Questionnaire
Summary of the main activities of a research institute of the Slovak Academy of Sciences

Period: January 1, 2016 - December 31, 2021

1. Basic information on the institute:

1.1. Legal name and address

Ústav materiálov a mechaniky strojov SAV, v. v. i.
Institute of materials and machine mechanics SAS (IMMM SAS)
Dúbravská cesta 9/6319
845 13 Bratislava
Slovakia

1.2. URL of the institute web site

http://www.umms.sav.sk/
http://www.umms.sav.sk/en/

1.3. Executive body of the institute and its composition

Directoriat	Name	Year of birth	Years in the position, from - to
Director	Ing. Martin Nosko, PhD.	1979	2020 - present
Former director	Ing. Karol Iždinský, CSc.	1959	2012 - 2020
Deputy director	Ing. Mária Lazarová	1972	2012 - present
Scientific secretary	Ing. Alena Opálková Šišková, PhD.	1983	2021 - present
Former scientific secret	Ing. Ján Košút, CSc.	1958	2012 - 2021

1.4. Head of the Scientific Board

Ing. Peter Múčka, CSc. (2022 - present)
Ing. Juraj Lapin, DrSc. (2006 - 2021)

1.4.1 Composition of the International Advisory Board

Prof. Dr. Ing. Dalibor Vojtěch, Department of Metals and Corrosion Engineering, UCT Prague, Czech Republic.

Prof. Dr. Herbert Danninger, Institute of Chemical Technologies and Analytics, Vienna University of Technology, Austria.

Dr. Ludger Weber, EPFL, Lausanne, Switzerland.

Dr. Ing. Thomas Weißgäber, Frauenhofer Institute for Manufacturing Technology and Advanced Materials, Dresden. Germany.

Prof. Ing. Václav Sklenička, DrSc., Institute of Physics of Materials, Czech Academy of Sciences, Brno, Czech Republic.

1.5. Basic information on the research personnel

1.5.1. Fulltime equivalent work capacity of all employees (FTE all), FTE of employees with university degrees engaged in research projects (FTE researchers)

2016		2017		2018		2019		2020		2021		2016-2021	
FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	average FTE all per year	average FTE researchers per year
59,21	33,79	59,30	34,91	60,12	36,10	60,35	36,68	58,73	35,25	60,69	36,64	**59,73**	**35,56**

1.5.2. If applicable, add also a short information on the merger of the institute in the evaluation period. You can also add rows in the above table corresponding to the founding institutes

1.6. Basic information on the funding of the institute

1.6.1. Institutional salary budget, other salary budget[1], non-salary budget[2]

Salary budget	2016	2017	2018	2019	2020	2021	average
Institutional salary budget *[millions of EUR]*	0,799	0,917	0,968	0,909	1,272	1,209	**1,012**
Other salary budget *[millions of EUR]*	0,177	0,202	0,193	0,209	0,332	0,331	**0,241**
Total salary budget *[millions of EUR]*	0,976	1,119	1,161	1,118	1,604	1,540	**1,253**
Non-salary budget *[millions of EUR]*	0,498	0,435	1,801	0,786	0,529	0,570	**0,770**

1.7. Mission Statement of the Institute as presented in the Foundation Charter indicating the years when it was adopted and revised

According to the Foundation Charter agreed by the Presidency of Slovak Academy of Sciences (Act. No 716) on August 13th 2015 concerning the amendment agreed by the Presidency of Slovak Academy of Sciences (Act. No 861) on November 15th 2021.

- The Institute performs basic and applied research in the field of materials engineering and mechanical engineering.
    - Materials engineering is oriented to the development of advanced metallic materials, especially composites, metallic foams, nanostructured materials, and intermetallic alloys using modern technologies such as powder metallurgy, idirectional solidification, pressure infiltration, and metal foaming technologies. The main objective of the research is focused

[1] Salary budget originating outside the regular budgetary resources of the organization, e.g. from the project funding.
[2] Includes Goods and Services and PhD fellowships

on the exploitation of relationships between the processing parameters, microstructure and properties of various materials, e.g. biomaterials, materials for the transport, energy sector, construction, etc.
    - In the field of mechanical engineering, analytical and numerical modelling of deformation behaviour, crack initiation, crack propagation and predictions of fracture life of investigated materials are carried out. Moreover, mechanical engineering is also focused on a new way of characterizing the surface irregularities of roads and their impact on the driving comfort and safety of vehicle crews.
- The Institute provides consultation and other expert services related to the main institute activities. Transfer of knowledge at IMMM SAS is accomplished through:
    - Industrially oriented research projects on new and existing materials, technology development and development of unique expertise for industry (energy, engineering, automotive, etc.)
    - Prototyping and small-series production of selected materials (e.g. aluminium foam parts, materials for the nuclear industry, biomaterials, etc.)
- Interdisciplinary research activities especially in the field of archaeology, conservation and restoration of cultural heritage, and health are supported at IMMM SAS.
- The Institute carries out the doctoral study under applicable laws.
- The IMMM SAS publishes results of its R&D activity using periodical and non-periodical press governed by resolutions of the Presidium of SAS.
- The IMMM SAS, beyond the main activity to which it has been established, carries out the business activities in the following areas:
    - Manufacturing and sale of equipment for testing of new materials,
    - Manufacturing and sale of technological equipment for the production of new materials,
    - Production of specimens and components in small batches from new materials and their sale.

1.8. Summary of R&D activity pursued by the institute during the evaluation period in both national and international contexts. Describe the scientific importance and societal impact of each important result/discovery. Explain on general level – the information should be understandable for a non-specialist (recommended 5 pages, max. 10 pages for larger institutes with more than 50 average FTE researchers per year as per Table 1.5.1.)

The institute's research mission builds on the research in the field of **lightweight structural and functional materials and materials for high-temperature structural applications**. The research reflects the global needs for material science and mechanics in several main sectors especially in **Transport, Energy and Environmental Engineering, Biomaterials and Space** through targeted basic research. Besides these main pillars of the research, attention is also paid to the **Interdisciplinary/Multidisciplinary Research**. Interdisciplinary research is mainly represented by the PhD students, whose research projects cover the field of engineering and biological sciences. Multidisciplinary research is represented by common projects, which involve research teams from different research disciplines and institutions. The IMMM SAS research strategy at the national and international levels is in line with EU missions. The achieved results can be attributed both to the human potential and up-to-date research infrastructure acquired in the previous evaluation period and via constant adaptation and construction of further scientific infrastructure.

Transport

In the field of transport, the research of the Institute is focused on **lightweight structural materials, new materials for high-temperature structural applications, and mechanics of materials and structures.**

The scientific importance of the research:

- **Near- and sub-micrometer aluminium metal matrix composites (Al MMC) in-situ stabilized by low volume fraction of nanoscale alumina (Al_2O_3) component (developed at IMMM SAS and named HITEMAL®) was systematically studied.** HITEMAL® features exceptional thermal stability, mechanical strengths and creep resistance at elevated temperatures up to 600°C. The

focus was paid to a description of the strengthening, deformation and stabilization mechanisms active in HITEMAL® within a broad temperature range. **Furthermore, we reported on the joining procedure of extruded HITEMAL® bars by friction stir welding (FSW). The effect on the Al_2O_3 phase induced by FSW, which is crucial to the properties of HITEMAL®, was pursued.** A novel technique of small punch testing (SPT) was developed in order to determine the mechanical properties of HITEMAL® in a broad temperature range. A mutual correlation between the tensile test and SPT results was established.

- Ultrafine-grained Al MMC reinforced and stiffened with 15 and 30 vol% of in-situ Al_3Ti filaments were fabricated by direct extrusion of Al-titanium (Ti) powder mixtures followed by solid-state reactive diffusion. In parallel, a small portion (2.4 vol%) of nanoscale γ-Al_2O_3 particles, which originated from native amorphous films on fine Al powders, formed in situ and were homogeneously dispersed in the Al matrix.
- **In order to improve Young's modulus of Al+SiC MMC, the matrix-reinforcement interface was modified via chemical reactions between the Al matrix and SiC particles.** To prepare diverse interfaces, various types of MMC were fabricated using the direct hot extrusion of Al-based powder mixtures containing 30 vol% untreated or oxidized SiC particles. The extruded MMC were subjected to different annealing treatments. The effect of the interface on Young's modulus and on the other mechanical properties of the MMC was systematically investigated. **Depending on the interface quality, Young's modulus of the composites can be varied over the range of 88-121 GPa.** The results proved the importance of a stiff phase - comparable to SiC stiffness at the interface, which leads to the SiC particles contributing more effectively to the increase in the composite Young's modulus.
  The above-mentioned Al-AlN, HITEMAL®, Al+Al_3Ti and Al+SiC MMC were all targeted for structural load-bearing applications in energy and transportation sectors, which require low mass, high strength, creep resistance and enhanced stiffness, with an expected service at elevated temperatures not normally associated with use of conventional Al-based alloys and MMC.
- **A new cost-effective process for the preparation of carbon-containing TiAl-based alloys with reproducible chemical composition** has been developed and successfully used for the preparation of various TiAl-based systems. The method allows controlling the content of carbon resulting from the reactions between the melt and graphite crucibles as well as the content of light elements showing a tendency to evaporation during melting and casting. It was found that the process can be applied for the preparation of TiAl based alloys with well-controlled chemical composition and reproducible carbon content ranging from 0.4 to 5.5 at.%. This invention has been already protected and an international patent.
- **Novel lightweight in-situ TiAl-based composites reinforced with MAX-phase particles for high-temperature structural applications were designed** and prepared by vacuum induction melting followed by tilt or centrifugal casting. The design involves about 30 different optimised compositions based on Ti-Al-Nb, Ti-Al-Nb-Mo, Ti-Al-W, and Ti-Al-Nb-Ta, which allow preparing in-situ composites with three types of intermetallic matrices such as single-phase TiAl, lamellar TiAl+Ti_3Al and pseudo-duplex composed of lamellar and single-phase grains. The centrifugally cast and heat-treated **in-situ composites with lamellar matrices reinforced with a low volume of Ti_2AlC particles have excellent creep resistance at 800°C, which is superior to that of the existing TiAl-based alloys and composites**.
- The as-cast in-situ composites with TiAl based matrix reinforced with Ti_2AlC particles can be processed by hot forming at temperatures of 900-1000°C. The analytical and numerical simulations of hot forming including strain hardening as well as strain softening stages have been carried out. The dynamic recrystallisation led to the grain refinement of coarse-grained as-cast microstructure and changed the orientation of lathe-shaped carbide particles in the matrix. **The hot forming allows redistributing of randomly oriented carbide particles in a preferential direction parallel to the plastic flow of the matrix, which led to an additional improvement in the mechanical properties of these composites.**
- **Unique long-term creep experiments ranging from 10 000 to 30 000 h were carried out on intermetallic Ti-46Al-8Ta (at.%) alloy.** The minimum creep rate was measured to be as low as $1.47\times10-10\ s^{-1}$ and total deformation was only 2.5% after an interrupted 30000 h creep test at 200 MPa. The predicted time to fracture was calculated to occur after 76000 h of creep exposure at 700°C/200 MPa. **The achieved results extended the existing knowledge about the long-**

term behaviour and stability of lamellar microstructure of TiAl-based alloys. The microstructural analysis of the crept specimens revealed the instability of lamellar microstructure connected with the precipitation of two novel phases, which were identified to belong to Ti_3Al_2Ta and $L1_2$. **The experiments proved that the novel TiAl-based alloy can operate not only in aircraft engines but also in stationary gas turbines where a minimum operation time of 30000 h is required.**

- The brittle-ductile transition temperature of in-situ composites with TiAl-based matrix reinforced with carbide particles was determined. Below the transition temperature, the composites show brittle fracture behaviour. The reinforcing carbide particles increase the fracture toughness of the intermetallic matrix and affect the crack propagation through crack deviation, microcrack formation, carbide fragmentation, delamination on the matrix-carbide interfaces, and pullout of the carbide particles from the TiAl matrix. Using data from acoustic emission and high-speed cameras, the mechanisms of crack initiation and propagation were described. **Critical stress leading to crack initiation in the notch region was numerically calculated for quasi-static loading conditions using finite element analysis (FEA).**
- Numerical analysis using the finite element method (FEM) was carried out **to simulate heat transfer from TiAl alloy during Jominy en-quench test.** The cooling curves calculated by FEM and available material properties deviated significantly from the experimentally measured data. The application of the inverse correlation method allowed us to reconcile the numerically calculated cooling curves with the experimentally measured data. The results showed that fan cooling can be applied for the grain refinement of cast TiAl components with a thickness of up to 24 mm.
- **The unique relationship between road profile vertical displacement power spectral density (PSD) parameters (ISO 8608: 2016) and the whole-body vibrations in the passenger car (ISO 2631-1: 1997) was determined for different driving speeds and the road categories.** It was done with extensive parallel measurements of vehicle vibration and road profile unevenness. The relationship between the most popular road unevenness index IRI and whole-body vibration was derived. The road roughness thresholds depending on vehicle speed and road category have been proposed as a function of whole-body vibration exposure action and limit values.
- The research within the aluminium foam was focused on the development of the bracket for the Hyunday company in cooperation with Hyundai Motor Europe Technical Center. **The aim was to eliminate the mechanical vibration from the engine through the bracket containing aluminium foam.** The aluminium foam was incorporated into the bracket due to the affordable vibration element. More alternatives were tested e.g., aluminium foam, aluminium foam inserts, aluminium foam with metal sheer insert to strengthen the certain parts of the bracket. **By incorporating the damping element into the bracket brings increased driving comfort.**

<u>The international contexts and societal impact of the achieved results</u>

- **In the field of research on TiAl alloys, these materials are developed to be used for manufacturing low-pressure turbine blades of aircraft engines and turbocharger wheels.** The development and applications of these lightweight materials for temperatures up to 700 °C instead of nickel-based superalloys currently in use, leads to a reduction in weight of the aircraft engines, 15% less CO_2 emissions, 55% reduction of NOx, and 15% reduction in fuel consumption. Further significant reduction in weight and emissions of the aircraft engines requires the development of cost-effective processes and more creep-resistant lightweight TiAl-based alloys and their composites, which can operate at temperatures above 800°C. **Aircraft pollutants (NOx, HC, CO, and SOx) directly or indirectly deplete stratospheric ozone (O3), others generate tropospheric O3 and others induce noxious effects on the health of humans and ecosystems.** From the point of view ot hte international context of this research, **the Institute belongs to the leader in the field of cast in-situ TiAl-based matrix composites** reinforced with carbide particles processing its own cost-effective patented technology for their production.
- **In the field of vehicle vibration, the negative impact of vibration on health and ride safety will be mitigated.** The achieved experimental and simulation data will contribute to the design of appropriate thresholds of road roughness to ensure the safe level of motor vehicle vibration and car accidents prevention.

Energy and environmental engineering

- **Hydrogen embrittlement resistance of precipitation-hardened complex concentrated alloys is studied recently at IMMM SAS.** Laboratory methods of hydrogenation at room and elevated temperatures were developed and successfully tested on steels and high entropy alloys (HEAs). The effect of hydrogenation conditions on hydrogen content and stability of absorbed hydrogen was analysed and the existing data on hydrogen embrittlement were critically reviewed. The experimental methodology of mechanical testing of hydrogen charged samples was proposed to increase the reliability of the data published on the effect of hydrogenation on the mechanical behaviour of structural materials. **The type of this research is very important from a national, European as well as global perspective**, as it reflects the need **to store and distribute produced hydrogen for end-users, e.g. as a green fuel for fuel cells used in ships, trains, trucks, and personal cars.**
- **A very important topic addressed at IMMM SAS is the development of new composite material for spent nuclear fuel storage based on fine-grained Al powders and the B10 isotope.** This research was carried out in cooperation with an international and national industrial partner in the field of nuclear energy. Many years of knowledge in the field of basic research of ultrafine-grained Al-Al_2O_3 composites known as HITEMAL®, which meet the demanding material requirements for the intended application, were used. As part of the feasibility study, IMMM SAS succeeded in defining the exact material compositions and optimizing the production of profiles by extrusion the powder mixture into the desired shape. Testing has shown that the **material meets all the required parameters while having a significantly better thermal conductivity than currently used steel**. Such material is currently being prepared for further processing by IMMM SAS. **Social impact is of global importance as it is a new, safe and long-term way of storing nuclear fuel in a dry way without the presence of water.** The advantage is in longer life and elimination of the risk of environmental pollution than is currently the case with wet roads.
- **In the case of the study of progressive materials in a combination of Al foam and Phase Change Materials (PCMs)**, IMMM SAS developed a cooling/heating panels based on fundamental knowledge from both areas and explore its thermophysical properties concerning their use to reduce energy costs and effective use of the surplus heat. From a scientific point of view, this is **a unique technical solution, as it is possible to store more latent heat from the phase transformation of the PCM due to the microcracks in the walls and the targeted oversized microstructure as in existing comparable solutions.** If such material is used in combination with thermosolar panel, the effectivity of the panel is increased by heat consumption throught the phase transformation of the PCM.
- The manufacturing possibilities of roofing for sloping building roofs using aluminium foam have been also investigated. **Developed roof cladding serves as a heat exchanger between exterior air and the liquid heat transfer medium flowing in the indoor heat exchangers**. The possibility of efficient heat recovery from solar radiation, as well as the removal of undesirable summer heat surplusses to the surroundings of the building during colder summer nights, has been verified on the manufactured prototypes of roofing. The solution of the project led to the creation of an invention related to the seasonal storage of energy using a thermochemical reaction, for which the Slovak patent application PP 61-2021 was granted on August 11, 2021. The successful solution of the project resulted in a highly innovative technical solution of solar roofing, which has a significantly better ability to efficiently convert solar energy or heat from the building surroundings using a heat transfer fluid into the building interior or into a heat exchanger providing heating of domestic hot water. **The developed foamed aluminium alloy roofing has a huge potential for use in reducing the construction and operating costs of buildings with almost zero overall energy balance,** which have already become a necessary standard in the whole region of EU.
- **In the copper matrix reinforced with continuous carbon fibres (Cu-Cf) electrical and thermal conductivities were analysed by application of the Wiedeman-Franz law.** Results showed that in comparison with simple analytical models, this method can also be used for predicting the thermal conductivity of the Cu-Cf composite in longitudinal and transverse directions. The unidirectional composite was produced by diffusion bonding and contained 40 - 60 vol.% of unidirectional fibres. **The results will enrich the database of knowledge in this field, which may serve for young and senior researchers in their work.** The data can also

be applied in the teaching process of the subject Composite Materials with a Metal Matrix and for the education of new experts.

- **Cu-ZrB2 composites material containing a ceramic hard phase with extremely high melting temperature was prepared by gas pressure infiltration method** into molten Cu, respectively Cu alloys. The improved interfacial conductivity was formed due to the presence of the Zr in both the copper alloy and the ceramic skeleton and therefore, the material possesses increased resistance to high temperatures, good corrosion resistance, and improved thermal and electrical conductivity in hand with good ablation resistance. **The social impact lies in the possibility of producing new types of tools with higher production efficiency.** Moreover, the data will be applied in the process of teaching: the subject Metal Matrix Composites or Construction and Design of Machines.
- Novel economical **method for preparation of magnesium hydride** has been developed and verified in the APVV-14-094 project MAGRID. MgH_2 was prepared from evaporated Mg which, when condensed under hydrogen pressure, forms solid particles directly in the form of MgH_2. This method is many times cheaper and faster than conventional processes based on intensive grinding/milling of magnesium powder mixtures, which are very energy and time consuming. The result of the project was included by the agency in the publication of the best results for the year 2019.
- **Our study focused on the further use of agricultural waste** reflects the demand to mitigate the environmental issues caused by the agriculture and food industry debris. Thermal treatment of such debris leads to carbon-based material production with a maximum carbon content of 75.5% without using additional chemicals. **Such carbon material adsorbs the organic dye with more than 99% of the cationic dye's removal efficiency and 94% of the anionic dye's removal efficiency.** Based on the published article, we were approached by partners from Cukurova University, who prepare kitchen waste-based carbon composites for use in the automotive industry. Based on this cooperation, we are preparing an international project for the M.ERA-net program. **The use of agricultural waste can lead to a motivation of the public and companies to more consistent waste separation** from households and / or from the production and processing process, as well as farmers whose products can not be due to unsatisfactory quality, the unattractive look redeemed by the sales chains.

Space

- **The international project GRADECET with the European Space Agency (ESA), which was experimentally finalised by a successful launch of the rocket MAXUS 9**, was focused on the study of the effect of gravity conditions on columnar to equiaxed transition in TiAl alloys. During the parabolic flight of the rocket, the solidification experiments were carried out in microgravity conditions in the apparatus designed in the frame of the project. From the scientific point of view, the successful research activities allowed us **to explain the effect of hypergravity, earth and microgravity conditions on microstructure formation during solidification and columnar to equiaxed transition in TiAl alloys.** Based on the achieved experimental results, the boundary conditions were defined and the validity of the proposed numerical 2D model for the columnar to equiaxed transition was verified. **The social impact of research is in reducing both fuel consumption and aircraft engine emissions.**
- As part of the European Space Agency's project, "**Novel magnesium composites for ultralight structural components (PECS)," a new magnesium-fibre-reinforced composite material with a high modulus of elasticity was developed.** The insufficient strength of the interface between the fibres and the magnesium matrix was increased by the formation of the stable carbide at the interface between the fibre and matrix via adding the alloying elements (Zr, Cr, Ti, Y). Material with strengths above 600 MPa and Young's modulus above 300 GPa at a density of 1.8 $g.cm^{-3}$ was prepared. **Thus, one of the lightest construction materials in the world** with excellent strength and stiffness-to-weight ratio, good machinability, damping, thermal conductivity, and dimensional stability **was prepared experimentally, from which even more complex-shaped parts can be produced. The social impact of research is in reducing both fuel costs and rocket exhaust gases.**
- In 2021, **the cooperation with the start-up company Space scAvengers was launched with a topic focused on a detailed study of the Contact Capacitor Discharge Stud welding called LA-WE (Landing welding) procedure for space debris capture in vacuum**

conditions. It is done by performing welding tests in vacuum conditions on a laboratory model of L-WE respecting its key HW parts and typical Spacecraft surfaces. The Horizon Europe and the 7th PECS ESA project were proposed. The scope of this activity is the feasibility study including the design and manufacturing of a simplified laboratory model followed by testing in a vacuum chamber and analysis of the welding procedure and resulting joints are realized with another industrial partner Prvá zváračská. **Social impact is mainly the first step towards the recovery of space waste, which can be recycled directly into space. The result adds in the long run to reducing CO_2 when carrying more material into space.**

- An aluminium (Al)-based composite material known as HITEMAL® was developed **in cooperation with the Institute of electrical engineering (IEE) SAS**, for the application of the casing ultralight superconducting wire with magnesium diboride (MgB_2) core. R&D was motivated by the industry's demand for the preparation of lightweight superconducting wire for active shielding of space modules and astronauts from cosmic radiation during long-term flight. **Thanks to the unique combination of properties of the new HITEMAL®, it was possible to produce for the first time a high-quality ultralight superconducting wire with MgB_2 core by conventional technologies.** This solution is patented as documented in Table 2.1.6. and 2.1.7.

Biomaterials

- **The development of the new biodegradable material used in prosthodontic surgery based on Ti-Mg was successfully realized at IMMM SAS**. It was possible due to the mixing of accurate amounts of Ti and Mg powders which were subsequently extruded under specific conditions. Due to admixing of Mg into Ti, the modulus of elasticity was decreased and biodegradability was assured. The research output of dental implants is unique in a national and international context since no similar approach is known and the approach developed by IMMM SAS **is already patented – EP16763311.4** and **IL256877** (Composite material for implants, its use and method of its production). Material is protected by a **trademark BIACOM®. Academic collaboration with domestic and foreign institutions was established. Societal impact** is in the extended life cycle of the BIACOM® implant and reduced risk of inflammation and dental implant rejection which results in decreased healthcare burden and public finances.
- **The possibility of the alternative to the currently used biodegradable Mg alloy WE 43 in bioimplants (e.g. stents, screws, etc.) was studied due to the presence of the rare earth elements within WE 43.** Due to the risk diversification, a new type of biodegradable material made of pure magnesium powders, surface-treated Mg powders (chemical route, cold plasma-assisted treatment, etc.) or mixing the Mg powders with hydroxyapatite (which has a positive effect on the healing effect) was studied. It was possible to control the biodegradability positively in comparison to the WE 43 alloy at the required strength by the proper modification of the Mg powder surface treatment or by powder mixture. The international cooperation with the University of chemistry and technology Prague, the Institute of Physics of the CAS and the Institute of normal and pathological and physiology SAS. **Societal impact** is in reduced environmental impact and decreased financial input.
- Powder metallurgy (PM) commercial purity titanium (CP Ti) was fabricated and **studied to utilize the use for dental applications.** PM CP Ti was manufactured **using a cost-effective approach**, where affordable hydrogenated dehydrogenated (HDH) Ti 99.4 wt.% powder was consolidated via PM techniques at temperatures below 500°C. Processing, microstructure, testing of mechanical properties, fatigue performance and bonding strength with different veneer coatings were analysed. PM CP Ti used as a metal base material in restoration metal-ceramic systems showed **very good bond strength in comparison with three commercially available veneering ceramics and complied with the ISO 9693 standard. This research is part of the pioneer studies, which are already studied worldwide as a cost-effective alternative to the currently produces Plasma atomised Ti powder.**

Interdisciplinary/multidisciplinary research

- **Archaeological research - analysis of the composition and method of processing metal objects from the Middle Neolithic to the Late Bronze Age, which come from the archaeological site of a high fortified settlement in Spišský Štvrtok (SR) in Slovakia** is thoroughly studied. The work is done in cooperation with The Institute of Archaeology of the

Slovak Academy of Sciences. **The trade routes in Europe in the period of 3500 to 1000 BC were revealed**. Thanks to detailed chemical analysis, we have geographically determined the location of metal mining and we found that there was a sensitive trade with the people of Scandinavia. The study was supported by the national research agency and the National Geographic grant.

- At the national level, research at IMMM SAS has also focused on mapping the organ positives fund from the mid-17th century to the beginning of the 20th century. An important finding consists mensural development of wooden registers of these instruments in the context of their sound and acoustic properties. **This led to the creation of a unique map of the organ metal used to build the metal registers of these tools and the wood used to build the wooden registers.** Another important finding is knowledge acquisition of intonation and tuning of individual organ positives, also concerning the preserved period repertoire.
- **In the field of archiving**, we cooperate with the Faculty of chemical and food technology of the Slovak University of Technology in monitoring the elemental distribution of the deacidifying agent in a cross-section of paper samples, which were previously subjected to deacidification. This is done due to a unique way of monitoring magnesium in a cross-section of paper using element maps with the assistance of the SEM - WDS image analysis.
- **Biological research in cooperation with the Institute of Molecular Biology Slovak Academy of Sciences** aimed to monitor the biological samples (e.g. skin tissue, platelets) and bacteria at different stages of incubation (e.g. staphylococci). The preparation of biological samples and testing of the parameters for scanning electron microscopy (SEM) analyses, as well as the observation itself, have been optimized.

In addition to the above-mentioned research, also industrial-orientated activities are well established in IMMM SAS, where we successfully succeed in helping Slovak and foreign companies in the field of technology development, quality control of production processes and tailor-made material, as evidenced by several applications mentioned above. The most important collaborations are described in part 2.6.3.

2. Partial indicators of main activities:

2.1. Research output

2.1.1. Principal types of research output of the institute: basic research/applied research, international/regional (in percentage)

Basic research/applied research = 50% / 50%
International/regional = 90% / 10%

2.1.2 List of selected publications documenting the most important results of basic research. The total number of publications should not exceed the number of average FTE researchers per year. The principal research outputs (max. 10% of the total number of selected publications, including Digital Object Identifier – DOI if available) should be underlined. Authors from the evaluated organizations should be underlined.

No.	The principal research outputs
1	BALOG, Martin** - HASSAN IBRAHIM, Ahmed Mohamed - KRÍŽIK, Peter - BAJANA, Otto KLIMOVÁ, Alena - CATIC, Amir - SCHAUPERL, Zdravko. Bioactive Ti + Mg composites fabricated by powder metallurgy: The relation between the microstructure and mechanical properties. In *Journal of the Mechanical Behavior of Biomedical Materials*, 2019, vol. 90, p. 45-53. (2018: 3.485 - IF, Q1 - JCR, 1.037 - SJR, Q1 - SJR). ISSN 1751-6161. https://doi.org/10.1016/j.jmbbm.2018.10.008
2	LAPIN, Juraj - KLIMOVÁ, Alena - GABALCOVÁ, Zuzana - PELACHOVÁ, Tatiana - BAJANA, Otto - ŠTAMBORSKÁ, Michaela. Microstructure and mechanical properties of cast in-situ TiAl matrix composites reinforced with (Ti,Nb)(2)AlC particles. In *Materials and Design*,

	2017, vol. 133, p. 404-415. (2016: 4.364 - IF, Q1 - JCR, 1.760 - SJR, Q1 - SJR, Current Contents CCC). (2017 - Current Contents). ISSN 0261-3069. https://doi.org/10.1016/j.matdes.2017.08.012
3	MÚČKA, Peter** - STEIN, George Juraj - TOBOLKA, Peter. Whole-body vibration and vertical road profile displacement power spectral density. In *Vehicle System Dynamics*, 2020, vol. 58, no. 4, p. 630-656. (2019: 2.581 - IF, Q2 - JCR, 1.103 - SJR, Q1 - SJR, Current Contents - CCC). (2020 - Current Contents). ISSN 0042-3114. https://doi.org/10.1080/00423114.2019.1595675
4	BALOG, Martin** - KRÍŽIK, Peter - BAJANA, Otto - HU, Tao - YANG, Hanry - SCHOENUNG, Julie M. - LAVERNIA, Enrique J. Influence of grain boundaries with dispersed nanoscale Al2O3 particles on the strength of Al for a wide range of homologous temperatures. In *Journal of Alloys and Compounds*, 2019, vol. 772, p. 472-481. (2018: 4.175 - IF, Q1 - JCR, 1.065 - SJR, Q1 - SJR, Current Contents - CCC). (2019 - Current Contents, WOS, SCOPUS). ISSN 0925-8388. https://doi.org/10.1016/j.jallcom.2018.09.164

No.	**Selected publications documenting the most important results of basic research**
1	BALOG, Martin** - ROSOVÁ, Alica - SZUNDIOVÁ, Bronislava - OROVČÍK, Ľubomír – KRÍŽIK, Peter - ŠVEC, Peter Jr. - KULICH, Miloslav - KOPERA, Ľubomír - KOVÁČ, Pavol HUŠEK, Imrich - IBRAHIM, Ahmed Mohamed Hassan. HITEMAL-an outer sheath material for MgB2 superconductor wires: The effect of annealing at 595-655 degrees C on the microstructure and properties. In Materials and Design, 2018, vol. 157, p. 12-23. (2017: 4.525 - IF, Q1 - JCR, 1.820 - SJR, Q1 - SJR, Current Contents - CCC). (2018 - Current Contents). ISSN 0261-3069. https://doi.org/10.1016/j.matdes.2018.07.033
2	BALOG, Martin** - OROVČÍK, Ľubomír - NAGY, Štefan - KRÍŽIK, Peter - NOSKO, Martin – OSLANEC, Peter, Jr. - ZIFČÁK, Peter. To what extent does friction-stir welding deteriorate the properties of powder metallurgy Al? In *Journal of Materials Research and Technology-JMR&T*, 2020, vol. 9, iss. 3, p. 6733-6744. (2019: 5.289 - IF, Q1 - JCR, 0.898 - SJR, Q1 – SJR, Current Contents - CCC). (2020 - Current Contents). ISSN 2238-7854. https://doi.org/10.1016/j.jmrt.2020.04.087
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5	HASSAN IBRAHIM, Ahmed Mohamed - BALOG, Martin** - KRÍŽIK, Peter - NOVY, Frantisek - CETIN, Yuksel - ŠVEC, Peter Jr. - BAJANA, Otto - DRIENOVSKY, Marian. Partially biodegradable Ti-based composites for biomedical applications subjected to intense and cyclic loading. In *Journal of Alloys and Compounds*, 2020, vol. 839, 155663. (2019: 4.650 – IF, Q1 - JCR, 1.055 - SJR, Q1 - SJR, Current Contents - CCC). (2020 - Current Contents, WOS, SCOPUS). ISSN 0925-8388. https://doi.org/10.1016/j.jallcom.2020.155663
6	HASSAN IBRAHIM, Ahmed Mohamed - TAKÁČOVÁ, Martina - JELENSKÁ, Lenka – CSÁDEROVÁ, Lucia - BALOG, Martin** - KOPÁČEK, Juraj - ŠVASTOVÁ, Eliška - KRÍŽIK, Peter. The effect of surface modification of TiMg composite on the in-vitro degradation response, cell survival, adhesion, and proliferation. In *Materials Science and Engineering C*, 2021, vol. 127, no. 112259. (2020: 7.328 - IF, Q1 - JCR, 1.234 - SJR, Q1 - SJR, Current Contents - CCC). (2021 - Current Contents). ISSN 0928-4931. https://doi.org/10.1016/j.msec.2021.112259
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33	OPÁLKOVÁ ŠIŠKOVÁ, Alena** - MOSNÁČKOVÁ, Katarína - HRŮZA, Jakub - FRAJOVÁ, Jaroslava - OPÁLEK, Andrej - BUČKOVÁ, Mária - KOZICS, Katarína - PEER, Petra - ECKSTEIN ANDICSOVÁ, Anita**. Electrospun poly(ethylene terephthalate)/silk fibroin composite for filtration application. In *Polymers : Open Access Polymer Science Journal*, 2021, vol. 13, art. no. 2499, [23] p. (2020: 4.329 - IF, Q1 - JCR, 0.770 - SJR, Q1 - SJR, Current Contents - CCC). (2021 - Current Contents). ISSN 2073-4360. Dostupné na: https://doi.org/doi.org/10.3390/polym13152499
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2.1.3 List of monographs/books published abroad

2.1.4. List of monographs/books published in Slovakia

2.1.5. List of other scientific outputs specifically important for the institute, max. 10 items for institute with less than 50 average FTE researchers per year, 20 for institutes with 50 – 100 average FTE researchers per year and so on

Besides the basic research, also strong targeted research at IMMM SAS leads to the several fundamental findings. The most important include:

- **The resistance of piping components of nuclear power plants made of austenitic stainless steel against intergranular corrosion was investigated.** The effect of Ti, C, and N content on the susceptibility of the heat-affected zone of welding joints to intergranular corrosion was analyzed. Using the multistage isothermal and anisothermal heat treatment experiments, the effect of stabilizing annealing during the processing route of the piping components and the influence of welding technique and welding procedure on the intergranular corrosion were determined. **The methodology and practical recommendations were elaborated to assess resistance to intergranular corrosion of welding joints and treatment procedures to eliminate intergranular corrosion to assure long-term and safe operation of welded piping components installed in nuclear power plants.**
- **Determination of the relationship between hardness and mechanical tensile properties in austenitic stainless steel at 20°C and 350°C.** The methodology for non-destructive testing of mechanical properties of installed pipe components made of austenitic stainless steel has been proposed and its reliability is tested in nuclear power plants. The methodology is based on a large statistical database of tensile tests, hardness measurements, evaluation of strain hardening behaviour using parameters of a novel model, and statistical relationships between hardness values, yield strength and ultimate tensile strength. **The methodology allows predicting tensile properties of installed piping components with defined precision and reliability from simple hardness measurements.**
- **The effect of anisotropic as-cast microstructure on high-temperature compression deformation of multiphase Co24Cr19Fe24Ni19Al8(Ti,Si,B,C)6 complex concentrated alloy (CCA) was studied at temperatures ranging from 750 to 900°C.** The measured compression deformation curves exhibit a work hardening stage which is followed by a steady-state deformation at constant flow stress. The finite element analysis (FEA) of 3D distribution of local equivalent strains and stresses corresponds qualitatively quite well to the observed structural changes within the barrelled specimens. **The achieved results can be used for predicting the deformation behaviour of novel CCA during hot forming.**
- **The solidification path of Al0.5CoCrFeNi complex concentrated alloy (CCA) was determined experimentally and compared to that resulting from the thermodynamic calculations.** The microstructure of the as-solidified alloy consisted of FCC(A1) dendrites and an interdendritic region composed of BCC(B2), BCC(A2) and FCC(A1) phases. The solution annealing followed by water quenching and ageing led to the precipitation of needle-like BCC(B2) particles in FCC(A1) dendrites and the formation of the interdendritic region composed of BCC(B2) and FCC(A1) phases. The solid solution annealing results in low compressive yield strength, moderate strain hardening rate, and good ductility at room temperature. Hardness and room temperature compressive yield strength of the precipitation hardened alloy increase with decreasing ageing temperature and increasing ageing time. **The achieved results contributed to experimental verification of the calculated phase diagram and allow us to evaluate the contribution of the precipitation hardening to the strength of the studied CCA**.
- **Bonding between native Al_2O_3 layers in powder-metallurgical compacts prepared by quasi-isostatic forging of Al powders with minimal plastic deformation induced during consolidation was analysed.** Such consolidation results in fine grain Al structure stabilized with a continuous nanometric thick amorphous network of native amorphous Al_2O_3 characterised by enhanced high-temperature properties and thermal stability of the material. The conditions for the formation of bonding between initial amorphous Al_2O_3 layers on the surfaces of Al powders, that later forms the continuous nanoscale thick network in compacts were systematically described.
- **Micrometric Ti filaments were prepared by the extraction of powder metallurgy fabricated aluminium - titanium composite in sodium hydroxide solution.** During the hot extrusion consolidation process, ultrafine aluminium powder particles heavily deformed the titanium powder particles into the titanium filaments of high aspect ratio and micrometric size, which were homogeneously embedded and arrayed in the aluminium matrix. Ti filaments sintered into porous material can be used for various applications: filters, OHN scavengers, etc.
- **The preparation and the study of aluminium (Al) composite materials made by the unique technology of low-pressure casting of powder composite mixture into complex casting parts were thoroughly studied.** The unique approach allowed overcoming many disadvantages associated with standard manufacturing methods of Al composites. The result of

such an approach is a fine-grained Al (A1050, AlSi, A6061) composite reinforced with ceramic particles stabilized by the network of nanometric Al_2O_3 particles. This guaranteed favourable mechanical properties, especially at high operating temperatures and structural stability.

- **The development of Al-Mg alloy from a mixture of elementary Al and Mg powders for HYDRO Extrusion Slovakia, s.r.o. in the form of extruded profiles for marine applications was done by application of the fundamental knowledge in a field of powder compaction at IMMM SAS**. The alloying of Al with Mg runs in-situ during the hot extrusion process in the extrusion die, which resulted in higher extrusion speed, lower resistance to plastic deformation and the possibility to produce profiles with complex shapes compared to ingot Al-Mg alloy. For this, we systematically optimised all microstructural and technological parameters to obtain profiles with desired surface quality and mechanical properties.
- **Development of the Fe based PM components with increased fatigue strength was done for the Miba Sinter Slovakia, s.r.o.** The problem with the current serial production of PM-based Fe parts is low density in the range of 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. There was possible to obtain the PM-based Fe parts with a density above 7.2 $g.cm^{-3}$ with a special manufacturing approach and adjusted sintering atmosphere at a higher temperature.
- **Besides the main research area, the up to date characterization techniques including HR SEM and HR TEM allows us to participate in the hard coating research with the following outputs:**
    - **High-resolution STEM approaches at the atomic level and chemical nanoanalysis of elemental distribution in films help to thoroughly characterize** phase transformations, decomposition mechanisms, and distributions of internal stresses at grain boundaries in binary and ternary systems based on diborides and nitrides of transition metals (e.g. TaB_2, VMoN, etc.). These analyzes were able to comprehensively explain the different mechanical behaviour during high temperatures. The results and their interpretations were very necessary for the design of thin-film material systems to be able to fulfil their function in extreme thermal and mechanical conditions. All achieved results were accepted into renowned CC journals (Scripta Materialia, SCT, JVST A).
    - **Two ceramic quaternary films based on nitrides of transition metals Ti-Al-Nb-N and Ti-Al-Ta-N with a high proportion of alloying elements Nb and Ta were prepared.** Due to proper selection of the alloying elements, a high hardness value above 32 GPa and a significant reduction in Young's modulus of about 350 GPa were achieved. **In this way, the typical inherent brittleness of nitride films was suppressed.** At the application level, this leads to a significant extension of the lifetime of the cutting tools covered by these films. The results were published in the renowned CC journals Acta Materialia and JVST A and in 5 years, the 73 citations (without self-citations) were recorded.
    - **A prolonged lifetime of the cutting tools was done due to Ta-Al-N new generation films.** The mechanical behaviour of these films under high thermal loads is surprising because instead of softening, there is a significant increase in hardness. **The STEM investigation at the atomic level was able to visualize the early stages of decomposition processes and understand the mechanisms that accompany this hardening.** These excellent results have been published in the renowned J. of. Appl. Physics.

2.1.6. List of patents, patent applications, and other intellectual property rights registered abroad

List of patents applications and inputs to national / regional phases in evaluation period:

Year	Title	Number	Inventors
2019	Method of controlled alloying of intermetallic γ-TiAl alloys with	PCT/SK2019/000002	Juraj Lapin, Tomáš Čegan, Ivo Szurman, Miroslav Kursa

	carbon during vacuum induction melting in graphite crucibles.		
	Method of controlled alloying of intermetallic γ-TiAl alloys with carbon during vacuum induction melting in graphite crucibles.	PV2021-49	Juraj Lapin, Tomáš Čegan, Ivo Szurman, Miroslav Kursa
2018	Superconductor wire based on MgB_2 core with Al based sheathand method of its production.	PCT/IB2018/053540 US16613471 CN110651371A	Martin Balog, Peter, Krížik, Pavol Kováč, Imrich Hušek, Ľubomír Kopera, Alica Rosová
	Composite material for implants, its use and method of its production	IL256877	Martin Balog, Peter Krížik, Amir Ćatić, Zdravko Schauperl
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	US2018257135, CA2996474, KR20180063087, MX2018002444, AU2015407251, IN 201827011430, MYPI2018700780	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
2016	Composite material for implants, its use and method of its production.	PCT/IB2016/054220	Martin Balog, Peter Krížik, Amir Ćatić, Zdravko Schauperl

List of patents:

2021	Composite material for implants, its use and method of its production.	EP3322454B1	Martin Balog, Peter Krížik, Amir Ćatić, Zdravko Schauperl
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	IL257774	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	EP3135404B1	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
2020	Composite for heat transfer with high-temperature resistance.	US10755821B2	Štefan Kavecký, Pavol Štefánik, Karol Iždinský, František Simančík
	Composite for heat transfer with high-temperature resistance.	EP3398192B1	Štefan Kavecký, Pavol Štefánik, Karol Iždinský, František Simančík
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	JP6748208B2	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	CN108136494B	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
2019	Method of production of component from metal foam, component produced by said method and mould for the realization of said method	ZA201801984 (B)	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka

	Method of production of component from metal foam, component produced by said method and mould for the realization of said method	KZ 33981	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method	RU 2 696 998 C1	František Simančík, Ľubomír Pavlík, Ján Španielka, Peter Tobolka

2.1.7. List of patents, patent applications, and other intellectual property rights registered in Slovakia

List of patents applications:

Year	Title	Number	Inventors
2017	Superconductor wire based on MgB_2 core with Al based sheathand method of its production.	PP 50037-2017	Martin Balog, Peter, Krížik, Pavol Kováč, Imrich Hušek, Ľubomír Kopera, Alica Rosová
2016	Composite material for implants, its use and method of its production.	PP 50046-2016	Martin Balog, Peter Krížik, Amir Ćatić, Zdravko Schauperl

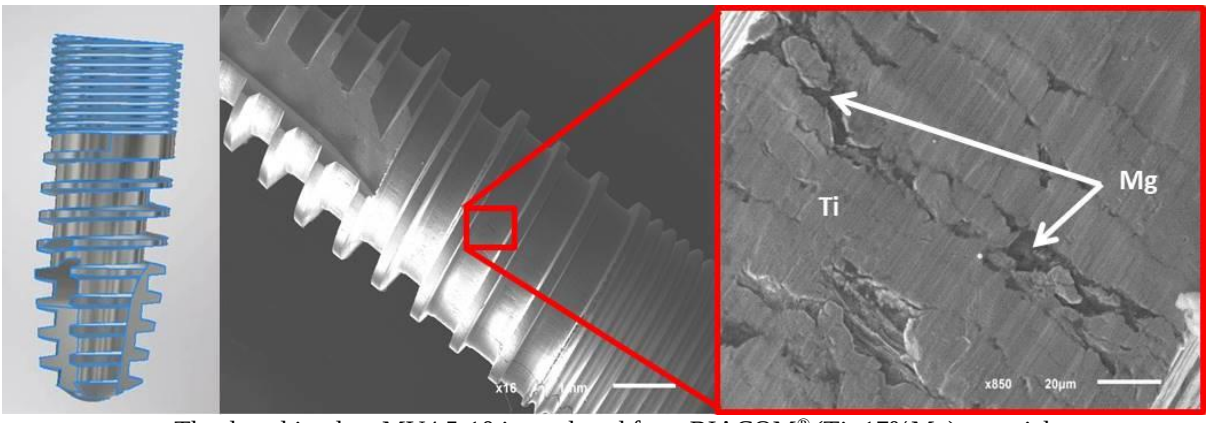
List of patents:

Year	Title	Number	Inventors
2021	Composite material for implants, its use and method of its production.	288928	Martin Balog, Peter Krížik, Amir Ćatić, Zdravko Schauperl
	Method of production of component from metal foam, component produced by said method and mould for the realization of said method.	288885	František Simančík
2020	Method of controlled alloying of intermetallic γ-TiAl alloys with carbon during vacuum induction melting in graphite crucibles.	288792	Lapin Juraj Čegan Tomáš Szurman Ivo Kursa Miroslav
2019	Magnetic vibration damper, working on the basis of eddy currents.	288648	Juraj Stein
	Composite for heat transfer with high-temperature resistance.	288690	Štefan Kavecký, Pavol Štefánik, Karol Iždinský, František Simančík

2.1.8. Narrative on the most important research outputs of the institute – especially focused on their importance for society (3-5 pages)

Most of our research projects are aimed to bring highly positive impact to society. The 5 most successfull cases are introduced in 2.6.1. In this chapter we add more detailed description on another ones, briefly defined in previous sections 1.8. and 2.1.5.

- **A unique partially biodegradable composite (BIACOM®) based on titanium (Ti) was developed at IMMM SAS as a material for use in prosthodontic surgery.** BIACOM® is prepared by the powder metallurgy approach, where a biodegradable component - magnesium (Mg) is added to the load-bearing matrix Ti structure with an optimal content of 17 vol.%. Owing to its specific fine-grained microstructure, the bioinert permanent Ti matrix controls the mechanical properties of the implant throughout its function in the human body. Thanks to the Mg component, BIACOM® minimizes the shortcomings of contemporary commercial Ti implants as shielding effect and insufficient surface bioactivity. Moreover, Mg lowers Young's modulus (E) of BIACOM® and thus reduces the mechanical incompatibility of the implant with the bone. In addition, the Mg component degrades selectively and in a controlled manner upon the reaction of the implant in reaction with human body tissue and fluid, which is accompanied by the gradual formation of surface porosity. **Two different ways of stabilizing the surface of the BIACOM® samples were optimized, which led to the desired viability and cell proliferation and a negative cytotoxic effect.** In cooperation with MARTIKAN, s.r.o. (core business in Martikan is production and sale of conventional Ti-based dental implants (DI)), a pilot batch of BIACOM® DI were CNC machined. Such DI were subsequently tested with a positive result for fatigue life, and in-vitro and in-vivo biological response according to the relevant standards for testing of biomedical implants. **The research results confirmed that BIACOM® can be considered a promising material for use in prosthodontic surgery as DI, which minimizes the basic shortcomings of current commercial Ti implants. All this at relatively low production costs.**



The dental implant MV4.5-10 is produced from BIACOM® (Ti+17%Mg) material.

The research on BIACOM® was supported by two APVV projects under fundamental (APVV-16-0527) and development (APVV-20-0417) research schemes. Academic collaboration with domestic and foreign institutions was established during project implementations e.g., School of Dental Medicine (University of Zagreb), Biomedické centrum (SAV), Institute of Genetic Engineering and Biotechnology (Marmara Research Center, Gebze), etc. The results of the research were disseminated in numerous scientific publications in high-rank prestigious journals and presented at international conferences. **The patents EP 16763311.4 and IL 256877 titled "COMPOSITE MATERIAL FOR IMPLANTS, ITS USE AND METHOD OF ITS PRODUCTION" were granted.** An application of BIACOM® as DI is being intensively communicated with established companies MARTIKAN s.r.o. an EONEX Medical d.o.o. **The research on BIACOM® was selected as the most important fundamental research output at IMMM SAS and for the annual report of SAS in the year 2020, as one of the most important outputs of the Scientific Section 1: Physical, Space, Earth, and Engineering Sciences.**

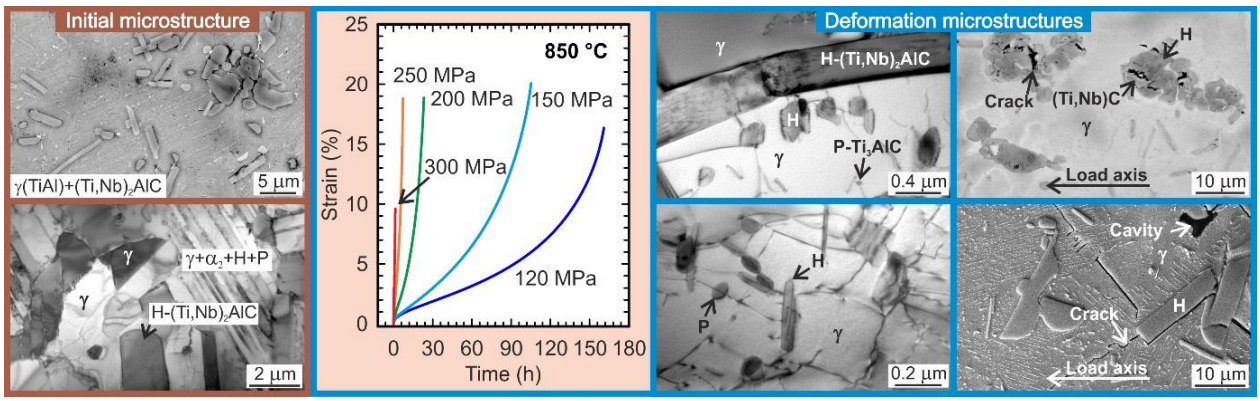
- **Development and characterisation of novel creep-resistant in-situ TiAl-based matrix composites reinforced with carbide particles**
  Intermetallic TiAl-based alloys are of large interest for applications in aerospace, power engineering, and the automotive industry due to their high melting point, low density, high specific strength, and oxidation resistance. However, insufficient high-temperature strength above 750 °C restricts their wide range of applications. The **original cost-effective technology** based on vacuum induction melting in graphite crucibles followed by casting into graphite moulds has been **developed and patented for processing novel high-temperature creep-resistant in-situ**

TiAl-based matrix composites reinforced with carbide particles. High reproducibility of the chemical composition and microstructure of cast composites was achieved by optimisation of the parameters of vacuum induction melting in graphite crucibles and tilt or centrifugal casting into graphite moulds.

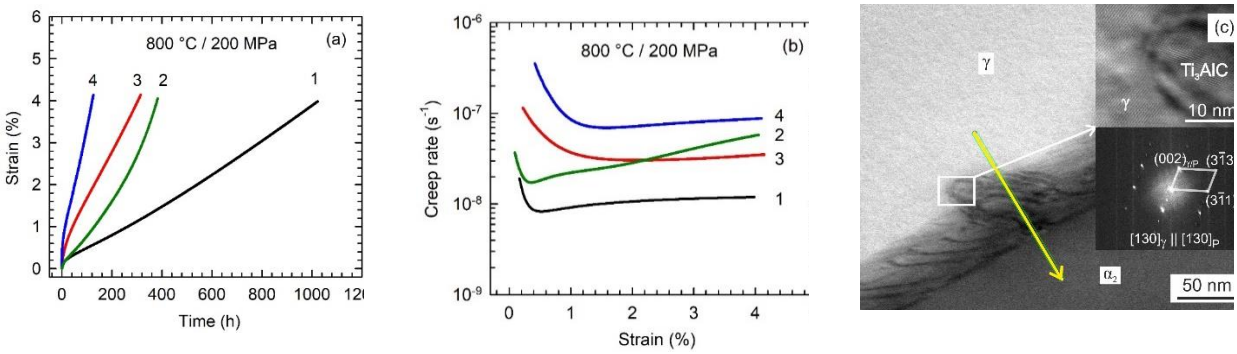
The room and high-temperature mechanical properties of the in-situ composites can be tailored for specific structural applications. The morphology of the primary carbide particles formed during solidification depends on the content of carbon and cooling rates. For composites with a nominal composition of Ti-44.5Al-8Nb-0.8Mo-0.1B-(1.4-5.2) C (at.%), the effect of the matrix microstructure and the volume fraction of primary Ti_2AlC particles on the hardness, compressive and tensile properties, impact strength and fracture toughness was determined at room temperature. The finite element method (FEM) was applied to calculate the stress distribution around the notch tip. The critical stress required to initiate a crack in the notch of the tested specimens was numerically calculated and experimentally verified. **The randomly oriented carbide particles in the TiAl-based matrix can be rearranged to a prefered direction by hot working.** The effect of temperature and strain rate on the deformation behaviour of composites was defined. The critical stress and critical deformation of the onset of dynamic recovery and recrystallization increased with increasing strain rate and decreasing temperature. A constitutive model for the prediction of compression deformation curves was proposed and experimentally verified.

The measured **creep deformation curves** showed an area of **primary creep** characterized by a decrease in creep rate with increasing deformation. After reaching the **minimum creep rate**, the creep rate increased with increasing plastic deformation until fracture. **Dislocations dominated the structure of the composite at small deformations** corresponding to the minimum creep rate, and the **mechanical twin contributed to creep deformation in the tertiary creep** region. The kinetics of creep deformation is controlled by a diffusion-assisted non-conservative motion of dislocations at a creep strain corresponding to the minimum creep rate. Dynamic recovery and dynamic recrystallization of the matrix caused an increase in creep rate in the tertiary creep region. By comparing the creep deformation behaviour of **the in-situ Ti-46.4Al-5.1Nb-1C-0.2B (at.%) composite** with the available creep data, it was found that the in-situ composite **has significantly better creep resistance at a temperature of 800 °C and applied stress of 200 MPa than all previously published TiAl-based alloys.**

The IMMM SAS belongs to the world-leading institutions in the field of cast-in-situ TiAl-based matrix composites reinforced with carbide particles. The **cast-in-situ composites developed at the Institute have been recognised by the international scientific community as a perspective and promising direction for the improvement of high-temperature mechanical properties of TiAl-based alloys** during the International Conference on Gammalloys Technology GAT 2019, Dunhuang, 2019, China. The IMMMM SAS as the internationally reorganised institution in the field of TiAl was selected to organise GAT 2020, Bratislava, 2nd – 6th August 2020, Slovakia.

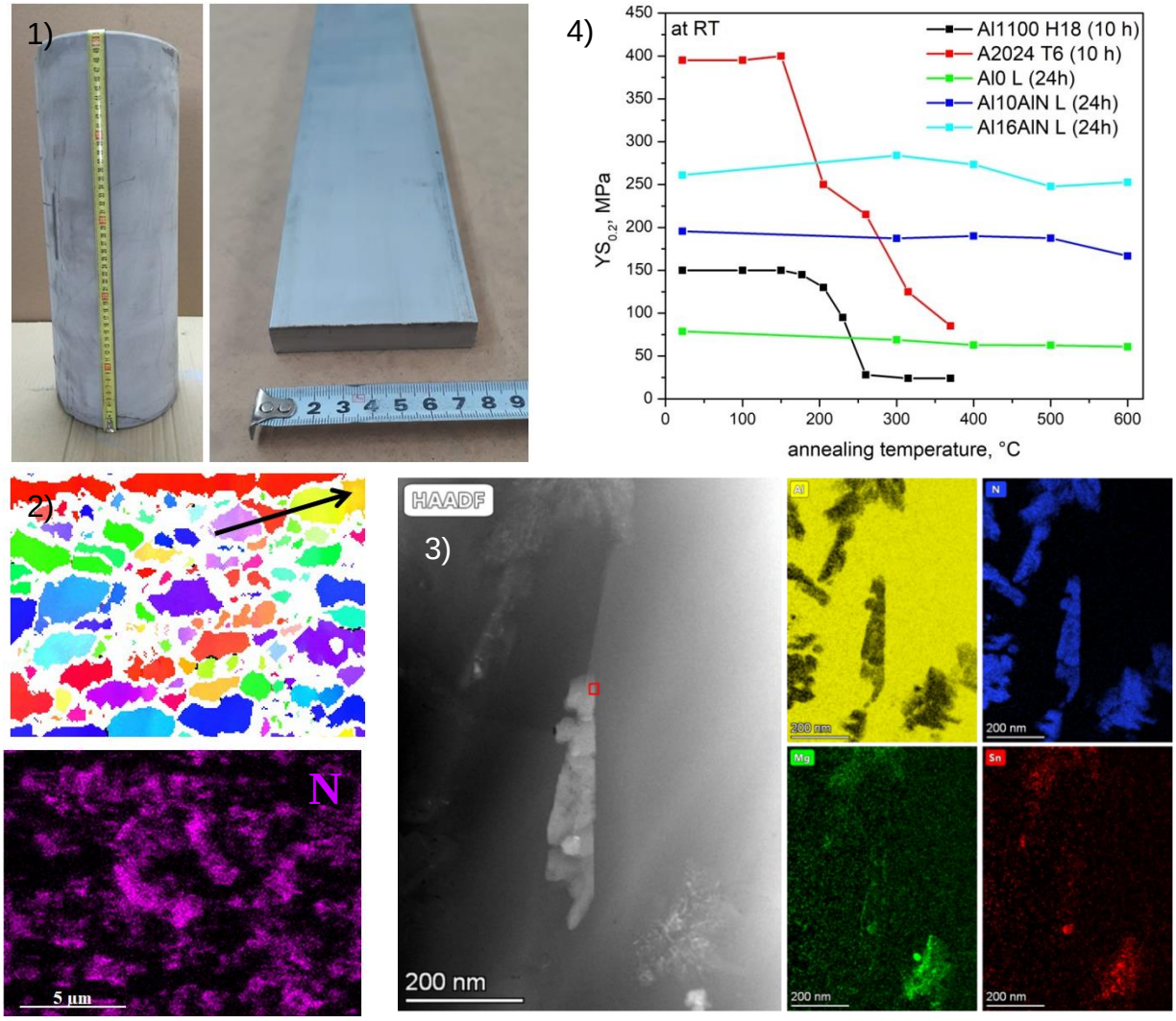


Microstructure and creep deformation curves of in-situ Ti-44.5Al-8Nb-0.8Mo-0.1B-3.6C (at.%) composite.



Creep deformation curves at a temperature of 800 °C and applied stress of 200 MPa: (a) dependence of creep strain on time; (b) dependence of creep rate on the strain. 1 – studied in-situ composite, 2 – Ti-45Al-2W-0.6Si-0.7B (at.%) alloy, 3 – Ti-46Al-8Ta (at.%) alloy, 4 – Ti-46Al-2W-0.5Si (at.%) alloy; (c) Formation of Ti_3AlC particles at lamellar interface.

- **As an output of long-term fundamental R&D realized at IMMM SAS since 2009 are the metal matrix composite (MMC) materials with aluminium (Al) matrix reinforced with ultrafine aluminium nitride (AlN) particles.** A unique affordable in-situ Al-AlN MMC prepared by conventional and available industrial-scale powder metallurgy methods in dimensions and volumes covering the real needs of industrial applications. Al-AlN MMC in the form of long profiles with a cross-section of 80x15 mm was prepared by partial nitriding of permeable Al powder, magnesium (Mg) and tin (Sn) mixtures, followed by compaction by hot extrusion (Fig. 1). The microstructure of extruded Al-AlN MMCs consists of fine Al grains with a size of ~1.8 μm and evenly dispersed micrometric regions (Fig. 2) formed by ultrafine AlN crystals concentrated in an Al matrix (Fig. 3). Due to the effective stabilization of the fine-grained Al structure by stable and fine AlN dispersoids, there are no microstructural changes and changes in the mechanical properties of Al-AlN MMC even after long-term exposure up to 500 °C. This is in contrast to reference Al alloys designed for high-temperature applications, which lose their mechanical strength even at ~200°C (Fig. 4). Advantageous mechanical, fatigue, creep and thermal properties, structural stability and low density predetermine Al-AlN MMC for lightweight construction applications with expected operation at high temperatures, which are not commonly associated with the use of conventional Al-based alloys and MMCs. The research on Al-AlN MMC was disseminated in scientific papers and conferences, and it was selected as the most important fundamental research output at IMMM SAS in the year 2021.
  In 2016, when IMMM SAS was approached by ORANO TN (France), a well-established company and a large player in the energy sector, a novel Al-based material, based on Al-AlN MMC was developed within the next 5 years for an application of a neutron absorbent material located within the transportation and storage gaskets of used nuclear fuel. Neutron poisoning B_4C component was successfully incorporated into the Al-AlN matrix and sound Al-AlN-B_4C MMC in the form of large-scale extruded profiles was developed. In 2020 a qualification stage was accomplished, whereas production will be partially held at IMMM. In 2022 the first gasket is scheduled to be assembled using approx. 5 tons of extruded Al-AlN-B_4C. In the coming years, 3-4 gaskets are expected to be built annually. **Development and study of Al-based MMC for nuclear industry incl. the one on Al-AlN-B_4C MMC was selected for the annual report of IMMM SAS and SAS in 2019, as the most important output for Problem-solving for the social practice of the Scientific Sectionat Slovak Academy of Sciences.**



1. Photographs of an as-extruded Al + 16.6 vol% AlN composite profile.
2. EBSD Al grain orientation map of Al16AlN annealed at 500 °C for 24 h shown in the longitudinal direction with the corresponding EDS maps of N element.
3. HAADF STEM micrograph of a separate fractured AlN crystal embedded in the Al matrix with the representative EDS maps of Al, N, Mg, and Sn elements of the Al16AlN composite material that was annealed at 500 °C for 24 h shown in the transversal direction.
4. Loss of 0.2% strain offset yield stress (YS0.2) measured at room temperature after annealing at a given temperature for Al0 L, Al10AlN L, and Al16AlN L. It is compared to data on the wrought commercial purity A1100 in the severely cold worked full-hard condition (H18) and the precipitation strengthened A2024 (Al-Cu-Mg) alloy after solution heat treatment and artificial ageing (T6). Al0 L, Al10AlN L, and Al16AlN L were annealed for 24 h, while A1100 H18 and A2024 T6 for 10 h.

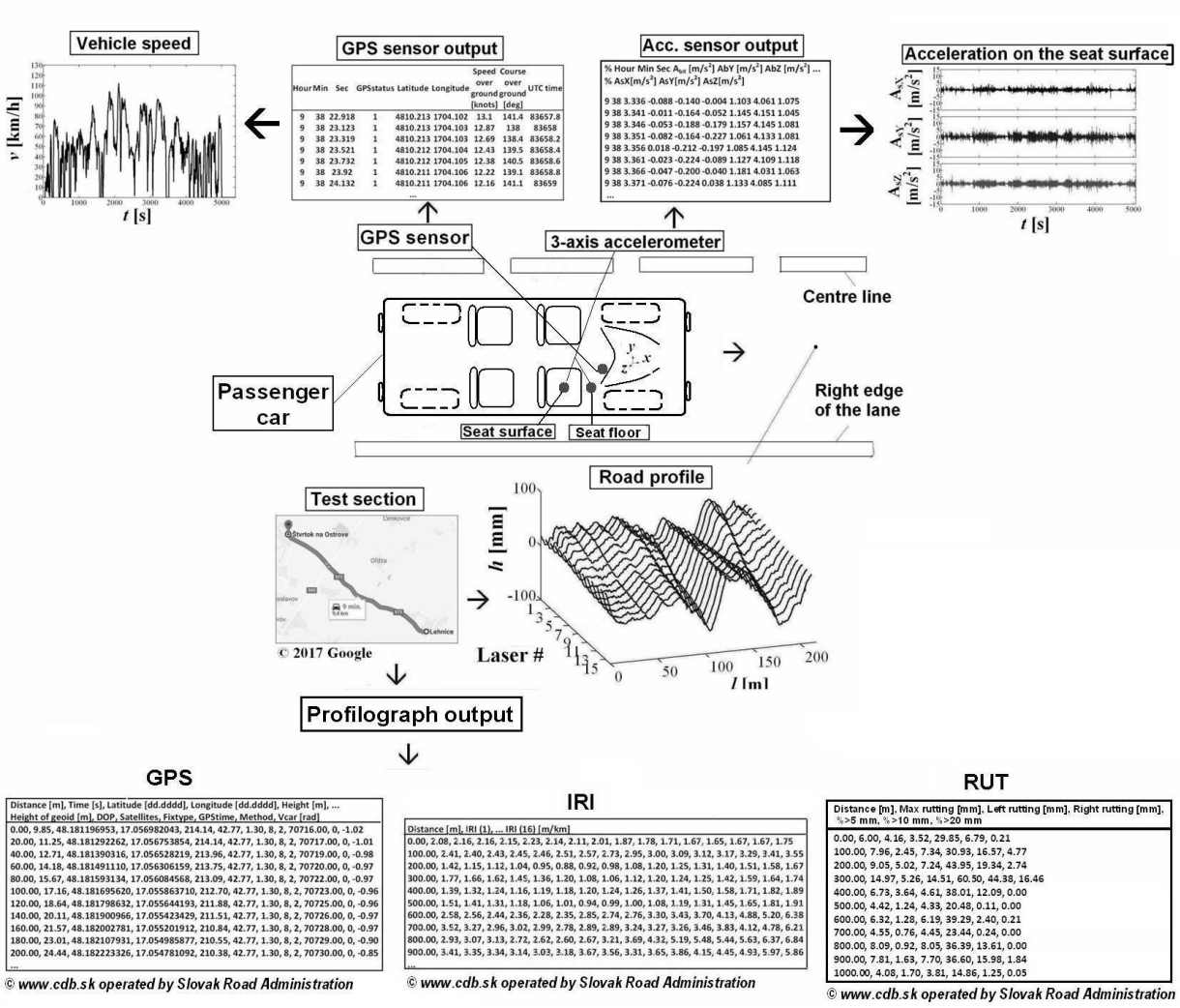
- **Relationship between whole-body vibration of the seated subject in passenger car and road unevenness.**
  Internationally unique measurements of whole-body vibrations (WBV) in a passenger car in real operation were performed (> 2,000 km) and processed in three axles on the driver's and passenger's seats for various vehicle types, road categories (motorways, 1st and 2nd class roads), levels of longitudinal and transverse unevenness and vehicle speed. Significant differences in WBV were observed depending on the type and condition of the motor vehicle (up to 40%) in the same sections.
  Regression relationships between power spectral density (PSD) of the vertical road profile displacement (ISO 8608: 2016) and induced WBV of the seated subject (ISO 2631-1: 1997) in the passenger car were derived for various road and vehicle categories. **Similar relationships have not yet been published.** These results are internationally significant because the ISO 8608 specifies the road unevenness classification according to displacement PSD, which is often used for the generation of random road profiles and simulation of vehicle vibration in the

time and frequency domain. **The correlation of such synthetic road profiles with seated subject WBV has not yet been published.**

The critical vehicle speed was determined depending on the displacement PSD with respect to the WBV exposure action and limit values. These results are important for simulating the vibration and driving of vehicle models.

Based on experimental measurements, the relationships between the most widely used road roughness indicator, IRI, and frequency-weighted acceleration RMS and Vibration Dose Value were derived (ISO 2631-1). **The new IRI thresholds have been proposed** for different road categories depending on the permitted speed as a function of the vibration exposure action and limit values. **These differ significantly from the proposed and published IRI thresholds, mainly for lower vehicle speeds (<60 km/h) based on vibration simulation.**

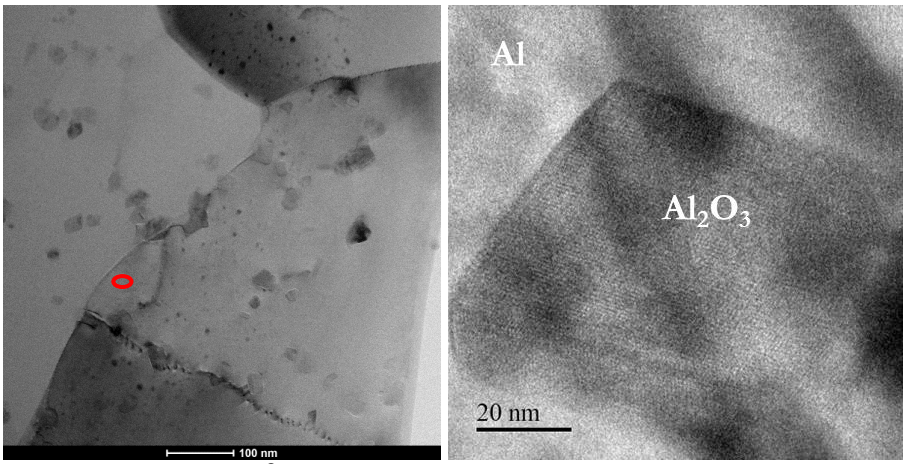
These results are **beneficial in the assessment of the impact of road roughness on ride comfort, safety and health**, the assessment of road roughness, as well as the use of simulated road profiles according to ISO 8608.



Scheme of in-situ measurement of whole-body vibrations in a passenger car.

- **The multidisciplinary cooperation** with the Institute of electrical engineering (IEE) SAS, an aluminium (Al)-based composite material was developed for the application of the casing ultralight superconducting wire with magnesium diboride (MgB_2) core. **R&D was motivated by the industry's demand for the preparation of lightweight superconducting wire for applications in the energy sector e.g., wind turbines, transport e.g., Maglev trains or in the space program e.g., active shielding of space modules and astronauts from cosmic radiation during long-term flight.** The current technical solutions of MgB_2-based superconductors use high-density metal sheath materials typically based on copper (Cu), which forms a substantial part of the wire volume. A substantial increase in efficiency and a reduction in consumption

motivates compensation Cu sheaths with Al-based solutions. However, during the preparation of superconducting wire (in-situ synthesis of MgB_2), temperatures is very close to the melting point of pure Al and high-strength Al alloys have insufficient electrical and thermal conductivity required when applied in a superconductor. **These challenging and conflicting requirements were met using the innovative HITEMAL® composite developed at IMMM SAS.** Optimized ultrafine-grained Al structure of HITEMAL® with well-dispersed nanometric Al_2O_3 particles shown in figure below ensures sufficient mechanical stabilization of the Mg+B core during processing and exceptional microstructural stability up to 650°C. Moreover, the HITEMAL® sheath retains its excellent mechanical properties required during the post-processing of superconducting wire under cryogenic conditions. In addition, due to the low Al_2O_3 content, the HITEMAL® sheath exhibits the required electrical and thermal conductivity. **Thanks to the unique combination of properties of the new HITEMAL®, it was possible to produce for the first time a high-quality ultralight superconducting wire with MgB_2 core by conventional technologies.**



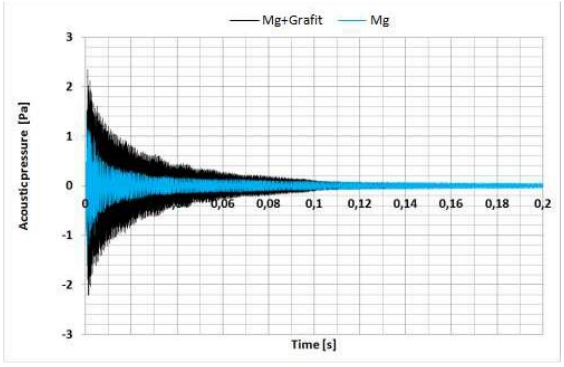
Microstructure of HITEMAL® sheath with ultrafine Al grains and nanometric Al_2O_3 particles.

The results of the research were heavily disseminated in the numerous scientific publications in high-rank prestigious journals and presented at international conferences. The patent EP 18737410.3 titled "SUPERCONDUCTOR WIRE WITH MgB2 CORE AND Al BASED SHEATH AND METHOD OF ITS PRODUCTION" was granted, and CB/P21374CN00 and US/16/613,471 patent applications are pending. Currently, the use of a given superconductor in the industry is communicated with the relevant companies in the area. The research on HITEMAL®+MgB_2 superconducting wire was selected as the **most important output at IMMM SAS and for the annual report of SAS in the year 2018, as one of the most important outputs of Problem-solving for social practice in the Scientific Section 1: Physical, Space, Earth, and Engineering Sciences.** IMMM and IEE SAS scientists were awarded a Prize for the best research team – the award for Science and Technology by the Ministry of Education, Science, Research and Sports of the Slovak Republic in 2020.

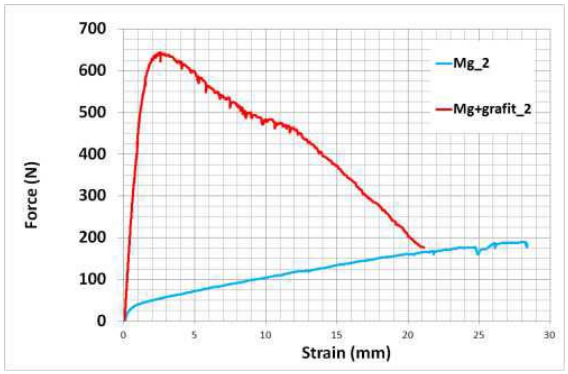
- **New magnesium-based composite material reinforced with carbon fibers with a high modulus of elasticity has been developed within European Space Agency's project, "Novel magnesium composites for ultralight structural components (PECS)".** The project was primarily focused on solving the problem of insufficient strength of the interface between the fibers and the magnesium matrix by adding suitable alloying elements (Zr, Cr, Ti, Y) to the matrix, which form stable carbides at the fiber interface without deteriorating the matrix properties or corrosion resistance of the composite. The composites were prepared by reactive pressure infiltration of the molten matrix into a suitable skeleton formed of continuous carbon fibers and were subjected to a systematic study of microstructure and testing of properties, including corrosion tests. In mechanical tests, flexural strengths above 600 MPa and Young's modulus reached greater than 300 GPa at a density of 1.8 g / cm^3. To demonstrate the properties, a cantilever beam was made of the composite, which was compared to a beam made of a light magnesium alloy. With the same geometry, shape and weight, the new composite beam showed three times the strength, eight times the rigidity and significantly better vibration damping. Thus, one of the lightest construction materials in the world with excellent strength and stiffness-to-weight ratio, good

machinability, damping, thermal conductivity and dimensional stability has been experimentally prepared, from which even more complex shaped parts can be produced. The result of the project was included in the annual presentation of ESA's technological innovations. **The social impact of research is in reducing both fuel costs and rocket exhaust gases.**

Cantilever made of composite (left) and Mg alloy, bending test on cantilever (right).



Vibrational response/damping.



flexural test on cantilever.

2.1.9. Table of research outputs

Papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) have to be listed separately

Scientific publications	2016			2017			2018			2019			2020			2021			total			
	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. /1 million total salary budget	number	averaged number per year	av. No. / FTE researches	av. No. / one million total salary budget
Scientific monographs and monographic studies in journals and proceedings published abroad *(AAA, ABA)*	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**0**	**0,000**	**0,000**	**0,000**
Scientific monographs and monographic studies in journals and proceedings published in Slovakia *(AAB, ABB)*	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**0**	**0,000**	**0,000**	**0,000**
Chapters in scientific monographs published abroad *(ABC)*	0	0,000	0,000	0	0,000	0,000	**0**	0,000	0,000	0	0,000	0,000	0	0,000	0,000	1	0,027	0,649	**1**	**0,167**	**0,005**	**0,133**
Chapters in scientific monographs published in Slovakia *(ABD)*	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**0**	**0,000**	**0,000**	**0,000**
Scientific papers published in journals registered in Current Contents Connect *(ADCA, ADCB, ADDA, ADDB)*	23	0,681	23,566	23	0,659	20,554	34	0,942	29,285	27	0,736	24,150	37	1,050	23,067	37	1,010	24,026	**181**	**30,167**	**0,848**	**24,076**
Scientific papers published in journals registered in Web of Science Core Collection and SCOPUS not listed above *(ADMA, ADMB, ADNA, ADNB)*	13	0,385	13,320	14	0,401	12,511	13	0,360	11,197	7	0,191	6,261	3	0,085	1,870	8	0,218	5,195	**58**	**9,667**	**0,272**	**7,715**
Scientific papers published in other foreign journals (not listed above) *(ADEA, ADEB)*	2	0,059	2,049	2	0,057	1,787	0	0,000	0,000	4	0,109	3,578	0	0,000	0,000	1	0,027	0,649	**9**	**1,500**	**0,042**	**1,197**
Scientific papers published in other domestic journals (not listed above) *(ADFA, ADFB)*	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**0**	**0,000**	**0,000**	**0,000**
Scientific papers published in foreign peer-reviewed proceedings *(AECA)*	0	0,000	0,000	3	0,086	2,681	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**3**	**0,500**	**0,014**	**0,399**
Scientific papers published in domestic peer-reviewed proceedings *(AEDA)*	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	0	0,000	0,000	**0**	**0,000**	**0,000**	**0,000**
Published papers (full text) from foreign scientific conferences *(AFA, AFC)*	5	0,148	5,123	0	0,000	0,000	5	0,139	4,307	6	0,164	5,367	1	0,028	0,623	5	0,136	3,247	**22**	**3,667**	**0,103**	**2,926**
Published papers (full text) from domestic scientific conferences *(AFB, AFD)*	2	0,059	2,049	2	0,057	1,787	2	0,055	1,723	2	0,055	1,789	0	0,000	0,000	0	0	0	**8**	**1**	**0**	**1**

2.2. Measures of research outputs (citations, etc.)

2.2.1. Table with citations per annum (without self-citations)

Citations of papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) are listed separately

Citations, reviews	2015		2016		2017		2018		2019		2020		total		
	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	averaged number per year	av. No. / FTE researchers
Citations in Web of Science Core Collection (1.1, 2.1)	363	10,74	381	10,91	420	11,63	539	14,69	716	20,31	796	21,72	**3 215**	**535,83**	**15,07**
Citations in SCOPUS (1.2, 2.2) if not listed above	97	2,87	79	2,26	98	2,71	99	2,70	113	3,21	111	3,03	**597**	**99,50**	**2,80**
Citations in other citation indexes and databases (not listed above) (3.2,4.2)	1	0,03	1	0,03	0	0,00	0	0,00	0	0,00	0	0,00	**2**	**0,33**	**0,01**
Other citations (not listed above) (3.1, 4.1)	28	0,83	39	1,12	29	0,80	29	0,79	23	0,65	13	0,35	**161**	**26,83**	**0,75**
Reviews (5,6)	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	**0**	**0,00**	**0,00**

2.2.2. List of 10 most-cited publications published any time with the address of the institute, with number of citations in the assessment period (2015 – 2020).

No.	Authors, Title and Bibliograhic data	Number of citations
1.	MEAD, D.J. - MARKUŠ, Štefan. The forced vibration of a three-layer, damped sandwich beam with arbitrary boundary conditions. In *Journal of Sound and Vibration*, 1969, vol. 10, no. 2, p.163-175. ISSN 0022-460X.	215
2.	KOVÁČIK, Jaroslav - EMMER, Štefan - BIELEK, Jozef - KELEŠI, Jozef. Effect of composition on friction coefficient of Cu-graphite composites. In *Wear*: An international journal on the science and technology of friction, lubrication and wear, 2008, vol. 265, no.3-4, p.417-421. (2007: 1.395 - IF, Q1 - JCR, 1.269 - SJR, Q1 - SJR). ISSN 0043-1648.	101
3.	DUSZA, Ján - MORGIEL, Jerzy - DUSZOVÁ, Annamária - KVETKOVÁ, Lenka - NOSKO, Martin - KUN, Péter - BALÁZSI, Csaba. Microstructure and fracture toughness of Si3N4+graphene platelet composites. In *Journal of the European Ceramic Society*, 2012, vol. 32, p. 3389-3397. (2011: 2.353 - IF, Q1 - JCR, 1.343 - SJR, Q1 - SJR, karentované - CCC). (2012 - Current Contents, WOS, SCOPUS). ISSN 0955-2219.	101
4.	KOVÁČIK, Jaroslav. Correlation between Young's modulus and porosity in porous materials. In *Journal of Materials Science Letters*, 1999, roč. 18, č. 13, s. 1007-1010.	96
5.	LAPIN, Juraj - ONDRÚŠ, Ľuboš - NAZMY, M. Directional solidification of intermetallic Ti-46Al-2W-0.5Si alloy in alumina moulds. In *Intermetallics* - Oxford: Elsevier Science, 2002, vol. 10, p.1019-1031. ISSN 0966-9795.	54
6.	POLETTI, C. - BALOG, Martin - SCHUBERT, T. - LIEDTKE, V. - EDTMAIER, C. Production of titanium matrix composites reinforced with SiC particles. In *Composites Science and Technology*, 2008, vol. 68, no.9, p.2171-2177. (2007: 2.171 - IF, Q1 - JCR, 1.408 - SJR, Q1 - SJR, karentované - CCC). (2008 - Current Contents). ISSN 0266-3538.	53
7.	MARKUŠ, Štefan. The mechanics of vibrations of cylindrical shells. Bratislava : Veda SAV, 1988. 176 s.	51
8.	LAPIN, Juraj - GABALCOVÁ, Zuzana. Solidification behaviour of TiAl-based alloys studied by directional solidification technique. In *Intermetallics*, 2011, vol.19, pp.797-804. (2010: 2.335 - IF, Q1 - JCR, 1.573 - SJR, Q1 - SJR, karentované - CCC). (2011 - Current Contents, WOS, SCOPUS). ISSN 0966-9795.	49
9.	KOZA, Elzbieta - LEONOWICZ, M. - WOJCIECHOWSKI, S. - SIMANČÍK, František. Compressive strength of aluminium foams. In *Materials Letters*, 2004, vol.58, nos.1-2, p.132-135.	47
10.	DROZD, Zdeněk - TROJANOVÁ, Zuzanka - KÚDELA, Stanislav. Deformation behaviour of Mg-Li-Al alloys. In *Journal of Alloys and Compounds*, 2004, vol. 378, p. 192-195. ISSN 0925-8388.	46

2.2.3. List of 10 most-cited publications published any time with the address of the institute, with number of citations obtained until 2020

No.	Authors, Title and Bibliograhic data	Number of citations
1.	MEAD, D.J. - MARKUŠ, Štefan. The forced vibration of a three-layer, damped sandwich beam with arbitrary boundary conditions. In *Journal of Sound and Vibration*, 1969, vol. 10, no. 2, p.163-175. ISSN 0022-460X.	404
2.	KOVÁČIK, Jaroslav - EMMER, Štefan - BIELEK, Jozef - KELEŠI, Jozef. Effect of composition on friction coefficient of Cu-graphite composites. In *Wear : An international journal on the science and technology of friction,*	162

	lubrication and wear, 2008, vol. 265, no.3-4, p.417-421. (2007: 1.395 - IF, Q1 - JCR, 1.269 - SJR, Q1 - SJR). ISSN 0043-1648.	
3.	DROZD, Zdeněk - TROJANOVÁ, Zuzanka - KÚDELA, Stanislav. Deformation behaviour of Mg-Li-Al alloys. In *Journal of Alloys and Compounds*, 2004, vol. 378, p. 192-195. ISSN 0925-8388.	135
4.	LAPIN, Juraj - ONDRÚŠ, Ľuboš - NAZMY, M. Directional solidification of intermetallic Ti-46Al-2W-0.5Si alloy in alumina moulds. In *Intermetallics*. - Oxford : Elsevier Science, 2002, vol. 10, p.1019-1031. ISSN 0966-9795.	130
5.	KOVÁČIK, Jaroslav. Correlation between Young's modulus and porosity in porous materials. In *Journal of Materials Science Letters*, 1999, roč. 18, č. 13, s. 1007-1010.	128
6.	DUSZA, Ján - MORGIEL, Jerzy - DUSZOVÁ, Annamária - KVETKOVÁ, Lenka - NOSKO, Martin - KUN, Péter - BALÁZSI, Csaba. Microstructure and fracture toughness of Si3N4+graphene platelet composites. In *Journal of the European Ceramic Society*, 2012, vol. 32, p. 3389-3397. (2011: 2.353 - IF, Q1 - JCR, 1.343 - SJR, Q1 - SJR, karentované - CCC). (2012 - Current Contents, WOS, SCOPUS). ISSN 0955-2219.	124
7.	KOZA, Elzbieta - LEONOWICZ, M. - WOJCIECHOWSKI, S. - SIMANČÍK, František. Compressive strength of aluminium foams. In *Materials Letters*, 2004, vol.58, nos.1-2, p.132-135.	106
8.	MARKUŠ, Štefan. *The mechanics of vibrations of cylindrical shells*. Bratislava : Veda SAV, 1988. 176 s.	97
9.	LAPIN, Juraj - GABALCOVÁ, Zuzana. Solidification behaviour of TiAl-based alloys studied by directional solidification technique. In *Intermetallics*, 2011, vol.19, pp.797-804. (2010: 2.335 - IF, Q1 - JCR, 1.573 - SJR, Q1 - SJR, karentované - CCC). (2011 - Current Contents, WOS, SCOPUS). ISSN 0966-9795.	79
10.	POLETTI, C. - BALOG, Martin - SCHUBERT, T. - LIEDTKE, V. - EDTMAIER, C. Production of titanium matrix composites reinforced with SiC particles. In *Composites Science and Technology*, 2008, vol. 68, no.9, p.2171-2177. (2007: 2.171 - IF, Q1 - JCR, 1.408 - SJR, Q1 - SJR, karentované - CCC). (2008 - Current Contents). ISSN 0266-3538.	77

2.2.4. List of 10 most-cited publications published during the evaluation period (2016-2021) with the address of the Institute, with number of citations obtained until 2021

No.	Authors, Title and Bibliograhic data	Number of citations
1.	MÚČKA, Peter. International Roughness Index specifications around the world. In *Road Materials and Pavement Design*, 2017, vol. 18, no. 4, p. 929-965. (2016: 1.401 - IF, Q2 - JCR, 0.938 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 1468-0629.	59
2.	MÚČKA, Peter**. Simulated Road Profiles According to ISO 8608 in Vibration AnMalysis. In *Journal of Testing and Evaluation*, 2018, vol. 46, no. 1, p. 405-418. (2017: 0.669 - IF, Q4 - JCR, 0.339 - SJR, Q2 - SJR, karentované - CCC). (2018 - Current Contents). ISSN 0090-3973.	49
3.	KHODABAKHSHI, F.** - NOSKO, Martin - GERLICH, A. P. Effects of graphene nano-platelets (GNPs) on the microstructural characteristics and textural development of an Al-Mg alloy during friction-stir processing. In *Surface and coatings technology*, 2018, vol. 335, p. 288-305. (2017: 2.906 - IF, Q1 - JCR, 0.928 - SJR, Q1 - SJR, karentované - CCC). (2018 - Current Contents). ISSN 0257-8972.	46
4.	MIKULA, Marian - PLAŠIENKA, Dušan - SANGIOVANNI, Davide G. - SAHUL, Martin - ROCH, Tomáš - TRUCHLÝ, Martin - GREGOR, Maroš -	39

	ČAPLOVIČ, Ľubomír - PLECENÍK, Andrej - KÚŠ, Peter. Toughness enhancement in Highly NbN-alloyed Ti-Al-N hard coatings. In *Acta Materialia*, 2016, vol. 121, p. 59-67. (2015: 5.058 - IF, Q1 - JCR, 3.417 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 1359-6454.	
5.	MÚČKA, Peter. Energy-harvesting potential of automobile suspension. In *Vehicle System Dynamics*, 2016, vol. 54, no. 12, p. 1651-1670. (2015: 1.306 - IF, Q2 - JCR, 1.016 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 0042-3114.	35
6.	MÚČKA, Peter. Current approaches to quantify the longitudinal road roughness. In *International journal of pavement engineering*, 2016, vol. 17, no. 8, p. 659-679. (2015: 0.877 - IF, Q3 - JCR, 0.519 - SJR, Q2 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 1029-8436.	33
7.	MÚČKA, Peter. Road Roughness Limit Values Based on Measured Vehicle Vibration. In *Journal of Infrastructure Systems*, 2017, vol. 23, iss. 2, s. 04016029-1 - 04016029-13. (2016: 1.516 - IF, Q2 - JCR, 0.859 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 1076-0342.	32
8.	ROSSI, Marco - PIERRON, Fabrice - ŠTAMBORSKÁ, Michaela. Application of the virtual fields method to large strain anisotropic plasticity. In *International Journal of Solids and Structures*, 2016, vol. 97-98, p. 322-335. (2015: 2.081 - IF, Q1 - JCR, 1.456 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 0020-7683.	29
9.	LINUL, Emanoil** - MARSAVINA, Liviu - LINUL, Petrica-Andrei - KOVÁČIK, Jaroslav. Cryogenic and high temperature compressive properties of Metal Foam Matrix Composites. In *Composite Structures*, 2019, vol. 209, p. 490-498. (2018: 4.829 - IF, Q1 - JCR, 1.967 - SJR, Q1 - SJR, karentované - CCC). (2019 - Current Contents). ISSN 0263-8223.	29
10.	AZIMI-ROEEN, Ghasem - KASHANI-BOZORG, Seyed Farshid - NOSKO, Martin - ŠVEC, Peter. Reactive mechanism and mechanical properties of in-situ hybrid nano-composites fabricated from an Al-Fe2O3 system by friction stir processing. In *Materials Characterization*, 2017, vol. 127, p. 279-287. (2016: 2.714 - IF, Q1 - JCR, 1.222 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 1044-5803.	28

2.2.5. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations in the assessment period (2015– 2020). The cited papers must bear the address of the institute

Categories	J. Lapin	J. Kováčik	F. Simančík	P. Múčka
Citations in international publications in Web of Science Core Collection **1.1**	495	458	394	326
Citations in international publications in Scopus **1.2**	62	62	88	94
Citations in national publications in Web of Science Core Collection **2.1**	20	2	4	1
Citations in national publications in Scopus **2.2**	0	0	0	2
Citations in international publications in unregistered collections **3.1**	9	7	13	70
Citations in national publications in unregistered collections	0	0	0	2

4.1				
Total	**586**	**529**	**499**	**495**

2.2.6. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2020. The cited papers must bear the address of the Institute

Categories	J. Lapin	J. Kováčik	F. Simančík	P. Múčka
Citations in international publications in Web of Science Core Collection **1.1**	869	664	612	409
Citations in international publications in Scopus **1.2**	120	153	161	140
Citations in national publications in Web of Science Core Collection **2.1**	55	3	6	1
Citations in national publications in Scopus **2.2**	1	0	0	2
Citations in international publications in unregistered collections **3**	14	6	11	114
Citations in international publications in unregistered collections **3.1**	11	7	16	84
Citations in international publications in other collection as WOS CC and Scopus **3.2**	0	0	0	2
Citations in national publications in unregistered collections **4**	7	2	4	46
Citations in national publications in unregistered collections **4.1**	0	0	0	2
Total	**1077**	**835**	**810**	**800**

2.2.7. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2021 of their papers published <u>during</u> the evaluation period (2016– 2021). The cited papers must bear the address of the Institute

Categories	M. Nosko	P. Múčka	J. Kováčik	J. Lapin
Citations in international publications in Web of Science Core Collection **1.1**	256	159	186	155
Citations in international publications in Scopus **1.2**	40	55	30	18
Citations in national publications in Web of Science Core Collection **2.1**	3	0	0	4
Citations in national publications in Scopus **2.2**	0	1	0	0
Citations in international publications in unregistered collections **3.1**	0	22	0	0
Total	**299**	**237**	**216**	**177**

2.3. Research status of the institute in international and national context

- **International/European position of the institute**

2.3.1. List of the most important research activities demonstrating the international relevance of the research performed by the institute, incl. major projects (details of projects should be supplied under Indicator 2.4). Max. 10 items for institute with less than 50 average FTE researchers per year, max. 20 for institutes with 50 – 100 average FTE researchers per year and so on

The IMMM SAS has long been active in international research in research calls as well as in industrial projects and through the published research results. In the past, we have been involved in several projects, mainly in calls FP 5, FP 6 and FP 7. In the last evaluation period, we successfully realized two projects in ESA calls and actively participated in the submission of projects under calls H2020. Unfortunately, we were not successful in IA and RIA actions, but we **succeeded in the CSA actions e.g. aimed at supporting the participation of low-representative regions in the H2020 programs to increase their participation in the Horizon Europa calls.** We have launched and motivated scientists to join and participate in the COST calls, overall, we are active in 5. Among the most important projects from the international point of view are:

ESA projects:

Novel magnesium composites for ultralight structural components was developed under the Grant number: ESA-IPL-PTS-Nde-ra-LE-2016-201.

Gravity dependence of CET in peritectic TiAl Alloys was studied under Grant number: AO-2009-1105).

Project H2020:

Strategic and targeted support to incentivise talented newcomers to NMBP project under Horizon Europe is being solved at IMMM SAS beginning in 2021 (Grant number: 958255).

INTERREG:

Create synergies in the region Slovakia – Austria by sharing best practices and awareness of innovative technologies to advance digitalized manufacturing is focused on the development of the stronger connection between the Slovak and Austrian companies and research institutes. (Grant number: NFP305010AWJ4).

SAS-TUBITAK:

Cooperation between the Turkish and Slovak research institutes lead to the project focused on the development of the Magnesium Nanocomposites for Biodegradable Medical Implants.

Investment casting of turbine blades from nickel-based superalloys was also studied under the SAS-TUBITAK call.

SAS-CONICET:

Argentinian university was involved in the study of the formation of the bonding between native powder surface oxide layers in composites fabricated by forging of Mg, Al, and Ti powders. The results of this study were published in several scientific journals.

SAS-PAS:

With the Polish Academy of Sciences following topics were studied:

- Investigation of the influence of plastic strain instabilities on the fracture of Mg-Li-Zn alloys with the application of the acoustic emission method.
- Investigation of concrete matrix composites, shape-memory foams and selected aggregates with the application of X-ray microtomography.
- Mechanical properties of ultra-light metal and novel cement composites.

COST Actions where the institute is involved covers almost all European countries:

- European MIC network – new paths for science, sustainability and standards – Euro-MIC (CA20130).
- Reliable roadmap for certification of bonded primary structures (CA18120).
- European forum for advanced practices (CA18136).

- European network to connect research and innovation efforts on advanced smart textiles (CA17107).
- MULTI-modal imaging of forensic science evidence – tool fo forensic science (CA16101).

Strong engagement of the IMMM SAS in the applied and targeted research led to several fruitful international cooperation with industry, as declared in Chapter 2.4. and 2.6.3. Most important cooperation includes:

- Development of a unique partially biodegradable composite **(BIACOM®)** based on titanium (Ti) was developed at IMMM SAS as a material for use in prosthodontic surgery. The material is patented under the following patents: IL256877(Israel), PCT/IB2016/054220, EP3322454B1 and by trademark BIACOM®.
- Development of the novel Al-based material, based on Al-AlN MMC **for an application of a neutron absorbent material located within the transportation and storage gaskets of used nuclear fuel.** This research was done in cooperation with the well-established French company ORANO TN (France). More detail is given in part 2.6.1.
- **The production of the laser projector box is the output of the institute's know-how for the economically attractive structural application of aluminum foam for the shaped part of the box.** The technology is patented as documented in Table 2.1.6. The Slovak manufacturer Kvant spol. s r.o. that supplies to the international markethas a highly competitive product with high added value from state-of-the-art material. **It combines lightweight, magnetic shielding and sufficient heat transfer ability. The pilot serial production of the laser projector box starts in 2022 at INOVAL branch.**
- Development work on roof systems for Porsche and BMW was mainly aimed at the possibility to replace HPDC technology for small series production with light-metal foam product. High pressure die casting (HDPC) technology has a high environmental impact and is economically feasible only for mass production where several thousands of high-profile low-demand products do not meet the treshold to implement HDPC. **We used our patented casting-foaming method to demonstrate the feasibility for such products.**

2.3.2. List of international conferences (co)organised by the institute

- 10th International conference “Mechanical Technologies and Structural Materials” **MTSM 2021**, Split, Croatia, 23rd – 24th September 2021.
- World Symposium on Mechanical – Materials Engineering and Science – **WMMES 2021**, Prague, Czech Republic, 9th – 11th September 2021.
- International conference **MATRIB 2021** - Materials, tribology, recycling, Vela Luka, Croatia, 30th June – 1st July 2021.
- International Conference on Gammalloys Technology **GAT 2020**, Bratislava, Slovakia, 2nd – 6th August 2020.
- 9th International conference “Mechanical Technologies and Structural Materials” **MTSM 2019**, Split, Croatia, 26th – 27th September 2019.
- 8th International conference “Mechanical Technologies and Structural Materials” **MTSM 2018**, Split, Croatia, 27th – 28th September 2018.
- International conference **MATRIB 2017** - Materials, tribology, recycling, Vela Luka, Croatia, 29th June – 1st July 2017.
- 7th International conference “Mechanical Technologies and Structural Materials” **MTSM 2017**, Split, Croatia, 21st – 22nd September 2017.
- International conference **MATRIB 2016** - Materials, tribology, recycling, Vela Luka, Croatia, 23rd -25th 2016.
- 6th International conference “Mechanical Technologies and Structural Materials” **MTSM 2016**, Split, Croatia, 22nd -23rd September 2016.

- 10th International Tooling Conference **TOOL 2016**, Bratislava, Slovakia, 4th – 7th October 2016.

2.3.3. List of edited proceedings from international scientific conferences

2.3.4. List of journals edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

The Institute is publisher of scientific journal:

Kovové Materiály – Metallic Materials (ISSN: 0023-432X)

The journal is dedicated to publishing original theoretical and experimental papers concerned with structural, nanostructured, and functional metallic and selected non-metallic materialist has been published bimonthly since 1963. The journal is indexed in WOS, Scopus and other databases. It is included in Materials Science Citation Index (MSCI) database published by Thomson ISI, Philadephia, USA.

Year	2016	2017	2018	2019	2020
Impact factor	0.366	0.636	0.593	0.765	1.068
Quartile	Q4	Q4	Q4	Q4	Q3

URL: http://www.kovmat.sav.sk/

- **National position of the institute**

2.3.5. List of selected activities of national importance

At the national level, the IMMM SAS is traditionally successfully engaged in solving projects in national calls. During the evaluation period, the institute was successful in **19 projects from the VEGA agency and 16 projects from the APVV agency as principal investigator or co-investigator as demonstrated in 2.4.3. and 2.4.4. IMMM SAS usually cooperates with other Institutes of the Slovak Academy of Sciences as well as with Slovak Universities in the whole country and Slovak companies.** Some projects led to completely new knowledge published in scientific journals or conferences, some led to the establishment of foreign cooperation as mentioned in chapter 2.3.1. and some research led to the successful innovation in industry or the patents (see chapter 2.1.6 and chapter 2.1.7). The most important are:

- Development of unique TiMg composite dental implant.
- Resistance of precipitation-hardened complex concentrated alloys to hydrogen embrittlement.
- Large-capacity air purifier from pathogens in aerosols.
- New high-temperature composite materials for turbochargers.

The IMMM SAS is actively involved in the projects from the EU Structural Funds financed through national calls, where we have received 4 in the amount of EUR 1,217,882.

- International center of excellence for research of intelligent and secure information and communication technologies and systems - II.
- Establishment of the Center for the Use of Advanced Materials of the Slovak Academy of Sciences.

- Research and development of new products for efficient transfer and storage of thermal energy from renewable sources.
- Research and development of a new plasma milling system PLASMABIT BHA for efficient and ecological closure of wells and introduction of a new product into the production process.

The IMMM SAS is one of the 6 founding partners of a Centre for advanced materials application SAS. The research of the Centre is focused on certain topics, where IMMM SAS is active within the two of them: Special light construction materials and composites and advanced materials for biomedicine and biotechnologies. We are partner of the two projects founded by Slovak research and development agency (**Development of unique TiMg composite dental implant and Tribological properties of 2D materials and related nanocomposites**).

As mentioned earlier (e.g., in Chapter 2.4.7 and 2.6.3), **IMMM SAS researchers work intensively with industry, which is reflected mainly in turnover at a level of approximately 300 000 EUR per year.** This turnover in hand with national calls ensure sufficient payment conditions so that we retain skilled scientists. **Own resources were at the level of about 38% last year.** The most important activities include mainly expert activities for Slovenské elektrárne, a.s., Miba Sinter Slovakia, Finalcast, s.r.o., Hydroextrusion Slovakia, s.r.o., Aplik s.r.o. etc.

In addition to project-based activities, the researchers are also very actively involved in popularization activities, as declared in Table 2.7.1. In addition, together with other institutions, we engage in the scientific education of students mainly in primary schools. The main activities are:

- Find a scientist in yourself
- Summer school for the talented youth
- Night of scientist

In 2021, we have obtained financial support from The Ministry of Education, Science, Research and Sport of the Slovak Republic for the implementation of a program of experiential education in schools in the teaching of natural subjects such as physics, chemistry, biology and finally technical education. **The program is known as "Creative Science".**

2.3.6. List of journals (published only in the Slovak language) edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

- **Position of individual researchers in the international context**

2.3.7. List of invited/keynote presentations at international conferences, as documented by programme or invitation letter

SIMANČÍK. F.: Potential use of aluminium foam - Lightweight construction of car body structures & thermal management. Aluinvent meeting and press conference, 25 April 2016, Lillafuered, Hungary.
LAPIN, J.: Development of cast TiAl matrix in-situ composites reinforced with carbide particles. Joint Visegrad 4 - Japan Seminar on Cooperation in Science and Technology: “Current trends in composite materials in Central Europe”, 14 June 2017, Embassy of the Republic of Poland in Tokyo, Japan.
LAPIN, J.: Microstructure and mechanical properties of in-situ TiAl matrix composites reinforced with Ti2AlC particles. Gamma Alloys Technology (GAT) 2017, 27 February – 2 March 2017, San Diego, CA, USA.
LAPIN, J.: Microstructure evolution in TiAl-based alloys during directional solidification. Gamma Alloys Technology (GAT) 2017, 27 February – 2 March 2017, San Diego, CA, USA.
JERZ, J., SIMANČÍK, F., ŠEBEK, J., KOVÁČIK, J., ŠPANIELKA, J.: Keynote lecture "Phase Change Materials Reinforced by Aluminium Foam – Breakthrough Solution for Thermal Energy Storage", 3rd Global Congress & Expo on Materials Science & Engineering, 14 – 16 June 2018, Rome, Italy.
JERZ, J., SIMANČÍK, F., TOBOLKA, P.: Invited lecture "Highly efficient storage of solar gains using aluminium foam heat exchangers", European Advanced Materials Congress, 20 - 23 August 2018 Stokholm, Sweden.

LAPIN, J., KLIMOVÁ, A., ŠTAMBORSKÁ, M., KAMYSHNYKOVA, K., PELACHOVÁ, T.: "Development and properties of cast TiAl matrix in-situ composites reinforced with carbide particles" Thermec 2018, International Conference on Processing & Manufacturing of Advanced Materials, 8-13 July 2018, Paris, France.
LAPIN, J., KLIMOVÁ, A.: "Design, processing and properties of cast TiAl + Ti3Al matrix in-situ composites reinforced with MAX phase particles" 8th International Conference on Mechanical Technologies and Structural Materials 2018, 27 - 28 September 2018 Split, Croatia.
LAPIN, J., PELACHOVÁ, T.: "Creep resistance enhancement in engineering gammalloys", Gamma Alloy Technology (GAT) 2018, 3 - 7 June 2018, Harbin, China.
MIKULA, M.: "Structure evolution and mechanical properties of yttrium based ternary diborides" The 83rd IUVSTA Workshop, 2-6.9. 2018, Vadstena, Sweden.
JERZ, J.: Aluminium foam heat exchangers of thermally active pitched roofing systems. Global Experts Meeting on Frontiers in Materials Science & Nanotechnology, 17 – 19 October 2019, Rome, Italy.
JERZ, J., GOPINATHAN, A., KOVÁČIK, J., DVORÁK, T., ŠPANIELKA, J.: Thermal Conductivity of Materials for Latent Heat Storage by Microporous Open-Celled Aluminum Foam Skeleton. 1st International Conference PHRONESIS on Materials Research & Nanotechnology, 10 – 12 June 2019, Rome, Italy.
LAPIN: J.: Recent progress in development of cast in-situ TiAl-based matrix composites reinforced with carbide particles, Gammalloys Technology (GAT) 2019, 22-25 July 2019, Dunhuang, Gansu, China.
BALOG, M., IBRAHIM, A.M.H., KRÍŽIK, P., CATIC, A., SCHAUPERL, Z., CETIN, Y., BESIROVIC, H.: From the powder to implantation - the development of novel biomedical TiMg Composite (Biacom©). In Book of Abstracts: 21th International Conference on Materials, Tribology & Recycling MATRIB 2021. Zagreb, Croatia. 2021, p. 9-31. ISSN 2459-5608.
JERZ, J., GOPINATHAN, A., PUŠKÁR, A., KOVÁČIK, J.: Morphology and heat transfer performance of high-density aluminium foam. In European Advanced Materials Congress with Hybrid Setups, IAAM 2021, p. 32-33. ISBN 978-91-88252-28-9, 23. – 25. August 2.
JERZ, J., GOPINATHAN, A., PUŠKÁR, A., KOVÁČIK, J.: Multifunctional Applications of Aluminium Foam Based Composites, 2nd Global Congress and Expo on Materials Science and Nanoscience, 25 – 26 March 2021, Prague, Czech Republic.
LAPIN, J., KAMYSHNYKOVA, K.: Enhancing high-temperature creep resistance of in-situ TiAl-based matrix composite by low volume fraction of Ti2AlC particles, International Conference on Processing & Manufacturing of Advanced Materials - Virtual Conference, THERMEC 2021, 1 – 5 June 2021, Vienna, Austria.

2.3.8. List of researchers who served as members of the organising and/or programme committees

	International conferences	
Researcher	**Programme committee**	**Organizing Committee**
J. Jerz	7	2
J. Kováčik	3	0
F. Simančík	4	0
J. Lapin	7	2

2.3.9. List of researchers who received an international scientific award

Researcher	**Award**	**Year**
J. Jerz	IAAM Scientist Award	2020

Position of individual researchers in the national context

2.3.10. List of invited/keynote presentations at national conferences, as documented by programme or invitation letter

SIMANČÍK. F.: New manufacturing methods for automotive car body structures allowing flexibility in serial production for low and high production volumes. Consultation of Science and Technology MOST & SAS, 27 June 2016, Bratislava, Slovakia.
SIMANČÍK.F.: Je technický rozvoj zodpovedný za súčasné environmentálne problémy? Konferencia k 20 výročiu založenia Fakulty environmentálnej a výrobnej techniky TUZVO 12 September 2016, Zvolen, Slovakia.
SIMANČÍK, F.: Growing Automotive Industry in Slovakia a Great Potential for Novel Tooling Materials. Úvodná prednáška na medzinárodnej konferencii Tool 2016, 5 October 2016 Bratislava, Slovakia.
SIMANČÍK F.: Radical innovations are the only way to sustainable living standards - It is our responsibility towards future generations, 13 October 2016 - CIDIC 2016, Bratislava, Slovakia.
SIMANČÍK F.: Radical innovations are the only way to sustainable living standards - It is our responsibility towards future generations, 27 October 2016 2016, Bratislava, Slovakia.
LAPIN, J.: Mikroštruktúra a mechanické vlastnosti zliatin a in-situ kompozitov na báze TiAl. Kolokvium „Progresívne materiály a technológie “, 28 March 2017, Košice, Slovakia.
LAPIN, J.: Cast TiAl matrix in-situ composites reinforced with MAX phase particles. ICPMAT, 12th IC - The Physical Properties and Application of Advanced Materials, 6 - 9 August 2017, Košice, Slovakia.
JERZ, J., SIMANČÍK, F., TOBOLKA, P.: Tepelná pohoda v budovách dosahovaná efektívnym využívaním dostupnej energie pomocou penového hliníka", XLI. ročník Vanovičových dní, 27. – 29. August 2018, Trnava, Slovakia.
JERZ, J., KOVÁČIK, J., GOPINATHAN, A.: Applications of aluminium foam in structural design. Konferencia s medzinárodnou účasťou. Konštrukčné materiály 2019, 24 October 2019, Žilina, Slovakia.
SIMANČÍK, F.: Challenges for joining novel materialsin future car body structures. Plenárna prednáška na svetovom kongrese IIW (International Institute of Welding), 11 July 2019, Bratislava, Slovakia.
SIMANČÍK, F.: Výroba kovového horčíka z magnezitu - Inovatívny slovenský priemysel je najväčšou šancou pre zvyšovanie kvality života obyvateľov SK. Seminár: Kultúrne dedičstvo Gemera a Malohontu a jeho sprístupňovanie, 8 September 2020, Revúca, Slovakia.
SIMANČÍK, F.: Do autonomous vehicles need new structural materials and technologies. Invited lecture on Autonomous vehicle summit – 18 September 2020, Bratislava, Slovakia (online)
SIMANČÍK, F.: Dokážeme si udržať svoj komfort, a súčasne zlepšiť vyhliadky ľudstva? Alebo Klimatická zmena inžinierskymi očami. Vedecká cukráreň CVTI – Bratislava 26 May 2020 (online).
JERZ, J.: Práškovo-metalurgický prístup k syntéze hydridov na báze horčíka na skladovanie vodíka, 3. vodíkový workshop, 24 June 2021, Bratislava, Slovakia.
JERZ, J.: Materiály pre udržateľné využívanie energie včera, dnes a zajtra. Vedecká cukráreň CVT, 23 December 2021, Bratislava, Slovakia (online: https://www.youtube.com/watch?v=v56sKGFGZsQ&list=PLYvt3SMlRFlzMXI31AkaHDdB04Ja8pwuN).
SIMANČÍK, F.: Treba nám regionálne inovačné centrá? Ak áno, čo by mali robiť? Prednáška v rámci kombinovanej konferencie a webináru COINTT 2021 – panel RIC na Slovensku, 20 October 2021, Bratislava, Slovakia.
SIMANČÍK, F.: Transformation of SAS -an excellent opportunity for monetizing of accumulated knowledge. ITRI-SAS Webinar on Technology Management, 1 December 2021, Bratislava – Taipei (on-line).

2.3.11. List of researchers who served as members of organising and programme committees of national conferences

	National conferences	
Researcher	**Programme committee**	**Organizing Committee**
J. Jerz	1	1
K. Iždinský, CSc.	3	1
M. Nosko, PhD.	1	1
A. Opálková Šišková	0	2

2.3.12. List of researchers who received a national scientific award

Researcher	**Award**	**Year**
P. Krížik	Prize for science and technology for the year 2020 in the category Scientific-technical team of the year.	2021
M. Balog	Prize for science and technology for the year 2020 in the category Scientific-technical team of the year.	2021
J. Lapin	Honorary plaque of the SAS Aurel Stodola for merits in technical sciences.	2021
K. Kamyshnykova	2nd place for work Design, processing, and properties of TiAl-based alloys for industrial applications.	2021
A.M.H. Ibrahim	2nd prize in the competition of young researchers of the SAS up to 35 years of age in the category of PhD. Students.	2021
J. Kováčik	Award for Top publication SAS in the category Publications in scientific journals with the highest impact according to SJR for work KOVÁČIK, Jaroslav – EMMER, Štefan. Cross property connection between the electric and the thermal conductivities of copper graphite composites. In International Journal of Engineering Science, 2019, vol. 144, no. 103130. ISSN 0020-7225. IF for 2019: 9.219.	2020
J. Kováčik	Award Research projects with an excellent level of 2019.	2019
K. Iždinský	Honorary plaque of the SAS Aurel Stodola for merits in technical sciences.	2019
M. Nosko	Award of SAS for popularization of the Science.	2018
J. Kováčik	Award for Research projects with excellent level.	2018
M. Nosko	Award of SAS for international scientific and technical cooperation	2016
K. Iždinský	Commemorative plaque of the Institute of Hydrology of the Slovak Academy of Sciences for merits in the development of hydrological sciences	2016
F. Simančík	Commemorative plaque from the Rector of TUZVO on the occasion of the 20th anniversary of FEVT TUZVO.	2016
F. Simančík	Commemorative letter from the Dean of the Faculty of Environmental and Production Engineering TUZVO.	2016

2.4. Research grants and other funding resources

(List type of project, title, grant number, duration, total funding and funding for the institute, responsible person in the institute and his/her status in the project, e.g. coordinator "C", work package leader "W", investigator "I". Add information on the projects which are interdisciplinary, and also on the joint projects with several participating SAS institutes)

- **International projects**

2.4.1. List of major projects of Framework Programmes of the EU (which pilar), NATO, COST, etc.

Title	Type / grant number	Duration	Total funding Eur	Funding for institute Eur	Responsible person/status
Strategic and targeted support to incentivise talented newcomers to NMBP project under Horizont Europe	Horizon 2020 / 958255 Pilar 2	1.1.2021 - 31.12.2023	1 500 000	126 500	Karol Ižd inský/I
Activity in the network: IMMM SAS covers the project activities in Slovakia, Slovenia, Croatia and North Macedonia. It actively contributes to all workpackages particularly by identifying and prioritising underrepresented regions in the H2020 NMBP programme, identifying NMBP hotspots, NMBP groups and NMBP top innovators; organising innovation workshops on selected R&I priorities from Horizon Europe Pillar 2 Cluster 4; delivering training and hands-on support to prepare proposals for Horizon Europe; organizing technology-transfer training courses in underrepresented regions; delivering training and hands-on support to use European networking portals; surveying the challenges limiting the participation of talented newcomers in NMBP projects, identifying best practices and formulating policy measures; promoting talented newcomers at EC networking events as well as at networking events in the underrepresented regions					
Building-up Centre of Excellence for advanced materials application	Horizon 2020 / WIDESPREAD-1-2024-Teaming	1.6.2015 - 31.5.2016	390 300	**0**	František Simančík / W
Activity in the network: Project´s main objective in the long run was to establish a joint Centre of Excellence for advanced materials application (CEMEA) based on long-term strategic cooperation between VTT Technical Research Centre of Finland and the University of Helsinki (Finland) on the one hand and the Slovak Academy of Sciences (Slovak) on the other. The aim of the project was to ensure sustainable financing and quality of research in the field of advanced materials in Slovakia as one of Key Enabling Technologies (KETs).					
Novel magnesium composites for ultralight structural components MagUltra.	ESA-IPL-PTS-Nde-ra-LE-2016-201 (PECS)	2016 - 2018	167 580	167 580	F.Simančík / C
Activity in the network: As part of the European Space Agency's project, “Novel magnesium composites for ultralight structural components (PECS),” a new magnesium-fibre-reinforced composite material with a high modulus of elasticity was developed. The insufficient strength of the interface between the fibres and the magnesium matrix was increased by the formation of the stable carbide at the interface between the fibre and matrix via adding the alloying elements (Zr, Cr, Ti, Y). Material with strengths above 600 MPa and Young's modulus above 300 GPa at a density of 1.8 $g.cm^{-3}$ was prepared. Thus, one of the lightest construction materials in the world with excellent strength and stiffness-to-weight ratio, good machinability, damping, thermal conductivity, and dimensional stability was prepared experimentally, from which even more complex-shaped parts can be produced. The social impact of research is in reducing both fuel costs and rocket exhaust gases.					

Gravity dependence of CET in peritectic TiAl Alloys (GRADETEC)	ESA AO-2009-1105	2010 - 2017		16 667	J. Lapin / I
Activity in the network: The research team of the IMMM SAS participated in an international project entitled "Gravity dependence of CET in peritectic TiAl alloys" (acronym GRADECET). The international consortium was composed of ACCESS (Germany), Ecole des Mines de Nancy, Institut Jean Lamour France, DLR (Germany), Dublin University of Technology (Irland), Research Institute for Solid State Physics (Hungary), and IMMM SAS (Slovakia). The project was coordinated by ACCESS (Germany) and the role of IMMM SAS was to study the earth gravity conditions on solidification behaviour of TiAl alloys, participate in the design of experimental equipment for hypergravity and microgravity experiments, numerical modelling of solidification, and participation in microgravity mission experiments. The project was carried out in close collaboration with the European Space Agency (ESA), which was responsible for the microgravity experiments and procurements and the launch of ballistic rocket MAXUS 9. These key international activities of IMMM SAS had also an important impact on the signing official PECS agreement between Slovakia and ESA.					
European MIC Network – new paths for science, sustainability and standards – Euro-MIC	COST CA 20130	1.12.2021 – 25.10.2025			Andrej Opálek / I
Activity in the network: The high open porosity of composites based on Ni/Al_2O_3 developed at IMMM SAS manifested by large, interconnected pores is a fundamental flow-through application such as filtration or acoustic absorption. In the case of filtration, the metal and metal-ceramic material could be exposed to fresh, demineralized, or seawater, process chemicals, soils, fuels, or sewage. In such an application, the microbially influenced corrosion negatively affects the material and its performance. MIC shortens the life of such filters. Therefore, anti-corrosion measures are essential. The plan is to prevent the microorganisms attach to metals and colonizing the surface to form biofilms producing an environment at the biofilm/metal interface that is radically different from that of the bulk medium in terms of pH, dissolved oxygen, and organic and inorganic species, to prevent the electrochemical reactions that control corrosion rates in such way. The microbially influenced corrosion could be stopped before or eventually after processing by treatments or coatings, using nanotechnologies according to European standards.					
Reliable roadmap for certification of bonded primary structures	COST CA 18120	4.4.2019 – 3.4.2023			Štefan Nagy/ I
Activity in the network: This Action tackles the scientific challenges in the different stages of the lifecycle of a bonded structure through the synergy of multidisciplinary fields and knowledge transfer. Despite the motivation being aircraft structures, which is believed to have the most demanding certification, it directly involves other application fields requiring similar needs. Štefan Nagy is a member of WG3 which establishes an optimal and robust manufacturing process for composite bonded structures. The objectives are to identify key manufacturing parameters and to implement a quality control strategy using destructive and non-destructive testing methods during the process. The particular tasks are to Specify and select the key parameters that influence the manufacturing process on an industrial scale, evaluate destructive and non-destructive testing for quality control of the manufacturing process, and propose novel embedded sensing solutions to evaluate adhesion strength. The WG meets twice a year to address the above-mentioned tasks. IMMM has collaborated with industrial partners involved in the field of bonded structures. With the company Porsche Werkzeugbau, s.r.o. the institute cooperated in the quality control of rivet bonded structures and adhesively bonded structures which brought the institute experience in this field and identify key manufacturing parameters.					

European forum for advanced practices	COST CA 18 136	1.4.2019 – 31.3.2023			Tomáš Dvorák / I
Activity in the network: The European Forum on Advanced Practices project aims to bring together different scientific disciplines to create communication channels between institutions with different areas of activity. We have created a link between the arts and technology. We are trying to introduce new procedures in the restoration of works of art, initial analysis of works of art, examination of the surface on the works before the restoration process, determination of the structure and the influence of the environment on its change using microtomography and electron microscopy.					
European network to connect research and innovation efforts on advanced smart textiles	COST CA 17137	11.10.2018 – 10.10.2022			Alena Opálková Šišková / I
Activity in the network: The activity is related to create a smart textile material that actively affects its environment. Such smart textiles respond or adapt to changes in the environment, and has potential applications in many industries, especially in the healthcare, automotive, and aerospace industries, protective equipment, sports, wearable objects, buildings, and interior design. Due to the cooperation of the COST CA17107 COST members, we were able to discuss state of the art in the recovery of plastic waste, especially the recovery of disposable packagings such as PET bottle or the recovery of textiles. With colleagues - members of the action committee Dr. P. Peer (Czech Republic), Prof. I. Jordanov (Northern Macedonia) and Dr. P. Rychter (Poland) the publication by Opálková Šišková, A., Peer, P., Eckstein Andicsová, A., Jordanov, I., Rychter, P. entitled: Circulatory management of polymer waste: Recycling into fine fibers and their applications was published.					
MULTI-modal imaging of forensic science evidence – tool for forensic science	COST CA 20130	21.2.2018 – 1.9.2021			Martin Nosko / I
Activity in the network: Verification of the usability of available imaging techniques for forensic science has been performed. Imaging technologies enable multiple physical and chemical information to be captured in one analysis from one specimen, with data being more easily conveyed and understood for more rapid exploitation. The 'enhanced' value of the evidence gathered will be conducive to much more informed investigations and judicial decisions, thus contributing to savings to the public purse and a speedier and more robust criminal justice system. In particular, the authenticity of a multi-page (3 pages) printed and signed document sponsored by Scientific Judicial Police Laboratory, Lisbon, Portugal, has been investigated. To meet the study's aims on verification of available multi-modal imaging techniques for forensic science, the round-robin testing methodology was used in 17 laboratories from 16 countries. The delivered documents, including printer toner, used paper, and pen ink used to make signatures, were investigated by microscopy at IMMM SAS.					
Create synergies in the region Slovakia – Austria by sharing best practices and awareness of innovative technologies to advance digitalized manufacturing	INTERREG NFP305010AWJ4	1.4.2021 – 30.11.2022	779 986	59998	Jaroslav Jerz / W
Activity in the network: The project is focused on the cooperation of key actors involved in the research of new technological processes through the implementation of long-term pilot projects in the field of industrial assistance services and sustainable production systems.					

- **National projects, incl. international projects with only national funding**

2.4.2. List of ERA-NET projects funded from SAS budget

2.4.3. List of projects of the Slovak Research and Development Agency, APVV

Title	**Grant number**	**Duration**	**Total funding Eur**	**Funding for institute Eur**	**Responsible person/status**
Development of unique TiMg composite dental implant	APVV-20-0417 *	1.7.2021 – 30.6.2025	249 908	164 908	Martin Balog/C
Coordinator: IMMM SAS, **Partners**: Centre for advanced materials applications SAS (CEMEA SAS) and Biomedical Research Center SAS (BRC SAS).					
Resistance of precipitation hardened complex concentrated alloys to hydrogen embrittlement	APVV-20-0505	1.7.2021 – 30.6.2024	250 000	250 000	Juraj Lapin/C
Large-capacity air purifier from pathogens in aerosols	PP-COVID-20-0098 *	16.9.2020 – 31.12.2021	261 741	111 380	František Simančík/C
Coordinator: IMMM SAS, **Partners**: Biomedical Research Center SAS and APLIK spol. s r.o.					
Anodes for Li-ion batteries based on carbon-silicon composites	APVV-19-0461 *	1.7.2020 – 30.6.2024	249 989	25 000	Erik Šimon/W
Coordinator: CEMEA SAS, **Partners**: IMMM SAS, Polymer Institute of SAS, Institute of Inorganic Chemistry SAS and Institute of Physics SAS.					
Development of the Fe based PM components with increased fatigue strength	APVV-18-0508	1.7.2019 – 30.6.2022	249 638	149 860	Martin Nosko/C
Coordinator: IMMM SAS, **Partners**: Faculty of Materials and Technology in Trnava, Slovak University of Technology, Bratislava					
Tribological properties of 2D materials and related nanocomposites	APVV-17-0560	1.7.2018 – 30.6.2022	249 599	50 000	Martin Nosko/W
Coordinator: CEMEA SAS, **Partners**: IMMM SAS, Institute of Physics SAS and Institute of Electrical Engineering SAS					
Research of additive manufacturing of biodegradable magnesium alloys and their applications in implantology and regenerative medicine	APVV-17-0278 *	1.7.2018 – 30.6.2022	248 077	60 041	Milan Škrobian/W
Coordinator: Faculty of Mechanical Engineering, Technical University of Košice, **Partners**: IMMM SAS and Faculty of medicine, Comenius University Bratislava					
Research of roofing with integrated function of heat exchanger	APVV-17-0580	1.8.2018 – 30.6.2021	250 000	172 445	Jaroslav Jerz/C
Coordinator: IMMM SAS, **Partners**: Faculty of Civil Engineering, Slovak University of Technology.					
Multicomponent boride and nitride coatings for ultrahigh temperature applications	APVV-17-0320	1.8.2018 – 30.6.2021	248 949	72 000	Marián Mikula/W

Coordinator: Institute of Materials Research SAS, **Partners**: IMMM SAS and Faculty of mathematics, Physics and Informatics, Comenius University, Bratislava					
Titanium-magnesium composite for implants	APVV-16-0527	1.7.2017 – 30.6.2020	250 000	250 000	Martin Balog/C
New high temperature composite materials for turbochargers	APVV-15-0660	1.7.2016 – 30.6.2020	310 900	310 900	Juraj Lapin/C
Development of a new type of solar thermal collector for medium-temperature applications	APVV-14-0936	1.7.2015 – 1.7.2018	250 000	150 000	Martin Nosko/C
Coordinator: IMMM SAS, **Partners**: Welding Research institute.					
Efficent preparation of powdered magnesium hydrid directly from the magnesium melt	APVV-14-0934	1.7.2015 – 30.6.2018	249 999	123 835	František Simančík/C
Coordinator: IMMM SAS, **Partners**: Institute of Physics SAS					
Multicomponent nanocomposite coatings prepared by highly ionized deposition technologies	APVV-14-0173	1.7.2015 – 29.6.2018	275 700	44 000	Marián Mikula/W
Coordinator: Faculty of mathematics, Physics and Informatics, Comenius University, Bratislava, **Partners**: IMMM SAS and Institute of Materials Research SAS.					
Aluminium based composites formed in situ through reactive synthesis	APVV-0556-12	1.10.2013 – 31.12.2016	250 000	250 000	Martin Balog/C
Heating/cooling panel based on aluminium foam filled by PCM	APVV-0692-12	1.10.2013 – 31.12.2016	215 885	215 885	Jaroslav Kováčik/C

*****Interdisciplinary research

2.4.4. List of projects of the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education, VEGA (for funding specify only total sum obtained from all VEGA grants in particular year)

Project title	Project number	Duration	Responsible person and status
2021			
Study of the use of pure magnesium powders for the preparation of biodegradable materials	2/0098/19	1/1/2019 – 31/12/2021	Miroslav Čavojský/C
Study of the possible using of carbon based reinforcement from waste for engineering applications	2/0135/19	1/1/2019 – 31/12/2021	Tomáš Dvorák/C
Complex concentrated alloys for high temperature structural applications	2/0074/19	1/1/2019 – 31/12/2021	Juraj Lapin/C
Influence of transverse and longitudinal road unevenness on a whole-body vibration of driver/passenger in a motor car	2/0148/19	1/1/2019 – 31/12/2021	Peter Mučka/C
Wooden pipe configuration of historic organ positives in Slovakia	2/0106/19	1/1/2019 – 31/12/2022	Andrej Štafura/C*
Coating of powder metallurgical Titanium using electromagnetic	2/0135/20	1/1/2020 – 31/12/2022	Jaroslav Kováčik/C

radiation under working atmosphere, study of microstructure and coatings properties			
On the creep properties of powder metallurgical Al-Al2O3 composites by small punch testing method	2/0143/20	1/1/2020 – 31/12/2022	Peter Krížik/C
Lithium-stimulated interfacial bonding in magnesium composites	2/0117/20	1/1/2020 – 31/12/2022	Stanislav Kúdela jr./C
			Total Sum: 73 758 Eur
2020			
Fabrication and study of composite materials manufactured by casting of aluminium and ceramic powder blends	2/0114/18	1/1/2018 – 31/12/2020	Martin Balog/C
Study of the use of pure magnesium powders for the preparation of biodegradable materials	2/0098/19	1/1/2019 – 31/12/2021	Miroslav Čavojský/C
Study of the possible using of carbon based reinforcement from waste for engineering applications	2/0135/19	1/1/2019 – 31/12/2021	Tomáš Dvorák/C
Complex concentrated alloys for high temperature structural applications	2/0074/19	1/1/2019 – 31/12/2021	Juraj Lapin/C
Influence of transverse and longitudinal road unevenness on a whole-body vibration of driver/passenger in a motor car	2/0148/19	1/1/2019 – 31/12/2021	Peter Mučka/C
Wooden pipe configuration of historic organ positives in Slovakia	2/0106/19	1/1/2019 – 31/12/2022	Štefan Nagy/W
Coating of powder metallurgical Titanium using electromagnetic radiation under working atmosphere, study of microstructure and coatings properties	2/0135/20	1/1/2020 – 31/12/2022	Jaroslav Kováčik/C
On the creep properties of powder metallurgical Al-Al2O3 composites by small punch testing method	2/0143/20	1/1/2020 – 31/12/2022	Peter Krížik/C
Lithium-stimulated interfacial bonding in magnesium composites	2/0117/20	1/1/2020 – 31/12/2022	Stanislav Kúdela jr./C
			Total Sum: 80 049 Eur
2019			
Investigation of advanced materials suitable for highly effective heat storage	2/0152/17	1/1/2017 – 31/12/2019	Jaroslav Jerz/C
The study of physical and mechanical properties, machinability and surface treatment of Ti and Ti composites prepared by powder metallurgy	2/0044/17	1/1/2017 – 31/12/2019	Jaroslav Kováčik/C
Chemical compatibility between components in magnesium-carbon composites	2/0144/17	1/1/2017 – 31/12/2019	Stanislav Kúdela jr./C
Fabrication and study of composite materials manufactured by casting of aluminium and ceramic powder blends	2/0114/18	1/1/2018 – 31/12/2020	Martin Balog/C
Study of the use of pure magnesium powders for the preparation of biodegradable materials	2/0098/19	1/1/2019 – 31/12/2021	Miroslav Čavojský/C

Study of the possible using of carbon based reinforcement from waste for engineering applications	2/0135/19	1/1/2019 – 31/12/2021	Tomáš Dvorák/C
Complex concentrated alloys for high temperature structural applications	2/0074/19	1/1/2019 – 31/12/2021	Juraj Lapin/C
Influence of transverse and longitudinal road unevenness on a whole-body vibration of driver/passenger in a motor car	2/0148/19	1/1/2019 – 31/12/2021	Peter Mučka/C
Wooden pipe configuration of historic organ positives in Slovakia	2/0106/19	1/1/2019 – 31/12/2022	Štefan Nagy/W
			Total Sum: 74 178 Eur
2018			
Study of thermophysical properties of composites based on TiB_2 and ZrB_2 with copper matrix for high temperature applications	2/0172/16	1/1/2016 - 31/12/2018	Naďa Beronská/C
On the bonding between native Al2O3 layers and the effect of intentionally entrapped gasses in forged Al powders	2/0065/16	1/1/2016 - 31/12/2018	Peter Krížik/C
In-situ TiAl-based composites for high temperature structural applications	2/0125/16	1/1/2016 – 31/12/2018	Juraj Lapin/C
Research on the relationship between longitudinal road unevenness and ride comfort in vehicle	2/0089/16	1/1/2016-31/12/2018	Peter Múčka/C
Development of the methodology for preparation of ultrafine and fine grain materials based on Al and AlTi for microstructural characterization via EBSD method	2/0158/16	1/1/2016 – 31/12/2018	Martin Nosko/C
Investigation of advanced materials suitable for highly effective heat storage	2/0152/17	1/1/2017 – 31/12/2019	Jaroslav Jerz/C
The study of physical and mechanical properties, machinability and surface treatment of Ti and Ti composites prepared by powder metallurgy	2/0044/17	1/1/2017 – 31/12/2019	Jaroslav Kováčik/C
Chemical compatibility between components in magnesium-carbon composites	2/0144/17	1/1/2017 – 31/12/2019	Stanislav Kúdela jr./C
Fabrication and study of composite materials manufactured by casting of aluminium and ceramic powder blends	2/0114/18	1/1/2018 – 31/12/2020	Martin Balog/C
			Total Sum: 69 401 Eur
2017			
Study of thermophysical properties of composites based on TiB_2 and ZrB_2 with copper matrix for high temperature applications	2/0172/16	1/1/2016 - 31/12/2018	Naďa Beronská/C
On the bonding between native Al2O3 layers and the effect of intentionally entrapped gasses in forged Al powders	2/0065/16	1/1/2016 - 31/12/2018	Peter Krížik/C
In-situ TiAl-based composites for high temperature structural applications	2/0125/16	1/1/2016 – 31/12/2018	Juraj Lapin/C

Research on the relationship between longitudinal road unevenness and ride comfort in vehicle	2/0089/16	1/1/2016 - 31/12/2018	Peter Múčka/C
Development of the methodology for preparation of ultrafine and fine grain materials based on Al and AlTi for microstructural characterization via EBSD method	2/0158/16	1/1/2016 – 31/12/2018	Martin Nosko/C
Investigation of advanced materials suitable for highly effective heat storage	2/0152/17	1/1/2017 – 31/12/2019	Jaroslav Jerz/C
The study of physical and mechanical properties, machinability and surface treatment of Ti and Ti composites prepared by powder metallurgy	2/0044/17	1/1/2017 – 31/12/2019	Jaroslav Kováčik/C
Chemical compatibility between components in magnesium-carbon composites	2/0144/17	1/1/2017 – 31/12/2019	Stanislav Kúdela jr./C
			Total Sum: 60 941 Eur
2016			
On the study of the novel Al based composites prepared in situ via powder metallurgy approach	2/0025/14	1/1/2014 - 31/12/2016	Martin Balog/C
Deformation behavior of short-fiber reinforced Mg-Li-Zn matrix composites	2/0186/14	1/1/2014 - 31/12/2014	Stanislav Kúdela, jr./C
Study of thermophysical properties of composites based on TiB_2 and ZrB_2 with copper matrix for high temperature applications	2/0172/16	1/1/2016 - 31/12/2018	Naďa Beronská/C
On the bonding between native Al2O3 layers and the effect of intentionally entrapped gasses in forged Al powders	2/0065/16	1/1/2016 - 31/12/2018	Peter Krížik/C
In-situ TiAl-based composites for high temperature structural applications	2/0125/16	1/1/2016 – 31/12/2018	Juraj Lapin/C
Research on the relationship between longitudinal road unevenness and ride comfort in vehicle	2/0089/16	1/1/2016 - 31/12/2018	Peter Múčka/C
Development of the methodology for preparation of ultrafine and fine grain materials based on Al and AlTi for microstructural characterization via EBSD method	2/0158/16	1/1/2016 – 31/12/2018	Martin Nosko/C
			Total Sum: 56 239 Eur

2.4.5. List of projects supported by EU Structural Funds

Project title	**Project number**	**Duration**	**Responsible preson/status**	**Funding**
International center of excellence for research of intelligent and secure information and communication technologies and systems - II. Phase.	313021W404	13.3.2020/30.6.2023	František Simančík/W	414 106 Eur (total sum: 7 924 385 Eur)
Establishment of the Center for the Use of Advanced Materials	NFP313020T081	1.1.2019/30.6.2023	Martin Balog/W	172 500 Eur (total sum:

of the Slovak Academy of Sciences.				29 444 664,57 Eur)
Research and development of new products for efficient transfer and storage of thermal energy from renewable sources.	NFP313010 P272	1.6.2019/30. 6.2022	František Simančík/W	104 962,80 Eur (total sum: 1 122 136,51 Eur)
Research and development of a new plasma milling system PLASMABIT BHA for efficient and ecological closure of wells and introduction of a new product into the production process.	ITMS 313012N94 4	3.6.2019/31. 5.2022	František Simančík/W	526 314,94 Eur (total sum: 5 937 732,92 Eur)

2.4.6. List of other projects funded from national resources

Project title	**Project number**	**Duration**	**Responsible preson / status**	**Funding**
Strategic and targeted support to incentivise talented newcomers to NMBP project under Horizont Europe	MVTS/H2020 FIT-4-NMBP 21	1.1.2021/31.12.2 023	Karol Ižd inský/I	2 870 Eur
Reliable roadmap for certification of bonded primary structures	MVTS/COST CA18120	4.4.2019 – 3.4.2023	Štefan Nagy/I	9 016 Eur
European forum for advanced practices	MVTS/COST CA18136	1.4.2019 – 31.3.2023	Tomáš Dvorák/I	9 158 Eur
European network to connect research and innovation efforts on advanced smart textiles	MVTS/COST CA17107	11.10.2018- 10.10.2022	Alena Opáková Šišková/I	11 056 Eur
MULTI-modal imaging of forensic science evidence – tool for forensic science	MVTS/COST CA16101	21.2.2018- 1.9.2021	Martin Nosko/I	13 497 Eur

2.4.7. List of projects funded from private funds

Name of private partner	**Project title**	**Funding value Eur**	**Country of partner**	**Purpose**
TNT International	The development of a novel Al-AlN-B_4C metal matrix composite for nuclear industry.	394 071	France	Al-AlN-B_4C composite profiles for application of neutron absorbent material located within the transportation and dry cask storage of used nuclear fuel.
VUJE, a.s., Trnava	Materials development and expert evaluation of industrial induction melting technology in air.	228 015	Slovakia	Development of novel materials and experimental methodologies for power engineering
Hydro Extrusion Slovakia a.s, Žiar nad Hronom	Optimization of the process of pressing	219 678	Slovakia	Aluminium powder mistures

	aluminum powder mixtures, including modifications of pressing tools for pressing profiles of Al and its alloys			technological process optimization in hand withoptimizing the manufacturing process via tool design optimization.
Auerhammer Metallwerk	Optimization of the production process of thin metal foils	168 000	Germany	Year-round production support, microstructural monitoring of the compacting process, testing of mechanical properties, and understanding of causes of plate defects associated with designing process modifications to remove them.
CVaV Mochovce	Expert consultations on materials aspects of nuclear power plan Mochovce	140 105	Slovakia	Assesment of stainless steel and welding joints of piping components
IMR Metallverbareitung GmbH, Velden am Wortersee	Development of metal powders for industrial use, including 3D printing	17 809	Austria	The aim was to develop new light metal powders for selective laser sintering (SLS).
Aplik s.r.o., Kvant Lases, s.r.o.	Development of a laser projector cabinet made of aluminum foam	12 000	Slovakia	The aim of the development was to decrease the weight in combination with the electromagnetic shielding ability and increased heat transfer of aluminium foam.

2.4.8. List of projects funded from other competitive funds

Project title	**Project number**	**Duration**	**Responsible preson / status**	**Funding**
Development of powder metallurgy components based on iron powder with higher fatique strength for high performance application in automotive component	Doktogrant: APP0031	1.1.2020/31.12. 2020	Prateek Srivastava/C	2000 Eur
Mechanical properties of ultra light metal and novel cement composites	MAD SAS-PAS	1.1.2019/31.12. 2022	Stanislav Kúdela ml./C	Mobility
On the formation of bonding between native powder surface oxide layers in composites	MAD SAS-CONICET	1.1.2017/31.12. 2018	Martin Balog/C	Mobility

fabricated by forging of Mg, Al, and Ti powders				
Investigation of concrete matrix composites, shape memory foams and selected aggregates with application of X-ray microtomography	Bilateral project between SAS and PAS	1.1.2016/31.12.2018	Stanislav Kúdela ml./C	Mobility
Investigation of the influence of plastic strain instabilities on the fracture of Mg-Li-Zn alloys with the application of acoustic emission method.	Bilateral project between SAS and PAS	1.1.2016/31.12.2018	Stanislav Kúdela st./C	Mobility
Magnesium Nanocomposites for Biodegradable Medical Implants.	JRP SAS - TUBITAK	1.12.2014/30.11.2017	František Simančík/C	75 000 Eur (120 000)
Investment casting of turbine blades from nickel based superalloys.	SAS - TUBITAK	1.11.2013/31.10.2016	Juraj Lapin/C	75 000 Eur (120 000)

2.5. PhD studies and educational activities

2.5.1. List of accredited programmes of doctoral studies, period of validity, source of funding

Program title	Study field	Faculty	Period of validity	Source of funding
Progressive materials and material design	Engineering	Faculty of Materials Science and Technology, Slovak Technical University of Technology in Bratislava	2015 -	SAS/private source
Engineering technologies and materials	Engineering	Faculty of Engineering, Slovak Technical University of Technology in Bratislava	2020 -	SAS/private source

2.5.2. Summary table on doctoral studies (number of internal/external PhD students at the end of the year; number of foreign PhD students, number of students who successfully completed their theses during the year, number of PhD students who quit the programme during the year)

PhD study	2016			2017			2018			2019			2020			2021		
Number of potential PhD supervisors	4			3			5			6			6			5		
PhD students	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted	unumber, end of yea	defended thesis	students quitted	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted	number, end of year	defended thesis	students quitted
Internal total	5	1	0	5	1	0	7	1	0	8	1	0	7	0	1	5	1	2
from which foreign citizens	1	0	0	2	0	0	4	0	0	5	1	0	4	0	1	3	1	2
External	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other supervised by the research employees of the institute	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.5.3. PhD carrier path – Information on the next career steps of the PhD graduates who received their degree from the institute

Five PhD students successfully defended their thesis and received PhD degrees in the assessed period of time. Namely, Ing. Štefan Nagy (2016); Ing. Matej Štěpánek (2017); RNDr. Tatiana Pelachová (2018); Ing. Kateryna Kamyshnykova from Ukraine (2019) and MSc. Ahmed Mohamed Hassan Ibrahim from Egypt (2020). Due to their high-quality standards, they were offered to stay and work in IMMM SAS as postdocs and some of them are already working as senior researchers (S. Nagy and T. Pelachova).
Meanwhile, Ing. Štefan Nagy PhD. became a recognized specialist in transmission electron microscopy in the **Division of microstructure of surfaces and interfaces**, Ing. Matej Štěpánek PhD. And MSc. Ahmed Mohamed Hassan Ibrahim PhD. are valuable members of the powder metallurgy group in the **Division of new materials and technologies.** Ing. Kateryna Kamyshnykova PhD. and RNDr. Tatiana Pelachová PhD. are key members in **Division of properties of materials and structures.**
Dr. Kamyshnykova won 2nd place in the Competition of young researchers of the Slovak Academy of Sciences in the category of doctoral students and Dr. Hassan 2nd prize in the competition of young researchers of the SAS up to 35 years of age in the category of doctoral students. Moreover, Dr. Kamyshnikova was awarded by a prestigious Stefan Schwarz fund.

2.5.4. Summary table on educational activities

Teaching	2016	2017	2018	2019	2020	2021
Lectures (hours/year)*	11	9	0	2	2	2
Practicum courses (hours/year)*	0	0	8	3	0	0
Supervised diploma and bachelor thesis (in total)	3	0	0	0	0	0
Members in PhD committees (in total)	3	3	6	3	2	2
Members in DrSc. committees (in total)	0	1	1	1	1	1
Members in university/faculty councils (in total)	3	3	3	3	3	3
Members in habilitation/inauguration committees (in total)	1	1	1	0	0	0

2.5.5. List of published university textbooks

2.5.6. Number of published academic course books

2.5.7. List of joint research laboratories/facilities with universities

Name of Faculty, University	Field of Cooperation	The sear the joint workplace
Faculty of Engineering, TUKE	Cooperation within the Competence Center for Light Metals and Composites	Inoval, Ladomerská Vieska
Faculty of Engineering, University of Žilina	Cooperation within the Competence Center for Light Metals and Composites	Inoval, Ladomerská Vieska
Academy of Fine Arts in Bratislava	Cooperation within the consortium of the Center for Applied Research in New Materials and Technology Transfer.	-
Faculty of materials science and technology of Slovak	Research and development of special metal materials	Pavilion of Materials Sciences, Dúbravská cesta 9, Bratislava

University of Technology in Bratislava	prepared by vacuum melting and isostatic pressing	
Slovak University of Technology in Bratislava.	Implementation of top research in new materials, advanced technologies and energy on a coordinated project principle.	-

2.5.8. Supplementary information and/or comments on doctoral studies and educational activities – focused on what changes have occurred since the last evaluation in 2016

In 2020 „Internal system for the evaluation of the quality of PhD studies“ at IMMM SAS was adopted. It aims to set the criteria that need to be fulfilled during the PhD studies. It defines the role of guarantor as well as supervisor and PhD student. The internal system defines the procedure for the selection of topics for PhD studies as well as milestones that need to be met before the student is admitted to defend the thesis. Newly defined standards are aimed to increase the quality of PhD studies at IMMM SAS.

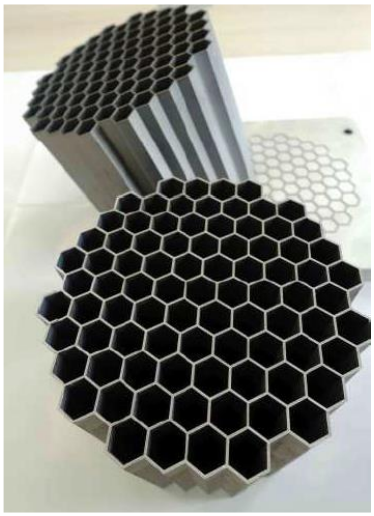
2.6. Societal impact

2.6.1. The most important case studies of the research with direct societal impact, max. 4 for institute with up to 50 average FTE researchers per year, 8 for institutes with 50 – 100 average FTE researchers per year and so on. Structure: Summary of the impact; Underpinning research; References to the research; Details of the impact; Sources to corroborate the impact. One page per one case study

Direct applicability of research results in practice and their positive contribution to society is the main goal of practically all projects solved at the Institute. In this part we present some of successful results, which were selected in the evaluated period as the best results of the Scientific Section 1 in the annual reports of the SAS in the field of applied research:

- **A new composite material for containers for storage of spent nuclear fuel**
  In cooperation with VÚJE a.s and ZTS VVÚ a.s. a study of the applicability of an aluminium composite containing particles with B^{10} isotopes in containers for long-term storage of spent nuclear fuel was performed. Containers should be used in a dry storage facility in which the fuel is transferred from water pools after the initial reduction of residual radioactivity and then stored for a long time for decades until its radioactivity drops to a safe level. Due to the fact that in a dry warehouse the cooling of fuel is less efficient than in a water pool, the material of the containers must ensure sufficient heat dissipation from all cells in which heat is still slightly generated by neglecting uncompleted reactions. Aluminium with its high thermal conductivity is a suitable candidate for the replacement of special steel, which is usually used for this purpose, but it is important that in addition to excellent thermal conductivity it also provides all required mechanical properties. Moreover the material of container must be capable to absorb all residual neutron radiation. This can be effectively achieved by adding ceramic particles containing the B^{10} isotope to the aluminum matrix. As part of the feasibility study, such a composite material was prepared at IMMM SAS by extruding a mixture of aluminum and ceramic powders into shape profiles that were subsequently tested for all relevant properties. It has been shown that all required mechanical properties have been achieved at significantly better thermal conductivity than obtained at steel. The profiles were prepared in a shape suitable for storing a fuel cartridge. A modern friction stir welding technology was used for their mutual connection, which ensures the same absorption properties in the joints as in the basic profile. Finally, a scaled-down demonstration model of the entire container was prepared using 3D printing, on which potential operating loads were simulated and verified. Based on the

successful results of the study, VÚJE a.s. started the production of the first test containers from this material in 2020. (success case SAS 2019)

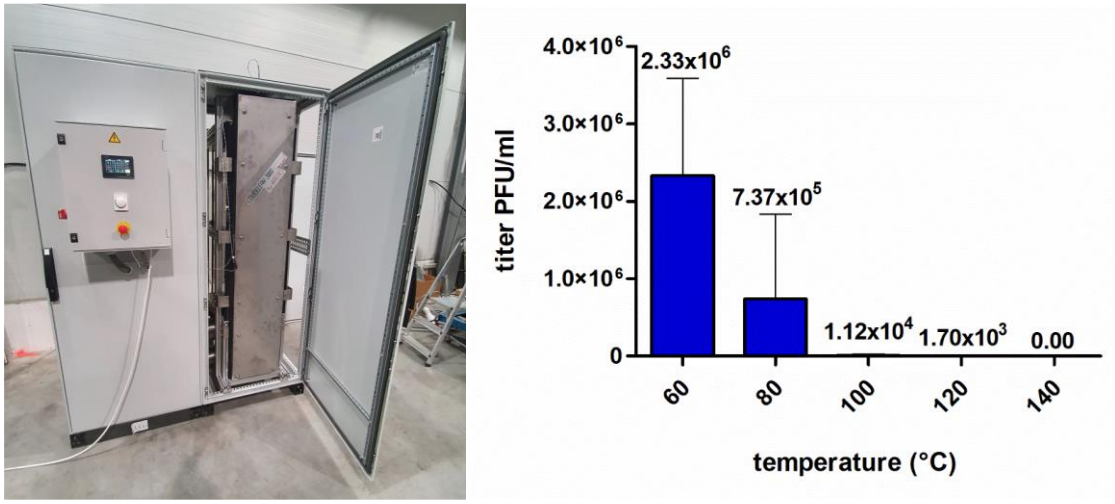


3D model of whole container made by laser 3D print of aluminium powders.

Besides, containers for storage of spent nuclear fuel, the research team of the IMMM SAS have carried out numerous certified mechanical testing of piping components installed in the nuclear power plant Mochovce Unit 3 and Unit 4, which are currently under the construction. These expert activities included the development of testing methodology, design of testing specimens, and elaboration of methods of extraction of test specimens from the piping components. **In addition, the leading scientist of the Institute is a member of the material expert team of the energy company Slovenské elektrárne, a.s. and collaborates with the Nuclear Regulatory Authority of Slovakia.** The aim of these extensive expert activities of the IMMM SAS is to verify independently the quality of all installed piping components and contribute to putting in safe service operation of new nuclear reactors, which will be important energy sources and will contribute to the energy security of Slovakia.

- **The high-capacity air purifier from viral pathogens**
  The need to help resolve the COVID 19 pandemic almost immediately initiated several activities at our Institute aimed at mitigating its negative consequences. As part of the APVV interdisciplinary COVID PP-20-0098 project, **it was possible to develop and successfully test in laboratory conditions a prototype of an air purifier from pathogens in aerosols, which works on the principle of rapid heating of air to a high temperature up to 200 °C**. Measurements at the partner Biomedical Center of the Slovak Academy of Sciences have confirmed that such a high temperature can effectively destroy human pathogenic viruses in just a few seconds of exposure, which allows relatively large areas to be repeatedly cleaned in a short time with a flow of purified air of up to 600 m^3 per hour. The innovative design of the multiple shape exchangers ensures efficient heat exchange between the incoming contaminated and the outgoing cleaned air with minimal energy requirements at high flow rates and thus creates good economic preconditions for continuous operation of the treatment plant. This method of cleaning poses no risk to humans and can therefore be used in full operation, especially where more people are moving and large amounts of air need to be cleaned at short intervals. Due to the fact that there is no exchange of air with the exterior, no special installation conditions are required (no ventilation pipes are required), and there is no contamination of the indoor environment with dirt from the exterior. The cleaned air retains its original humidity, composition and temperature. In addition, operation significantly reduces the need for regular maintenance, as there are no filters or components with a limited-service life in the treatment plant, as is the case with treatment plants using UV radiation or ozone. The purifier principle has therefore been claimed for patent protection. Although the primary goal of the project was to develop a device designed to decontaminate areas from human coronaviruses such as SARS-CoV-2, the new treatment device will have a much wider use, as high temperatures can eliminate virtually all dangerous airborne microorganisms such as

other influenza viruses, again emerging viruses of measles, mumps, varicella, or groups of rhinoviruses causing various rhinitis and colds. In addition, hot air is able to kill airborne bacteria such as bacillus tuberculosis, mycoplasma pneumoniae, some strains of streptococci or coxiella burnetii, which causes the well-known and highly contagious Q fever. Practical use is envisaged wherever prevention against aerosol infection is needed - in hospitals, schools, cinemas and theaters, gyms, congress halls, restaurants, but also in closed production areas with a large movement of staff or in means of transport (trains, planes, buses, etc.). (Project APVV COVID PP-20-0098 - SARSkill - Large-capacity air purifier from pathogens in aerosols. Partners IMMM SAS, BMC SAS, APLIK spol. S r.o. (success case SAS 2021)



Prototype of cleaning unit (left), the results of culturing the virus following its 5s exposure to the specified temperature (right).

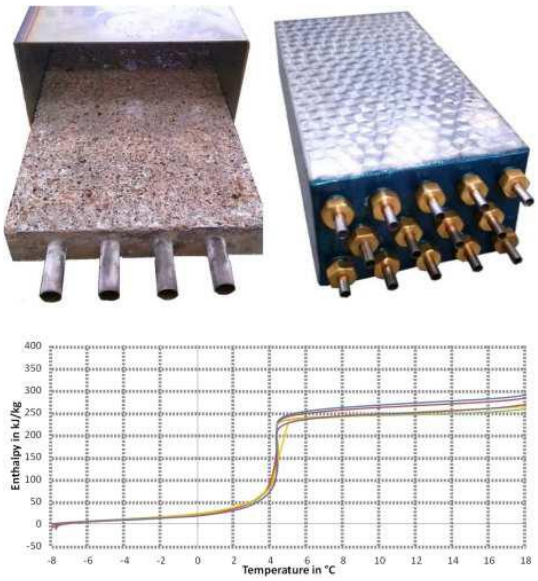
In cooperation with Polymer Institute of SAS, COVID 19 pandemic reaction where the research was focused on the worldwide topic of recovery of plastic waste such as disposable packaging (PET bottles) or textiles (PA) to fabricate the products with higher value. **A comparable efficiency to commercially available EPA and HEPA filters with incomparably lower production costs was achieved.** The outcome of this research is important on a national scale because it brought a new research direction to Slovakia. It gives Slovak producers and entrepreneurs a new alternative for the disposal and recovery of certain types of plastics. **Recognition of this research on an international scale includes invitations to joint projects related to the topic of protective textiles as well as recycling, including several COST projects.** Since 2020, we have made progress in research and published several articles that have improved the performance of user properties while maintaining excellent filtration properties.

- **Innovative laser projector cabinet**
  I**n cooperation with the Slovak innovative companies Kvant Lasers s.r.o. and Aplik s.r.o. an original type of laser projector cabinet was developed in 2020**, which is unlike the traditional projectors made of hybrid castings of aluminum foam and "solid" aluminum, while contains only a minimum of plastic parts, which are also produced in an innovative way using 3D press. This unique combination significantly reduces the weight of the projector, improves heat dissipation from built-in sources as well as the protection of the external environment from electromagnetic radiation. Due to the fact that the individual parts of the cabinet are cast into complex molds, its rigidity is significantly improved compared to the original screwed version. At the same time there is a flexibility in a design, that allows to give the cabinet, in addition to new functionality, also timeless elegance. The reduced number of parts places less demands on assembly and CNC machining, which required 15 – 20 hours of work, which ultimately leads to a reduction in production costs. In 2020, the first prototypes were made and functionally tested. Based on successful test results, partner Kvant Lasers s.r.o. started certification of new product and the continuous serial production is planned from 2022. Highly innovative production will be provided by the Slovak company Aplik s.r.o. on the basis of a license for the original foaming technology developed and patented by IMMM SAS.

It is first time when Institute becomes contracted royalty for the use of its patented technology. Both industrial partners (SMEs) become high added value for innovative product (Kvant Lasers s.r.o.) and innovative technology (Aplik s.r.o.), respectively.

The prototype of innovative laser projector cabinet made from aluminium foam developed at IMMM SAS.

- **In cooperation with the Austrian company i2m GmbH,** a conceptually new heat storage tank was developed using a paraffin-based material that requires high latent heat (PCM) to melt. Heat is stored in the material through a phase change, with the PCM gradually melting but its temperature remains constant. Up to 250 kJ of heat can be stored in 1 kg of material by melting, on the contrary, this heat is released from it during solidification. The melting / solidification temperature of the material can be precisely set with the help of various additives, which makes it possible to produce heat accumulators for various constant temperatures in a wide range from -20 to 80 °C. **The new concept consists in the fact that PCM is integrated into the small pores of aluminum foam, whose task is to transport or dissipate latent heat evenly and quickly throughout the volume of the PCM.** The high thermal conductivity of aluminum is used, which forms the pore walls and a small volume of PCM in each pore. Such a design solves the basic problem of PCM, which is its low thermal conductivity preventing sufficient heat transport in the volume of PCM. Heat enters the aluminum foam by means of an integrated tubular heat exchanger with heat transfer medium or directly through its surface. Products of various shapes and sizes can be made from the foam, the heat storage can thus be integrated directly into the jacket or. supporting structure of the product. Heat / cold storage tanks can be used in a wide range of applications for long-term maintenance of a stable temperature of rooms, food, electronic components or. other heat generating devices.



Heat accumulator made of aluminum foam filled with a PCM with a melting point of 5°C (dimensions 15 x 25 x 50 cm). Approximately 2400 kJ of heat can be stored in it. Fig. bottom ilustrates heat release at solidification of PCM at 5°C at different flow rates of the heat transfer medium.

2.6.2. List of the most important studies and/or other activities commissioned for the decision-making authorities, the government and NGOs, international and foreign institutes (title, name of institution, contract value, purpose (max 20 words))

Tables of important studies and expertises:

Name	Year	Name of Institution	Purpose
František Simančík	2021	Banská Bystrica self-governing region	Member of the thematic working group for innovation at the BBSK Partnership Council, documents preparation.
		Banská Bystrica self-governing region	Member of the CURRI BBSK project coordination group for the R&D component: Linking industry and R&D workplace in the region.
	2020	National Council for Competitiveness of the Slovak Republic	As a member of the National Council for Competitiveness of the Slovak Republic, he participates in the preparation of the Report on Productivity and Competitiveness of the Slovak Republic
		Ministry of Investments, Regional Development and Informatization of the Slovak Republic	Contribution to the preparation of RIS3 as a coordinator-visionary of the domain "Industry for the 21st Century"
		Office of the Government of the Slovak Republic - Institute for Strategies and Analyzes	Review of the material “University Science Parks and Research Centers at Slovakia: A handbook for success "
		Banská Bystrica self-governing region	In cooperation with experts from the World Bank and the BBSK, he participated in the elaboration of the territorial BBSK development strategy

Table of active participation of Institute employees in national and international committees:

Name	Year	Title	Position
Juraj Lapin	2016	Horizon 2020 - Program Committee - Space	National delegate
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		Monitoring Committee for operations research and innovation program	Member
		SAS Commission for Intellectual Property, Innovation and Technology Transfer (member)	Member
		SAS Commission for Space Activities	Chairman
		Jury for the International Prize of the SAS	Member
		SAS Commission	Member

František Simančík	2016	Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		Innovation Council of the Banská Bystrica Self-Governing Region	Member
		Association of the Engineering Industry	Supervisory board member
		Member of the Industrial Working Group Technologies set up by the Ministry of Education, Youth and Sports at creating a strategy to support the science of research and innovation in the Slovak Republic	Member
		Commission High level group ManuFuture SK - MH SR	Member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research commission and development
		SAS Commission for Intellectual Property, Innovation and Technology Transfer (member)	Member
Peter Múčka	2016	VEGA Commission no.7	Chairman
		VEGA	Vice-Chairman
Martin Nosko	2016	VEGA Commission no.7	Member
Pavol Štefánik	2016	VEGA Commission no.7	Member
Juraj Lapin	2017	Monitoring Committee for operations research and innovation program	Member
		Horizon 2020 – Program Committee – Space	National delegate
		SAS Commission for Intellectual Property, Innovation and Technology Transfer (member)	Member
		SAS Commission for Space Activities	Chairman
		Jury for the International Prize of the SAS	Member
		SAS Commission	Member
František Simančík	2017	Commission High level group ManuFuture SK – MH SR	Member
		Innovation Council of the Banská Bystrica Self-Governing Region	Member
		Association of the Engineering Industry	Supervisory board member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research and development commission
		Industrial Technologies Working Group set up by the Ministry of Education, Youth and Sports at creating a strategy to support research science and innovation in the SR	Member
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member

		SAS Presidium for the 1st Department of Sciences	Member
		Scientific Board	Member
		SAS Commission for Intellectual Property, Innovation and Technology Transfer (member)	Member
Peter Múčka	2017	VEGA Commission no.7	Chairman
		VEGA	Vice-Chairman
Martin Nosko	2017	VEGA Commission no.7	Member
Pavol Štefánik	2017	VEGA Commission no.7	Member
Juraj Lapin	2018	Monitoring Committee for operations research and innovation program	Member
		Horizon 2020 – Program Committee – Space	National delegate
		APVV Council for Technical Sciences	Member
		SAS Commission for assessment of scientific qualifications of emloyees	Member
František Simančík	2018	Association of the Engineering Industry	Supervisory board member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research and development commission
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		Committee for the preparation of a new law on SAS, The Ministry of Education, Youth and Sports	Member
		Council for the preparation of the state R&D program: Materials and products with higher added value on the basis of effective recovery of domestic raw materials and waste	Member
		SAS Presidium for the 1st Department of Sciences	Member
		Scientific Board	Member
		SAS Dislocation Commission	Member
		SAS Transformation Commission	Member
		SAS Commission for Intellectual Property, Innovation and Technology Transfer	Vice-Chairman
		SAS Commission for economic affairs	Member
		SAS Commission for Infrastructure and Structural Funds	Chairman
Karol Iždinský	2018	SAS Scientific College for Electronics, Materials Research and Technology	Member
Peter Múčka	2018	VEGA Commission no.7	Vice-Chairman
		VEGA	Chairman
Martin Nosko	2018	VEGA Commission no.7	Member
Pavol Štefánik	2018	VEGA Commission no.7	Member
Juraj Lapin	2019	Horizon 2020 - Program Committee - Space	National delegate
		SAS Commission for assessment of scientific qualifications of emloyees	Member

František Simančík	2019	Association of the Engineering Industry	Supervisory board member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research and development commission
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		National Productivity Council of the Slovak Republic	Member
		EASAC - Working Group on decarbonisation of buildings	Member
		Council for the preparation of the state R&D program: Materials and products with higher added value on the basis of effective recovery of domestic raw materials and waste	Member
		SAS Presidium for the 1st Department of Sciences	Member
		Scientific Board	Member
		SAS Dislocation Commission	Member
		SAS Transformation Commission	Member
		SAS Commission for Intellectual Property, Innovation and Technology Transfer	Vice-Chairman
		SAS Commission for economic affairs	Member
		SAS Commission for Infrastructure and Structural Funds	Chairman
		Commission for the formation of the concept of the development of the SAS complex at Patrónka	Chairman
Karol Iždinský	2019	SAS Scientific College for Electronics, Materials Research and Technology	Member
Peter Múčka	2019	VEGA Commission no.7	Vice-Chairman
		VEGA	Chairman
Martin Nosko	2019	VEGA Commission no.7	Member
Pavol Štefánik	2019	VEGA Commission no.7	Member
Juraj Lapin	2020	Horizon 2020 - Program Committee - Space	National delegate
		SAS Commission for assessment of scientific qualifications of emloyees	Member
František Simančík	2020	Association of the Engineering Industry	Supervisory board member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research and development commission
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		National Productivity Council of the Slovak Republic	Member
		SAS Presidium for the 1st Department of Sciences	Member

		Scientific Board	Member
		EASAC - Working Group on decarbonisation of buildings	Member
		SK3: Standing Committee on RIS3 Domain Coordinator-Visionary Industry for the 21st century	Coordinator-Visionary Industry for the 21st century
		SAS Dislocation Commission	Member
		SAS Transformation Commission	Member
		SAS Commission for Intellectual Property, Innovation and Technology Transfer	Vice-Chairman
		SAS Commission for economic affairs	Member
		SAS Commission for Infrastructure and Structural Funds	Chairman
		Commission for the formation of the concept of the development of the SAS complex at Patrónka	Chairman
Peter Múčka	2020	Commission for the Reform of the Grant System of R&D Support (advisory body of the State Secretary of the Ministry of Education, Youth and Sports of the Slovak Republic RNDr. Ľudovít Paulis, MD, PhD. MPH.)	Member
		VEGA Commission no.7	Vice-Chairman
		VEGA	Chairman
Karol Iždinský	2020	SAS Scientific College for Electronics, Materials Research and Technology	Member
Martin Nosko	2020	VEGA Commission no.7	Member
Pavol. Štefánik	2020	VEGA Commission no.7	Member
Juraj Lapin	2021	Interdepartmental Commission for Space Activities in the Slovak Republic	Member
František Simančík	2021	Association of the Engineering Industry	Supervisory board member
		Association of the Automotive Industry of the Slovak Republic ZAP	Member of the research and development commission
		Commission for the evaluation of the application for incentives for research and development at the Ministry of Education, Youth and Sports of the Slovak Republic	Member
		SAS Presidium for the 1st Department of Sciences	Member
		Scientific Board	Member
		National Productivity Council of the Slovak Republic	Member
		EASAC - Working Group on decarbonisation of buildings	SAS Delegate
		NCTT National Technology Transfer Center	SAS Delegate
		MIRRI - Commission for the Preparation of the Innovation Act	SAS Delegate
		Industrial Property Office of the Slovak Republic - commission for the preparation of the national strategy for the protection of intellectual property	SAS Delegate

		SK3: Standing Committee on RIS3 Domain Coordinator-Visionary Industry for the 21st century.	Coordinator-Visionary Industry for the 21st century
		SAS Dislocation Commission	Member
		SAS Transformation Commission	Member
		SAS Commission for economic affairs	Member
Peter Múčka	2021	Commission for the Reform of the Grant System of R&D Support (advisory body of the State Secretary of the Ministry of Education, Youth and Sports of the Slovak Republic RNDr. Ľudovít Paulis, MD, PhD. MPH.)	Member
		VEGA Commission no.7	Vice-Chairman
		VEGA	Chairman
Martin Nosko	2021	VEGA Commission no.7	Vice-Chairman
Tatiana Pelachová	2021	VEGA Commission no.7	Member

2.6.3. List of contracts and research projects with industrial and other commercial partners, incl. revenues (study title, name of institution, contract value, country of partner, purpose (max 20 words))

Name of partner	Study title	Contract value	Country of partner	Purpose
Miba Sinter Slovakia, s.r.o., Dolný Kubín	Development of new materials from powder alloys	72 485	Slovakia	Preparation of PM compacts for sintering, and microstructural and EDS analysis, mechanical properties testing, porosity observation
Finalcast, s.r.o., Žiar nad Hronom	Optimization of casting of aluminum alloy components.	47 772	Slovakia	Aim is to increase castings quality and implementation of the innovative Al alloys into production.
Porsche AG	Application of metal foam in the car body	42 900	Germany	Aim of the study was to decrease the weight of the body parts.
Slovenské elektrárne	Quality assessment of pipe components of nuclear power plants.	39 950	Slovakia	Mechanical testing and intergranular corrosion tests of stainless steel.
Hydro Extruded Solution	The development of powder metallurgy Al-Mg alloys for extrusion.	30 872	Sweden	Al-Mg alloys prepared from mixture of elementar Al and Mg powders in the form of extruded profiles for marine applications.

i2mUnternehmensberatung GmbH	Development of heat exchangers based on aluminum foam	29 440	Austria	Aim was to develop the energy efficient heat exchanger using aluminium foam, especially for the building industry.
Havel metal foam GmbH	Production of prototype components from aluminum foam for BMW cars	26 857	Germany	The use of aluminium foam instead of the Mg alloys lead to decreased weight.
RHP – Technology GmbH, Seibersdorf	Study of microstructures of sintered materials	20 692	Austria	Microstructural and EDS analysis of different types of metal based sintered materials
GA Drilling, Bratislava	Design and manufacture of a new porous material for cooling high temperature reactors	20 057	Slovakia	To study the possibility of the cooling in the high temperature reactors.
Strojmetal, a.s., Kamenice	Quality assessment of equipment for continuous casting of aluminum semi-finished products intended for further forging	18 000	Czech Republic	Aim was to qualified assess the continuous casting process technology.
University of Stuttgart, Institute for Engineering Design and Industrial Design	Technology development and sample preparation from porous Al_2O_3 ceramics infiltrated with AlSi12 alloy	17 400	Germany	Aim was to develop alternative material for the mixing machine component and to replace conventionally used steel part.
Česká zbrojovka, Uherský Brod	Application of metal foam in products	12 100	Czech Republic	Shock shooting absorption in hand with decreased weight was achieved using the aluminium foam instead of the wood.

Furthermore, services with small values were provided to **17 companies** such as Výskumný Ústav Zváračský, Mincovňa Kremnica, š.p., or Gevorkyan, s.r.o. etc. **in the total sum 80 908 Eur**.

2.6.4.1 List of intangible fixed assets (internally registered IP (confidential know-how), patent applications, patents granted, trademarks registered) denoting background IPR

trademark	Type	Number of applications	Number of trademarks	Status
BIACOM	wordy	1261-2015	241435	valid
HITEMAL	wordy	2032-2013	237275	valid

2.6.4.2 List of licences sold abroad and in Slovakia, incl. revenues (background IPR identification, name of institution, contract value, country of partner, purpose (max 20 words))

In the last period, more inventions have been successfully patented than shown in Table 2.1.6. We are currently working on commercionalizing the patent registered abroad under the number PCT/IB2018/053540 and in Slovakia under the number PP50037-2017 (Superconductor wire based on MgB_2 core with Al-based sheathand method of its production.) to international industrial companies, European Space Agency, has also shown interest in the negotiations. Other patents were offered through the SAS Competence Center as well: Composite material for implants, its use and method of its production - BIACOM® and Method of production of the component from metal foam, component produced by said method and mold for the realization of said method.

One licence was sold- **Method of production of a component from metal foam, component produced by said method and mould for the realization of said method** (identification: EP3135404B1) to the company **Aplik s.r.o. (Slovakia)**, which participates in the further optimization of production and begins small-scale production of Al foam parts for laser boxes.
Contract value: According to the contract, the company we have licensed is obliged to pay annually the costs associated with maintaining patent protection within the scope of granted patents RU 2,696,998 C1, KZ33981, ZA201801984 (B), CN108136494B, JP6748208B2, US2018257135 B2, IL257774, EP3135404B1 validated in the countries: Czech Republic, Finland, France, Ireland, Germany, Norway, Austria, Slovakia, United Kingdom, Spain, Switzerland / Liechtenstein, Sweden and Italy, and in the scope of applications under assessment in Australia, Canada, Mexico, India and South Korea.

2.6.5. Summary of relevant activities, max. 300 words (describe the pipeline of valorization in terms of Number of disclosure, Number of registered IP internally, number of CCR/LIC contracts and their respective summary values, the support you are receiving in specific points internally at the institute, at SAS, externally – also the limitations and drawbacks.

During the years 2015 - 2021, our patents were validated in several countries (part 2.1.6. and part 2.1.7.):
Method of production of component from metal foam, component produced by said method and mould for the realization of said method has been validated in the frame of EP3135404B1 in Czechia, Finland, France, Ireland, Germany, Norway, Austria, Slovakia, United Kingdom, Spain, Switzerland / Liechtenstein, Sweden and Italy, then in Kazachstan (KZ 33981), Russian Federation (RU 2 696 998 C1), South Africa (ZA201801984 (B)), China (CN108136494B), Japan (JP6748208B2), Israel (IL257774).
Composite material for implants, its use and method of its production has been validated in Europe (EP3322454B1).
Composite for heat transfer with high-temperature resistance has been validated in the frame of EP3398192B1 in countries: Czech Republic, Germany, France, United Kingdom, Slovakia and then in USA (US10755821B2).
We also managed to register two trademarks **BIACOM®** (241435) a **HITEMAL®** (237275) (6.4.1.).
The patenting system is supported by PSAS, where the Center for Technology Transfer is newly established. This points to support in patent preparation, patent research, patent filing, as well as support in case of validation, country selection and potential sales. The support from the SAS is financial, namely EUR 5,000 in the case of an international patent and EUR 1,000 in the case of a domestic patent. In the case of a domestic patent, all patenting fees are also paid.

2.7. Popularisation of Science (outreach activities)

2.7.1. List of the most important popularisation activities, max. 20 items

No.	Author	type	Title/topic	Place and time of publication
1	Martin Nosko	press	Program pre systémové vzdelávania študentov odštartoval na expo v Dubaji, SAV bola pri tom.	https://www.minedu.sk/program-pre-systemove-vzdelavanie-studentov-odstartoval-na-expo-v-dubaji-sav-bola-pri-tom, 22.12.2021
2	František Simančík	radio	Veda SK	https://www.rtvs.sk/radio/archiv/11373/1646 699, 18.9.2021
3	Peter Múčka	radio	Transformácia vedeckej grantovej agentúry VEGA	https://www.rtvs.sk/radio/archiv/1124/15483 72, 17.4.2021
4	Jaroslav Jerz	press	Materiály pre udržateľné využívanie energie	https://www.quark.sk/materialy-pre-udrzatel ne-vyuzivanie-energie/, 6.12.2021
5	Veronika Nagy Trembošová	video	Predstavenie vedeckého kuriéra: Chemik detektív	https://www.nocvysku mnikov.sk/program/m esto-online-studio.html, 24.9.2021
6	Martin Nosko	video	Videovizitka ÚMMS SAV	https://www.sav.sk/doc/dod/UMMS.SAV.videovizitka.mp4, 12.4.2021
7	Peter Oslanec	radio	Veda na dve minúty	www.funradio.sk, 20.4.2021
8	Erik Šimon	radio	SAV reaguje na pandémiu. Vedci vzdelávajú pomocou videí	RTVS, Rádio Regina Západ. (https://www.rtvs.sk/radio/archiv/11124/1315 829; čas 44:32), 15.4.2020
9	František Simančík	TV	Kameň v prášku ako spása.	TV Markíza, Televízne noviny, 9.9.2020, 19:00
10	Alena Opálková Šišková	press	2. Strategický seminár pre podporu spolupráce medzi akadémiou, univerzitami a priemyslom	https://vedanadosah.cv tisr.sk/tlacove-spravy/ 425/2-strategicky-semi nar-pre-podporu-spolu prace-medzi-akademio u-univerzitami-a-priemyslom, 29.10.2019
11	Michaela Štamborská	exhibition	Európska noc výskumníkov	Stará Tržnica, 27.9.2019
12	Naďa Beronská	lecture	Nájdi v sebe vedca III.	Institute of materials and machine mechanics SAV, Dubravska cesta 9, 845 13 Bratislava. 3, 10, 17 a 24.4.2019. http://www.umms.sav.sk/10389-en/2019-styr i-aprilove-stredy-patril i-na-ustave-materialov -a-mechaniky-strojovsiestakom/?fbclid=IwAR0I9zPlPZiKbkLwN 0QS90

13	Martin Balog	press	Slovenskí vedci vyvinuli najľahší supravodivý kábel na svete	https://www.aktuality.sk/clanok/711902/slovenski-vedci-vyvinuli-najlahsi-supravodivy-kabel-na-svete/ 27.7.2019
14	Martin Nosko	press	Materiáloví vedci predstavia budúcim študentom aj firmám svoj výskum	http://vedanadosah.cvtisr.sk/materialovi-vedci - predstavia-buducim-studentom-aj-firmam-svoj-vyskum, 21.2.2018
15	Karol Iždinský	press	Aby veda nezobrela	www.zivot.sk, č. 14 / 7.4.2018
16	Milan Škrobian	lecture	Exkurzia študentov TU Košice, Hutnícka fakulta, 27 ľudí	Žiar nad Hronom 3.4.2017
17	Martin Nosko	press	Za tajomstvami materiálov	Quark, ročník XXIII, č. 9. 1.9.2017, str. 41
18	Martin Balog	radio	Príbeh na týždeň: Ústavy Slovenskej akadémie vied.	RTVS, Rádio Regina Západ, 20.11.2017, 8:09
19	Pavol Štefánik	press	Kompozit na vedenie tepla s vysokoteplotnou odolnosťou	Prešporský podnikateľ, č. 9/ ročník IX, str. 5. 1.9.2016
20	František Simančík	press	Materiály budúcnosti na Slovensku	Automotive Innovation Slovakia – štvrťročník zväzu automobilového priemyslu SR, electronický časopis, 1/2016, 1.2.2016, ISSN 1339-8377

2.7.2. Table of outreach activities according to institute annual reports

Outreach activities	2016	2017	2018	2019	2020	2021	total
Articles in press media/internet popularising results of science, in particular those achieved by the Organization	3	12	17	37	19	21	109
Appearances in telecommunication media popularising results of science, in particular those achieved by the Organization	0	2	1	2	3	7	15
Public popularisation lectures	8	14	10	13	1	8	54

2.8. Background and management. Infrastructure and human resources, incl. support and incentives for young researchers

2.8.1. Summary table of personnel

2.8.1.1. Professional qualification structure (as of 31 December 2021)

	Degree/rank				Research position				
	DrSc./DSc	CSc./PhD.	professor	docent/ assoc. prof.	I.	II.a.	II.b.		
Male	1	31	0	2	1	15	16		
Female	0	9	0	0	0	5	3		

I. – director of research with a degree of doctor of science/DrSc.

II.a – Senior researcher

II.b – PhD holder/Postdoc

2.8.1.2. Age and gender structure of researchers (as of 31 December 2021)

Age structure of researchers	< 31		31-35		36-40		41-45		46-50		51-55		56-60		61-65		> 65	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Male	6,0	4,3	4,0	1,2	8,0	6,0	8,0	6,7	3,0	3,0	2,0	2,0	6,0	5,2	6,0	5,5	2,0	2,0
Female	0,0	0,0	1,0	1,0	3,0	2,7	1,0	0,8	0,0	0,0	0,0	0,0	3,0	3,0	1,0	1,0	0,0	0,0

A – number

B – FTE

2.8.2. Postdoctoral fellowships (list of positions with holder name, starting date, duration. Add brief information about each fellow's career path before and after receiving PhD degree, etc.)

2.8.2.1. MoRePro and SASPRO fellowships

2.8.2.2. Stefan Schwarz fellowships

Ing. K. Kamyshnykova, PhD. – received funding from Stefan Schwarz Fund in period 5/2020 – 5/2022. She is actively working at IMMM SAS.

2.8.2.3. Postdoctoral positions from other resources (specify)

During the last accreditation period, we had two foreign and one Slovak postdoctoral position. There were more applicants and more open positions, but due to COVID19, two planned trips did not materialize.

Institute as a host

Year	Name	Home Institution	Duration	Funding source
2020	Farzad Khodabakhshi	School of Metallurgical and Materials Engineering, College of Engineering, University of Tehran, Iran	1.2.2020 – 30.11.2020	National Scholarship Programme of the Slovak Republic, SAIA
2019	Ghasem Azimi-Roeen	Isfahan University of Technology, Isfahan, Iran	1.7.2019 – 30.9.2019	National Scholarship Programme of the Slovak Republic, SAIA

Sent

Year	Name	Host Institution	Duration	Funding source
2018	Ľubomír Orovčík	Institute of Physics, Ivan Franko National University of Lviv	28.2.2018 - 1.5.2018	National Scholarship Programme of the Slovak Republic, SAIA

2.8.3. Important research infrastructure introduced during the evaluation period with the information about the sources of funding *(max. 2 pages)*

IMMM SAS is are well-equipped with technological facilities, structure characterization equipment and materials testing equipments, which were procured in previous periods. In this period, we have prepared the project focused to improve existing devices or comprehensive devices which are currently at IMMM SAS. However, we have developed at our own:

- **Semi-industrial nitridation furnace for Al powder billets**, non-budgetary financing sources (APVV).
- **Laboratory high-vacuum electric resistance furnace** (10 - 4 Pa, 1300°C), non-budgetary financing sources (APVV).
- **Equipment for "Small punch creep testing"**, non-budgetary financing sources (APVV).

Important in-housse infrastructure:

Technological facilities:

- 5 autoclaves for pressure infiltration with graphite and induction heating for samples with the diameter up to 300 mm and length of 550 mm
- furnace for foaming of aluminium panels
- equipment for injection molding of metallic foams
- foam expandometer
- vacuum press for hot diffusion bonding (up to 300 000 kp)
- furnace for unidirectional solidification
- 2 plasma melting furnaces
- vacuum furnaces for thermal treatments
- extrusion and ECAP hydraulic presses (up to 500 000 kp)
- screew forging press (2.7 MN, 14 kJ)
- laboratory and semi-industrial extrusion press (up to 3.5 MN)
- cold isostatic pressing (CIP), max. pressure 400 MPa
- vacuum hot press with induction heating
- vacuum and overpressure furnaces (up to 1600 °C)
- particle size distribution (PSD)
- 3D printing (Z Printer 650, Z Corporation)
- Vacuum induction melting furnace combined with till casting
- Centrifugal casting machine
- HAAS VF1-DHE Vertical machining center
- CUT 20P CNC wire cut electric discharge machine
- FORM 20 CNC EDM die sinking machine
- Indutherm VC1000D vacuum casting machine
- M2 Cusing Concept Laser – metal additive manufacturing machine

Structure characterisation equipment:

- light optical microscopy (Olympus GX 51 equipped with CCD digital camera ARTCAM 300)
- VHX 2000E Keyence Digital microscope
- Confocal scanning microscope LSM
- fully automated microhardness tester FM-ARS 9000 (10 – 500 p)
- X-ray tomography with resolution better than 0.5 μm (Phoenix X-ray microtomograph Nanotom 180)

- scanning electron microscope JEOL 7600F FEG with resolution from 1 nm equipped with energy and wave dispersive spectrometers (EDS; WDS) and electron backscatter diffraction (EBSD)
- scanning electron microscope JEOL JSM 6610 with energy dispersive X ray spectrometer
- Tescan VEGA 3 XMU scanning electron microscope equipped with EDX analyzer
- transmission electron microscope JEOL JEM 100 C
- precision ion polishing system (Gatan PIPS II)
- computer controlled dilatometer measurements, DTA, DSC, TG (up to 1600 °C) from Linseis, Netsch,
- LINSEIS LFA 1000/1250 Laser Flash Thermal Constant Analyzer
- SPECTROMAXx - optical emission spectroscope
- SPECTRO XEPOS - Table XRF spectrometer
- LECO CS844 C + S elemental analyzer
- GALILEO ONH elemental analyzer for O; N, H
- LECO ONH836 Oxygen/Nitrogen/Hydrogen Elemental Analyzer

Materials testing equipment:

- universal computer-controlled testing machine for determination of mechanical properties under static loading (tensile, compressive, bending tests) (Zwick; 10 000 kp loading force)
- static creep tests,
- thermomechanical testing
- fatigue tests (hydropulsator MTS, EDYZ)
- abrasive wear testing
- thermal conductivity measurement
- vibration and noise measurement and analysis (Bruel & Kjaer)
- hardness measurements (Vickers, Rockwell, Brinell)
- Universal testing machine Zwick 60 kN equipped for mechanical testing up to 1200 °C
- High speed tensile testing machine Instron 10 kN
- Creep-fatigue testing machine Zwick 5 kN
- Constant load creep machines Zwick
- Constant stress creep machines Zwick
- Instrumented Zwick impact testing machine
- Gleeble 3800 digital closed loop control thermal and mechanical testing system
- Nanoidentation hardness testing machine
- Industrial acoustic emission equipment for monitoring power plans

2.9. Supplementary information and/or comments on all items 2.1 – 2.8 (max. 2 pages in total for the whole section)

The international visibility, position and impact of the IMMM SAS documented the papers that are often the most cited among all publications in corresponding research field published in **respected international scientific journals** covered by Web of Science or Scopus databases. An overview of some publications published in 2016-2021 with **high citation percentile (Esential Science Indicators)** by the authors of IMMM SAS:

No.	Authors, Title and Bibliograhic data	Citation percentile in WoS	Citation Percentile in Scopus
1	KHODABAKHSHI, Farzad** - FARSHIDIANFAR, Mohammad Hossein - GERLICH, Adrian P. - NOSKO, Martin - NAGY TREMBOŠOVÁ, Veronika - KHAJEPOUR, Amir. Microstructure, strain-rate sensitivity, work hardening, and fracture behavior of laser additive manufactured austenitic and martensitic stainless steel structures. In Materials Science and Engineering A - Structural Materials Properties Microstructure and Processing, 2019, vol. 756, p. 545-561.	97th	95th

2	KHODABAKHSHI, F.** - NOSKO, Martin - GERLICH, A. P. Effects of graphene nano-platelets (GNPs) on the microstructural characteristics and textural development of an Al-Mg alloy during friction-stir processing. In Surface and coatings technology, 2018, vol. 335, p. 288-305.	97th	97th
3	LINUL, Emanoil** - MARSAVINA, Liviu - LINUL, Petrica-Andrei - KOVÁČIK, Jaroslav. Cryogenic and high temperature compressive properties of Metal Foam Matrix Composites. In Composite Structures, 2019, vol. 209, p. 490-498. ISSN 0263-8223.	97th	94th
4	MÚČKA, Peter. International Roughness Index specifications around the world. In *Road Materials and Pavement Design*, 2017, vol. 18, no. 4, p. 929-965.	96th	91th
5	MÚČKA, Peter**. Simulated Road Profiles According to ISO 8608 in Vibration Analysis. In *Journal of Testing and Evaluation*, 2018, vol. 46, no. 1, p. 405-418.	96th	94th
6	LAPIN, Juraj** - KAMYSHNYKOVA, Kateryna. Processing, microstructure and mechanical properties of in-situ Ti3Al+TiAl matrix composite reinforced with Ti2AlC particles prepared by centrifugal casting. In Intermetallics, 2018, vol. 98, p. 34-44. ISSN 0966-9795.	95th	94th
7	MIKULA, Marian - PLAŠIENKA, Dušan - SANGIOVANNI, Davide G. - SAHUL, Martin - ROCH, Tomáš - TRUCHLÝ, Martin - GREGOR, Maroš - ČAPLOVIČ, Ľubomír - PLECENÍK, Andrej - KÚŠ, Peter. Toughness enhancement in Highly NbN-alloyed Ti-Al-N hard coatings. In Acta Materialia, 2016, vol. 121, p. 59-67. (2015: 5.058 - IF, Q1 - JCR, 3.417 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 1359-6454.	94th	92th
8	KOVÁČIK, Jaroslav** - MARSAVINA, Liviu - LINUL, Emanoil. Poisson's Ratio of Closed-Cell Aluminium Foams. In Materials, 2018, vol. 11, iss. 10, art. no. 1904. ISSN 1996-1944.	94th	87th
9	AZIMI-ROEEN, Ghasem - KASHANI-BOZORG, Seyed Farshid - NOSKO, Martin - ŠVEC, Peter. Reactive mechanism and mechanical properties of in-situ hybrid nano-composites fabricated from an Al-Fe2O3 system by friction stir processing. In Materials Characterization, 2017, vol. 127, p. 279-287	94th	88th
10	LAPIN, Juraj** - PELACHOVÁ, Tatiana - BAJANA, Otto. High temperature deformation behaviour and microstructure of cast in-situ TiAl matrix composite reinforced with carbide particles. In Journal of Alloys and Compounds, 2019, vol. 797, p. 754-765. ISSN 0925-8388.	93th	93th
11	LAPIN, Juraj** - ŠTAMBORSKÁ, Michaela - PELACHOVÁ, Tatiana - BAJANA, Otto. Fracture behaviour of cast in-situ TiAl matrix composite reinforced with carbide particles. In Materials Science and Engineering A - Structural Materials Properties Microstructure and Processing, 2018, vol. 721, p. 1-7. ISSN 0921-5093.	93th	93th
12	LINUL, Emanoil - MARSAVINA, Liviu - KOVÁČIK, Jaroslav. Collapse mechanisms of metal foam matrix composites under static and dynamic loading conditions. In Materials Science and Engineering A - Structural Materials Properties Microstructure and Processing, 2017, vol. 690, p. 214-224. (2016: 3.094 - IF, Q1 - JCR, 1.669 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 0921-5093.	93th	91th

The international visibility and impact on the largest academic social network ResearchGate (RG) **is very high** among all SAS organizations.

IMMM SAS had in last years on RG frequent weekly representation among **the 10 top read publications of all SAS publications (39 000 in total)** and stable double representation (P. Múčka, J. Kováčik) among **the 10 most popular members of all SAS members (1 750 in total)**.
The weekly most watched works of IMMM SAS belonged in past years often to the **0.025th percentile of all SAS publications** (10/39 000 = 0.025 %) and researchers of IMMM SAS (P. Múčka, J. Kováčik) regularly belonged to **0.57th percentile** (10/1 750 = 0.57 %) **of the most popular authors of all SAS members.**
The most read works of IMMM SAS had about **80–100 reads/week** and the average weekly watch of IMMM SAS papers was over **1 000 reads/week**, which represents the weekly average of **~ 2 readings per work** and was **three times larger** than the average of the whole SAS - **0.65 reads per work**.
Jaroslav Kováčik (71 000 readings in total) and Peter Múčka (60 000) **belongs to the most watched authors of all SAS members** (1 750) at RG.

3. *Implementation of the recommendations from the previous evaluation period*

The previous assessment period was characterized by substantial improvement of infrastructure which formed good preconditions for IMMM SAS to hire new staff (20) and be successful in subsequent European Structural Funds calls as well as HORIZON 2020 calls. However, these goals were only partially achieved.
The government originally planned to launch new calls in the frame of EU Structural Funds aimed at personnel costs and costs to secure the operation of newly achieved and modern equipment. Unfortunately, these calls were not launched and the money was transferred to the Ministry of Transport and Construction to build highways. At the same time, the institutional budget of IMMM SAS was stagnant and required external money to be gained in order to keep the salaries for the current staff without the necessity to release regular employees. It has dramatically affected the scientific scene not only in IMMM SAS but in the whole of Slovakia. The operation of modern equipment is much more expensive than the previous generation however the channels for financing were not opened. Therefore, all resources were primarily invested to keep the infrastructure in operational mode and no additional staff could have been hired.
IMMM SAS was employed in several projects in FP5, FP6 ad FP7 and we expected that this will be the case also in H2020. However, except for FIT-4-NMBP we could not get another project in H2020. In our opinion current scheme of HORIZON projects disproportionally favoured the “big players” in the field who have already had their say in formulating the calls. In most cases these calls were tailor-made to their needs and there remained little room for the rest to show their readiness to compete. Anyway, the success rate in HORIZON projects for IMMM SAS was low and disappointing and we shall have to adopt some new strategy. **IMMM SAS has adopted its own policy of motivating researchers and supporting publication in high-quality scientific journals.** The number of published papers in respected scientific journals indexed in databases Current Contents Connect and SCOPUS and citations substantially increased in evaluated period 2016-2020 in comparison with previous one (Table below).

IMMM SAS – Averaged number of publications and citations per year.

	2012-2015	2016-2020	% change
Current Contents Connect publications	15.75	28.2	+ 79 %
Current Contents Connect publications/FTE	0.387	0.670	+ 106 %
SCOPUS publications	27.75	39.8	+ 43 %
SCOPUS publications/FTE	0.690	1.123	+ 63 %
Citations	396	695	+ 76 %
Citations/FTE	9.79	19.6	+ 100 %

Advisory board
The Meta-Panel repeatedly recommended the formation of an external Scientific Advisory Board to help and advise with the institute´s future scientific orientation. The board was formed and has 5 top internationally recognized scientists experienced in leading institutes. These include:

- **Prof. Dr. Ing. Dalibor Vojtěch**, Department of Metals and Corrosion Engineering, University of Chemistry and Technology, Prague
- **Prof. Dr. Herbert Danninger**, Institute of Chemical Technologies and Analytics, Vienna University of Technology, Vienna
- **Dr. Ludger Weber**, Swiss Federal Institute of Technology Lausanne
- **Dr.-Ing. Thomas Weißgärber**, Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung, Dresden
- **Prof. Ing. Václav Sklenička, DrSc.** Institute of Physics of Materials Czech Academy of Sciences, Brno

This Scientific Advisory Board was formed in April 2020 unfortunately in the very critical period for SARS CoV spreading where the most severe travel restrictions were adopted. Because of safety reasons, taking into account the age of the board members, the planned meeting had to be canceled and the visit of the board to the institute didn´t take place. **However, anew action plan was prepared for the period between 2021 – 2027 as well as propagation video of the institute and a summary of the research activities (IMMM SAS_EN), which is a good base for discussion with advisory board in short future.**

PhD studies
Meta-Panel in its assessment report stated that the number of PhD students (1-2 every year) defending their thesis is appropriate to the number of potential supervisors (10 – 11). However, only one student was from abroad at that time. Therefore, the Institute was recommended to make effort to internationalise the PhD programme and attract international students, but also actively encourage the students to spend part of their PhD-time abroad. Moreover, the potential of novel PhD programmes such as European Industrial Doctorates that would serve to increase linkage possibilities with both public and private enterprises were advised to examine.
The environment for PhD studies in machine and materials engineering got dramatically worse in the reported time. This is mostly due to the low scholarships that the students get during their PhD studies particularly when compared with salaries in the industry. Due to the high concentration of the automotive industry in Slovakia graduated students in the field of machine engineering are highly demanded. They typically earn 1450 € monthly as their starting salary. PhD students get a scholarship not exceeding 940 € in the period of 4 years. This is quite a big difference. IMMM SAS has been trying to mitigate this disproportion by employing the PhD students for a part-time job which slightly increases their income if working on projects with external funding.
However, they earn more than 500 € monthly less than their counterparts employed in the industry. This discrepancy tends to grow during the PhD studies clearly exceeding 24 000 € for the 4-year period. The young people react quite receptively to this difference and the number of those who can neglect it are quite limited. This problem is quite significant particularly in Bratislava, where the living costs are extremely high and the VW car producer with its attractiveness is settled.
To solve this situation, our employees gave promotional lectures on related faculties, we have organized competition for the best work in material engineering, invited students for summer practise, taking part in scientific exhibitions, etc. but the response was not as high as expected. IMMM SAS also tried to react to these undesired developments by attracting foreign students for PhD studies which was in line with Meta-Panel recommendations. We have massively engaged personal contacts as well as services of external worldwide active Keystone Academic Solutions Agency. We were happy to register the interest of hundreds of foreign students to come and make their PhD studies at IMMM SAS. In 2018 five students were accepted for PhD studies and four of them were abroad. **In the reported period of time (2016 – 2021) we have had students from Ukraine (1), Egypt (1), Iran (1), India (3) and Turkey (1). However, the way to proceed the students to Slovakia and the admittance procedure for students from non-EU countries is extremely complicated and time-consuming.** Usually, it takes several months to obtain all requested permissions and get the student to Slovakia. Moreover, it is very complicated and

expensive to get their life partners here as well and serious travelling restriction that had been imposed during the pandemic results in no enrolling some of them. On the other side, some candidates from non-EU countries recognize the PhD studies in Slovakia as a way to get into the EU where further opportunities for studies (with higher scholarships) or work positions (attractive salaries) are open. One student from Iran (Milad Roostaei) decided to quit and return home, one student from India (Prateek Prakash Srivastava) who could not cover the expenses for his family from the scholarship found a job in the industry, one student (Mukesh Nagarbhai Makwana) from India did not fulfil the demands and had to quit as well. On the other hand, Tatiana Pelachova, Kateryna Kamyshnykova from Ukraine and Ahmed Mohamed Hassan Ibrahim from Egypt belong to the best we have ever had and all three were awarded by the director among excellent workers in IMMM SAS. The pandemic period made mobility quite difficult and the intended internships of PhD students on foreign institutes mostly failed. In 2019 Ibrahim Ahmed Mohamed Hassan was admitted for PhD stay in Turkey (1 month) and Veronika Trembošová in Czechia for 2 weeks.
IMMM SAS like all other SAS institutes is in the position of an External Educational Institution that can perform the PhD studies exclusively in cooperation with the contractually bound university. In this sense IMMM SAS performs the education and the university gives the PhD degree. This position is not independent and it is the university that can officially act with regards to PhD studies. Our partner university (Slovak Technical University) has no agreement with foreign partners and is not involved in the novel PhD programmes such as European Industrial Doctorates that are aimed to increase linkage possibilities with both public and private enterprises. We have repeatedly asked the university to open this path for PhD students but it with no result. Currently, we have no way to engage our PhD students in novel PhD programs as recommended by the Meta-Panel in its statement.

4. ***Research strategy and future development of the institute for the next five years*** (Recommended 3 pages, max. 5 pages)

The research strategy of the institute was discussed during the last year and was approved as part of the IMMM SAS action plan for 2022 – 2026 in May 2022. The main task of the IMMM SAS is the research and development of new materials and technologies in a field of material science defined in the Foundation charter, as well as ensuring their applicability. In the field of materials development, it is mainly a study of the relationship between the microstructure, properties and processing. **The aim of the institute for the period 2022 - 2026 is to be successful within the International and European Innovation Area in the field of basic research, applied research and development following the need of solving integrated technological and social problems.** The action plan therefore partially reflects the aims and objectives set out in the European Green Deal, the need for energy independence, as well as the need to be more engaged in global topics that are in line with some EU destinations: transport, green energy, ecology, health and space. The action plan aims to develop a strategy for long-term and sustainable development in terms of a clear and tangible vision for ensuring the quality of human resources, the quality of scientific outputs, the building of scientific infrastructure and a dynamic system of support for research and application development.
From a national perspective, we will continue to be actively involved in national challenges focused on basic as well as applied research. These are VEGA and APVV financing schemes. Moreover, we will be active in the structural fund schemes in individual ministries. The Achilles heel of IMMM SAS is currently the lack of students who ensured the sustainability of research in the future and therefore we have developed an internal strategy for attracting PhD students (more in the annexe IMMM SAS Action Plan 2022-2026 (available at: http://www.umms.sav.sk/en/).
From the international point of view, it is very important to start forming strong international consortia, focused on solving all topics in the main areas of research at IMMM SAS, namely in the areas of:

4.1. Transport
4.2. Energy and environmental engineering
4.3. Space
4.4. Biomaterials
4.5. Interdisciplinary/multidisciplinary research

Transport

- **The next research and development activities for in-situ ultra-fine grained Al-Al_2O_3 composites (HITEMAL®),** which we consider a very promising light-weight high-temperature materials, can be summarised as follows:
  a) The verification of the performance of HITEMAL® in hydrogen environment at higher temperatures as a material with the potential to be highly resistant to hydrogen embrittlement.
  b) The methodology of small punch testing will be utilized to determine the creep performance and the creep mechanisms of HITEMAL® with various microstructures processed via several consolidation technologies.
  c) The detailed analysis of Al grain size refinement limits during plastic deformation and their effective stabilisation mechanisms against grain growth by the Al_2O_3 phases at higher temperatures.
- **Next activities in the field of powder metallurgy** will be also focused on the preparation and on the study of properties of **Al-, Mg- and Ti-based composites strengthened and stabilised by the continuous oxide network prepared from ALD (atomic layer deposition) coated powders**. The comprehensive testing (corrosion properties, creep, fatigue performance, thermal stability, cold working ability) of extruded in-situ Al-AlN composites prepared on the industrial level will be performed.
- **The research main objective is to develop the metal-ceramic porous preforms for pressure-assisted infiltration by molten metal or for direct filtering applications as well.** This complex NiO network determines the level of preform porosity, and our plan is to regulate it by adding ceramic powders such as Al_2O_3 and SiC. The advantages is the cheap and fast production of metal-ceramic composite skeletons/preforms with controlled porosity suitable for pressure infiltration with liquid metal. The skeleton can also be used as a lubricating element, where the lubricant is stored in the pores of the skeleton. After skeleton infiltration by liquid Al the unique metal-ceramic composite materials will be formed. The lower weight of the final material compared to conventional Ni-Al alloys leads to lower fuel consumption, higher performance, lower emissions, structural and thermal stability at higher temperatures, improved thermal conductivity, abrasion resistance and more durable chemical corrosion. The future research activities can be summarized as follows:
  a) Investigation of potential effects of the thermal oxidation regime.
  b) Fabricated skeletons will be examined, with a focus on their porosity, microstructure, and morphological homogeneity in the volume.
  c) Optimization of the infiltration of the porous skeletons by molten Al to validate their suitability for infiltration applications.
  d) Flow-through properties, mechanical and thermo-mechanical properties will be studied.

Energy and Environmental engineering

In the field of materials for hydrogen-related technologies, the future research effort **will be focused on the material design, technology development and characterisation of high entropy alloys (HEAs) and precipitation hardenable complex concentrated alloys (CCAs).** This research will aim to design the alloys, in which expensive elements such as cobalt will be replaced by cheaper ones to develop commercially interesting high-strength CCAs resistant to hydrogen embrittlement, which will be capable to operate at a wide range of temperatures. The future research activities can be summarized as follows:

a) Design of commercially interesting HEAs and CCAs for the production of components for new technologies for storage (pressure vessels) and the production of hydrogen at higher temperatures (e.g., thermochemical cycle).
b) Clarification of fundamental issues of hydrogen absorption in HEAs and CCAs and their resistance to hydrogen embrittlement. Investigation of the effect of precipitation hardening

and grain boundaries on the resistance of HEAs and CCAs to hydrogen embrittlement. The research will include the preparation of alloys with an equiaxed, columnar, and monocrystalline structure.

c) Development of hydrogenation methods (electrolytic, pressure in autoclave and hydrogenation at higher temperatures) and methodologies designed to characterize the hydrogen content and distribution in the investigated alloys. The research activities will be also focused on the development of appropriate methodologies for testing hydrogen-charged materials such as in-situ testing in hydrogen to standardise this process and eliminate the existing large discrepancies concerning the effect of hydrogen on the mechanical behaviour of various alloys.
d) Numerical simulations of deformation behaviour of HEAs and CCAs with a focus on tensile, compressive, impact notched toughness and fracture toughness testing. Numerical simulations of forming processes, especially cold and hot pressing, forging, and rolling with a specific focus on the production of semi-finished products from HEAs and CCAs.
e) Investigation of the relationships between the microstructure and mechanical properties of HEAs and CCAs. Defining analytical models and determining analytical relationships between microstructural parameters and mechanical properties.

Materials for the energy industry

a) Development of new precipitation-strengthened lightweight alloys based on TiAl. The research will focus on the development and optimization of technology for the production of new in-situ composites, characterization of their microstructure and definition of their mechanical properties in a wide range of temperatures.
b) Research and development of expertise for the energy industry with a focus on nuclear energy and new hydrogen technologies. These activities will be focused on the assessment of the long-term operation life of stainless steels used in the Slovak nuclear power plans, welding joins, intergranular corrosion, and non-destructive evaluation of mechanical properties of piping components. These activities will contribute also to the development of new standards for nuclear piping components.

Material for the energy environment

Research in the field of energy is also focused to extend the lifecycle of electrodes using the patented Cu/W method. It is focused on the basic study of erosive wear behaviour produced by the action of plasma arc, in the volume and on the surface of composite electrodes, prepared by gas pressure infiltration of molten Cu into a bundle of W-La_2O_3 rods. The main goal is to describe the formation of a functional layer on the surface of the Cu/W electrode, especially its stability during combustion and re-ignition of the plasma discharge in air at atmospheric pressure. For the analysis electron microscopy, thermo-cycling, as well as the measurement of weight loss at the electrode throughout the experiment will be used. The cooperation with Millennium Technologies, s.r.o. was launched. The research goals can be summarized as follows:

- Optimization of the structure of Cu/W electrodes prepared by gas pressure infiltration technology to achieve rapid heat dissipation from the exposed surface.
- Optimization of parameters of laboratory equipment to ensure ignition and long-term maintenance of plasma discharge for a given type of developed and commercial electrodes.
- Testing of Cu/W electrode in plasma discharge conditions up to the loss of its functional properties.
- Study the formation of a functional layer on the surface of a Cu/W electrode and its characterization. Analysis of the interface between the formed functional layer and the Cu/W electrode.
- Study of the mechanism of erosive wear of Cu/W electrode on the surface, resp. in its volume.
- Characterizations of erosive wear processes of electrodes at the beginning and during the experiment.
- To improve erosion resistance, the electrode structure would be optimized by changing: the shape of the electrodes, volume fraction of W rods with different content of lanthanum

oxide (La_2O_3) in wt. %, with changing density and W rods architecture/gradient, re-melting the surface of the composite electrode before the plasma arc influence.

Space

We plan to evaluate the feasibility of using the Contact Capacitor Discharge Welding procedure for space debris capture in vacuum conditions by performing welding tests in vacuum conditions on a laboratory model of LA-WE respecting its key HW parts and typical spacecraft surfaces. The capture procedure from the welding perspective is baselined as follows:

a) Reaching first contact with positive polarity (one of the three sharp-ended electrodes on the periphery of the Pad)
b) Equalizing electric charges between the objects
c) Achieving full contact with positive polarity (ejection of the electrodes towards the target to penetrate obstacles like e.g., metallic foils and anodized surface)
d) Ejection of the stud (negative polarity)
e) Welding (both polarities require contact with the target during at least 4 to 10 ms – proper suspension/robotic actuation required)
f) Rigidization of the mechanism to increase the stiffness and to enable the proper transfer of loads from the Agent's RCS and/or Propulsion System for Manipulation with Target

The proposed idea application is believed to be continued within the ESA's Space Safety Programme. We have submitted and were successful in the 7th call of PECS ESA Slovakia with a project aimed at Feasibility Study of Contact Capacitor Discharge Welding Gear for Space Debris Capture, and participate also in the call of HORIZON-CL4-2021-SPACE-01 with name Cooperative Multi-Agent Spacecraf, where we have submitted the project with a wide consortium of different countries (TELESPAZIO SPA, Italy as a Coordinator and with partners from following countries: Luxembourg, Slovakia, Italy, Germany, Lithuania, Belgium). The ambition of the consortium is to go beyond the well-established single-system servicing approach.

Biomaterials

New biodegradable material used in prosthodontic surgery based on Ti-Mg.

In the next five years, we expect the completion of preclinical and clinical testing of dental implants (DI) with the optimised design made from Ti-Mg composite (BIACOM®) in order to complex evaluate the final DI and provide them to the market. The study on the corrosion behaviour of Mg materials prepared by powder metallurgy for the use as a bioresorbable materials with respect to the microstructure will be continued.

Zn alloys

The part of biomaterials research will be focused on a study of corrosion of zinc and zinc alloys in conditions of residual or application stress. The aim will be to study the influence of residual or applied stress state on corrosion processes characterization taking place in selected binary and multicomponent Zn-based alloys. The future research activities can be summarized as follows:

a) Production of Zn alloys with regards to extending their corrosion protection (Zn-Al, Zn-Mg, Zn-Al-Mg systems) and biodegradability (Zn-Mg, Zn-Mg-Ca, Zn-Mg-Sr or Zn-Sr-Ca).
b) Complex characterization - microstructural characterization, determination of mechanical properties and residual stress.
c) A comprehensive evaluation of corrosion resistance via electrochemical methods and in in-vitro conditions.

Corrosion tests of non-stressed alloys, with residual stress and/or application stress using SCC stress corrosion cracking equipment.

Interdisciplinary/Multidisciplinary research

Our research will be focused on additive metal manufacturing (AMM) with an interest to develop the cheap metal fused filament fabrication (MF3) of composite materials. The development of Al/Al_2O_3 composite materials is worldwide under development. However, our study will be orientated to open the know-how also of other metallic and composite system procedures. The next perspective novelty here is the combination of additive manufacturing of porous material and gas pressure infiltration technology as an end-use method for the preparation of different types of products.

The research of metallurgical processes and structural transformations of duplex stainless steels (DSS) in the dual laser beam welding (DLBW) process will be carried out. The aim is to assure almost identical austenite and ferrite microstructure (50/50) of the weld, leading to the preservation of mechanical properties within high corrosion resistance of welded components based on previously obtained outputs from simulation programs. The whole process will be simulated and the welding parameters will be optimized. The mechanical and corrosion properties of the obtained welded joints will be tested in order to confirm their preservation with the properties of the base material. The main goals are presented:

a) Creation of a mathematical simulation model.
b) Optimization of the dual beam laser welding process.
c) Optimization of welding parameters.