates that the direction of further efficiency increase lies in the addressed defects passivation. Therefore, this project focuses on a detailed investigation of defect-induced nonradiative recombination processes in perovskite films and subsequent passivation of the defect states.

PROJECTS OF THE CENTRE FOR NANODIAGNOSTICS OF MATERIALS

Project Title	**Towards lithium based batteries with improved lifetime**
Coordinator	Ing. Viliam Vretenár, PhD.
Start Date	01/07/2021
End Date	30/06/2025
Program	APVV
Annotation	With the steadily increasing energy requirements of portable electronics and electromobility, conventional lithiumion batteries are facing new challenges. In the proposed project, we aim to stabilize the capacity and lifetime of lithium-ion batteries employing ultra-thin interfacial layers prepared by means of atomic layer deposition (ALD). The primary functions of interfacial layers are: i) preventing the dissolution of the cathode materials into electrolyte and ii) stabilizing the cathode morphology during lithiation and de-lithiation. Although the positive effect of ALD fabricated interfacial layers has already been demonstrated, systematic studies are still missing. The main bottleneck of such studies is the identification of appropriate feedback analytical techniques that enable real-time and in-operando insights into the charging/discharging mechanisms on the nanoscale. The conventional electrochemical characterization methods can only provide hints on the ongoing mechanism during degradation processes. Here we propose to utilize in-operando small-angle and wide-

angle X-ray scattering (SAXS, WAXS) to track the morphology and phase changes that occur during the charging/discharging of lithium-ion batteries in realtime. The main focus of this project is on the application of real-time SAXS/WAXS studies under laboratory conditions. In these circumstances, extensive, systematic studies of various ALD interfacial layers can be performed.

Project Title	**p-GaN electronics for energy savings and beyond-CMOS circuits**
Coordinator	Ing. arch. Ing. Ľubomír Vančo, PhD.
Start Date	01/07/2022
End Date	30/06/2025
Program	APVV
Annotation	III-N semiconductors are probably the most versatile and promising semiconductor family, consisted of artificial compounds made of GaN, AlN and InN. In the project proposal we describe new technological concepts with sufficient freedom to solve main problems of the III-N post-beyond CMOS age: in transistors co-existence of the parasitic n-channel along with the p-channel, as well as low hole gas density and mobility. Similarly, we aim to demonstrate scalable threshold voltage in the enhancement -mode p-doped power transistors, which are needed by the industry for efficient, energy-saving convertors. In these aspects, our laboratories already showed very promising results proving the competence to reach described targets. If successfully implemented, results of our proposed project would represent a significant step forward not only from the world-wide point of view but is also in full agreement with the RIS3 SK (perspective areas of specialization of the Slovak economy), particularly in the field of semiconductors for electric cars of automotive industry, as well as in information and communication sciences.

Project Title	**Photochemically Versatile Materials for Water Treatment**
Coordinator	Ing. Mária Čaplovičová, CSc.
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.