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AND DEVELOPMENT  
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2023 EXCELLENCE IN SCIENCE

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# FOREWORD

Dear friends,

we feel honoured to invite you to read the seventh publication The Excellence in Science by which the Agency presents the implementation of projects achieving outstanding level. The publication should meet the needs of everybody who is interested in finding more information on research support in Slovakia.

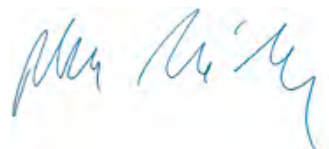
The publication informs about the implementation and results of several years lasting work of Slovak experts on projects from 2018 up to 2022 in the basic and applied research of natural, technical medical, agricultural, social sciences and humanities. Of course, the publication and its content cannot compete with the electronic sources of latest information that are much faster and updated. However, it definitely has certain positives, it enabled us to sum up all the activities conducted by project teams and co-operating institutions within a scientific community in Slovakia. As we have already published the seventh publication, we believe it can clearly present the progress achieved in particular fields of science in which the projects presented in this publication were implemented.

Since its establishment the Slovak Research and Development Agency has been a significant part of the state aid for basic and applied research and development in Slovakia. We are very pleased by the fact you can hardly find anyone from research and development that does not know the name of our Agency. However, it remains our goal to improve every year and support more projects that end up at an excellent level of solution.

Finally, our deepest thank you belongs to all solvers of the projects presented in the publication as well as to those who contributed to the preparation of the seventh publication of the research projects with excellent level 2023.



JUDr. Stanislav Mydlo  
Director

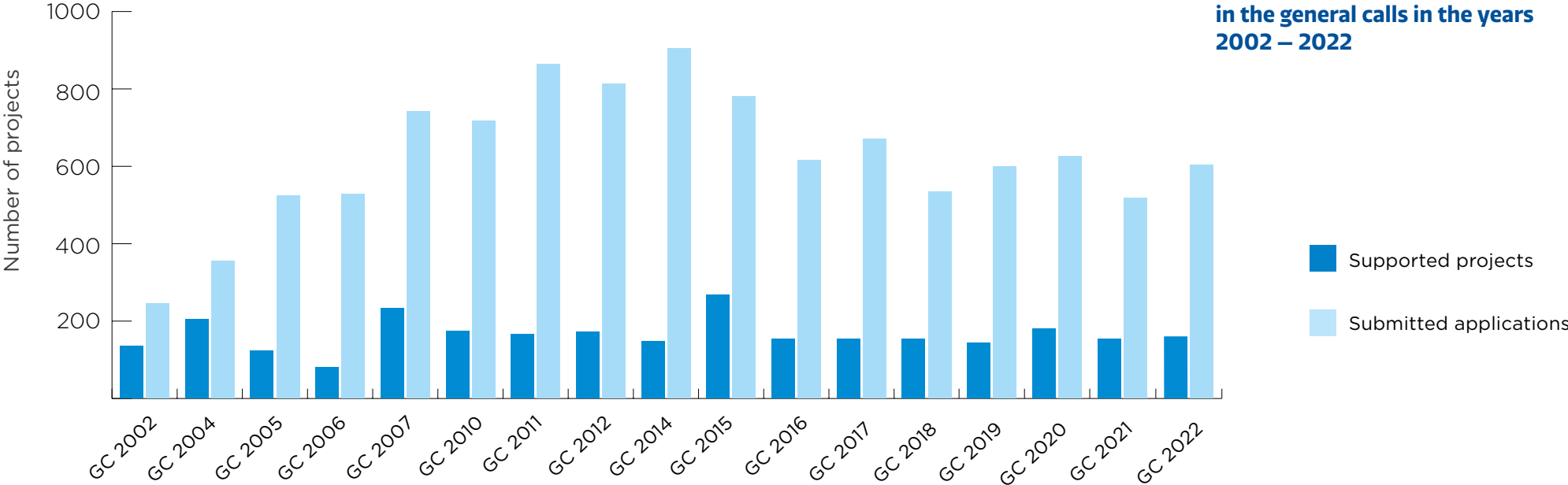


Dr. Ing. Robert Mistrík  
Chairperson



# INTRODUCTION

Summary of applications submitted and supported projects in the general calls in the years 2002 – 2022



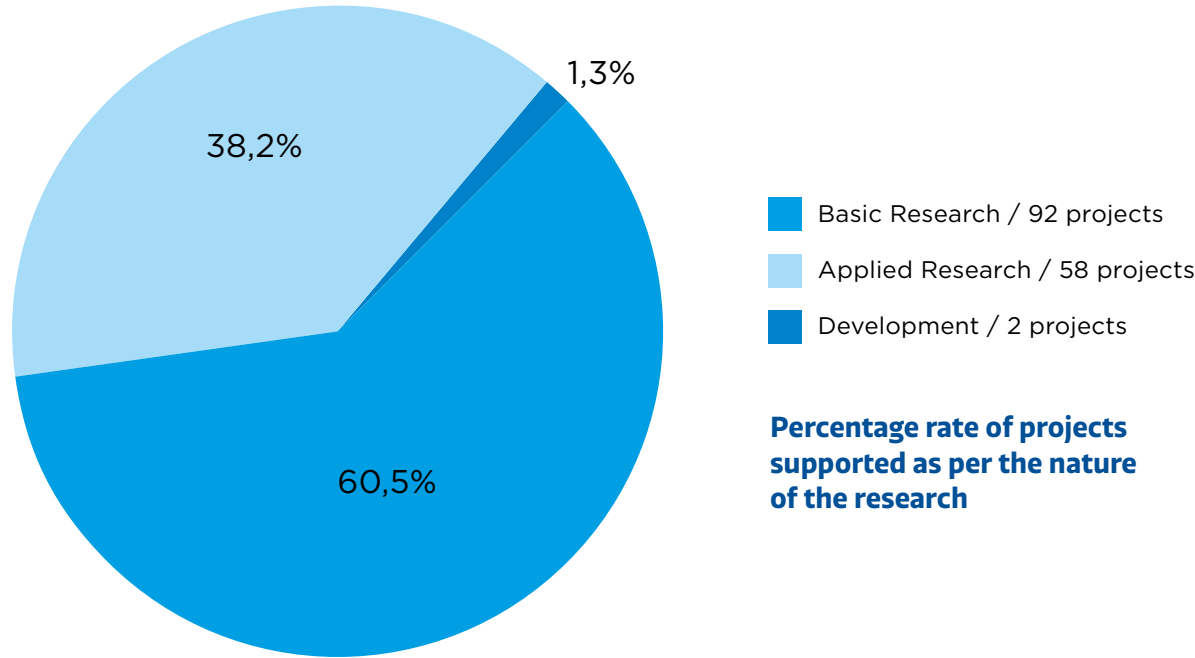
| Department of Science and Technology | Registered applications | Financed projects | Success Rate (%) |
|--------------------------------------|-------------------------|-------------------|------------------|
| Natural sciences                     | 125                     | 30                | 24,0%            |
| Technical sciences                   | 226                     | 48                | 21,2%            |
| Medical sciences                     | 65                      | 13                | 20,0%            |
| Agricultural sciences                | 79                      | 17                | 21,5%            |
| Social sciences                      | 116                     | 26                | 22,4%            |
| Humanities                           | 60                      | 18                | 30,0%            |
| Total                                | 671                     | 152               | 22,7%            |

Success rate of applications supported by GC 2017 as per scientific departments.

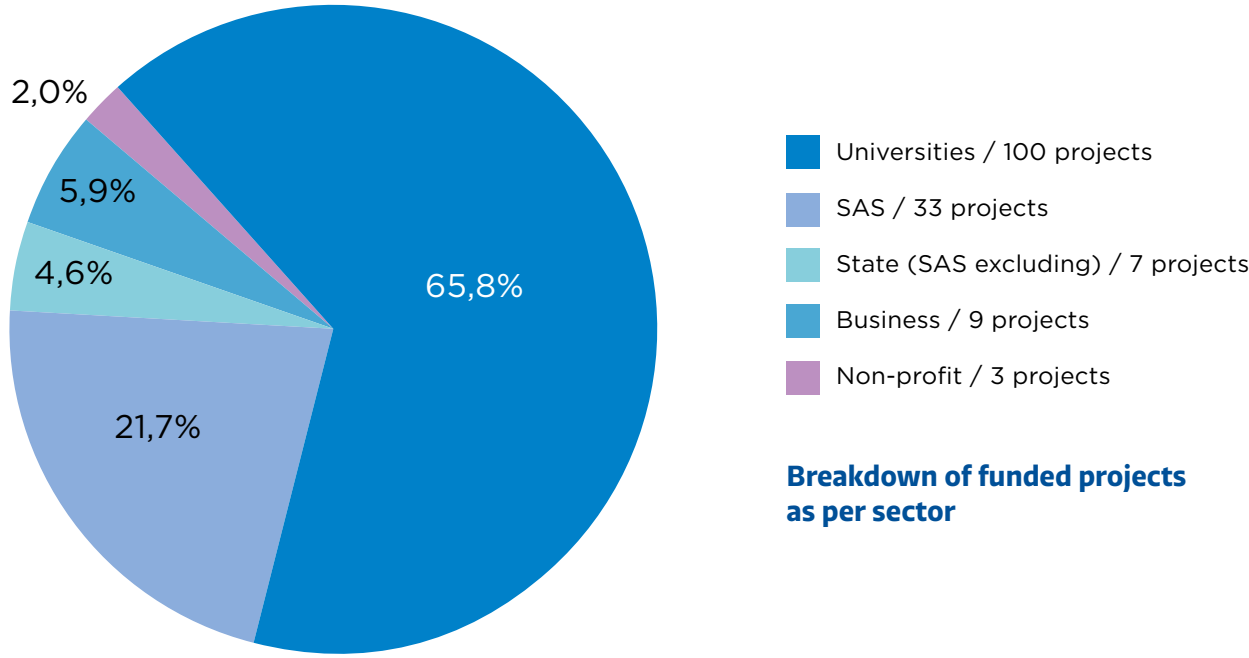
The projects presented in this publication have been submitted within the general call to the Slovak Research and Development Agency marked GC 2017. General Call GC 2017 had no limitations on the substantive focus of the projects. Specific focus, objectives and contents of the research and development were determined by the applicants themselves. Applications could be submitted by legal entities as well as natural persons – entrepreneurs without limitation as per sector of research and development. 671 applications for funding were received and registered as part of the general call GC 2017, in order to resolve research and development projects and 152 applications were supported. Start of the project solution was 1. 7. 2018. Latest date of completion of project solutions was 31. 12. 2022. In 2023 subsequently completed projects were evaluated by different scientific councils on the basis of the final reports on projects submitted by the principal investigator within 30 days of the end of solution.

In this publication the Slovak Research and Development Agency presents the selection of the most successful completed and subsequently evaluated projects from the general call GC 2017 in all sectors of Slovak science and technology.

Success rate of applications supported by GC 2017 as per scientific departments.



Percentage rate of projects supported as per the nature of the research



Breakdown of funded projects as per sector



# NATURAL SCIENCES



## Algorithm of collective intelligence: Interdisciplinary study of swarming behaviour in bats

### Research subject

Several artificial intelligence algorithms inspired by real biological mechanisms have been successfully applied in the life of human society. The joint research of scientific working groups with different foundations, methods and research subjects (biology, mathematics, computer science, technology) focused on the interdisciplinary study of the social self-organising behaviour of tree-dwelling bats in order to develop a new meta-heuristic method for space exploration.

### Aim of the research

The main aim of the project was to clarify the role of dawn swarming as a mechanism of information transfer between bats and to understand how this information flows. We also sought to formally represent swarming behaviour and social aggregation based on observations of a real biological system using a computer agent model. On this basis, we wanted to develop a new method for the spatial search of autonomous mobile robots established on the functional principle of bats.

### Achieved results

We were able to demonstrate that bats, as organisms with higher neural activity and developed cognitive abilities, use a complex social mechanism to keep individuals in a group during frequent changes of tree cavities. This specific mechanism is based on swarming behaviour and exhibits properties of fission-fusion dynamics. We found that the time course and intensity of this behaviour depend on sex, age (experience), the genetic distance of the individual to the colony and the relatedness between individuals, as well as on the hormonal activity of individuals in the social group. The result of the interdisciplinary research is the SkyBat computer model of swarm behaviour. Basic approaches of mathematical formalisation and social aggregation are combined in the algorithm of this agent model. The algorithm is based on the multi-agent behaviour of bats to efficiently search the

unknown space. The principles of the algorithm are directly motivated by the behaviour of a biological model, either at the level of a group or an individual.

### Benefits for practise

Thanks to its unique insights into the mechanisms of collective intelligence in the social structures of biological organisms, the project has potential not only for the fields of theoretical biology, behavioural and evolutionary ecology, but also for research in artificial intelligence. For example, in nature conservation, to simulate changes in the natural environment of forest bat species and to identify a critical number of potential roost sites for the preservation of the colony. In the field of robotics, on the other hand, the results can be used to deploy a series of simple autonomous robots to search an unknown space and look for dynamic objects of interest.

#### Principal investigator

Mgr. Kaňuch Peter, PhD.

#### Applicant organisation

Slovak Academy of Sciences, Institute of Forest Ecology

#### Participating organisations

Slovak University of Technology in Bratislava

- Faculty of Electrical Engineering and Information Technology

University of SS. Cyril and Methodius in Trnava

- Faculty of Natural Sciences of UCM

Slovak Academy of Sciences, Institute of Informatics

#### Term of solution

08/2018 - 12/2022

#### Budget from agency

238 000 €

#### Project ID

APVV-17-0116

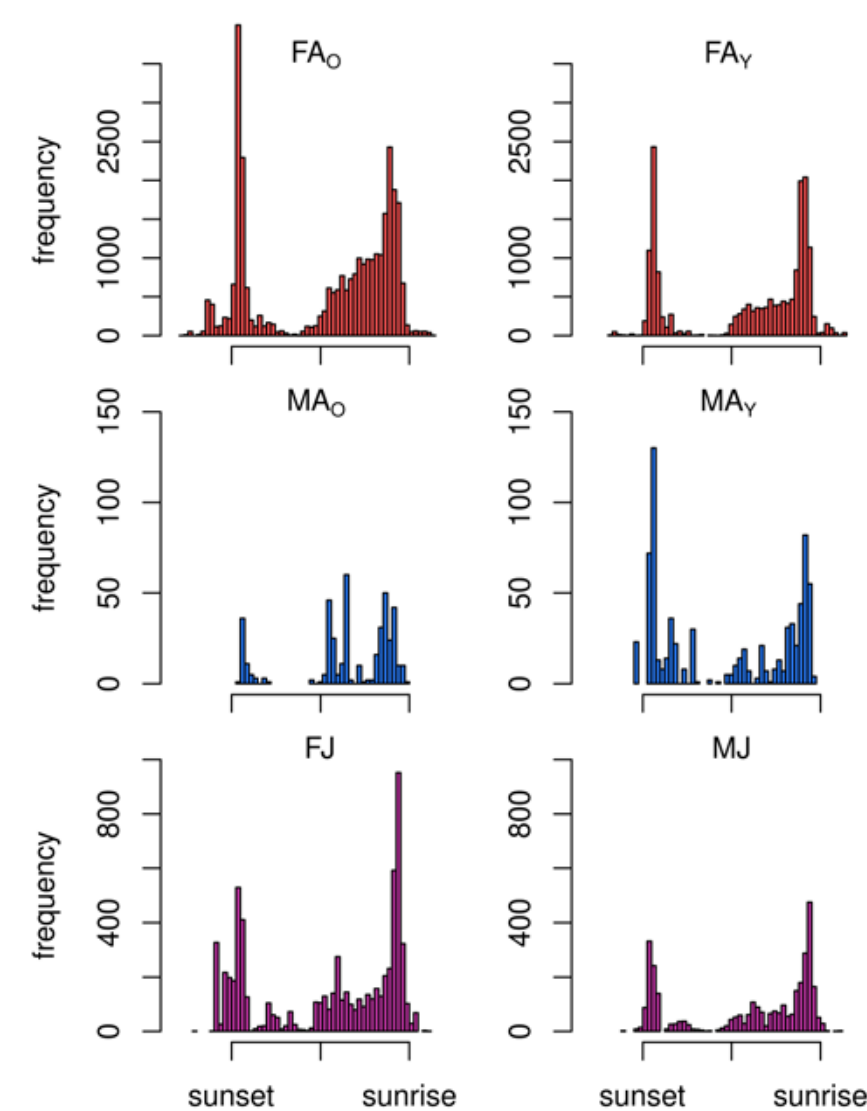


Fig. 1

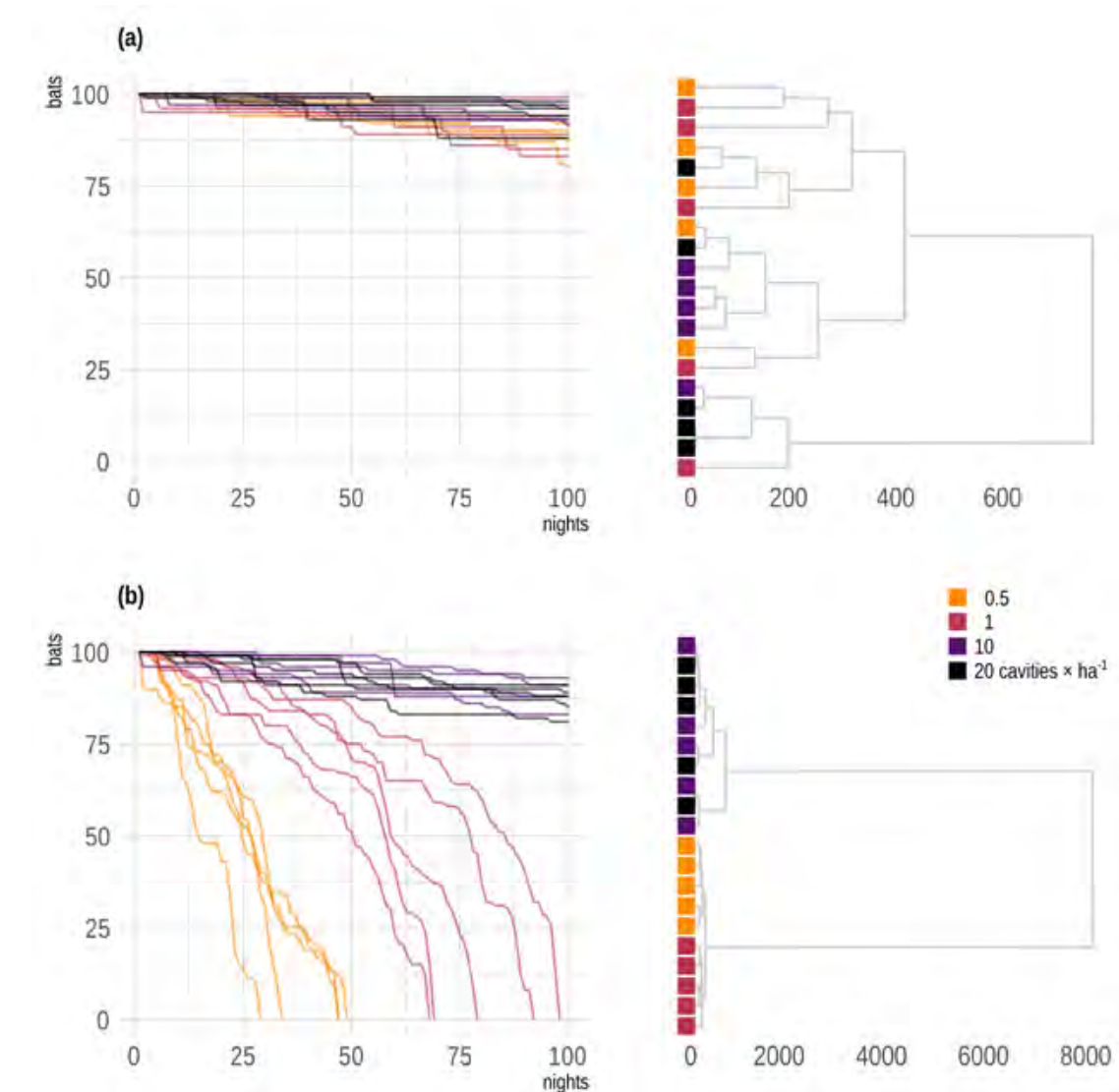


Fig. 2

Fig. 1. / Frequency of swarming events of individuals categorised by sex and age relative to the sunset and sunrise, respectively (codes: F = female, M = male, A = adult, O = old, Y = young, J = juvenile).

Fig. 2. / Results of SkyBat simulations showing the change over time in the number of bats in an environment with varying densities of tree cavities. Group size in which an individual should spend at least one day in the last five days, the so-called rule of "minimum social contact" was required to maintain membership in the colony: (a)  $\geq 5$  individuals, (b)  $\geq 10$  individuals.



## Impact of circadian disruption induced by artificial light at night on physiological and behavioural processes

### Research subject

Light pollution is one of the most pervasive effects of human activity, affecting up to 90% of the world population in areas with artificial light at night (ALAN). The intensity of ALAN is expected to increase, and epidemiological data suggest its negative consequences for human health. While field research demonstrates negative impacts on biodiversity, most studies are only correlative, making it difficult to distinguish cause from effect.

### Aim of the research

Therefore, our project focused on understanding the general mechanisms by which ALAN can disrupt physiological processes and potentially explain the negative consequences of light pollution for health. We studied these mechanisms on a rat model and in humans.

### Achieved results

One of the major outputs of the project is the paper "Light pollution, circadian photoreception, and melatonin in vertebrates" produced by 11 international teams. This study demonstrates that different vertebrate groups are more sensitive to light pollution than light intensities used by current standards. The paper has been cited over 130 times and serves as a reference source for the field and upcoming legislation in Germany.

Experimental results showed that dim ALAN (2 lx) affects circadian organization, lipid metabolism, and the immune system in rats. In the central oscillator, ALAN suppressed rhythms of clock gene expression (Per1, Per2, and Nr1d1), as well as the rhythmic expression of arginine vasopressin, which represents the output of the central clock. The Per1 rhythm was suppressed in the hypothalamic nuclei that transmit circadian signals to endocrine and behavioral rhythms, resulting in a deregulated corticosterone rhythm and eliminated rhythms of vasopressin, testosterone, and the "nocturnal" hormone melatonin. We observed an altered

daily profile of food and water intake, and an eliminated increase in drinking before the onset of sleep, suggesting impaired circadian control of anticipatory thirst and water balance during sleep. ALAN disrupted lipid metabolism and induced accumulation of triacylglycerols in the liver, increasing the risk of steatosis. At the molecular level, we found upregulation of genes involved in fatty acid synthesis and glucose and fatty acid transport. The disturbed balance of lipid biosynthesis may represent one of the causal mechanisms explaining the relationship between ALAN and metabolic diseases. Another negative effect of light pollution is disruption of immune mechanisms that are under circadian control. We show disturbed daily variability of major leukocyte populations in the blood and altered expression of the macrophage marker Cd68 and the chemokine Ccl2 in the renal cortex, suggesting consequences on the leukocyte trafficking to tissues. We also found impaired renal redox and immune balance.

From a translational point of view is important, that even low light intensity at night (1 lx) interferes with sleep quality in healthy people, without affecting melatonin levels. Melatonin levels decreased at intensity of 5 lx, but only when considering individual variability. This finding suggests that assessing the effect of ALAN on melatonin concentrations on a group basis is inadequate because it substantially underestimates the results due to the high interindividual sensitivity to light at night.

We presented the results of the project through invited talks at conferences such as "Artificial Light at Night" (2020, Spain), EALPO (2019 and 2022, Poland), and CSET (2022, Brno). Moreover, prof. M. Okuliarova received a financial award for her lecture at the World Congress "EBRS" (2022, Zurich, Switzerland). Additionally, a travel grant for presenting the project results at the meeting "Metabolism in Action" was awarded to PhD student Mgr. Rumanova (2022, Copenhagen, Denmark).

**Principal investigator**  
prof. RNDr. Zeman Michal, DrSc.  
**Applicant organisation**  
Comenius University Bratislava  
- Faculty of Natural Sciences  
**Term of solution**  
08/2018 - 11/2022  
**Budget from agency**  
238 000 €  
**Project ID**  
APVV-17-0178

### Benefits for practise

The project represents basic research with 24 papers in scientific journals, which were cited more than 250 times. The results were also presented to public through the mass media (RTVS, TV JOJ), as well as to the municipalities' staff at a seminar organized by the Ministry of Environment of the Slovak Republic and also Czech Republic. We participated in the realization of the documentary film "In the Light of the Night", This film and othe activities are available at "<https://fns.uniba.sk/kzf/>". The project also contributed to the education of students at all three levels of higher education, 4 PhD students successfully completed their studies and other 4 continue their studies.

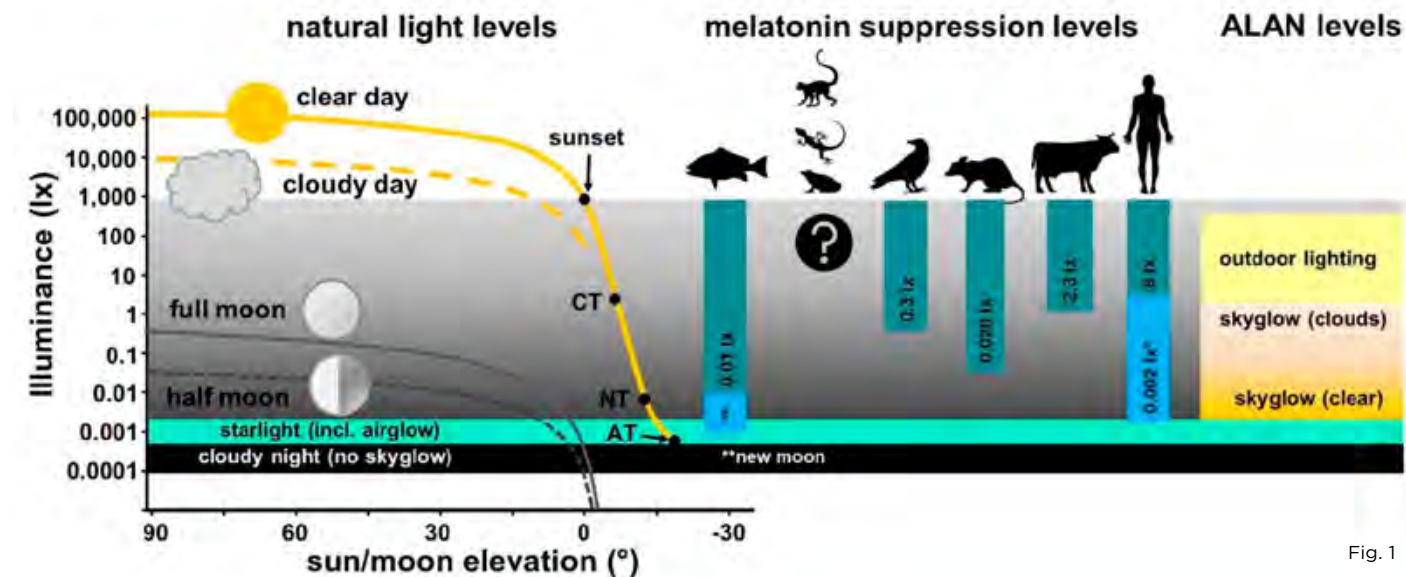


Fig. 1

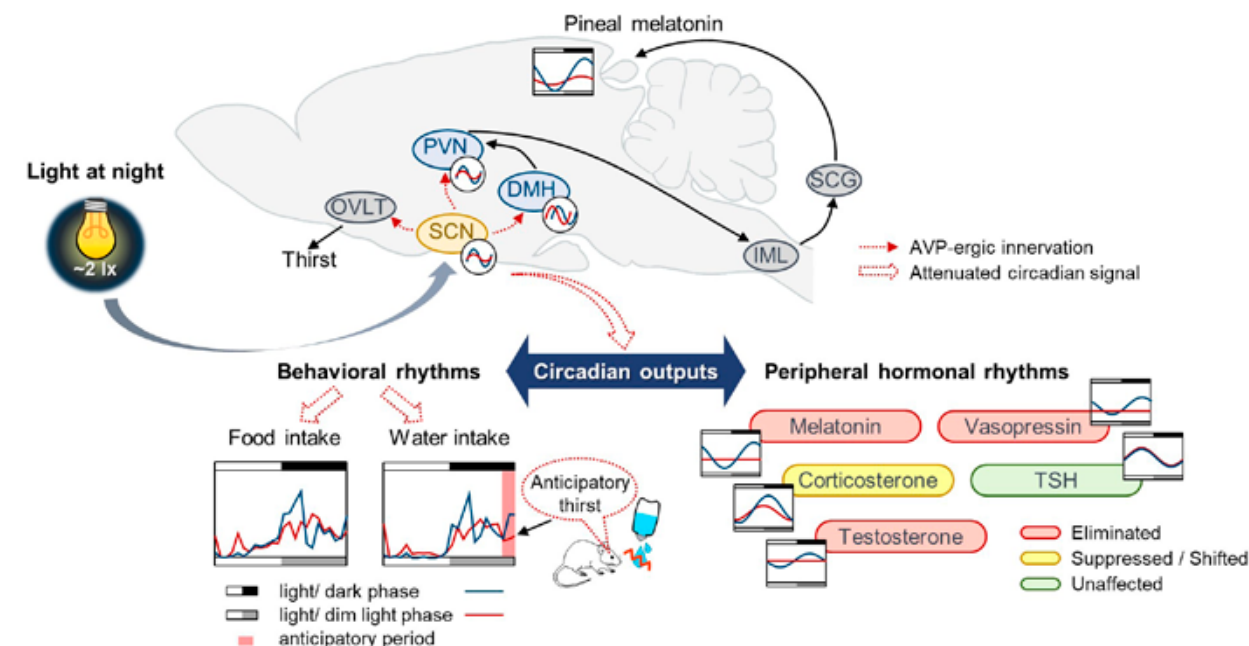


Fig. 2

Fig. 1 / Minimum lighting levels reported to suppress melatonin concentrations in different vertebrate groups relative to light levels by natural and artificial light (ALAN) sources.

Fig. 2 / Outline of multiple circadian output pathways compromised by dim light at night. Dim light at night suppresses rhythmic expression of the clock and clock-controlled genes in the suprachiasmatic nuclei (SCN). The suppressed rhythm of vasopressin (AVP) results in attenuated transmission of circadian information to the brain structures, which receive input via vasopressinergic innervation (red dotted lines) from the SCN, such as downstream nuclei PVN and DMH, and the OVLT (organum vasculosum of the lamina terminalis), which controls drinking behaviour.

Fig. 3 / Outline of pathways how artificial light at night (ALAN) disrupts control of metabolism in the liver and adipose tissue. ANS-autonomic nervous system; GLU-glucose, TAG-triacylglycerols; CH-cholesterol; metabolic genes.

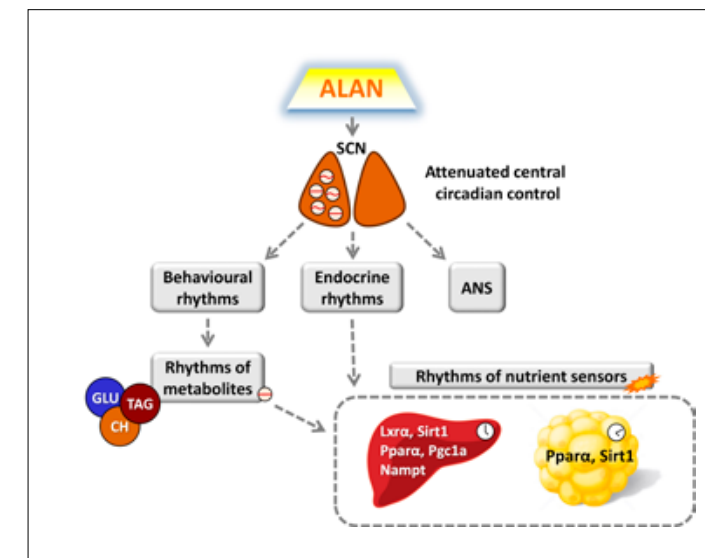


Fig. 3



# Metric and spectral invariants of graphs and their applications in modeling networks, molecules and other structures

## Research subject

The project focused on metric and spectral invariants of graphs and their applications in modelling networks, molecules and other discrete structures. These are naturally modelled by graphs in the way that nodes (or atoms, etc.) are represented by vertices and linkage elements (or chemical bonds, etc.) between a pair of nodes are represented by edges of a graph. By metric and spectral invariants one means numerical and structural parameters derived from distances and spectra (families of eigenvalues and eigenspaces associated with matrices that represent graphs). Particular emphasis was given on the study of invariants motivated by application in chemistry and in network design. Examples include various types of topological indices (such as the Wiener and Balaban indices, etc.) and spectral gaps representing bond energy in molecules, as well as invariants reflecting issues in network design, such as diameter and girth of graphs. Often a special role is played by symmetries, as their presence may greatly facilitate analysis and construction of the corresponding models. These aspects were successfully studied in the past (and also by members of the proposed team) with the help of methods originating in algebraic graph theory. Within this framework, specific aims of the project can be summed up in the following statement:

*The fundamental objects of investigation of the proposed project were metric and spectral invariants of graphs as models of various types of networks, molecules and other discrete structures, with focus on utilization of algebraic methods for analysis and properties prediction of models from the point of view of applications.*

## Aim of the research

The aim of the proposed project was to make progress towards solution of open problems in three specific areas of research, matching world-wide trends therein. Particular goals included:

(a) Obtaining new substantial results in the investigation of topological indices (the Wiener, Balaban, Graovac-Pisanski, and possibly other indices with applications in chemistry) of particularly interesting infinite families of graphs, including a development of the associated theory of relations between indices (often being defined in a hardly penetrable way).

(b) Deriving new and influential results in the area of graph inversion and related spectral bounds, and also in constructions of new infinite classes of invertible graphs by means that have not been used here before (e.g. covering spaces). We also anticipate development of a new methodology of meaningfully inverting graphs with a singular adjacency matrix (in the sense of inverting the non-zero part of the spectrum).

(c) Proving new substantial results in constructions of extremal vertex-transitive and Cayley graphs (and, in general, graphs with relatively few orbits compared to the order) in the degree-diameter and the degree-girth problem.

## Achieved results

Works on the project resulted in 34 peer-reviewed publications in various international journals, out of which 17 were published in journals covered by the Current Contents Database (CC), 14 were published in other peer-reviewed international journals, and 3 in peer-reviewed proceedings. As outcomes we obtained numerous influential results in algebraic theory of graphs and maps, metric graph theory and design theory, with the following highlights:

- influential results in the study of nanotubes [V. Andova, M. Knor, R. Škrekovski, Distance based indices in nanotubical graphs: part 3. J. Math. Chemistry 59 (2021), 250-263 (CC)]

- classification of symmetric maps without Gorenstein-Walter theorem [M. Conder, J. Širáň, Classification of regular maps of prime characteristic revisited: Avoiding the Gorenstein-Walter theorem, J. Algebra 548 (2020), 120-133 (CC)]

## Principal investigator

prof. RNDr. Širáň Jozef, DrSc.

## Applicant organisation

Slovak University of Technology in Bratislava

- Faculty of Civil Engineering

## Term of solution

08/2018 - 07/2022

## Budget from agency

93 175 €

## Project ID

APVV-17-0428

- results in a number of papers coauthored by M. Knor on topological indices of graphs, e.g. [S. Bessy, F. Dross, K. Hriňáková, M. Knor, R. Škrekovski, The structure of graphs with given number of blocks and the maximum Wiener index, J. Combinat. Optim. 39 (2020), 170-184 (CC)]

- constructions of nut-graphs of given valency [N. Bašič, M. Knor, R. Škrekovski, On 12-regular nut graphs, Art Discrete Applied Math. 5 (2022) #P2.01, 7s (CC)]

- classification of edge-biregular maps on surfaces of characteristic  $-p$  [O. Reade, J. Širáň, Classifying edge-biregular maps of negative prime Euler characteristic, The Art of Discrete Applied Mathematics 5 (2022), #P3.08, 29pp (CC)]

## Benefits for practise

The project was aimed at obtaining theoretical results.

## Smart chromogenic heterocycles

### Research subject

Smart heterocyclic compounds have an essential role in the creation and preservation of life in nature and society. Currently, the main challenges of the existence of human society are the preservation of food sufficiency with a good level of health, the preservation and renewability of energy and raw material resources. The solved project gives hope for the sustainability of life in two areas - energy and health.

### Aim of the research

Design, synthesis, optimisation of the performance and spectroscopic properties of novel responsive chromogenic heterocyclic systems e.g. bio- photo-, electro-, thermo-magneto- and piezo- chromic heterocycles, and their applications. Synthetic methodology related to the de-novo synthesis of chromogenic heterocyclic ring systems e.g. thiophenes, pyrroles, and various azoles including pyrazoles, isoxazoles and their benzologues. The investigation of new and alternative synthetic strategies to useful pi-conjugated organic molecules as building blocs and study of physico-chemical and biological properties of newly prepared compounds. Search and design of chromogenic structures based on requests of co-operating domestic and foreign scientific groups.

### Achieved results

The most important results are publications in Slovak and foreign journals - a total of 19 and 140 citations, which speak of the quality and response of these publications. The project resulted in 9 scientific works published in peer-reviewed scientific journals in the Slovak Republic and 2 abroad, 16 scientific works published in non-reviewed professional journals and collections in the Slovak Republic and 10 abroad, 5 scientific monographs, 2 university textbooks.

The prepared heterocycles proved to be ideal materials for the **study of various properties or applications** (smart chromogenicity).

Activated aromatics and alkenes can also provide suitable substrates for nucleophilic substitutions. Reactions with compatible nucleophiles lead to interesting products or intermediates of organic synthesis (Fig. 1).

A new method for the preparation of (hetero)arylnitriles based on the fragmentation of the corresponding pentafluorophenylhydrazones was described with moderately good yields ("green chemistry" approach)(Fig. 2).

We have published the discovery and detailed investigation of an unconventional photoswitching mechanism of metallofullerenes, in which the energy of a photon absorbed by the carbon cage of the pi-system is changed into mechanical movement of the endohedral cluster associated with the accumulation of spin density on the metal atoms. Comprehensive photophysical and EPR studies augmented by theoretical modeling were performed to elucidate the phenomenon of light-induced photo-switching and the dynamics of the triplet spin state (Fig. 3).

Redox-active resorcin[4]arene-quinone cavitands were modified with thioether functional groups on the spondal edge of the cavity, for easier anchoring to various surfaces and functionality as electro-controllable switches that change conformation in response to changes in applied electrical potential (Fig. 4).

We regioselectively de-O-methylated and then haloalkylated berberine as a biologically active alkaloid. We prepared berberine - bridge - ciprofloxacin bridge conjugates (Fig. 5) and found that new berberine derivatives are potential growth inhibitors of HeLa and HL-60 tumor cell lines.

**Principal investigator**  
prof. Ing. MILATA Viktor, DrSc.  
**Applicant organisation**  
Slovak University of Technology in Bratislava  
- Faculty of Chemical and Food Technology  
**Term of solution**  
08/2018 - 12/2022  
**Budget from agency**  
240 000 €  
**Project ID**  
APVV-17-0513

### Benefits for practise

The project was focused on the smart chromogenicity of heterocyclic compounds, which within the framework of basic research brings additional potential for the application of the research results obtained by the project solution for applications in practice. Part of the work is focused on the preparation of selected types of compounds. The study of their structure and properties is a basic starting point for future applications.

The use of prepared compounds is in several areas that we have studied theoretically and practically as potential semi-conductors, photovoltaic, magnetic materials or biologically active compounds. The potential for hydrogen absorption on graphenes was also studied in connection with our current studies of azagraphenes.

We expect the development of cooperation in the newly submitted APVV project in cooperation with the NBU SAS (APVV-22-0028). The theoretical study of potential antivirals from the structures synthesized by us in the previous period and in the near future within the focus of our project (smart chromogenicity) is taking place in the projects APVV-20-0213 and Project no. 313011ASS8 (ERDF).

Fig. 1. / Synthetic potential of the trisubstituted a,b-unsaturated nitrocompounds

Fig. 2. / Preparation and reactions of pentafluorophenylhydrazones

Fig. 3 / Molecular structures of  $YxSc3-xN@C_{80}$  ( $x = 0-3$ ; Y - green, Sc - magenta, N - blue, C - pale grey) and their luminescence and low-energy absorption spectra

Fig. 4 / Switching between open and closed conformation of cavitand anchored on Au surface during reduction from quinone(Q) to semi-quinone(SQ) (DFT-optimized model)

Fig. 5 / Berberine and its derivatives

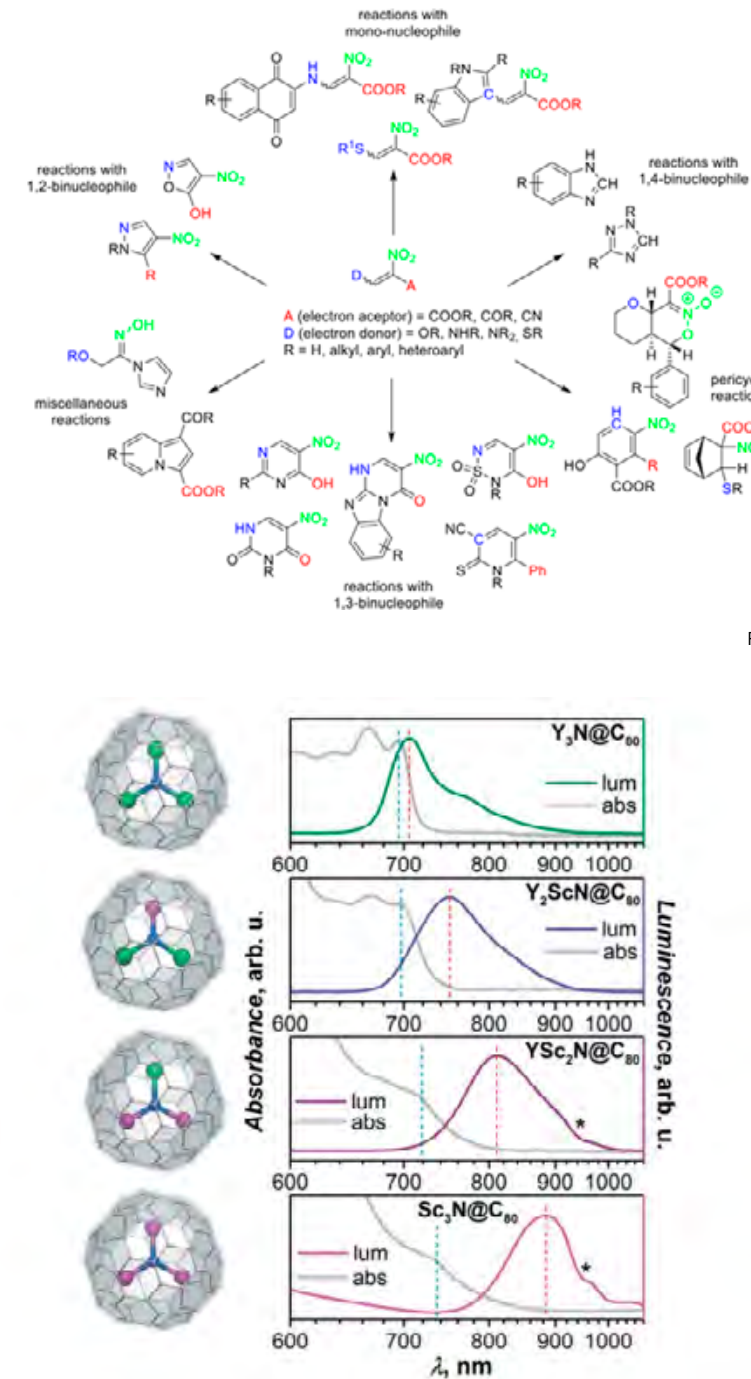


Fig. 1

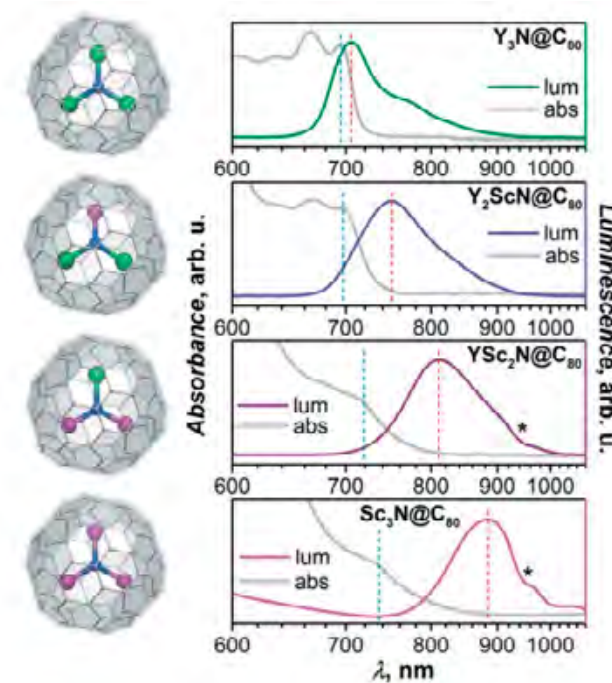


Fig. 3

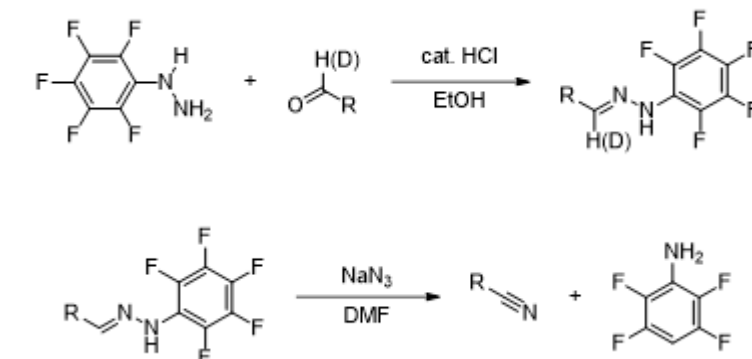


Fig. 2

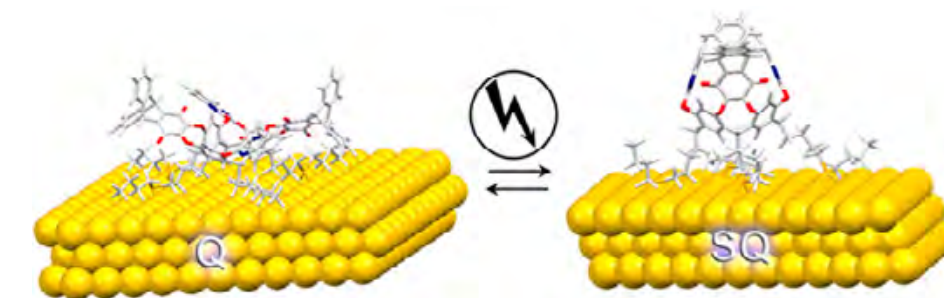


Fig. 4

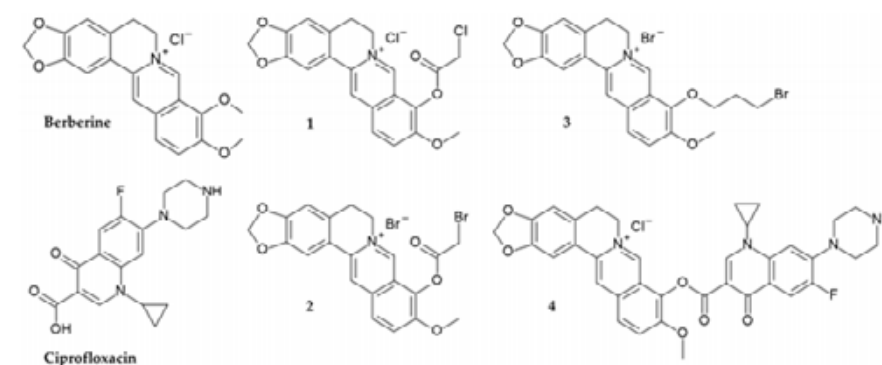


Fig. 5



## The mechanism of positional signalling in plants – understanding of the DEK1 pathway

### Research subject

Positional signalling plays a key role in plant growth and development. Positional signals determine what type of cell will develop in a certain position of plant body and how big this cell will grow. Ultimately, these factors contribute to the morphology and anatomy of plant organs. Genetic analyses in cereals uncovered a multi-domain membrane protein DEFECTIVE KERNEL 1 (DEK1) as a key regulator of position-dependent aleurone layer development in the seed endosperm. Aleurone cells represent an important source of energy-rich proteins, oils, and enzymes with industrial significance. Later, it has been shown that DEK1 is indispensable for any organized growth in plants starting from early embryogenesis. DEK1 also represents the only calpain in land plants. Despite essential functions of DEK1 in plant development, many aspects of its molecular mode of action remain unknown. In our lab, we use diverse approaches and technologies to unravel how DEK1 is regulated and what are its direct molecular targets in cells. Mechanistic understanding of DEK1 function will provide important information about molecular principles of plant development with implications for agriculture and biotechnology.

### Aim of the research

The aims of this project followed two major lines of DEK1 research in our lab: (i) genetic and functional dissection of DEK1, and (ii) efforts towards the DEK1 protein 3D structure determination. Using reverse genetics and targeted mutagenesis, we aimed to investigate the role of predicted DEK1 domains and functional sites in plant growth and development. Using transcriptome, proteome, and computational approaches, we aimed to identify DEK1 calpain targets. In the frame of structural biology efforts, we aimed to produce and purify particular DEK1 domains using diverse expression systems.

### Achieved results

In the model plant *Physcomitrium patens*, we generated lines with fluorescent protein inserted in the native DEK1 using the *knock-in* strategy. Thanks to these lines we were able for the first time to describe polar distribution of DEK1 in cells. We also observed differences in DEK1 accumulation depending on the developmental stage of particular organs. For instance, in the developing male reproductive organs (antheridia), DEK1 localizes in plasma membranes of neighbouring cells, while in mature antheridia this signal vanishes, and appears in the male sperm cells (spermatozooids).

Using targeted mutagenesis, we generated several *P. patens* mutants with specifically modified DEK1. Phenotyping of these lines revealed the importance of particular DEK1 functional sites for plant development. Five individual *P. patens* lines with diverse *dek1* genotype were used for robust transcriptomics and computational analyses. We generated and analysed *P. patens* life cycle gene regulatory network. The data mining identified several regulons positively and negatively affected by DEK1. One of the identified regulons associated with DEK1 activity was the APB-CLAVATA-CLE regulon that plays an important role in the control of plant meristems (stem cells).

In the frame of our long-term efforts to solve the DEK1 3D structure, we optimized protocols for expression and purification of selected recombinant DEK1 domains.

### Benefits for practise

The investigation of DEK1 function in the context of positional signalling in plants represents a basic research discovering fundamental molecular principles of plant growth and development. Mechanistic understanding of the „DEK1 pathway“ has implications for agricultural industry and biotechnology. Our gene regulatory networks analyses open

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**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
239 000 €  
**Project ID**  
APVV-17-0570

doors for prediction and association of particular developmental traits with particular genes. We also introduced a new concept for plant calpain function in the regulation of cell fate. This project enabled implementation of new progressive methods in the field of plant experimental biology and so significantly contributed to the education and training of young scientists.

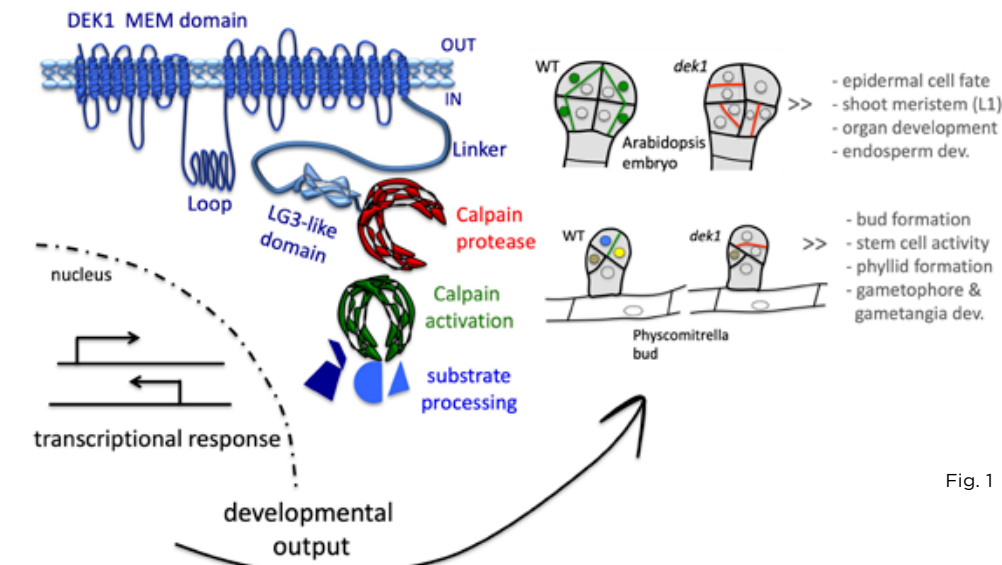


Fig. 1

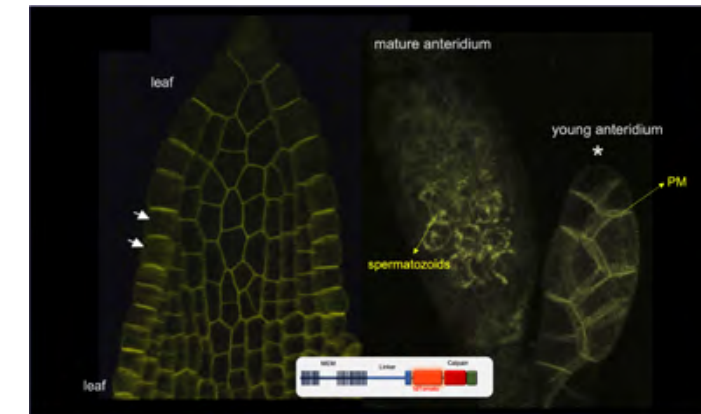


Fig. 2

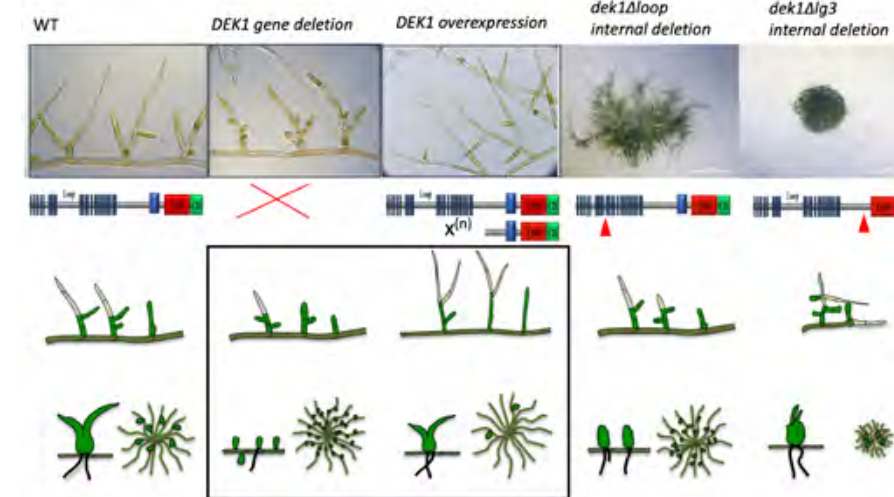


Fig. 3

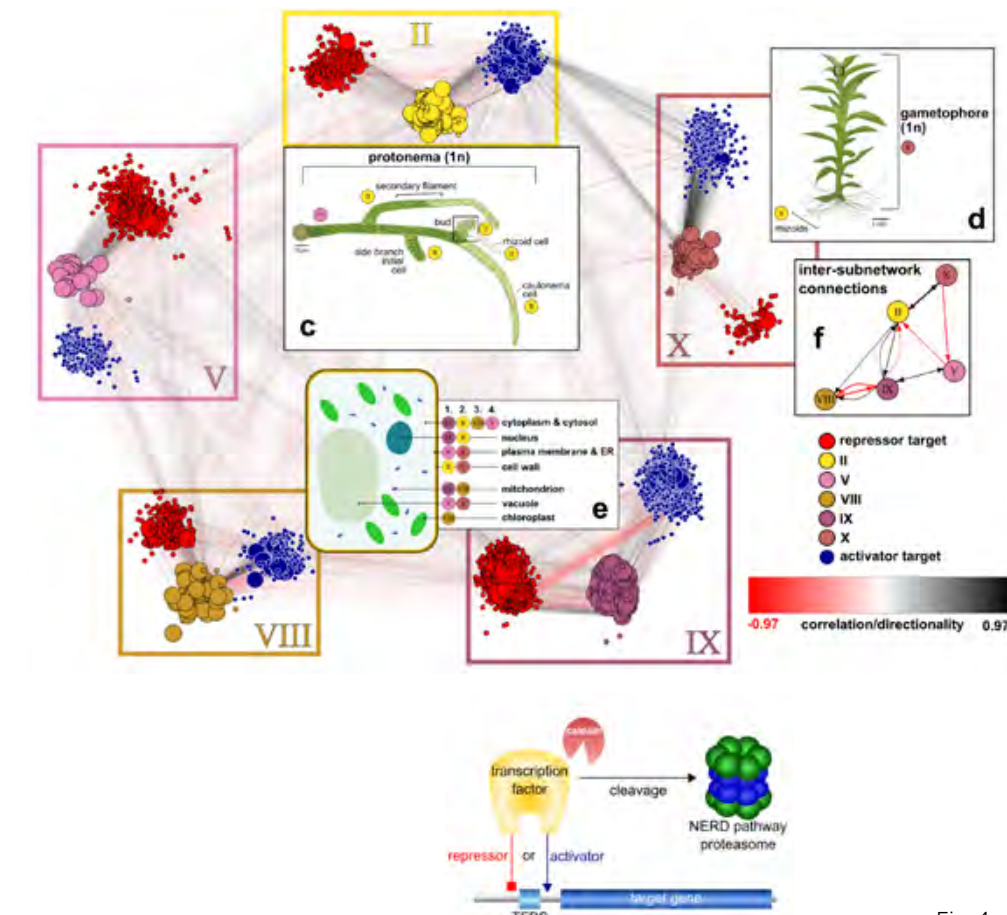


Fig. 4



# TECHNICAL SCIENCE



## Systematical approach to study the alterations of fire parameters using the progressive analytical and forensic methods

### Research subject

The research in the area of fire engineering in accordance with world trends in the use of progressive methods to determine important fire and material characteristics for the needs of calculations and modelling of internal fires. The use of latest knowledge of fire engineering and related scientific disciplines.. The benefit was the implementation of current scientific procedures in fire engineering and the use of its results in fire prevention, in the evaluation of fire-resistant modifications of materials and products and in reducing the negative environmental and socioeconomic consequences of fires.

### Aim of the research

The main scientific goal: The development and verification of a methodology for the application of a systematic approach to the study of changes in internal fire parameters based on mathematical modelling and calculations with original input parameters obtained through the application of progressive analytical and forensic methods.

The partial objectives: Characterization of selected progressive test methods, materials and test conditions; Multidimensional testing of representative materials, selected structural elements and building structures; Creation, validation and verification of fire models; Proposal of areas of implementation of project results.

### Achieved results

The creative use and modification of progressive laboratory methods in combination with standard methodologies for determining the fire and material characteristics of wood and wood-based materials. The methods were validated and used in obtaining original results.

Progressive methods were used for laboratory testing of changes in the macromolecular characteristics of the main components of wood and for the identification of chemical reactions that took place as a result of thermal loading.

Other progressive laboratory methods were used to evaluate the effect of flame retardants as additional methods to the standard and non-standard determination of fire characteristics.

New methods have been developed to determine the burning rate, the charred layer of wood and the fire resistance of wooden beams. The results of small-scale laboratory tests of test specimen were used in the verification of the calculation model of temperature profiles in wood. The medium-sized tests were aimed at determining the influence of the characteristics of the structures on the course of the fire and fire resistance. The results were further applied to the assessment of structural changes in wooden buildings during a fire.

The created database of original fire technical and material characteristics of polymeric materials was applied to computer-supported modelling for the needs of determining the causes of fire and fire safety of buildings. The modelling was aimed at estimating the charring thickness of wood and building elements after being loaded with heat flows corresponding to the first stage of internal fire development. Fire modelling has been extended to forest fires. The input data for the modelling were obtained through our own field research and subsequent progressive laboratory methods for characterizing the collected fuel.

Identified area of results implementation of the results is the section of determining the causes of the fire, e.g. for determination of the fire focus and the use of a fire accelerator. The measurement of the charred layer has a main application in the field of fire testing (solution of residual effective cross-sections), but also in the field of determining the causes of fires (places with the highest temperatures near the place of fire). The results of computer-supported modelling of the progress of fires are used in the assessment of fire safety and fire protection modifications.

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**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
248 820 €  
**Project ID**  
APVV-17-0005

The developed methodology of a systematic approach to the study of changes in internal fire parameters (material characteristics - medium-scale tests - large-scale tests and the use of computer-supported modelling and calculations) was applied for natural fires.

### Benefits for practise

The application of the original results: in fire testing (e.g. comprehensive assessment of changes in materials after thermal load and burning by combining standard and progressive laboratory methods, resp. developed new laboratory methodologies for sampling and analysis of thermal decomposition products), in the evaluation of the contribution of materials and statements to fire, in fire engineering (e.g. supplementing the database of fire and safety characteristics of materials and their use in a computer supported modelling).

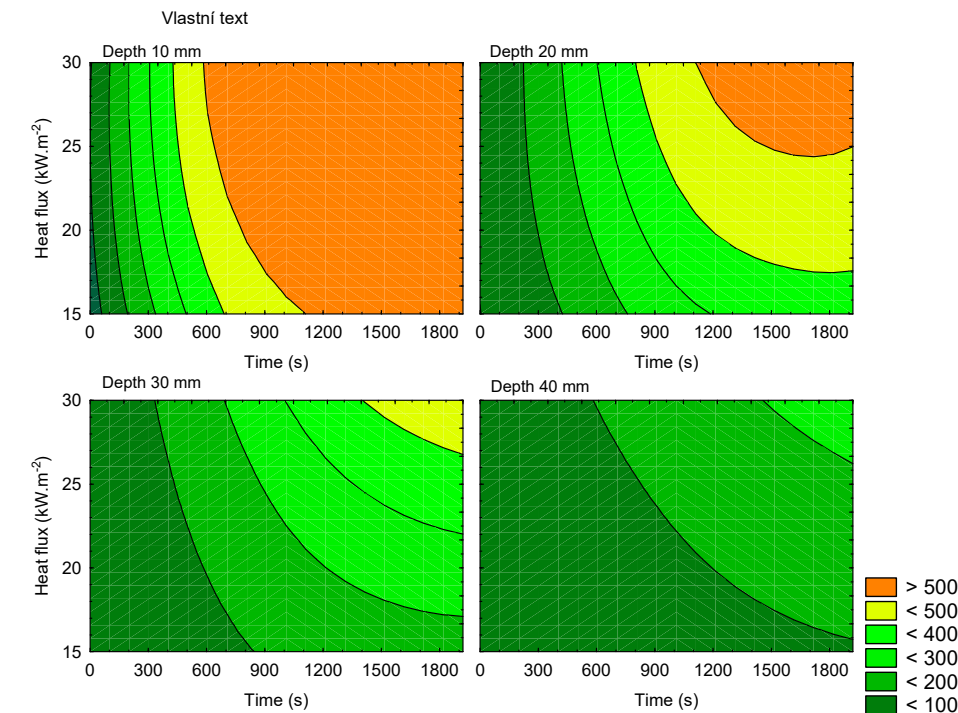


Fig. 1

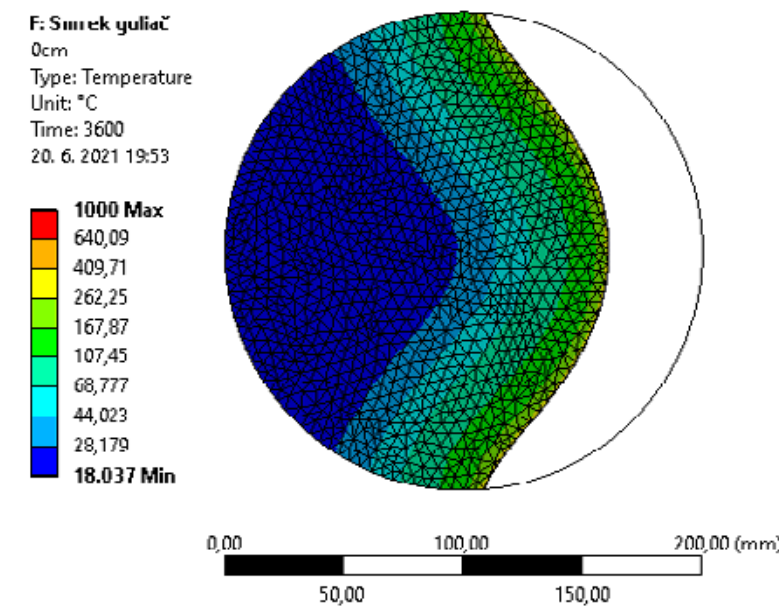


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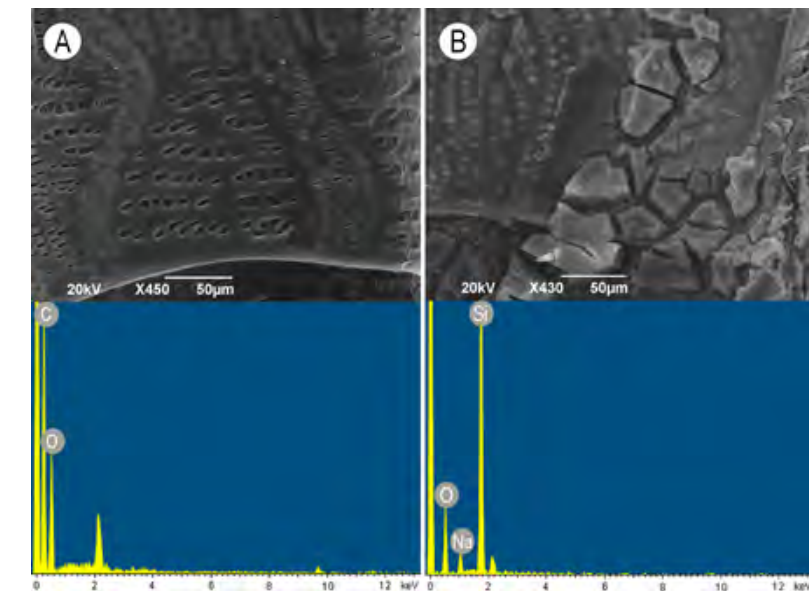


Fig. 2



Fig. 4

Fig. 1 / Charred layer formation in spruce wood after a radiant heat source loading

Fig. 2 / SEM images of original and water glass treated oak wood and EDX spectra

Fig. 3 / Computer simulation – a fir log after radiation source loading

Fig. 4 / Sample cut of a fir log after radiation source loading



## Development of new biodegradable metal alloys for medical and prosthetic applications

## Research subject

Metallic glasses are a subgroup of metal alloys whose internal structure is disordered (amorphous). A promising group are amorphous alloys based on calcium, due to their interesting properties from the point of view of use in medicine and surgery. Binary as well as ternary systems of the type Ca-Mg, Ca-Zn, Ca-Mg-Zn, Ca-Mg-Sr and Ca-Mg-Zn-X, X=(Sr, Si, Zr, Li) consist exclusively of bioabsorbable metals and thus their biocompatibility with the human body is guaranteed. Bioabsorbable metals/alloys consist of elements already existing in the human body. The organism has an inherent tolerance to them. They gradually dissolve in the host's body (in vivo), have a beneficial effect on the healing process and their presence in the patient's body ends without residues.

## Aim of the research

The main goal of the project was to prepare and characterize a series of ultralight amorphous alloys made from bioabsorbable elements (Ca, Mg, Zn, Sr, Si, Zr, Li), i.e. elements existing in human organism and to which the body has inherent tolerance. Applications of these materials are directed to the field of medicine - for the preparation of implants with targeted biodegradation in the patient's body, such as: osteosynthetic screws, discs, rivets and nails used in the process of reconstruction of osteoporotic fractures.

## Achieved results

In order to obtain metallic amorphous materials, a total of 70 completely new alloys of Ca-Mg-Au, Mg-Zn-Sr, Mg-Zn-Ca and Ca-Mg systems in the form of thin strips were designed and prepared (also by using artificial intelligence). The macro and microstructure, temperature stability, mechanical properties of these alloys were characterized by standard methods used in materials research, as well as chemical properties and corrosion resistance in the environment of solutions simulating body fluids.

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**Term of solution**  
08/2018 - 06/2021

**Budget from agency**  
249 996 €

**Project ID**  
APVV-17-0008



## Research of direct bonding of the ceramic and metallic materials by use of active soldering alloys

### Research subject

The project has dealt with the research of a direct soldering of ceramic and metallic materials by use of active soldering alloys. New active soldering alloys were designed and experimentally prepared. Their main basis was Sn and In and were alloyed with an active metal, mainly Ti, but also Sr. It was supposed that the active element will react in a soldering process with the substrate surface and will thus ensure the wettability of solder on the ceramic or other hard-to-solder material. Laser and electron beam were employed for heating process. The material solderability of the new solders was studied.

### Aim of the research

The project aims consider the new world trends in soldering materials, as application of lead-free fillers and flux-free soldering. Another aspect consists in the versatility of soldering technology, where the direct soldering of non-metallic, ceramic and metallic materials mutually and in combinations is employed. Based on those aspects and previous experience, the following project aims were suggested:

1. Research and experimental preparation of the new soldering alloys based on Sn and In. Design and manufacture of the new soldering alloys with aim of their application in flux-free soldering of a wide range of metallic (Cu, Ni, Ag, Au, Al, Ti and etc.), non-metallic (Si, Ge, C and etc.), ceramic ( $\text{Al}_2\text{O}_3$ ,  $\text{ZrO}_2$ ,  $\text{SiO}_2$ ,  $\text{TiO}_2$ , SiC, AlN,  $\text{Si}_3\text{N}_4$  and etc.) and metal-ceramic materials, which exert significant rank in electronics, micro-electronics, but also in engineering industry.
2. The research of direct flux-free soldering with application of laser, electron beam and power ultrasound. Research of processes and conditions of bond formation by use of advanced flux-free soldering technologies and creating the set of knowledge about those processes.
3. Study of interactions on substrate/solder boundary and assessment of mechanical properties of soldered joints.

Research of transition zone on the boundary of metallic and ceramic materials. Identification of formation and growth of intermetallic components. Clarification of bond formation mechanism.

### Achieved results

The subject of study and patented solution in practice consists in Sn-Sb-Ti - based active soldering alloy. This solder is especially devoted for ultrasonic soldering of metallic, ceramic or composite materials. It may be employed mainly in the field of production of sophisticated power electronic parts, operating at higher service temperatures. The merit consists mainly in efficiency and reliability in fabrication of soldered joints in the field of electronic and micro-electronic industry. By employing the advanced soldering technologies with use of lead-free solders at application of flux-free process, the most recent environmental requirements for the ecologic and at the same time also economically advantageous soldering of a wide range of materials are met. This solder is at present manufactured in the form of wire, foil and ingots. Also manufacture in the form of powder is possible. Our solder is alloyed with an active element (Ti). The active element ensures wettability of ceramic materials at high-temperature activation in vacuum, or by application of ultrasonic vibrations in the air. It is applicable without flux and does not contain lead nor cadmium by what it corresponds to the requirements of lead-free soldering (RoHS etc.).

### Benefits for practise

The solder is a direct competitor of the commercial solders produced by S-Bond company with global customer potential, which offers mainly the Sn-Ag - based solders alloyed with an active element. Advantage of our solder consists in the possibility of direct soldering and thus to exclude the necessity of deposition of ceramic surfaces by a solderable

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**Participating organisation**  
First Welding Company, Inc.  
**Term of solution**  
08/2018 - 07/2022  
**Budget from agency**  
250 000 €  
**Project ID**  
APVV-17-0025

coating. The merit consists also in higher shear strengths of soldered joints, by approximately 30 - 50 %. It allows direct soldering of metallic, ceramic or composite materials and their combinations. Moreover, our solder is cheaper, since the price of Sb in comparison to Ag on the stock-market is approximately by 77 % lower. A negotiation with the French company Métaux Blancs Ouvrés, which is a world-wide supplier of soldering alloys for electronics (<https://mbo-solder.com/>) took place in 2022. The MBO company signed a licence for manufacture and distribution of this soldering alloy. The production and distribution of this soldering alloy will start in 2023. This soldering alloy has been patented at the Industrial Property Office of the Slovak Republic and also at the European Patent Office in Germany.

Fig. 1 / a) Microstructure analysis of SnSb5Ti3 solder, b) the XRD analysis of SnSb5Ti3 solder

Fig. 2 / The map of Ti, Sn and Sb elements in the microstructure of SnSb5Ti3 solder

Fig. 3 / The wettability of ceramics by SiC solder type SnSb5Ti3 at the temperatures of 750, 850 and 950 °C, a) wetting angles, b) the course of wettability measurement

Fig. 4 / a) Test specimen for the shear test and scheme of specimen in a jig by the shear strength test b) The shear strength of joints fabricated with SnSb5Ti3 solder

Fig. 5 / The microstructure of SiC-SnSb5Ti3 boundary on the wettability test specimen at the soldering temperature of 850 °C, a) from the light microscope, b) from the SEM analysis

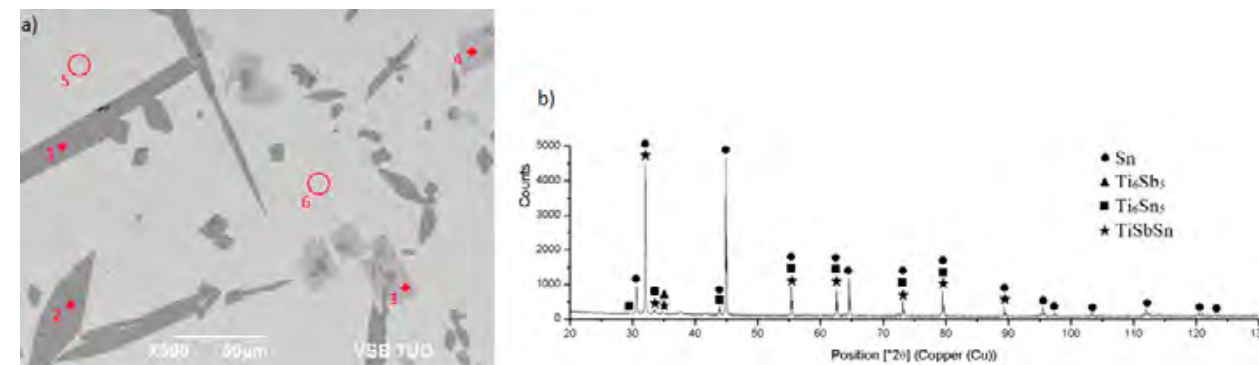


Fig. 1

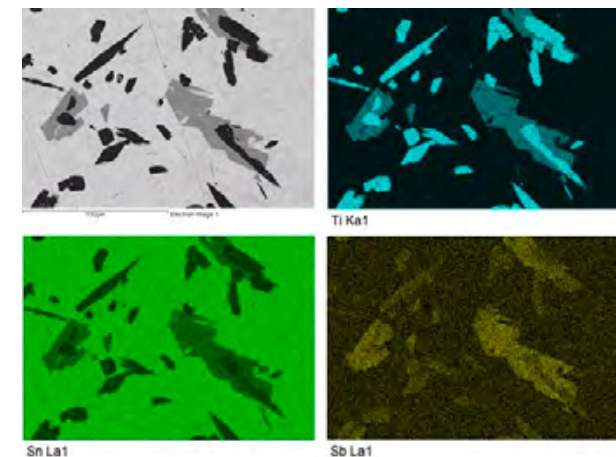


Fig. 2

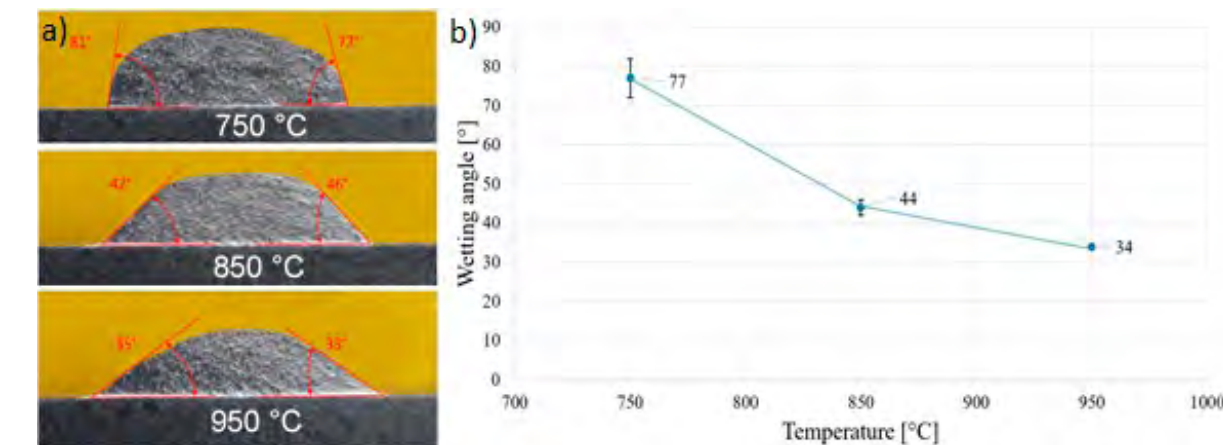


Fig. 3

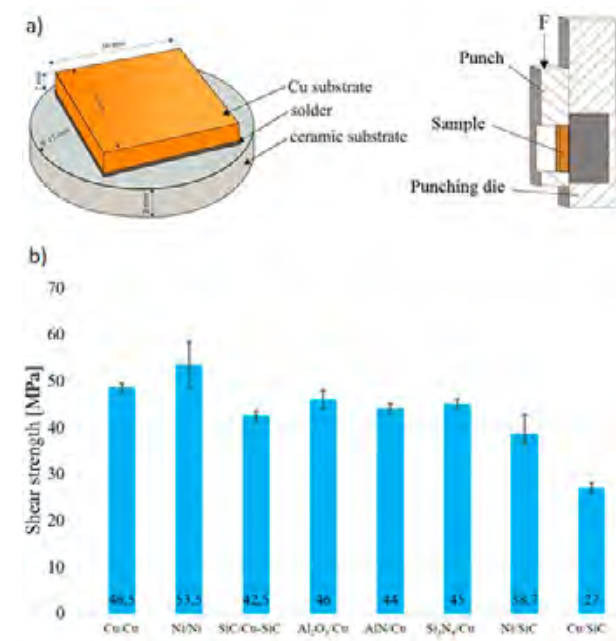


Fig. 4

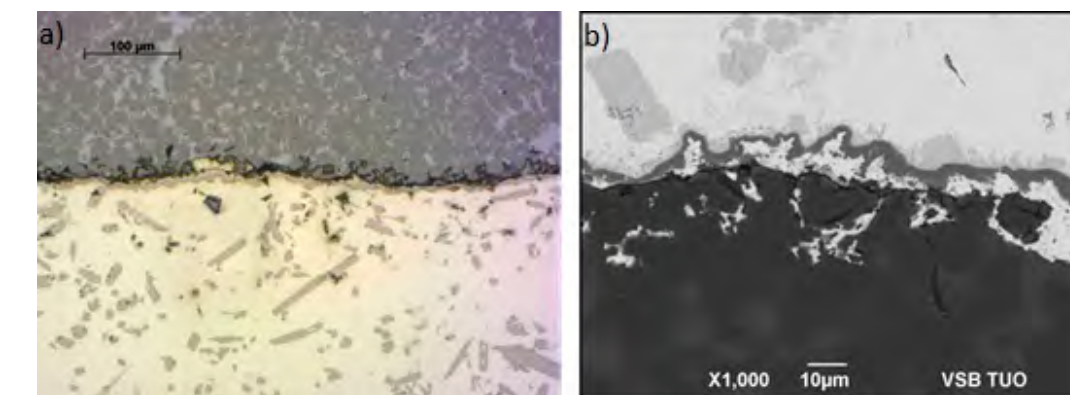


Fig. 5



## Novel glass and glass-ceramic rare-earth aluminates-based phosphors for energy-saving solid state lighting sources emitting white light (pc-WLEDs).

### Research subject

The reduction of energy consumption in production processes and in common life (a significant part of energy consumption is lighting) is very urgent, especially nowadays in the period of energy crisis. Closely related to this is the significant increase in the prices of material inputs. Therefore, the development of new efficient phosphors for applications in LED lighting technology with a lower content of rare earth (RE) elements, or their substitution by cheaper alternatives, e.g. transition metals or other elements, is currently of great importance. The solved project was focused on development of new glass, glass-ceramic and ceramic luminescent materials based on  $\text{Al}_2\text{O}_3$  and  $\text{RE}_2\text{O}_3$  for applications in LEDs emitting white light.

### Aim of the research

The goal of the project was the development of new glass, glass-ceramic and ceramics luminescent materials doped with rare earth (RE) and transition metal (TM) ions excitable mainly in the NUV region, for applications in LED light sources. Attention was mainly devoted to the preparation of materials with a homogeneous dopant distribution in the host matrix and to the determination of the relationship between the structure and morphology of the material and its emission spectral properties upon excitation by blue light as well as NUV (near UV) radiation. The preparation of PiG composites in the form of thin plates suitable for direct application to the excitation LED chip was optimised and PiG composites characterised.

### Achieved results

New yttrium aluminate glasses and glass-ceramics luminescent materials were developed both in powder form (glass microspheres) and in the form of PiG composites with good white light emission when excited by radiation in the NUV region, while reducing the content of luminescence active rare earth elements in the host matrix. The prepared new glasses and glass-ceramics materials were characterized in

detail from the point of view of structure, thermal properties, morphology and luminescence properties. The precursor synthesis methods and the preparation of aluminate glasses (undoped as well as doped with luminescent active ions Eu, Er, Ce, Tb, Dy, Mn, Cr) in  $\text{RE}_2\text{O}_3\text{-Al}_2\text{O}_3$  systems (RE=Y, Yb, La) were optimized. The valuable knowledge on thermal stability, crystallization mechanism and time-temperature evolution of phase composition during crystallization of aluminate glasses have been acquired. By using advanced spectroscopic methods, MAS NMR, IR and Raman spectroscopy, it was possible to identify and quantify structural units mutually co-existing in aluminate glasses, as well as unstable phases formed during the crystallization of aluminate glasses. White emission was achieved also with one luminescent active element (Eu) at its low concentration in the host matrix, and the proportion of the red component of the emitted light was possible to increase by changing the excitation wavelength. Also, luminescent materials exhibiting the emission of warm white light under NUV excitation, with replaced rare earth elements by cheaper dopants, have been developed. The suitable combination of RE/TM dopants in one matrix, allowed to tune the colour of the emitted light from green, through yellow, white to red, i.e. in a wide spectral range, depending on the excitation wavelength.

### Benefits for practise

The results and knowledge acquired during the project are applicable mainly in the field of semiconductor light sources (LED) emitting white light with high light output as well as in the preparation of new luminescent materials and PiG composites with a lower content of rare earth elements.

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### Participating organisations

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Slovak Academy of Sciences, Institute of Materials Research

### Term of solution

08/2018 - 12/2022

### Budget from agency

180 045 €

### Project ID

APVV-17-0049

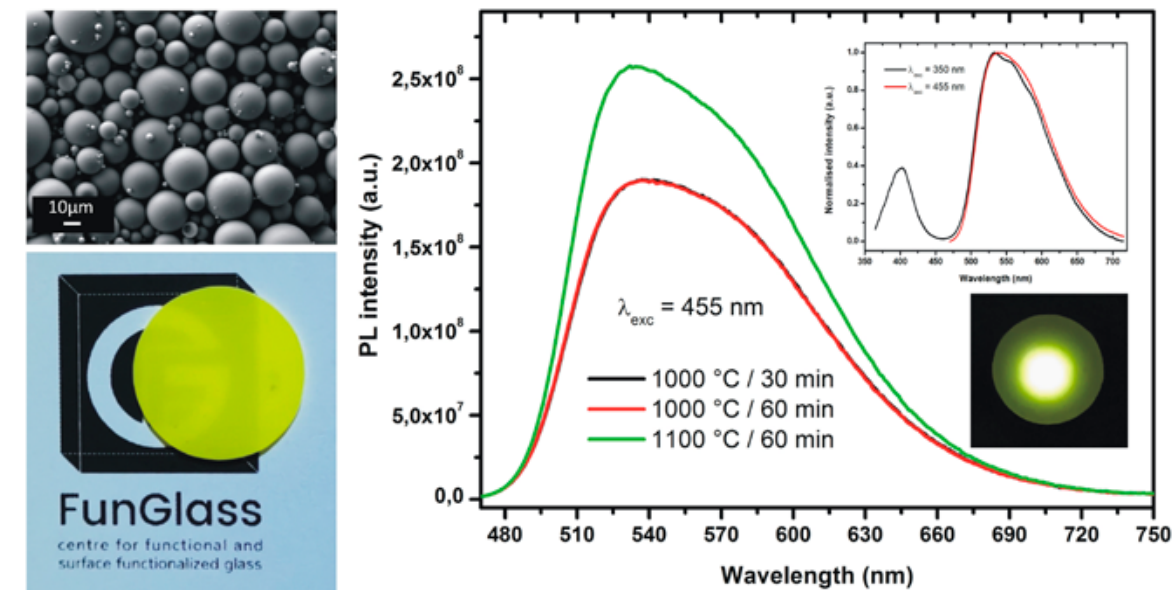


Fig. 1

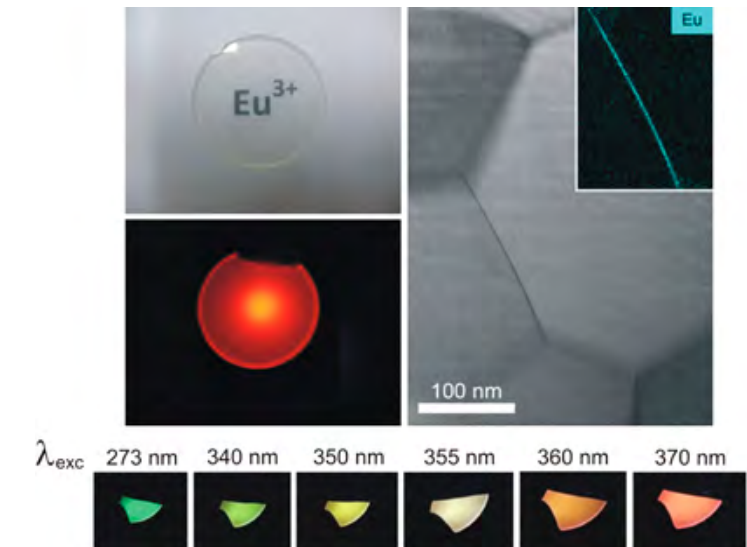


Fig. 3

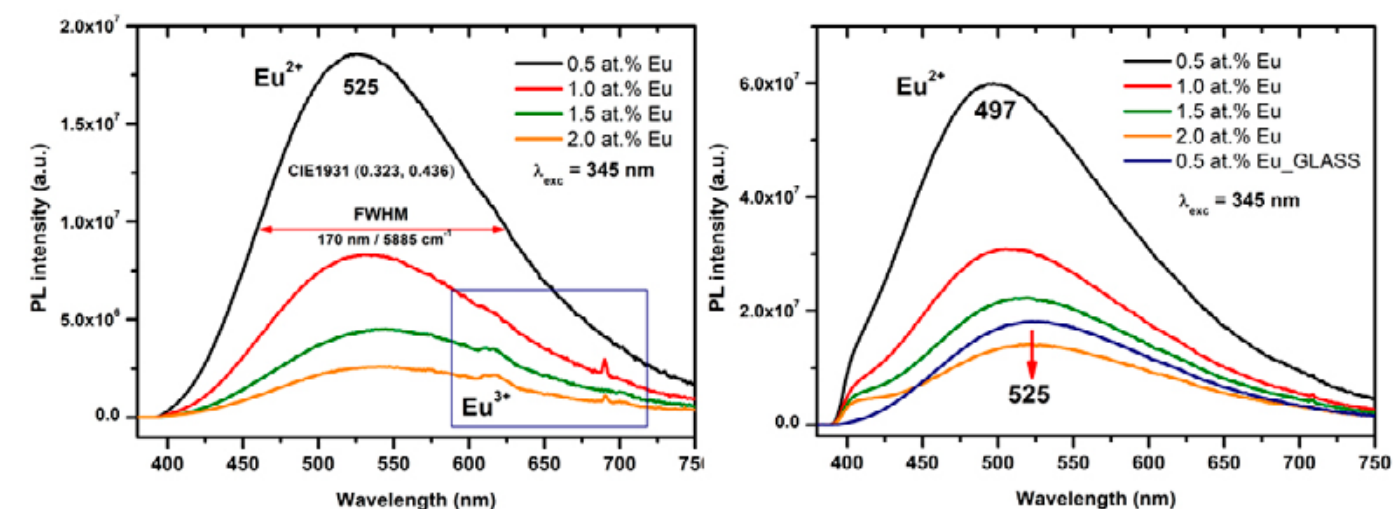


Fig. 2

Fig. 1 / Translucent glass-ceramic sample ( $\varnothing 10\text{mm}$  with thickness of  $0.5\text{mm}$ ) prepared by sintering of glass microspheres in a vacuum at  $1000^\circ\text{C}/1\text{h}$  under an applied pressure of  $40\text{MPa}$  (left). Emission spectra of compacts prepared under different conditions for the eutectic composition with a concentration of  $1\text{ at.}\% \text{ Ce}^{3+}$  (right).

Fig. 2 / PL emission spectra of glass samples (microspheres) with the composition  $\text{A60Y40:xEu}^{3+}$  reduced in an atmosphere of  $\text{H}_2/\text{N}_2$  ( $10\text{ v/v}$ ) at the temperature of  $750^\circ\text{C}/24\text{h}$  (left), subsequently crystallized in the same reducing atmosphere at the temperature of  $1050^\circ\text{C}/24\text{h}$  (middle). PiG composite prepared by hot pressing under NUV  $345\text{ nm}$  excitation (right).

Obr 3 / Photographs of  $\text{Al}_2\text{O}_3:\text{Eu}^{3+}$  ceramic compact ( $0.075\text{ at.}\% \text{ Eu}$ ) under NUV excitation and microphotograph from TEM/EDS analysis of the grain boundary for the same sample (top). Photographs of emitted light from  $\text{Al}_2\text{O}_3:\text{Tb}^{3+}/\text{Cr}^{3+}$  co-doped transparent ceramics under excitation at different wavelengths (bottom).

## Polymer systems from renewable resources for fibres and textiles

### Research subject

The subject of the solved project was preparation of fibres from PLA, PHB and special additives, evaluation of their structure, thermal, mechanical and colouristic properties. At the same time, it was necessary to study the influence of composition of blended systems on their processability and the associated determination of spinning and drawing conditions.

### Aim of the research

The project was focused on the study of systems based on polymers from polylactic acid-PLA and polyhydroxybutyrate-PHB, aimed to the preparation of oriented fibrous materials in terms of their material composition and preparation conditions. An important result of the solution of project was the determination of the material composition of blends from various PLA, PHB and special additives, which enabled their processability at the spinning and at the uniaxial drawing as well as increase their thermal, processing and oxidation stability. It was also focused on the preparation of bicomponent fibres from PLA, PHB and special additives and from PP of type C/S (core/shell). It was also studied of dyeing fibres from PLA, PLA/PHB and bicomponent PP/PLA fibres in the mass and from bath and evaluated the stability of dyeing in accelerated ageing and washing.

### Achieved results

An important result of the solution of the project was the determination of the material composition of the PLA/PHB blend with a nucleating agent, which enabled the preparation of fibres with acceptable structural parameters and mechanical properties. It was found that PLA fibres from L105, L130 and L175 have a significantly higher crystallinity than the fibres from I6202, the stability of drawing process decreases in the order of I6202, L130, L175 and L105, and the drawn fibres have a lower cold crystallization. In the opposite, the parameters of supramolecular structure and mechanical properties are better for the fibres from L175 than for fibres from L130, L105 and I6202. A positive result

was the finding that the observed properties of the prepared fibres did not depending on the ageing time. It was determined, that fibres drawn at a lower temperature need to be drawn to a higher drawing ratio and the fibres drawn at the higher drawing temperature to a lower drawing ratio. The nucleation agent improves the mechanical properties of prepared fibres. As part of the project solution bicomponent C/S PP/PLA fibres were also prepared with the determination of the content of individual components in the core and shell so that the prepared fibres have the required physical and mechanical properties. Another result of the project it was the knowledge finding about the possibility of dyeing prepared fibres from PLA with different concentrations of plasticizers, PLA/PHB fibres and bicomponent PP/PLA fibres. It has been found that when PLA fibres without and with a plasticizer are dyed, the dyeing stability decreases with increasing plasticizer content. After the dyeing of PLA/PHB fibres in the mass or dyed from bath, it was found that while for fibres dyed in the mass without nucleating agent, the addition of PHB reduces the washing stability after 5 and 20 washes, for dyeing of fibres from bath, the addition of PHB increases the dyeing stability after 5 washes but after 20 washes the dyeing stability is lower than for fibres dyed in the mass. It was found that a higher dyeing efficiency was achieved at the dyeing of bicomponent PP/PLA fibres with a higher content of PLA component.

### Benefits for practise

As part of the project, PLA, PLA/PHB and BICO PP/PLA fibres with different content of plasticizer, nucleating agent and compatibilizer were prepared. Fibres with the specified composition were spun using the melt process on a laboratory line with the required structure, thermal and mechanical properties. This result points to the fact that fibres from PLA, PLA/PHB, or bicomponent PP/PLA fibres can potentially be introduced into production and subsequently used for the preparation of flat textile products. Another significant result is the finding that the prepared fibres can be surface

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### Participating organisations

ENVIROCARE, s.r.o.

Research Institute for Man-Made Fibres, jsc.

### Term of solution

08/2018 – 06/2021

### Budget from agency

249 606 €

### Project ID

APVV-17-0078

dyed with dyes used in the surface dyeing of PES fibres and the dyeability from the bath as well as the stability of the dyeing of the monitored PLA and PLA/PHB fibres without plasticizer is at the required level. The results obtained as part of the project were published in domestic and foreign magazines and presented in the form of lectures and posters at foreign and domestic conferences. Another output from the results of the project solution was a utility model.

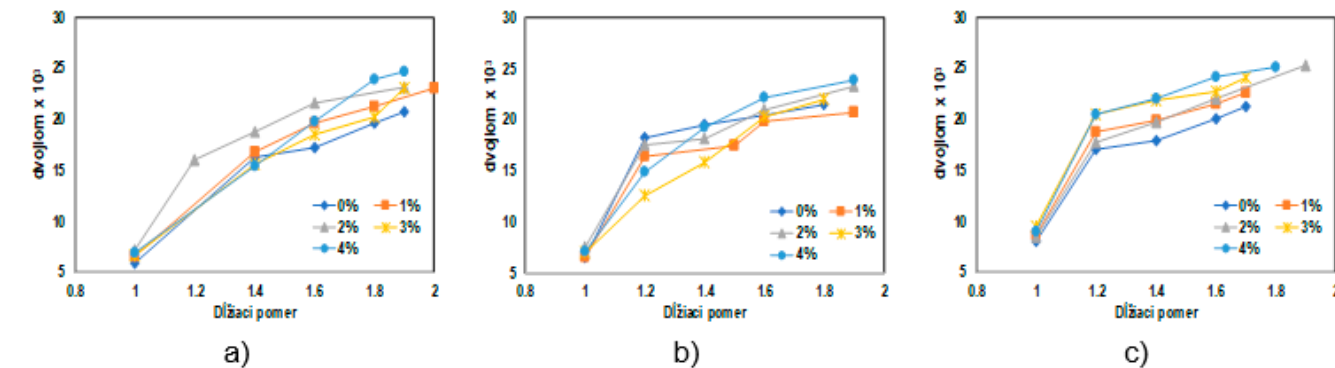


Fig. 1

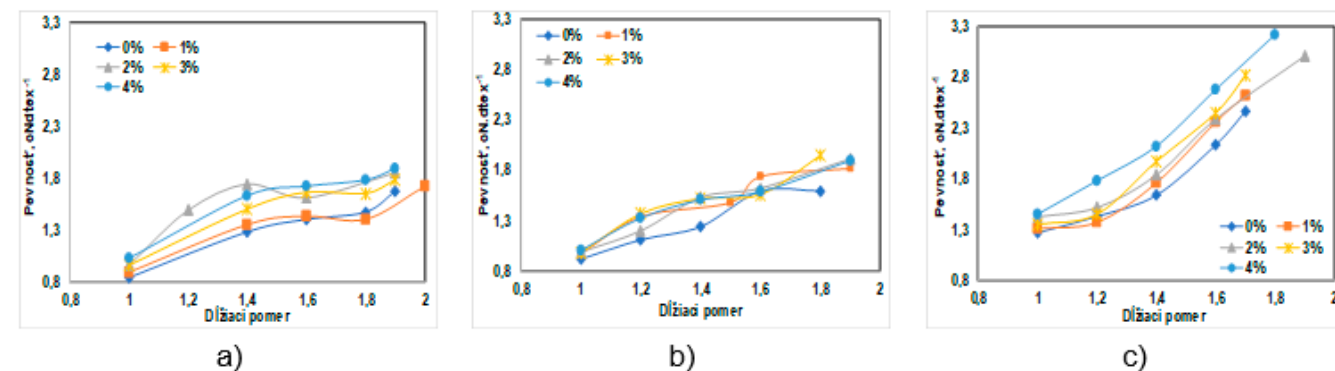


Fig. 2

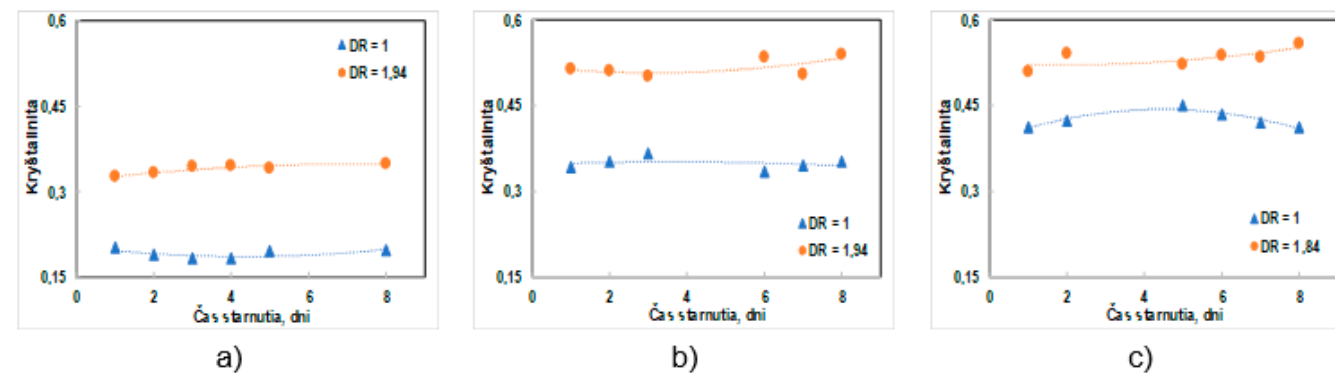


Fig. 3

Fig. 1 / Dependencies of birefringence on drawing ratio of fibres from various PLA – I6202 (a), L130 (b), L175 (c) with different content of special additives

Fig. 2 / Dependencies of tenacity at the break on the drawing ratio of fibres from various PLA – I6202 (a), L130 (b), L175 (c) with different content of special additives

Fig. 3 / Dependencies of crystallinity on the ageing time of fibres undrawn and drawn at the maximal drawing ratio from different PLA – I6202 (a), L130 (b), L175 (c)

Fig. 4 / Cross section of PLA (a) and PP (b) fibres and BICO PP/PLA (c-f) fibres type C/S (core/shell) with different PLA contents

Fig. 5 / The effect of the number of washes (5x and 20x washes) and the additive content (M1-0.25 a M2-0.5) on the colour difference for fibres from PLA, PLA/PHB, PLA/PHB/M1-2 dyed in the mass (HF) and dyed exhausted process from the bath (PF);  $T_{dl}$  is the drawn temperature.

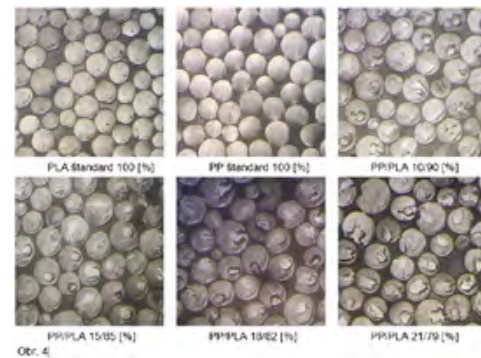


Fig. 4

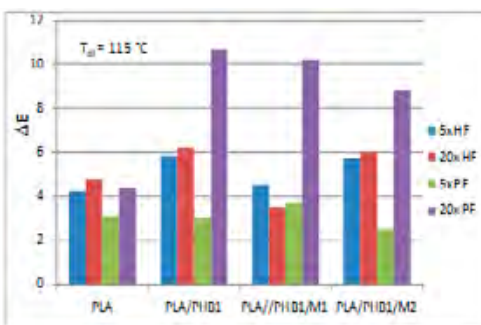
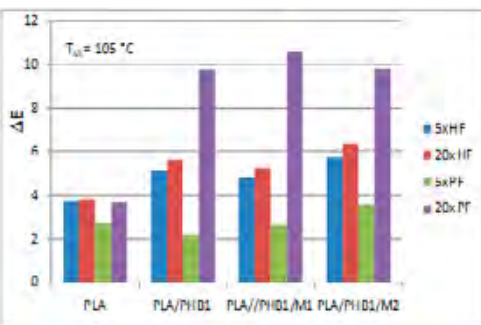


Fig. 5



## Injectable hybrid composite biocements

### Research subject

The project was focused on study of new types of injectable hybrid calcium phosphate biocements with required properties for medical applications, e.g. use in treatment of bone defects and fractures, regeneration and reconstruction of bone injuries in facial area.

### Aim of the research

The aim of project was synthesis, preparation and characterization of modified and new types of injectable biocements with high bioactivity, structural and chemical biocompatibility with bone tissue and it was done the in vitro and in vivo testing of biocement systems for characterizing the newly formed tissues after application of cements into artificially created bone defects in addition to the analysis of material properties.

### Achieved results

From the point of view of bone formation, a new modified biocement system was characterized, which also contained an additional natural source of phosphates in the form of phytic acid. It was possible to suppress the inhibitory effect of phytic acid on the transformation of biocement and to develop a new type of calcium phosphate biocement also in injectable form using a polyelectrolyte anionic mixture of carboxymethyl cellulose/polyacrylic acid. Setting was achieved by releasing the inorganic phosphate group from phytic acid via the enzyme - phytase. We verified that it is possible to control the setting process of biocement and to obtain fully injectable pastes, highly resistant to disintegration in aqueous solutions while maintaining excellent in vitro cell viability, proliferation and ALP activity of osteoblasts and the presence of phytic acid supported the in vitro formation of calcium deposits produced by osteoblasts as well as overexpression of osteogenic gene markers in cells.

### Principal investigator

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### Participating organisation

University of veterinary medicine and Pharmacy in Kosice

### Term of solution

08/2018 – 06/2021

### Budget from agency

247 022 €

### Project ID

APVV-17-0110

### Benefits for practise

Degeneration and violation of cartilage integrity in more severe cases up to the subchondral bone due to primary (genetic factors) or secondary factors (metabolic, inflammatory, post-traumatic) is currently a relatively significant societal problem. The disease affects 10-15% of population, while progressivity increases in older age (up to 50-80%) and is mostly manifested by chronic pain and limitation of mobility of limbs and parts of body. The results from pre-clinical in vivo testing pointed to fact that defects treated by means of developed biocement systems can represent a simple and promising solution for patients suffering from knee joint damage (osteoarthritis, osteoporosis, injuries). Similarly, in the case of cystic bone lesions, the developed cement mixture could be useful for successful treatment of mentioned types of pathological bone tissue damage.

We studied the calcium phosphate biocement mixture/fibroin system, where silk fibroin is a representative of natural protein biopolymers. We have developed a new method of preparing composites, allowing in principle to admix any amount of fibroin while maintaining its ability to positively influence the flow properties of cement paste after mixing with the liquid component. The addition of fibroin ensured complete injectability of the paste, resistance to disintegration in aqueous solutions and excellent cell proliferation on the surface of the composite with high expression of osteogenic gene markers.

An important result of the project was the analysis of material properties and in vivo results of experimental work on animal models of artificially created bone and osteochondral defects in knee joints treated using developed fast-setting biocement systems of the tetracalcium phosphate/monetite type with addition of amino acid complex component, and systems were transformed to the calcium-deficient form of hydroxyapatite. After their in vivo application, no inflammatory processes were observed at the defect healing site, and the quality of the newly formed tissues (hyaline cartilage, subchondral bone) in animals was comparable to the original tissues and was preserved even after 12 months of application. We identified an excellent integration of the newly formed hyaline cartilage with the surrounding tissue and an excellent connection between the hyaline cartilage and the newly formed subchondral bone.

The effectiveness of tetracalcium phosphate/monetite cement system for healing of a subchondral cystic lesion was tested on a horse model suffering from mentioned damage type, which occurs often in humans. Radiological analysis confirmed the successful formation of bone tissue that completely replaced the original area of bone defect containing the cyst, while cement was resorbed in healing process.

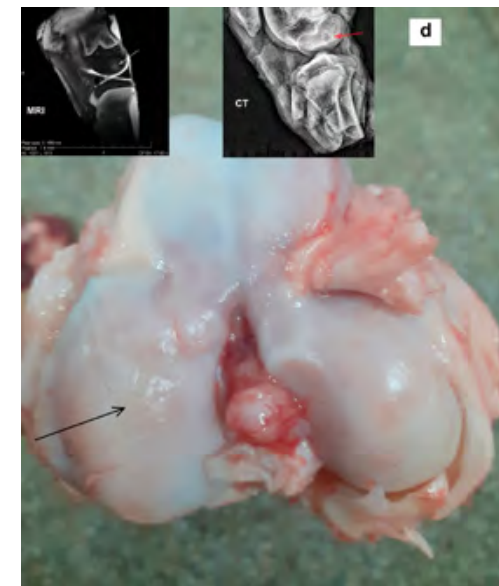
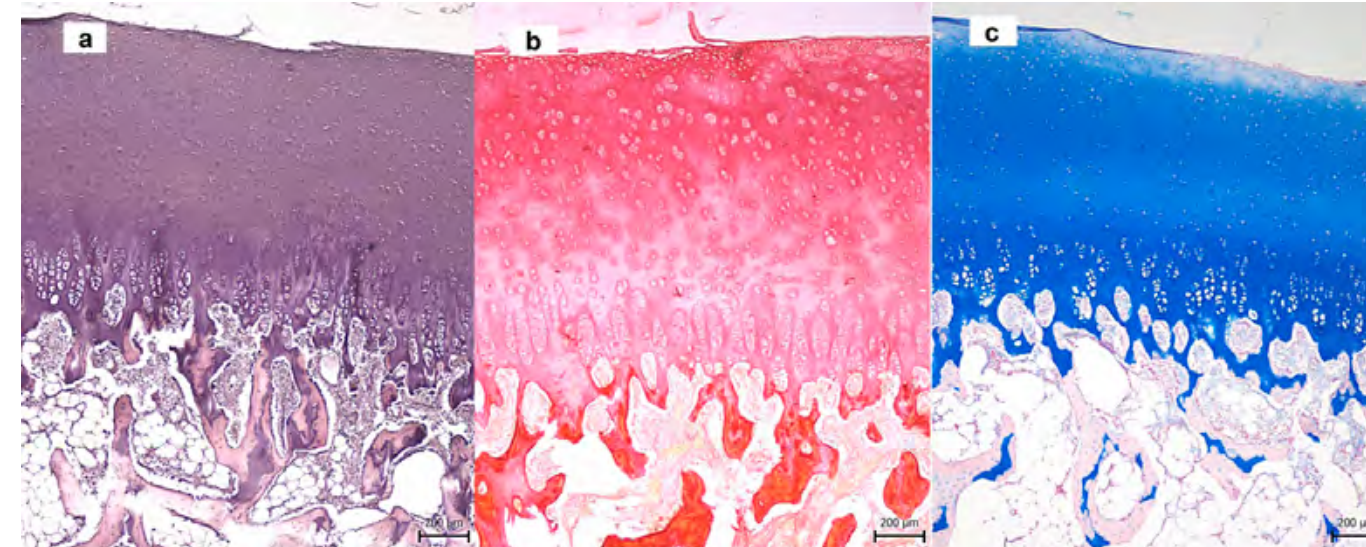
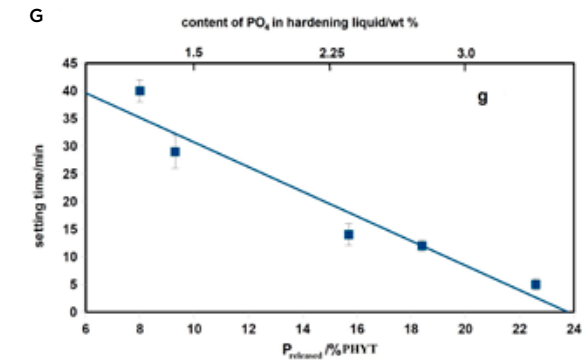
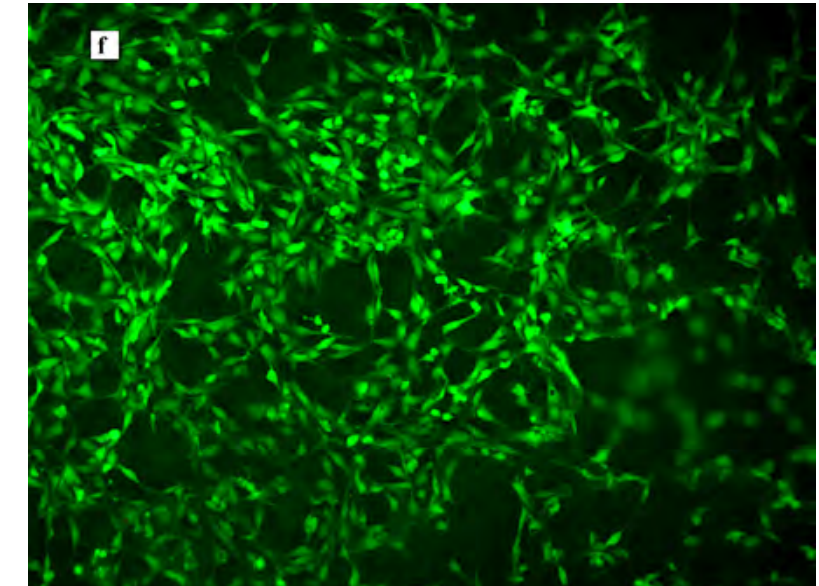


Fig. 7 / Histological analysis of porcine tissue in an artificially created knee injury after 3 months of healing using a biocement/amino acid system (staining: hematoxylin & eosin (a), Picrosirius red (b) and Alcian blue (c)) confirming the quality of formed cartilage tissue; macroscopic and MRI images of a healed porcine knee osteochondral defect 12 months after application documenting complete biocement resorption, smooth hyaline cartilage surface and its integrity with the same quality as the original tissue (d,e); live/dead staining of cells on the surface of non-cytotoxic biocements containing phytic acid after 9 days of culture (f) and a graph expressing the possibility to control the setting time of cement by the enzymatic hydrolysis of phytic acid by phytase (g).





## Monitoring of pharmaceutical fates from sewage sludge into soil, plants and underground water

### Research subject

A significant group of micropollutants in wastewater are pharmaceuticals, which include a wide range of drugs, hormones, drugs, etc. The source of pharmaceuticals in the environment is urban wastewater, which, even after undergoing treatment processes, still contains high concentrations of these substances, thus contaminating surface waters and affecting biological processes in them. However, an underestimated source of pharmaceutical contamination is also sewage sludge, which binds a significant amount of these micropollutants. By gradually decomposing sludge on the soil and desorption of micropollutants into the aqueous phase, micropollutants pass into groundwater or are ingested by soil-grown plants. In this way, micropollutants get through plants and animals into human food and can thus directly affect the health status of the population. This movement of micropollutants is very poorly described in the scientific literature, the sorption and desorption of pharmaceuticals for sewage sludge is limited by complicated analytical procedures, but also by the underestimation of this sensitive topic.

### Aim of the research

An important objective of the project was to monitor the current situation with the content of pharmaceuticals in wastewater and sewage sludge in Slovakia. As part of this objective, it was important to define what types of drugs and in what quantities they bind to sewage sludge, define their stability in sludge management processes, the ability of their release into the soil, input into plants, penetration into groundwater sources, etc. The second main objective of the project was to define ways of removing pharmaceuticals in processes at individual stages of WWTP, and thus also the effectiveness of removal of these substances in current and future WWTP technologies.

### Achieved results

**Monitoring of pharmaceuticals in sewage sludge.** As part of the project, we carried out hundreds of raw and treated wastewater or sludge samples. We have defined the dominant pharmaceuticals that are present in wastewater and sewage sludge. In addition, DNA fragments of the CoV-19 virus were analyzed, and based on the dynamics of virus content in wastewater, we were able to predict the presence of the virus in the inhabitants of the monitored city. From wastewater, we were also able to obtain information about new synthetic drugs or alcohol consumption in selected cities.

**Removal of pharmaceuticals from water and sludge.** An important part of the project results was also the application of advanced oxidation processes for the removal of pharmaceuticals from wastewater. Processes using nano iron,  $\text{Fe}^{\text{VI}}$ , boron-doped diamond electrodes, ozone, and sorption have been successfully tested. From other results, thermal removal of pharmaceuticals from sludge is effective even in low-temperature thermal processes, however, only processes above 500°C can achieve almost 100% efficiency of removal of these substances.

**The behavior of sludge on soil systems, the release of drugs, and their transport to soil, plants, and groundwater were also studied in detail.** The accumulation of diclofenac and caffeine directly in the cells of both watercress and lettuce has been confirmed. We have confirmed some experience from abroad that constructed wetlands can accumulate or decompose some pharmaceuticals in their enzymatic system more effectively than is the case with classical activated sludge systems.

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**Term of solution**  
08/2018 – 07/2022  
**Budget from agency**  
219 537 €  
**Project ID**  
APVV-17-0119

**During the project, we also focused on the effective removal of potentially resistant types of bacterial strains.** When removing potentially infectious RNA and DNA fragments, the application of a potassium iron (VI) tablet has been shown to be an effective degradation procedure capable of removing endpoints up to 75%. The effect of bacterial removal was even above 99%, while the presence of resistant types of bacteria was not confirmed in wastewater after iron application.

### Benefits for practise

The achieved results are important for practice at the level of knowing the real presence of pharmaceuticals in sewage wastewater and sewage sludge. An important knowledge for practice was also the definition of possible technological procedures for the removal of pharmaceuticals from wastewater and sludge. These results (together with the activities of other research groups in the EU) led to the formulation of legislative requirements for the removal of pharmaceuticals from wastewater in the new EU Urban Wastewater Treatment Directive..



Fig. 1

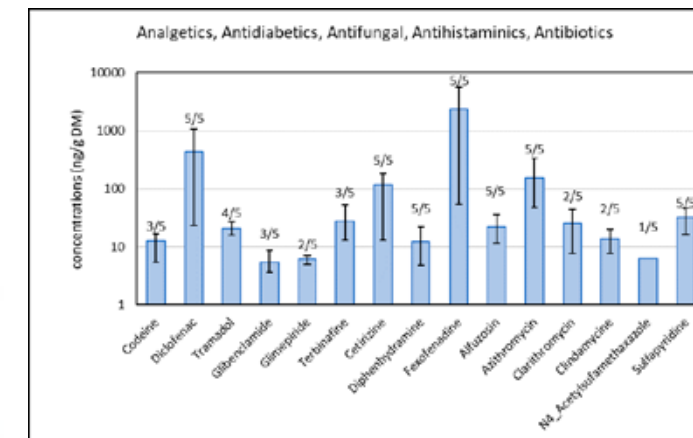


Fig. 2

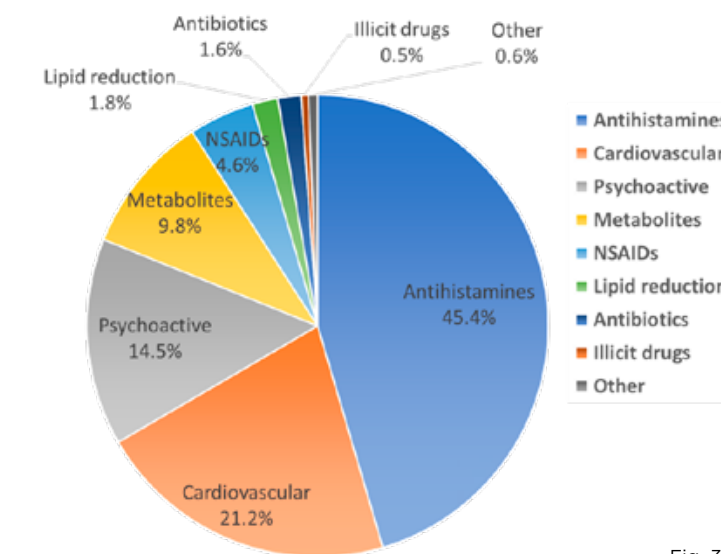


Fig. 3

Fig. 1 / Path of pharmaceuticals from population to agricultural soil.

Fig. 2 / The concentration of selected pharmaceuticals in sewage sludge from Slovak WWTPs (mean, minimum, maximum, and occurrence from five WWTPs).

Fig. 3 / Distribution of selected therapeutic groups in Slovakian sewage sludge.



## Nanotechnology preparation of a MIS photoelectrode with metallic oxides for systems for production of solar fuels

### Research subject

The efficient extraction of energy from renewable sources plays a more important role in terms of sustainability, energy self-sufficiency and ecology. In the project, we focused on the preparation and analysis of highly stable and efficient metal-insulator-semiconductor (MIS) structures with dielectric protective layers for photoelectrochemical (PEC) water decomposition. Such structures form a key element for stable systems that enable the conversion of solar energy into chemical energy, the so-called solar fuels with high energy density, for example hydrogen and oxygen. This way of using and storing energy obtained from the sun represents a highly prospective concept of a renewable and sustainable energy economy.

### Aim of the research

The project was focused on the preparation of highly efficient metal-insulator-semiconductor structures for the photoelectrochemical decomposition of water (MIS PEC) and the investigation of possibilities to qualitatively improve their optical and electrical properties and stability in a corrosive environment. The new findings of the research aimed to contribute to the preparation of MIS PEC structures with the largest possible photovoltage, photocurrent and stability for efficient hydrogen and oxygen generation. Achieving this goal required a) the preparation of dielectric layers of MIS PEC structures with appropriate leakage, b) the realization of a suitable passivation of the interface of the protective dielectric layer with silicon and c) the preparation and optimization of a suitable catalytic transparent conductive oxide layer (TCO), as a replacement for the metal catalytic gate. To realize these goals, it was necessary to understand the mechanism of transport of carriers through dielectric layers and through  $\text{SiO}_2$  passivation layers, the role of the catalytic gate in this transport, and the simulation of a possible antireflection adaptation of TCO to the MIS PEC electrode for photocurrent maximization.

### Achieved results

As part of the project solution, it was possible to successfully optimize the ALD growth of thin dielectric layers of metal oxides  $\text{TiO}_2$  and  $\text{HfO}_2$  with a thickness of units of nanometers. At the same time, the passivation possibilities of the  $\text{SiO}_2$  layers used at the interface of silicon and the dielectric layer prepared by several technologies were successfully investigated, while the  $\text{SiO}_2$  layer prepared by the ozonation process in the ALD reactor proved to be the most promising for MIS PEC technology. The transport of charge carriers through the MIS PEC structure formed by passivation and dielectric layers was described by a new model based on trap-assisted tunneling. As part of the project, it was possible to successfully grow catalytic oxide layers  $\text{RuO}_2$  and  $\text{RuO}_2\text{-IrO}_2$  using MOCVD and a  $\text{NiO}$  layer using magnetron sputtering and optimize their parameters in terms of achieving suitable optical properties and conductivity. Through simulation, these layers were analyzed in terms of anti-reflective adaptation to the silicon substrate. Experience in the optimization of individual layers was used in the preparation of MIS PEC structures with  $\text{RuO}_2$ ,  $\text{RuO}_2\text{-IrO}_2$ , and  $\text{NiO}$  catalytic layers. During the implementation of the project, it was possible to create MIS PEC structures with parameters of photovoltage  $\sim 0.5\text{V}$  and photocurrent  $\sim 30\text{ mA/cm}^2$ , which use  $\text{RuO}_2$  layers. These structures could be prepared with high reproducibility, which indicates a well-mastered technology. The layers showed stability for the photoelectrochemical decomposition of water when applying the redox potential of water oxidation in  $1\text{M H}_2\text{SO}_4$ .

### Principal investigator

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Slovak Centre of Scientific and Technical Information

### Term of solution

08/2018 - 12/2021

### Budget from agency

250 000 €

### Project ID

APVV-17-0169

### Benefits for practise

As part of the project, the growth technologies of thin dielectric layers  $\text{TiO}_2$ ,  $\text{SiO}_2$  and catalytic layers  $\text{RuO}_2$ ,  $\text{RuO}_2\text{-IrO}_2$ , and  $\text{NiO}$  were optimized, which will find direct application in the development of MIS PEC structures and the development of hydrogen and oxygen electrolyzers. The prepared photosensitive MIS structures with catalytic layers combine the advantages of solar cells and electrolyzers in one structure. These structures have the prospect of being used in the design and construction of hydrogen/oxygen generators working on the principle of water splitting, which uses the conversion of solar radiation into energy bound in hydrogen. In the project, we showed the usability of the developed photosensitive MIS structures in connection with additional solar cells with the 15% efficiency of solar energy conversion into hydrogen.

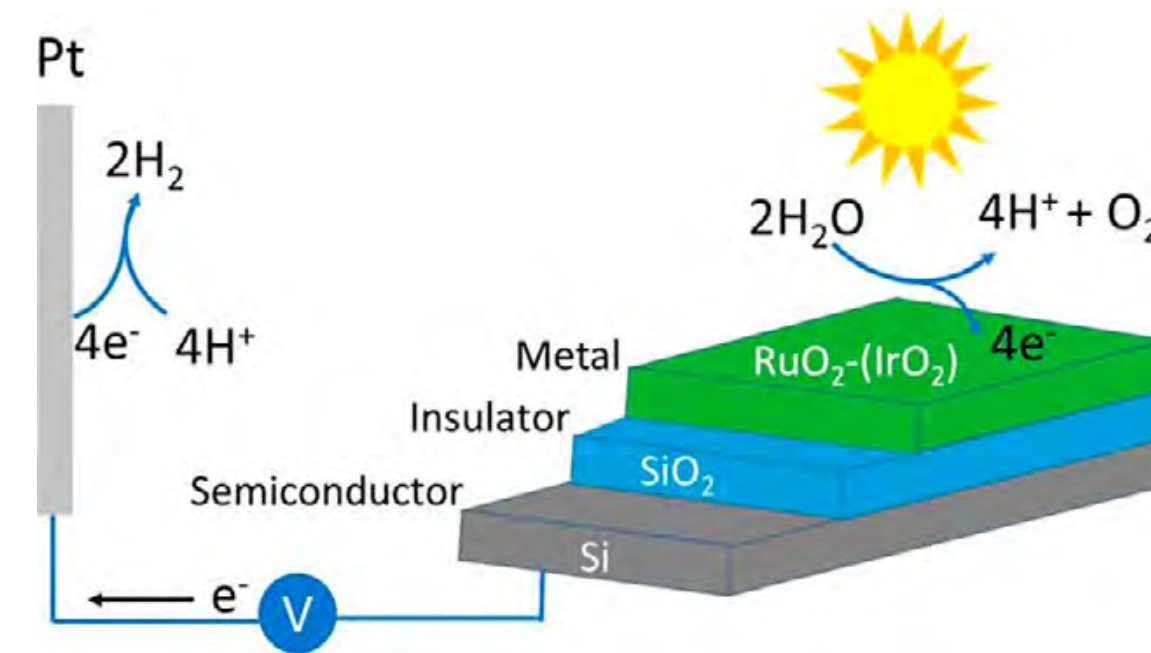


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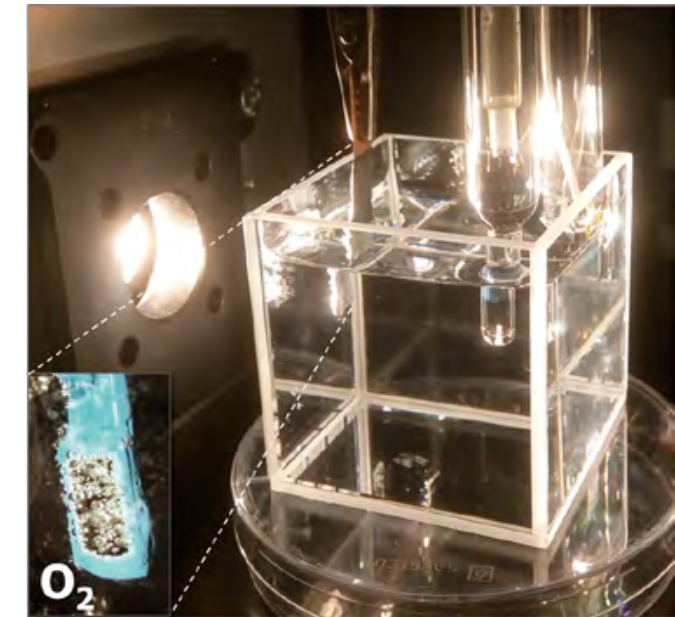


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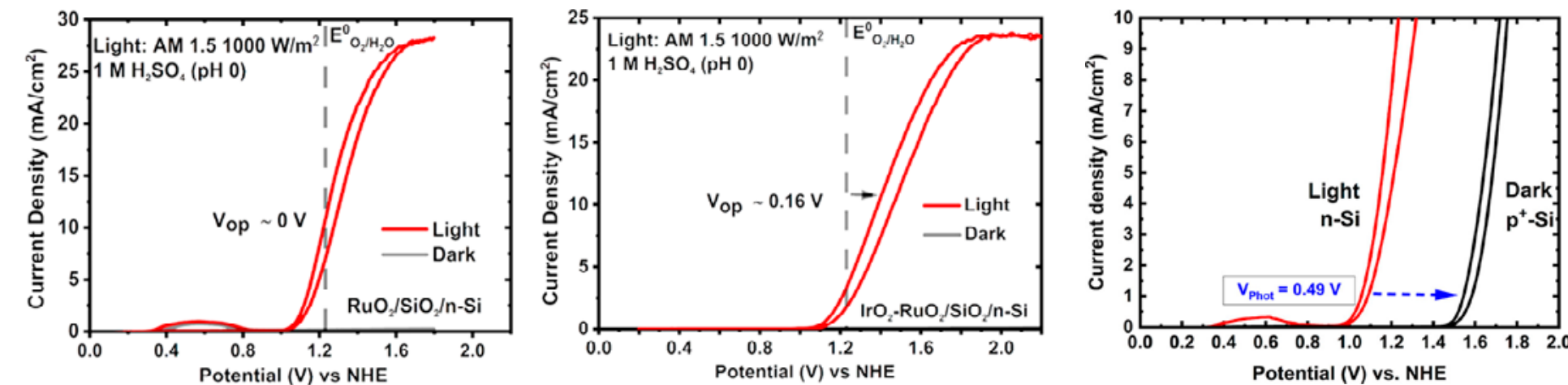


Fig. 3

Fig. 4

Fig. 1 / Schematic representation of the water splitting principle using the MIS PEC structure

Fig. 2 / Water splitting to  $\text{O}_2/\text{H}_2$  during illumination of the MIS PEC structure with a solar simulator.

Fig. 3 / Comparison of performance of  $\text{RuO}_2$  and  $\text{IrO}_2\text{-RuO}_2$  MIS PEC structures under dark and illumination.

Fig. 4 / Determination of photovoltage of 0.49 V generated during the illumination for  $\text{RuO}_2$  based MIS PEC structure.



# Resilient mobile networks for content delivery

## Research subject

The project (acronym REMONET) focused on fundamental research to enable resilient data communication in multi-hop mobile data networks. The applications of these networks will provide the information content delivery not only in Smart City environments but also in crisis scenarios caused by natural or technological disasters.

## Aim of the research

The goal of the project was basic research on resilient data communication through mobile multi-hop data networks usable not only in Smart Cities but also in crises. The project focused on three main areas of research. The first area dealt with new routing techniques and protocols. The second part dealt with high-speed data transmission, and the third part of the research addressed the self-contained delivery of the content in a given type of network. The research aimed at integrating sensor networks (WSN/MESH), mobile ad-hoc networks (MANET) and delay tolerant networks (DTN) as well as drone networks (DRONET). The objective of the integration was to create a resilient multi-hop network that would provide resilient and efficient content delivery methods. The aim of the project was also to create a new end-to-end communication model based on the idea that the next hop between nodes is unknown in advance. The project focused on the innovative use of multi-hop networks that will create a consistent mobile network with no infrastructure required. The project has been creative in using different types of networks and data processing methods that will enable resilient data communication when existing networks with infrastructure are unable to provide those types of services.

## Achieved results

The project aimed to provide basic research in the field of resilient data communication, employing various types of multi-hop networks without infrastructure. A multi-hop network model was designed to integrate different types of mobile multi-hop networks (MANET, DTN, DRONET and WSN) for data transmission among different types of networks. The efficient methods of clustering of the mobile nodes into clusters and routing algorithms enabling 2D and 3D routing using game theory or fuzzy logic have been proposed for the given model. Fuzzy logic, game theory, and other intelligent methods have been used to propose algorithms for efficient and resilient data transmission that emphasize the efficient use of the available communication spectrum. Another significant element of the proposed model was the methods for switching, acquiring and recording the data required to correctly predict link switching based on machine learning (e.g. RSSI). An essential aspect of the proposed model involved incorporating techniques for switching, acquiring, and recording data. These techniques are vital for accurate predictions in machine learning-driven link switching, such as RSSI. These techniques serve a dual purpose: enabling the development of an automated learning system for machine learning-based hard link switching and facilitating the design of an automated learning system for the challenging task of hard link switching in hybrid FSO/RF links. In this model, an anti-collision system has been proposed and implemented within DRONET networks. These networks are employed for transmitting and delivering information content between different nodes. Additionally, algorithms for processing multi-view video data have been developed. These algorithms will serve a dual purpose - not only for data transmission but also as an anti-collision system when integrated with virtual reality.

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**Term of solution**  
08/2018 - 12/2021  
**Budget from agency**  
123 342 €  
**Project ID**  
APVV-17-0208

## Benefits for practise

Intelligent communication technologies, smart cities, and intelligent parking and transport systems will benefit from the proposed solution. The deployment could be applied primarily in the fifth/sixth generation of networks as one of the key technologies for IoT data transmission and for extending the communication range of systems with infrastructure. The obtained results also open up new possibilities for exploiting and applying various scientific disciplines, such as artificial intelligence, to optimize the solutions from an efficiency, reliability and security point of view. Consequently, the model could be used in crises situations caused by natural disasters but also in the areas with damaged infrastructure, ensuring resilient data communications.

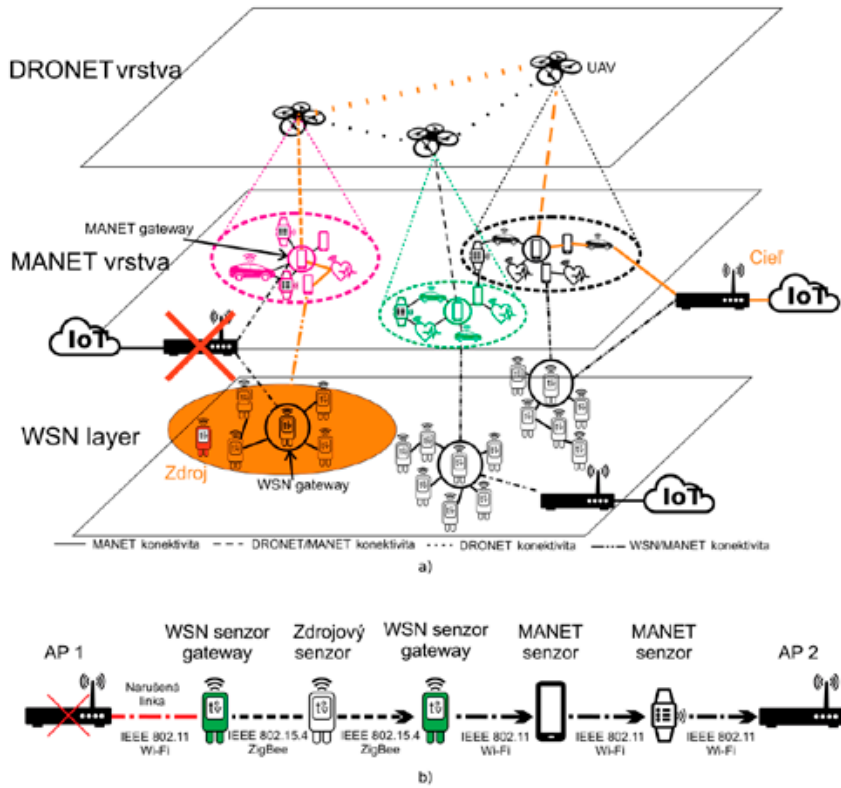


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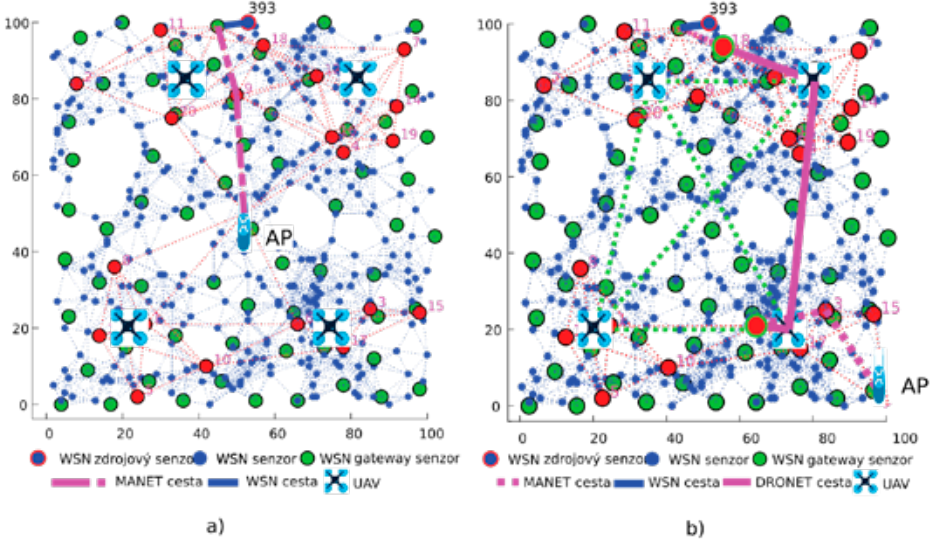


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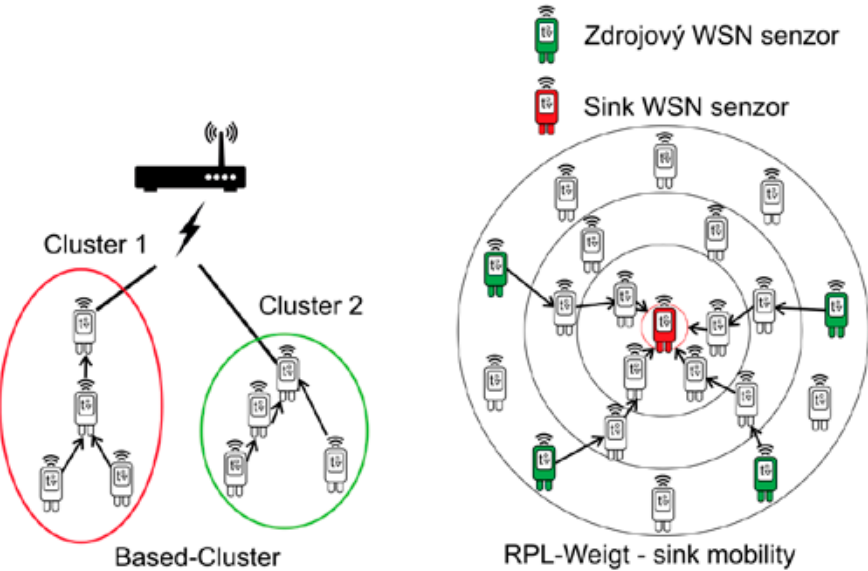


Fig. 2



Fig. 4

Fig. 1 / a) Multihop mobile network model enabling resilient data communication, b) Communication between nodes in a sensor network, gateways in a sensor and MANET nodes

Fig. 2 / Routing mechanisms based on clustering and RPL-Weight algorithms

Fig. 3 / Optimal communication path selection in a WSN-MANET-DRONET network: a) WSN and MANET. b) WSN, MANET and DRONET layers.

Fig. 4 / Hybrid FSO/RF transmission system implementation with weather measurement system



## Digital engineering elements application in innovation and optimization of production flows

### Research subject

The methodology of the project solution consisted of four stages: 1. analysis of the current state developed on the basis of the experience of the team of solvers in the field of designs and modification of processes in heterogeneous industrial enterprises, 2. design of application solutions for real and simulation systems aimed at defining acceptability parameters for simulation models, 3. programming and testing of the proposed system and application functionalities of the methodology with the help of test scenarios implemented on the basis of the experience of the team of researchers, 4. integration, the result of which was the incorporation of researched relationships defined on the basis of selected parameters into designed simulation models and their verification in laboratory and industrial practice conditions.

### Aim of the research

The main goal of the presented project was to propose a complex methodology for designing a new type of production system with the support of digital engineering elements in accordance with the strategy of intelligent specialization RIS3. A unique methodology was created that uses digital engineering tools in the field of designing, innovating and optimizing production flows of existing types of industrial production. The main supporting tools for ensuring high-quality information collection were the most modern software tools that we have at the research workplace and enabled the verification of corrections from the obtained data.

### Achieved results

The fundamental result of the presented project was the creation of a unique methodology that can be used in a virtual environment during the transition to digital production supported by the application of the latest software. A number of shortcomings were identified, which can either be parameterized or corrected by introducing change management

in leaps and bounds, or by reengineering existing business activities by proposing a complex methodology for designing a new production system, which integrates tools such as conventional modeling of changes in production parameters, simulation of production flows, animation of change proceedings, virtual, augmented reality and reverse engineering. This enabled the verification of corrections from the obtained data and the subsequent creation of a methodology that is often absent in the decision-making processes of organizations in Slovakia, but also abroad. In the past period, this workplace underwent a radical transformation in response to the demands and challenges of industrial practice, which was ultimately reflected not only in the creation of new and strengthening of existing ties with enterprises of industrial practice, but also in the creation of networks in the aforementioned area with scientific institutions at home and abroad.

### Benefits for practise

A more fundamental influence on the creation of a complex methodology was processed in the form of digital, virtual and 3D models of the investigated workplaces. The conception of this digital model and all its attributes was extremely important for the verification and comparison of the so far explored links of digital interactions within the enterprise processes of engineering production, ultimately leading to the creation of virtual manuals and the analysis of production and work spaces with all their parameters that can be modified according to the current requirements of industrial practice. A complex methodology for optimizing the production line and material flow was developed using the Tecnomatix Plant Simulation and Process Simulate software module. The mentioned methodology was built on the basis of a simulation task for the company Eco-bags, s.r.o., the design of a digital simulation model of the finished product warehouse of the company Calmar (Tauris Group, a.s.), the construction of which is currently underway according to the proposed solution by the responsible researcher and

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**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
249 164 €  
**Project ID**  
APVV-17-0258

selected members of the research team as well as digitized model of the PAIC Sjf TUKE workplace. The first method was a digital virtual tour through a virtual headset according to the exact data obtained from the proposed floor plan solution, the second was a capacity calculation of the status of finished and work-in-progress production, which enabled reconfiguration based on the scientific and research requirements of the project itself. The modularity of the solution allows the reconfiguration of the input parameters according to the client's requirements.

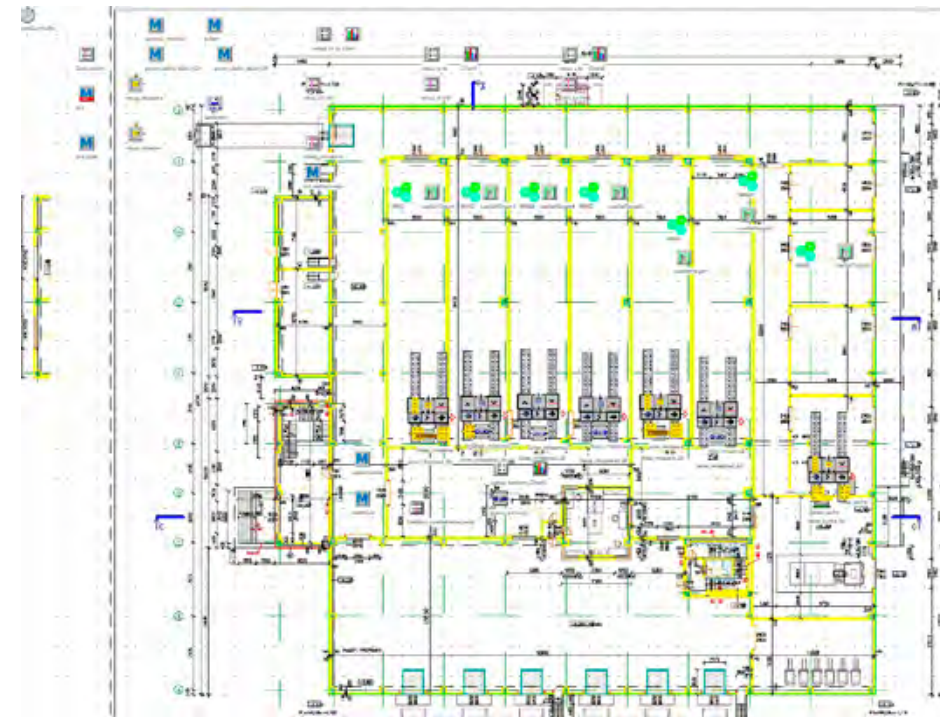


Fig. 4

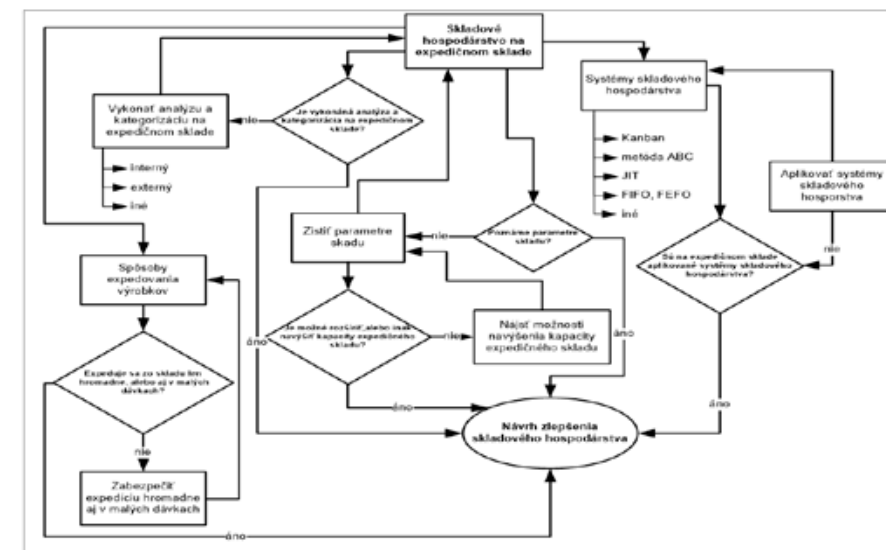


Fig. 1

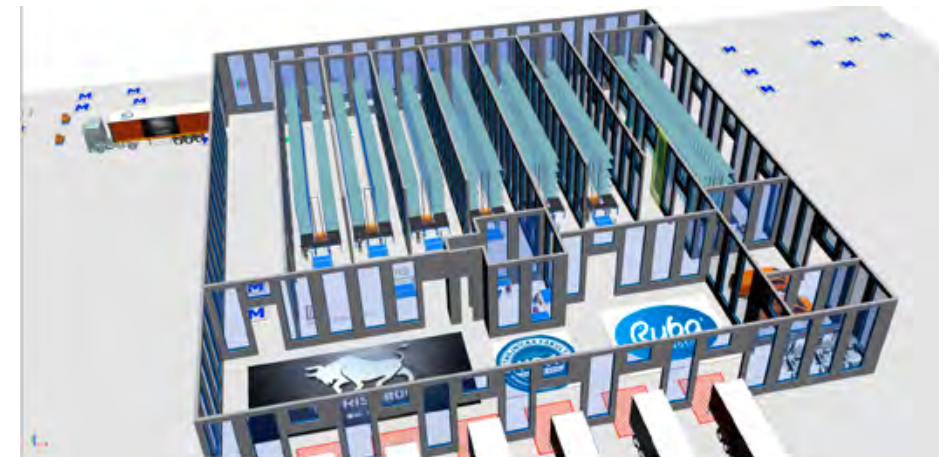


Fig. 5

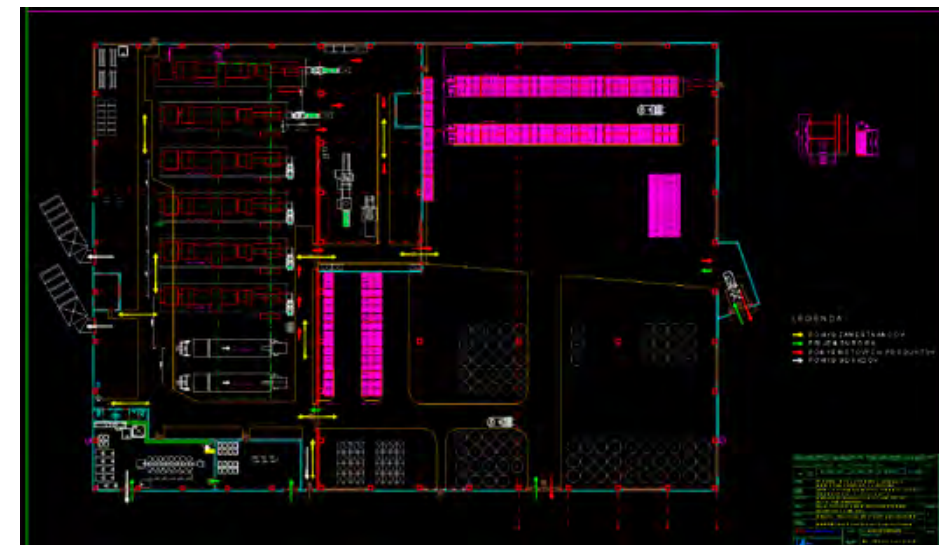


Fig. 3

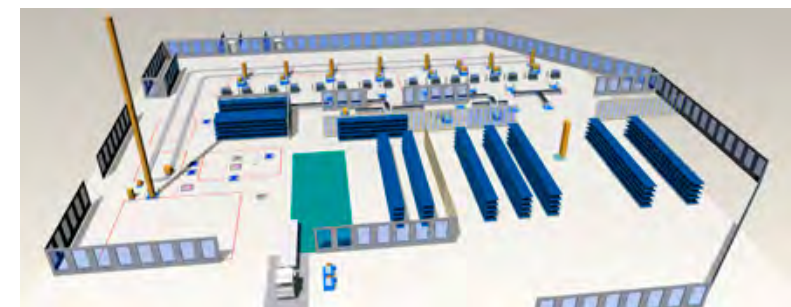


Fig. 2



## Selective conversion of waste biomass by chemical and biotechnological processes

### Research subject

The project was aimed to the conversion of waste lignocellulosic materials and their subsequent products by chemical and biotechnological processes. The catalytic conversion of hemicellulose, cellulose and their oligomers was focused on production of valuable chemicals traditionally obtained from fossil feedstock. The project emphasizes technological aspects of process with achieving the highest yields, conversions and selectivities of reactions as well as on waste minimization using recyclable nanostructured heterogeneous catalysts. It was also focused on biotechnological valorisation of xylose, glucose and their oligomers from hemicellulosic and cellulosic fraction of plant biomass by chemical treatment. Biotechnological processes were aimed on the cultivation of different types of oleaginous microorganisms and on optimization of the conversion efficiency of carbohydrates into microbial intracellular oil with attractive commercial application.

### Aim of the research

The project aims were focused on:

- Selective fractionation of lignocelluloses to maximally separate individual components and minimizing the formation of products negatively affecting biochemical processes
- Selective conversion of hemicelluloses to products which are up to now produced on a fossil base
- Microbial (biotechnological) conversion of hemicellulose, glucose and gluco-oligomers into microbial oils containing attractive biologically active compounds: polyunsaturated fatty acids, carotenoid pigments, coenzyme Q10
- Non-enzymatic conversion of cellulose into glucose and gluco-oligomers, optimization of reaction conditions and of used catalysts mainly recyclable to achieve maximum conversion to the desired products, with minimal production of substances affecting microbiological processes
- Selective conversion of cellulose mainly to formic acid
- Development of the selective catalytic conversion of bioethanol (the product of the conversion of glucose and gluco-oligomers) to butadiene

### Achieved results

Biotechnological part of the project has been focused on preparation of hydrolyzed lignocellulosic materials (acidic, basic, and enzymatic hydrolysis) and on their bioconversion by oleaginous microorganisms synthesizing attractive lipids. Straw and spruce sawdust after optimization of their hydrolysis and cultivation conditions appear to be as potential substrates for their biotechnological evaluation and production of biologically active polyunsaturated fatty acids by lower filamentous fungi. In chemical-technological part of the project were studied various types of materials with structure at the nanoparticle level and found applications as active and selective catalysts for the transformation of lignocellulose into valuable chemicals, which until now are produced on a petrochemical basis. By targeted changing the method and conditions of preparation of catalysts, their modification and using supports with different acid-base properties, we were able to influence their catalytic properties to obtain the desired reaction products. By characterizing the prepared materials and studying the relationship between their structure vs. performance, we contributed to a deeper understanding of catalytic transformation of lignocellulosic materials into desired chemicals. Many nanostructured catalysts in the studied processes demonstrated stability and high catalytic efficiency, thereby obtaining the desired valuable products with high selectivity.

### Benefits for practise

Hydrolysates of lignocellulosic materials are attractive substrates from the point of view of process economics for their biotechnological evaluation using oleaginous microorganisms synthesizing bioactive polyunsaturated fatty acids. Biotechnological transformation of hydrolyzed lignocellulosic materials is thus a significant contribution to solving the problem of processing agro-industrial waste by natural way. The results of studies published in the world indicate that the utilization of biomass by selective catalytic conversion processes is progressing rapidly and currently has enormous potential. The study results obtained by us brought new knowledge and contributed to a deeper understanding of

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08/2018 - 12/2022  
**Budget from agency**  
250 000 €  
**Project ID**  
APVV-17-0302

the issue of the catalytic transformation of lignocellulose into selected products in the presence of various types of nanostructured catalysts. It turned out that due to the scarcity and high price of fossil resources, the mentioned processes could be an alternative way of producing industrially important substances independent of petrochemicals in the future.

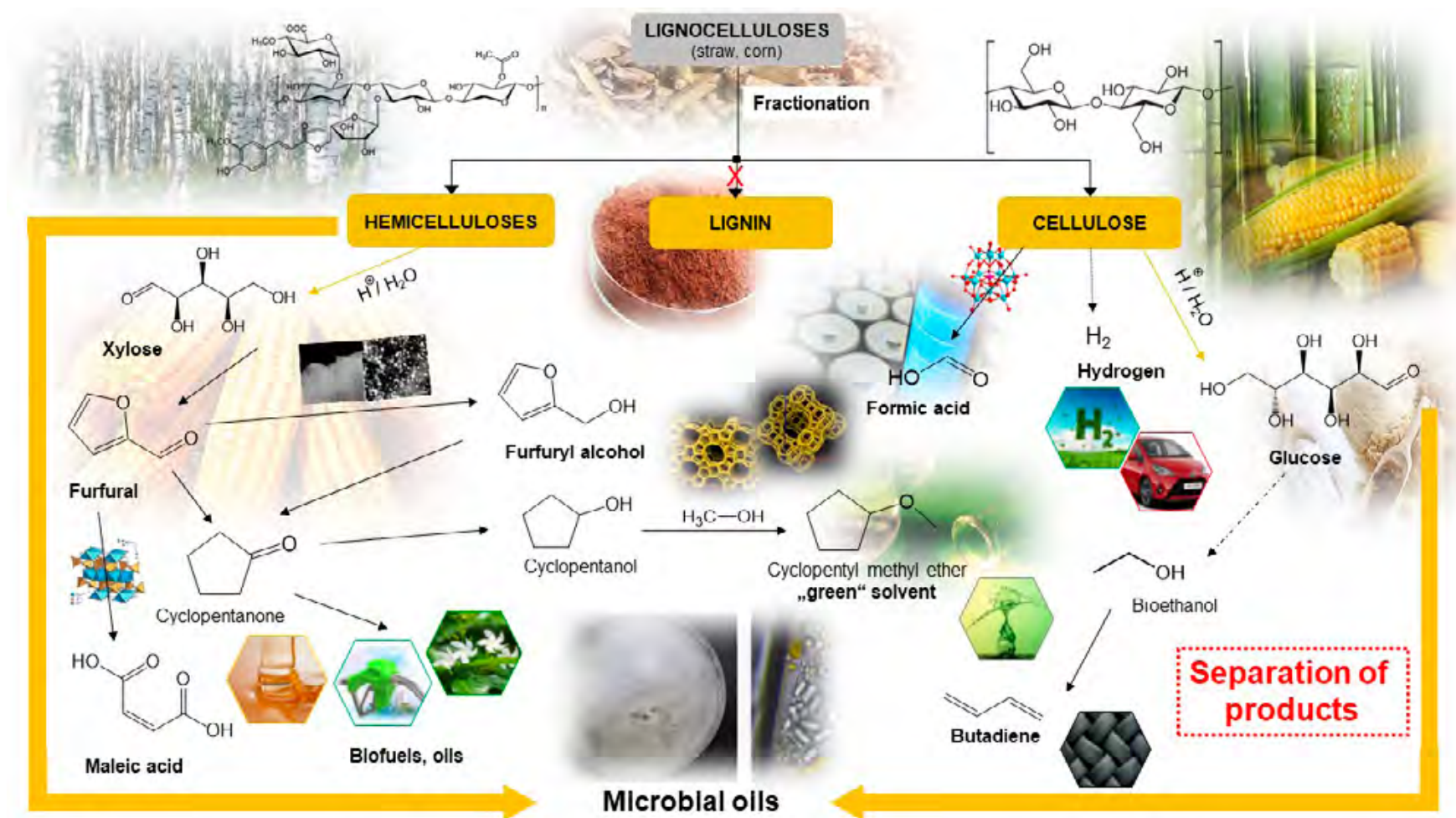


Fig. 1

Fig. 1 / Studied methods of waste lignocellulose utilization by chemical and biotechnological processes to valuable products.

Fig. 2 / Cultivation flask with filamentous fungi *Actinomucor elegans*.

Fig. 3 / Filamentous fungi *Actinomucor elegans* on Petri dish; Mycelium with microbial oil under microscope.



Fig. 2

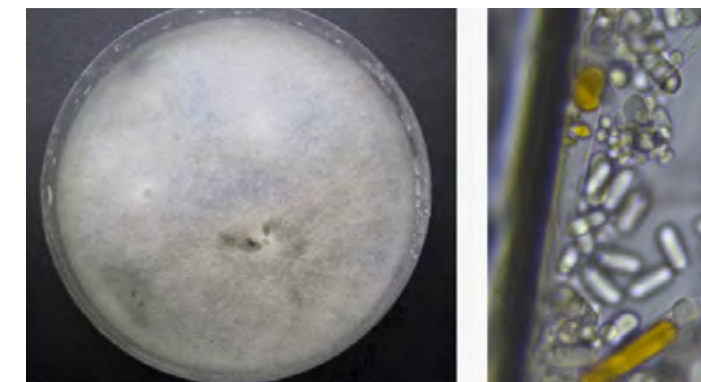


Fig. 3



# Implementation of the 4th Industrial Revolution Principles in the Production of Tyre Components

## Research subject

Creating a system of condition monitoring and proactive maintenance of a manufacturing device and tools for interactive communication between the device's user and supplier.

## Aim of the research

- designing means for acquisition, transfer, storing, and analysing data for the assessment of the device's technical conditions
- system for analysing the data from the device's condition monitoring by the tools of artificial intelligence
- creating interactive graphic 3D models for remote access to the device's modules
- designing communication interconnection of interactive graphic models with the remote service centre

## Achieved results

The device studied were tyre bead winding lines. The significance of individual mechanical and electronic modules of the lines for condition monitoring was determined by analysis of the data on failure occurrence in the year 2017 at a tyre manufacturer operating 5 bead winding lines from different suppliers. To assess the significance of individual modules, data visualisation techniques were used and statistical analyses, namely Pareto analysis, frequential analyses and Fourier analysis. The system of acquiring and storing the data was worked out as a local platform operated at the device's user and as remote processing module in a centralised service centre. For performing specific tasks of acquiring, storing and analyses of the data the IoT platform ThingWorx was chosen. As the decisive technological characteristics of bead winding devices, the bead diameter, resp. circumference and the rubber layer thickness were identified. For continual control of the produced tyre beads diameter an indirect method of measuring the consumption of wire spent on bead winding by an incremental sensor was developed, as described in the Patent Application (SK)PP 34-2023.

The concept of the determination of tyre bead diameter by optical scanning was worked out in two methods. The first one is based on analytical computation of the parameters of a generally positioned ellipse approximating the tyre bead by determining the coordination of points placed on the internal circumference of the tyre bead. The second method is based on the approximation of a tyre bead by a closed 2-dimensional shape rotated on a closed elliptical path. This method was used in the design of a prototype of a tyre diameter measuring device. During the project, the decrease of the rubber layer thickness with increasing wire speed as well as improving the rubber layer uniformity with increasing length of the rubberising die. A design of a rubbering head was worked out as described in the Patent SK289019. For identification of relations in datasets from technological experiments the method of neural networks was used. The structure of the neural network contained 4 neurons in the input layer for input parameters, 10 neurons in the in the first hidden layer, 20 neurons in the second hidden layer and 1 neuron for the outputting quantity. After training the neural network the correlation coefficient was 0.97 achieved. The proactive service system of the manufacturing device represents the environment containing condition monitoring, data analysis, prediction models, digital maintenance integration and virtual trainings of operators / maintenance staff. A component of the proactive maintenance system is represented by 3D graphic models of devices created in the system of Vuforia Augmented Reality. This functionality allows virtual objects to be perceived as a part of physical reality. The augmented reality system is able to control interactively a physical device through a user graphic interface implemented in Vuforia View. The IoT-based maintenance system of manufacturing devices allows the remote technical support of operators and maintenance staff through smart goggles with a voice output. The technical support is realised as an internet communication between an expert (device manufacturer) and the person wearing the goggles.

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209 845 €  
**Project ID**  
APVV-17-0310

During the communication, the expert can navigate the person at the device and thanks to the integrated camera the maintenance person can communicate with the expert and share the current look at the device.

## Benefits for practise

- complete condition monitoring of manufacturing systems
- analysis and interpretation of data from condition monitoring
- data integration and visualisation with hierarchical access
- implementation of virtual reality tools in the operation of manufacturing systems

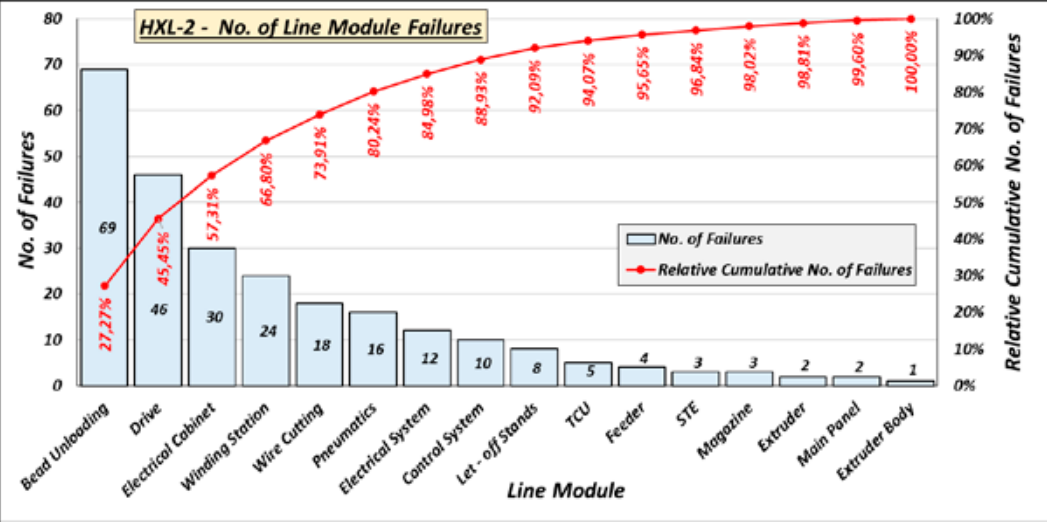


Fig. 1

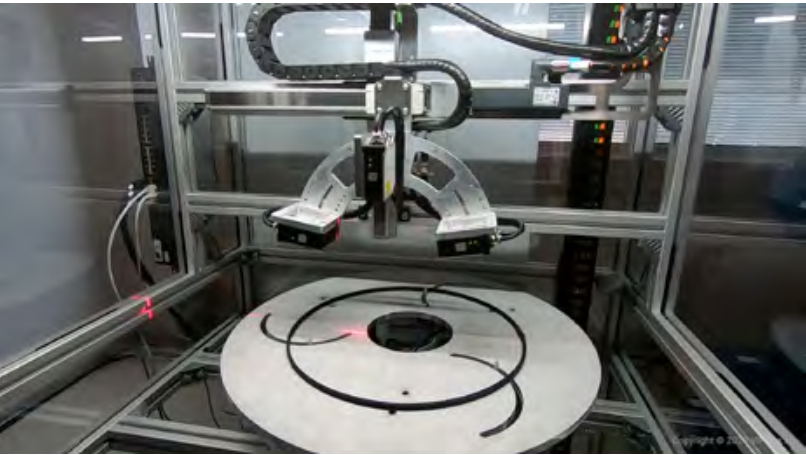


Fig. 2

## FFNN – regresná úloha

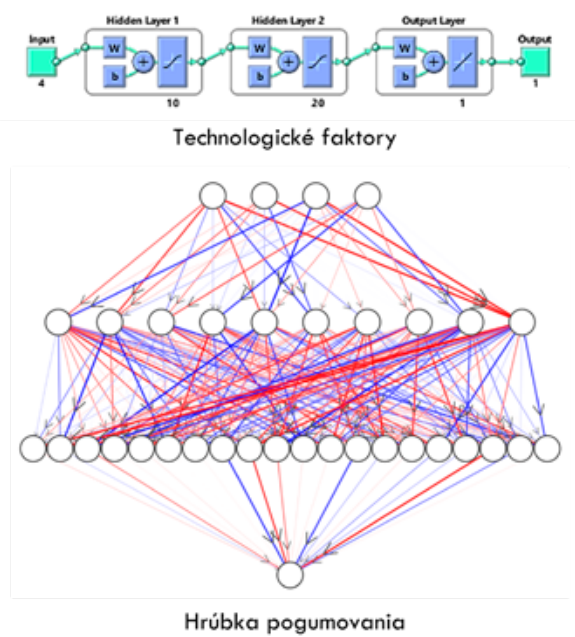
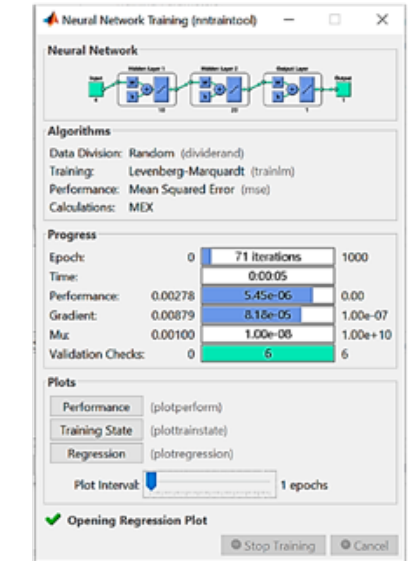


Fig. 3



Fig. 4

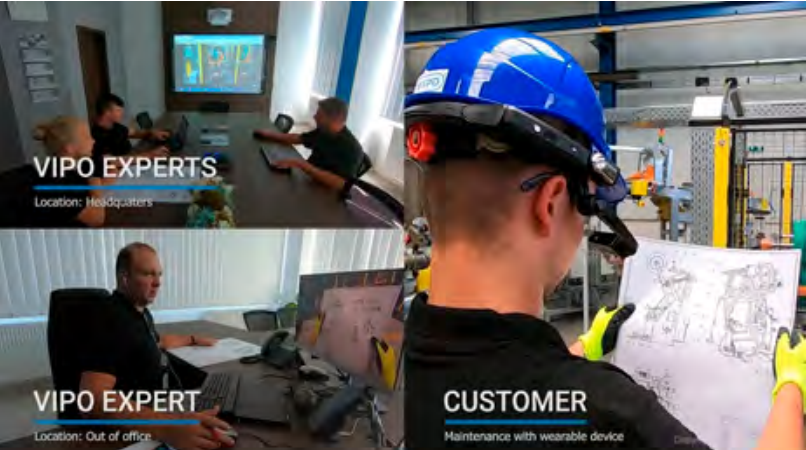


Fig. 5



Development of refractory pyrochlore phases for high temperature applications of non-oxide ceramics

Research subject

The main purpose of the project was to perform a systematic study on the effect of various rare-earth elements (RE) on the sintering, microstructure, and high-temperature properties of ZrB<sub>2</sub>-based ceramics. Due to their excellent combination of properties and a relatively low density, these materials are the mostly investigated materials for Thermal Protection System (TPS) of hypersonic vehicles. Monolithic ZrB<sub>2</sub>, however, cannot withstand temperatures over 2000°C. An innovative approach of the project consisted of the „in-situ“ formation of RE<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> pyrochlore phases during sintering or oxidation. The main hypothesis was that RE elements with a small cation size RE<sup>3+</sup> (i.e. with a higher atomic number, e.g. Yb and Lu) should increase immiscibility and viscosity of the in-situ formed oxide layer, leading to the significant reduction of the oxidation rate.

Aim of the research

The ultimate aim of the project was to develop next generation transition metal diboride ceramics (ZrB<sub>2</sub>) with significantly improved ultra-high temperature properties and long-term thermo-chemical resistance. The following most important specific objectives were set: 1) To understand the mutual effect of different types and amounts of RE and SiC additives on the densification, microstructure, and mechanical properties of ZrB<sub>2</sub>; 2) To understand and clarify the effect of RE elements on the in situ formation of pyrochlore refractory phases, and their effect on the oxidation/ablation resistance of the materials.

Achieved results

The project has generated new significant knowledge, which significantly improved the current state of the art in the concerned research field. In the first step, the effect of three different RE-based sintering additives was investigated (Eu<sub>2</sub>O<sub>3</sub>, Yb<sub>2</sub>O<sub>3</sub> a Lu<sub>2</sub>O<sub>3</sub>), which were added into the matrix of ZrB<sub>2</sub>-25vol.%SiC at different concentrations (2, 5, a 10 wt.%). A thorough analysis confirmed the scientific hypothesis that

the RE elements with a small cation size of RE<sup>3+</sup> have more significant impact on the oxidation and ablation resistance of the materials, which increased with the increasing amount of these additives. When the materials were sintered with 10 wt.% Yb<sub>2</sub>O<sub>3</sub>, the ablation resistance was three times higher when compared to the material without RE addition. This was attributed to the formation of Yb<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> pyrochlore phase during sintering. Since the in-situ formation of the pyrochlore phase occurred during sintering, the research team came up with an innovative idea to use this Yb<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> pyrochlore phase as the sintering additive, replacing Yb<sub>2</sub>O<sub>3</sub>. In order to further decrease the temperature of sintering, these materials with different content of both Yb<sub>2</sub>O<sub>3</sub> a Yb<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> were prepared using a reactive processing route. In this method, the final composition ZrB<sub>2</sub> – 25vol.% SiC was formed in-situ during sintering by the reactions between ZrSi<sub>2</sub>, B<sub>4</sub>C a C. When compared to the conventional (non-reactive) sintering, the temperature of the sintering was lowered by 450°C, from 2050°C to 1600°C. Due to the lower sintering temperature, a significantly finer microstructure was formed, leading to the significantly better mechanical properties and oxidation/ablation resistance of the materials. It was confirmed that the addition of Yb<sub>2</sub>O<sub>3</sub> led to the stabilization of tetragonal (i.e. high-temperature) modification of ZrO<sub>2</sub> in the oxide layer, which resulted in the best oxidation/ablation resistance of this material.

Benefits for practise

This project contributed to the clarification of the effect of RE-based sintering additives on the preparation, phase composition, microstructure, mechanical and high-temperature properties of ZrB<sub>2</sub> ceramics with 25 vol.%SiC. The results of the project will be mainly utilized by a research community during the development of new ceramic materials for applications performing in extreme conditions, such as highly oxidative environment at temperatures above 2000°C. A finding that the same material with identical chemical composition, finer microstructure and improved mechanical

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**Project ID**  
APVV-17-0328

properties can be prepared by a reactive sintering route at the temperature 450°C lower than the temperature of conventional non-reactive sintering (1600°C vs. 2050°C) can be considered as one of the most important result of the project. Such an innovative way of the preparation of these materials significantly lowers the processing costs of the materials for aerospace and other extreme applications. This fact significantly broadens the application potential of the results of this fundamental project.

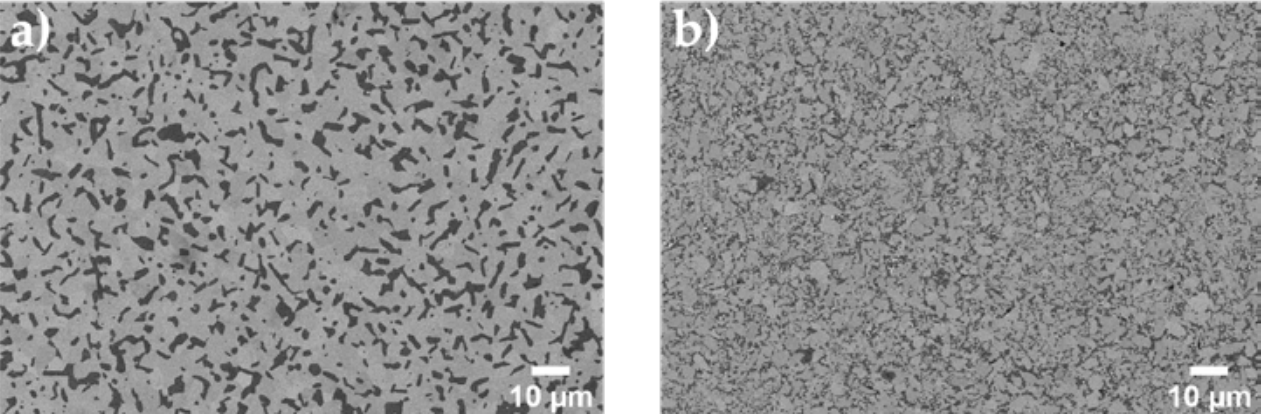


Fig. 1

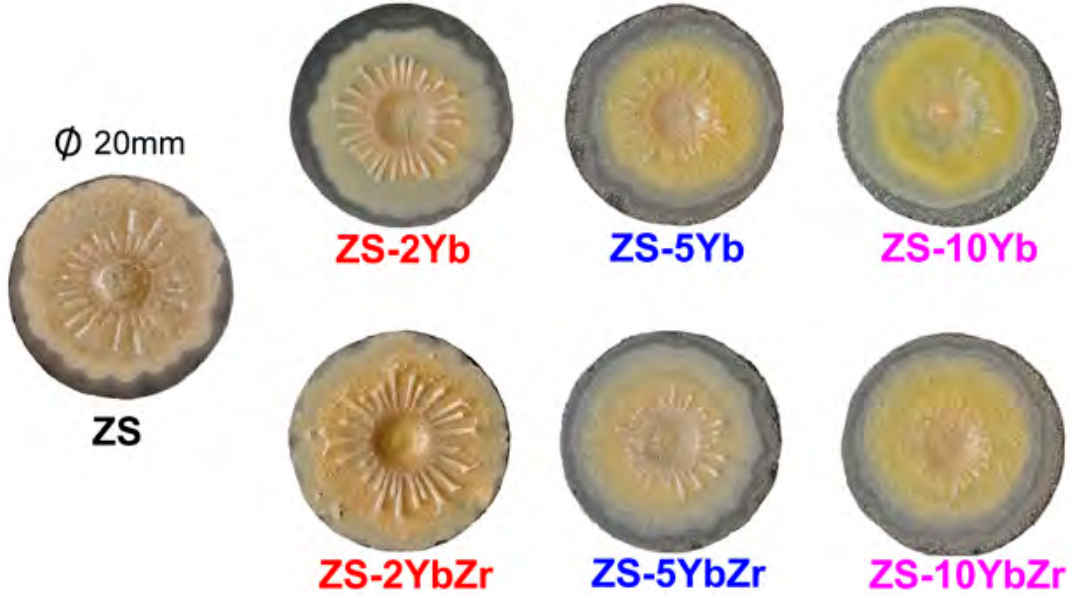


Fig. 2

Fig. 1 / Microstructure of ZrB<sub>2</sub>-25obj.%SiC material sintered by: a) conventional non-reactive sintering at 2050°C and pressure of 70 MPa; b) reactive sintering at 1600°C and pressure of 70 MPa.

Fig. 2 / Macro-images of the surfaces of reactive sintered ZrB<sub>2</sub>-25obj.%SiC samples with different content of Yb<sub>2</sub>O<sub>3</sub> (ZS-2Yb, ZS-5Yb a ZS-10Yb) and Yb<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> (ZS-2YbZr, ZS-5YbZr, ZS-10YbZr) additives after the ablation tests using oxy-acetylene flame at 2700°C for 60 s.

Fig. 3 / SEM microstructures of the cross-sections of reactive sintered ZrB<sub>2</sub>-25obj.%SiC samples: a) without sintering additive; b) with 10 wt.% Yb<sub>2</sub>O<sub>3</sub>; and c) 10 wt.% Yb<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> after ablation test at 2700°C for 60 s. In all materials, three distinct layers were observed: 1-ZrO<sub>2</sub>-based oxidation layer, 2-SiC-depleted ZrB<sub>2</sub> matrix, 3-non-affected material.

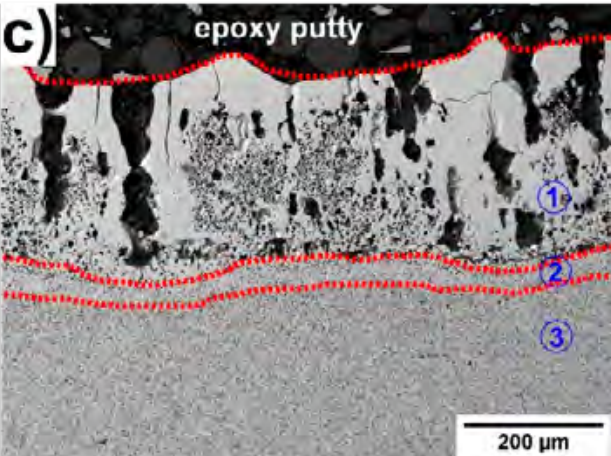
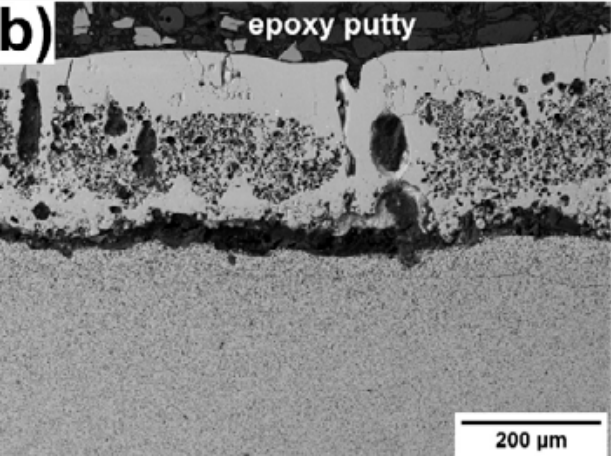
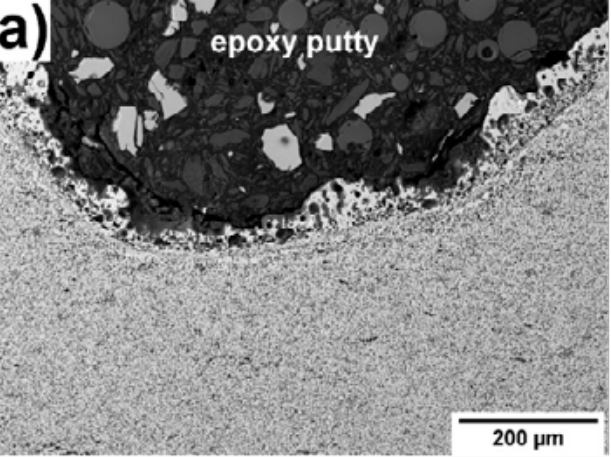


Fig. 3



# Cascade use of wood based waste from metropolitan agglomerations

## Research subject

The project was focused on the creation and implementation of a model of cascade recovery of waste wood and old wood products, for which there is no other systemic solution than incineration, mainly due to their voluminousness and chemical contamination. The project brought a new approach to the classification of wood waste and the proposal of methods for its further mechanical, thermomechanical and hydrothermomechanical processing according to the degree of contamination. Cascade recovery thus creates a higher degree of added value than can be achieved by energy recovery, which corresponds to the promoted concept of zero waste.

## Aim of the research

The timing of the implementation in the pre-covid years, which favored the development of the green economy in our country as well, helped to fulfill the strategic goal, which was to increase the volume of recycled wood with the incorporation of pre-processing of less chemically contaminated wood-based materials into the process of the existing wood recycling system in the context of creating a circular and low-carbon economy. The specific objectives of the project took into account its research-scientific nature and were aimed at the laboratory optimization of the pre-processing conditions of waste wood in order to take into account the classes of contamination, at the design of separation methods for the removal of unwanted chemical substances and at the design of new recycling technologies for their implementation in existing productions.

## Achieved results

As part of the solution, the flows of wood waste material from households and industry were characterized, under the conditions of its maximum concentration, in the metropolitan wider area. Developed models of furniture recovery and models of separate collection of wooden products after the end of their use have a multiplier effect, but they may

not be adopted in the future due to the development of environmental behavior in society, but their absence had to be pointed out. The proposed strategies were supplemented by developed own scientific procedures for the rapid determination of selected contaminations in waste wood and research activities in its sorting and recycling within the case study. The application part of the project was focused on research in the field of creating new thin-walled and flat-pressed wood-plastic materials based on wood fiber and wood particles, the creation of thin shells as well as lightweight materials.

## Benefits for practise

The social benefit was to use the achieved outputs to point out the little-solved issue of waste wood and especially wood-based products after the end of their useful life. The main intention is to increase the recycling level and limit energy use in the first stage without reuse or recycling, if technically feasible. As part of the project, monitoring of material flows of wood-based waste material was carried out, with the fact that its further material recovery was estimated at 23%. For the laboratory-oriented stage, a theoretical study of the determination of the chemical load incorporated during the last 50 years was developed. The practical outputs were two methods of rapid determination of formaldehyde and urea using HPLC directly on the spot (Fig. 1). During the creation of reference groups of waste wood and processes of its material evaluation, a case study was carried out, where it was proposed to divide the raw material into 4 reference groups according to the type of waste product, while this is simply pre-sorted and further separated into 3 to 4 material groups. Defining cascades for the creation of higher added value represented a typical academic part of the project, where the goal was to demonstrate, based on small laboratory experiments, the principle of the cascade use of wood (examples of good practice) (Fig. 2). The obtained results have been published and achieve a satisfactory citation rate. The last practical stage was focused on specific solutions to

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249 484 €  
**Project ID**  
APVV-17-0330

increase the recycling rate of waste wood, while two organizational models were developed for specialized collection yards. The conclusion of the solution was devoted to the preparation of a system solution for the processing of waste wood, for which a group of wood-plastic products with massive processing potential for the future was chosen. As part of the solution, one patent application was submitted for the field of lightweight construction materials (Fig. 3), one new product was created and two technologies were verified in semi-operation (Fig. 4 and 5).

Fig. 1 / Determination of formaldehyde on a Rezex ROA H+ column at a temperature of 30°C (left) and urea on a Rezex ROA Pb2+ column at a temperature of 80°C (right) by the internal standard method.

Fig. 2 / Scheme of the laboratory experiment of the multi-cascade model of waste wood recovery.

Fig. 3 / Lightweight boards with 10% plastic addition with hard shell and soft core (right), layered mat (left).

Fig. 4 / Rigid shells wood fiber/plastic (combination of fiber and powder), thickness 1.5 mm. Wooden decor (plastic content on the right 10%, 15% and 20%) (left), shaping with a hand heat gun (plastic content 35%) (right).

Fig. 5 / Manufactured thin wood fiber/plastic composites 3.2 mm thick, plastic content 5, 10, 15, 20, 30 and 40% (left), comparison of wood-plastic boards - fiber and shavings (right).

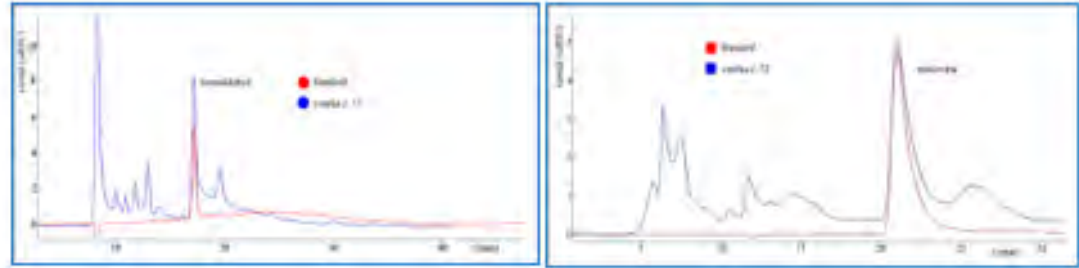


Fig. 1

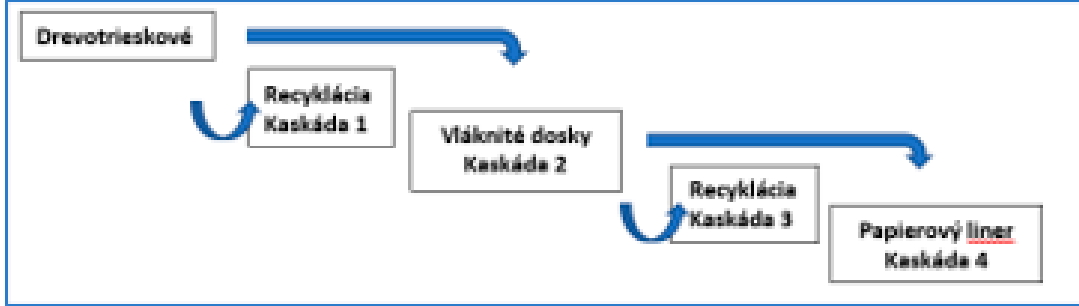


Fig. 2



Fig. 3



Fig. 4



Fig. 5



# Increasing the efficiency of forming and joining parts of hybrid car bodies

## Research subject

The subject of the research was the optimization of forming and joining conditions of steel sheets and aluminium alloy sheets intended for the production of hybrid car body parts. The current period is characterised by a constant pressure to reduce emissions produced by automobiles. One of the possible ways of reducing car emissions is to reduce the weight of car bodies. The way to reduce the weight of a car is through the concept of hybrid bodywork, which uses various types of materials based on light alloys, composite materials and high-strength steel sheets. The solutions associated with such hybrid body designs must address both the forming and the subsequent joining of these parts in a multi-material concept. Thus, the optimisation of the forming conditions of aluminium alloy and high-strength steel sheets is important in order to increase the efficiency of the process. Based on the results of the analysis of the stress-strain states on the stampings, a corresponding joining technology was proposed. The output is a comparison of the load-bearing capacity of the joints after different values of deformation and stress-strain states.

## Aim of the research

The objectives of the project were based on a systematic and comprehensive approach to solving the problem of forming and joining of steel sheets and aluminium alloy sheets of different grades. The original approach to solving the project consisted in planned experiments, which provide sufficient information on the process of forming and joining of aluminium alloy sheets and steel sheets. This knowledge will allow to increase the efficiency of forming and joining sheet metal of hybrid car bodies.

## Achieved results

FEM analyses were used to determine the stress-strain states of real parts of stampings joined by different technologies. The adequacy of the used computational and simulation methods was confirmed and optimized for real stampings according to the results of complex material analysis of these stampings (mechanical tests, light and electron microscopy and RDX diffraction, tribological tests on a friction simulator, etc.). Based on the results of both approaches to the analysis of stress-strain states of real parts of stampings, a corresponding technology for the experimental preparation of test specimens with analogous stress-strain states was proposed. The thus prepared experimental material with the desired stress-strain state was experimentally formed and joined in order to make the forming and joining process more efficient and to increase the load-bearing capacity of the joints. Different types of PVD coatings were used to increase the tool durability. Furthermore, the originality of the project consisted in the local modification of the topography parameters of the micro-geometry of the surface of the aluminium alloy sheets in order to limit (suppress) the galling of aluminium on the surface of the joining tool. The purpose of these modifications was to reduce the contact area between the tool and the sheet to be joined, while ensuring continuous lubrication during joining.

## Benefits for practise

The results of the project are applicable mainly to processors of thin aluminium and steel sheets engaged in forming and joining. The optimization of forming conditions leads to an increase in the durability and service life of forming tools by reducing the friction ratios between the processed sheets and the functional parts of the forming tool by suitable surface treatment of the forming tools. The results obtained in the investigation of the optimization of the joining processes of ferrous and non-ferrous materials will make it possible to increase the load-bearing capacity of

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**Term of solution**  
08/2018 – 05/2022  
**Budget from agency**  
249 010 €  
**Project ID**  
APVV-17-0381

the joints. The results are particularly applicable to the optimization of forming and joining processes, with particular emphasis on the production of hybrid car body parts. All manufacturers of components for the automotive industry in Slovakia, as well as companies focused on the production of components and products, especially for the consumer industry, can be the recipients of the results of the solution. The results can be used in the reduction of product weight, with particular emphasis on the production of automotive bodies and components. When using mechanical joining processes, the economic benefit lies in the reduction of energy costs for the production of joints and in the increase in the environmental friendliness of joining processes compared to welding processes.

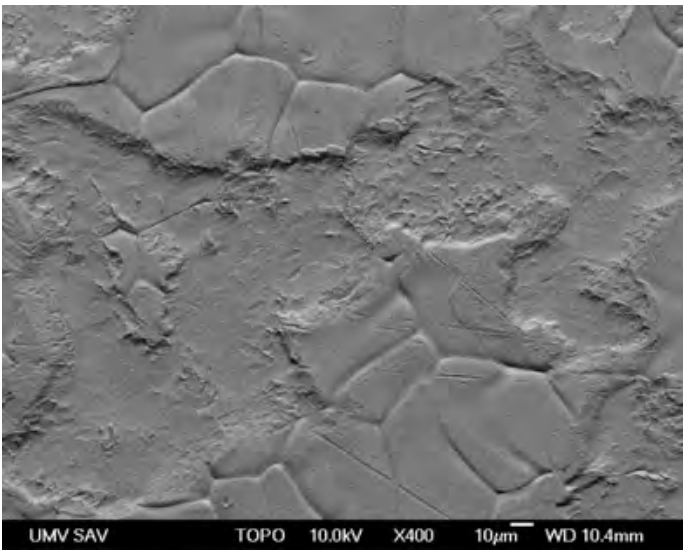


Fig. 1

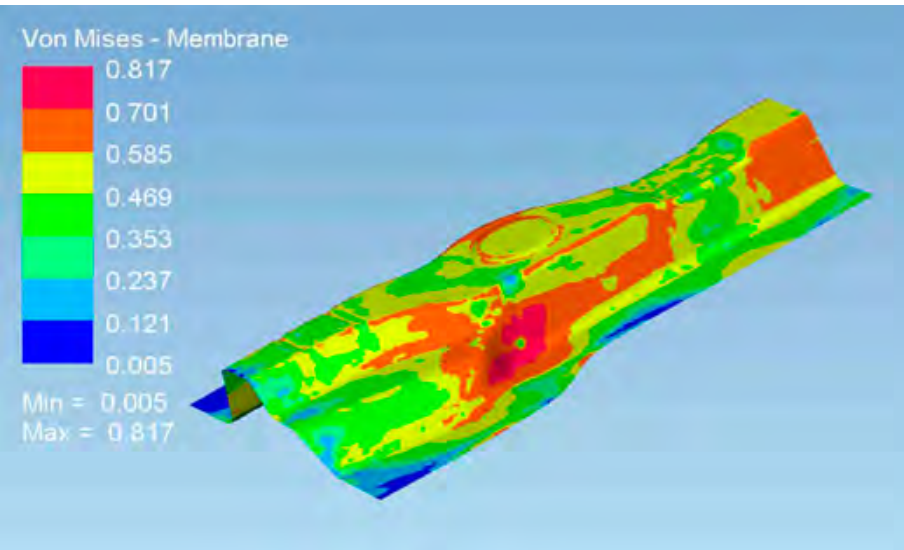


Fig. 2

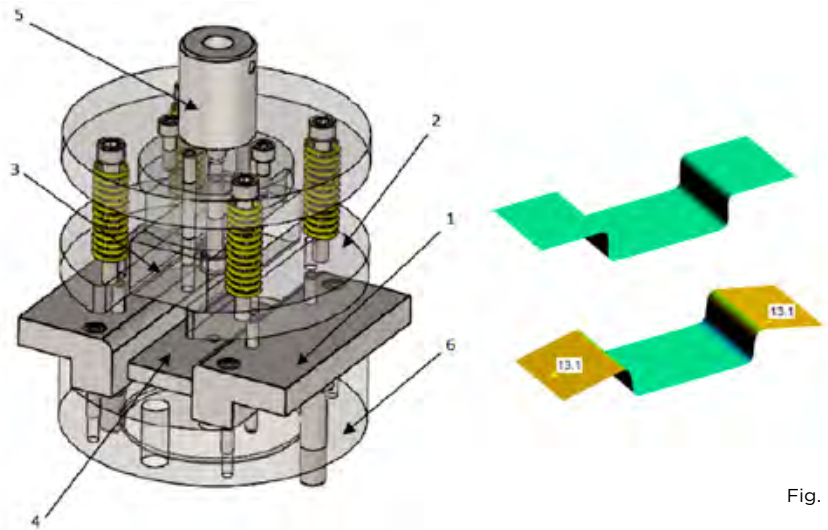


Fig. 3

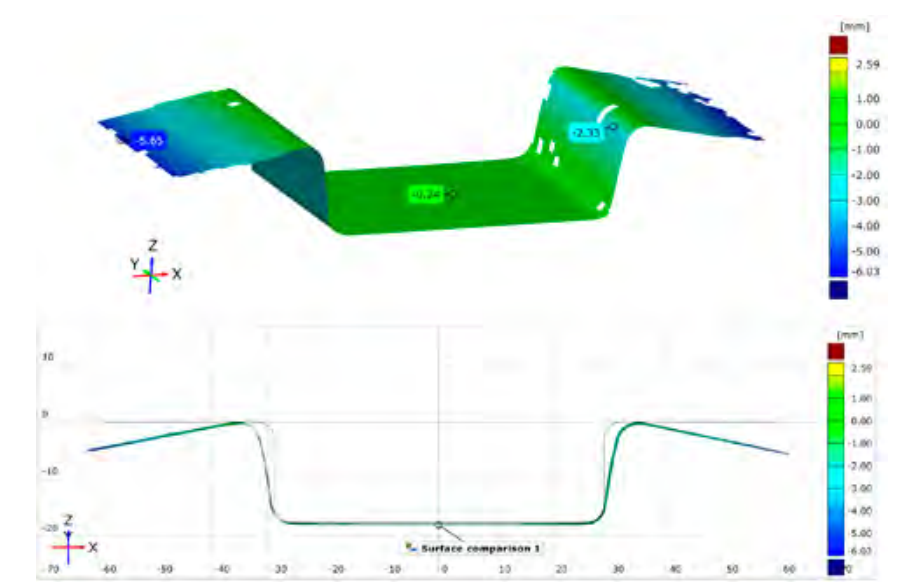


Fig. 4

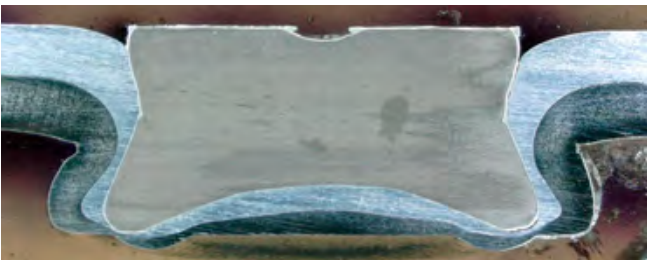


Fig. 5

Fig. 1 / Stochastic topography of zinc coating

Fig. 2 / Von Mises stress distribution in the stamping part

Fig. 3 / Fixture for sheet metal springback test

Fig. 4 / Springback measurement on the sample

Fig. 5 / Mechanical joint of a combination of steel and aluminum sheet



## Thermal modification of wood with saturated water steam for the purpose of a targeted and stable change in the color of wood

### Research subject

The project was focused on the research of changes in the physico-chemical properties of wood in the process of thermal modification with saturated water steam in the temperature interval  $t = 105\text{--}135\text{ }^{\circ}\text{C}$ , with a focus on analyzes of the influence of the hydrolysis of hemicelluloses and the amorphous part of cellulose on the change in wood acidity, which is initiated destruction of the chromophoric system of wood causing a change in the color of the wood.

### Aim of the research

The main aim of the project was the design of wood color modification technology - a process of steaming beech, birch, maple and alder wood into non-traditional color shades to increase the color variety of wood in construction products and 3D decorative objects.

### Achieved results

Through experimental research, the colors of thermally modified wood were identified in the CIE  $L^*a^*b^*$  color space. The degree of darkening and browning of *Fagus sylvatica* L. wood is shown in Fig. 1. From the measured values of the decrease in the acidity of the wood pH and the increase in the values of the total color difference  $\Delta E^*$ , the dependencies  $\Delta E^* = f(\text{pH})$  were derived for the analyzed woods. For the tree *Fagus sylvatica* L., the dependence shown in Fig. 2.

Analyzes of changes in the chemical composition of wood induced by steaming using FTIR-ATR spectroscopy show changes in the absorption bands of the lignin macromolecule at wavenumbers 1592, 1504, 1420 and 1461  $\text{cm}^{-1}$ , which correspond to C-H deformation vibrations in the  $\text{CH}_2$  and  $\text{CH}_3$  groups of the aromatic ring. The decrease in the intensity of the absorption band at the wavelength of 1648  $\text{cm}^{-1}$  is noteworthy, which increases with the increase in the vaporization temperature. The mentioned phenomenon is explained by the disappearance of  $\alpha$ -carbonyl groups due to the reactivity

of lignin side chains with neighboring benzene nuclei during the formation of quinine structures.

By monitoring the effect of UV radiation in the form of accelerated aging in the Xenotest Q-SUN Xe-3-HS, the positive effect of the destruction of the chromophoric system of wood caused by steaming on the resistance of steamed wood to photochemical reactions of wood and UV radiation was demonstrated. It aptly documents the different darkening and browning of unsteamed and steamed wood. The color difference expressed by the color difference  $\Delta E^*$  for maple wood is shown in Fig. 3. While the total color difference caused by UV radiation of unsteamed wood is  $\Delta E^* = 18.5$ , the total color difference caused by UV radiation of steamed wood with saturated water steam at temperature  $t = 135\text{ }^{\circ}\text{C}$  is  $\Delta E^* = 7.2$ . The reactivity of steamed wood towards the photochemical reactions of wood caused by UV radiation is about 2/3 lower.

The results of the project were published in 2 scientific monographs and in journals: CCC – 12, WOS – 17, others – 14.

### Benefits for practise

Based on the results of experimental research, wood steaming modes were designed for full-volume color change to non-traditional color shades: pink-yellow, red-brown and dark brown-gray. The contrasts of the color shades of spring and summer wood, or the accentuation of the wood texture of individual trees enrich the domestic market and foreign exports with lumber and blanks in new attractive colors. The proposed regimes are put into practice at Sundermann s.r.o. Banská Štiavnica.

Semi-operational tests verified the technology of low-temperature drying modes without changing the color of the wood during the drying process. The proposed modes differ from the classic drying modes in that the evaporation of free

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08/2018 – 12/2022  
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249 840 €  
**Project ID**  
APVV-17-0456

water from the wood is carried out at an air temperature in the drying room  $t \leq 45\text{ }^{\circ}\text{C}$ , which prevents the initiation of chemical reactions of changes in the chromophoric system of the wood.

At the workplace of VIPO a.s. Partizánske (Slovakia), in cooperation with the Faculty of Wood in Zvolen, demonstrated the positive effect of the addition of an additive - keratin biopolymer to polycondensation UF resins on the release of formaldehyde. Through the reactions of creatine with the UF resin, during the curing of the UF glue, formaldehyde binds to the glue and creates stable methylene bonds and reduces the emission of formaldehyde by 40%.

The results of the project are protected by 1 patent application, 1 utility model, 2 new products and 4 proven technologies.



Fig. 1

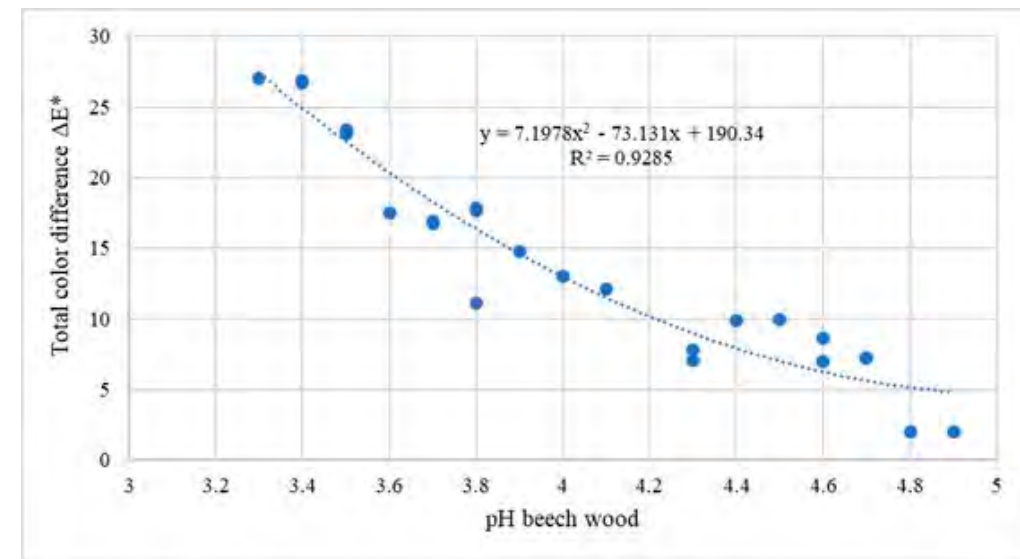


Fig. 2

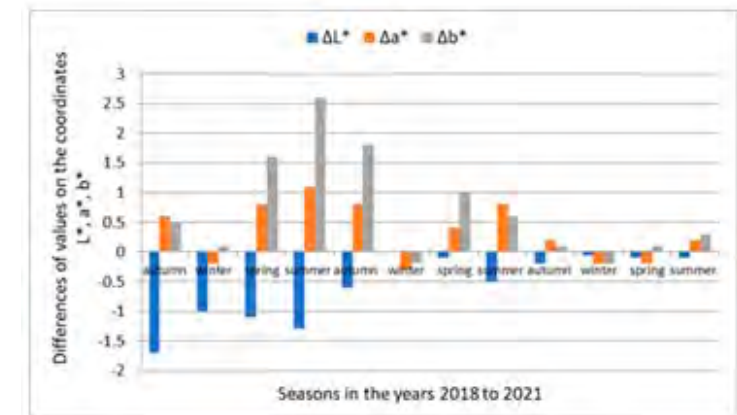


Fig. 4

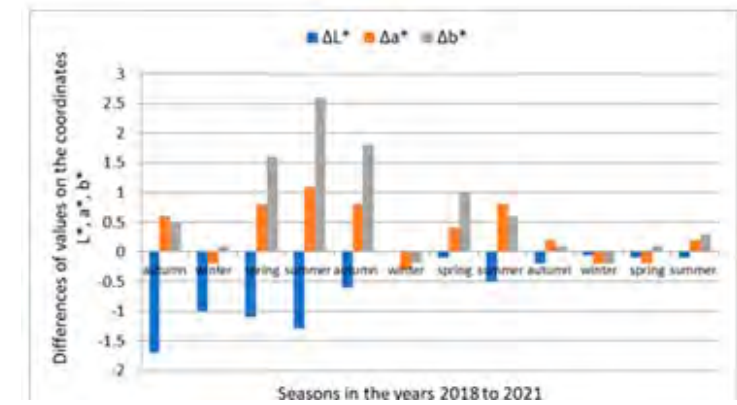


Fig. 5

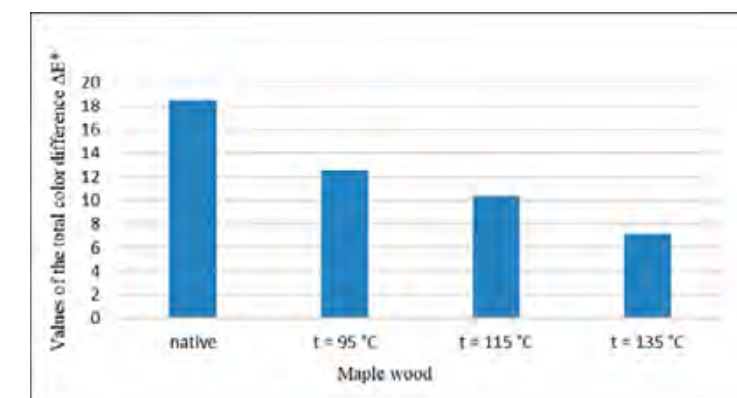


Fig. 3



## Detection of the erosive effect of pulsating water jet on material

### Research subject

Water droplet erosion is considered an aggravating phenomenon. Represents a specific material degradation process, leading to deformation and mass loss. Elucidation of the phenomena related to the water droplet impingement with the material surface can be used for the controlled treatment and for material disintegration.

### Aim of the research

- Comparison of erosion effects of Pulsating Water Jet (PWJ) with different methods of pulse generation.
- Prediction of the erosive effect of water droplets.
- Surface topography assessment.
- Description of structural and physical changes in the surface and subsurface layer.
- Determining the depth, degree of material strengthening in the subsurface layer.
- Detection of the residual stresses.

### Achieved results

New methodical procedures for ultrasound tuning into resonance for effective erosion of droplets for frequencies of 20 kHz or 40 kHz were created. Using vibration emission, exact data on the mechanical response of the material was obtained in real time, while erosion intervals - incubation, acceleration, culminating and terminal stages were determined. The incubation and acceleration stage can be used for surface treatment because of presence high density dislocations. Using this erosion stage it is possible to increase the fatigue resistance. Using X-ray  $\mu$ -CT, a network of microcavities resembling a fractal structure was detected in the subsurface area. The penetration ability of PWJ does not end with the formation of a groove, but continues into the core of the material in the form of micro tunnelling or piercing. Two types of cavities have been identified, blind and transitional. Result suggests that the lateral outflow causes hydrodynamic microtunnelling under the groove. This result subsequently led to further large-scale experiments, controlled surface treatment of the titanium surface. It was found that the roughened surface is characterized by a high degree of

capillary elevation due to the presence of microchannels. Such an eroded surface is effective in absorbing the energy of additional water droplets. After repeated exposure, erosion loses its progress. According to Sapoval's theory, this is a so-called self-stabilizing system and is an example of negative feedback loop. Further we analysed the modified morphologies and integrity of Ti6Al4V titanium alloy using the impact of water droplets generated by PWJ at the start frequencies  $f_s = 20$  kHz and 40 kHz. The water droplets were distributed along a linear trajectory. Two transition methods were compared to produce modified surface morphologies, one with a single transition and the other with an additional secondary transverse transition. The results positively support initial indications that PWJ surface treatment would be a preferable alternative to other conventional water jet techniques. Continuous water jets use the abrasives - solid particles whose artifacts can contaminate the treated surface. Moreover, these surface treatment processes can be carried out at pressures that are lower than 100 MPa, which is an advantage over the conventional abrasive water jet, which is generated at about 400-600 MPa.

### Benefits for practise

- By verifying a hypothesis dealing with PWJ interaction monitoring with a defined frequency, the project:
- created new experimental procedures focused on PWJ controlled erosion with significant interdisciplinary overlapping in mechanical engineering, material engineering and medicine,
  - elaborated the possibilities of using a pulsating water jet to increase the service life of the components through better mechanical resistance of the surface layer,
  - opened a new research direction of a minimally invasive, selective and non-thermal technique for on-line controlled surgical processes for removing residual bone cement in limited visual access, during reoperation of large joints by replacing water with physiological solution without affecting the structural integrity of the surrounding tissues,
  - brought the possibility of rapid determination of the

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**Term of solution**  
08/2018 - 12/2022  
**Budget from agency**  
242 355 €  
**Project ID**  
APVV-17-0490

- erosion resistance of materials as a new test technique focusing on materials used in blades in wind power plants and in jet turbines,
- indicated the possibility of research in testing the erosion resistance of applied of newly developed protective layers for sandstone reliefs for the cultural heritage protection,
  - created the possibility to create a surface with high capillary elevation using multiple droplet impact on the surface of titanium alloys, which can be used for endoprosthesis.

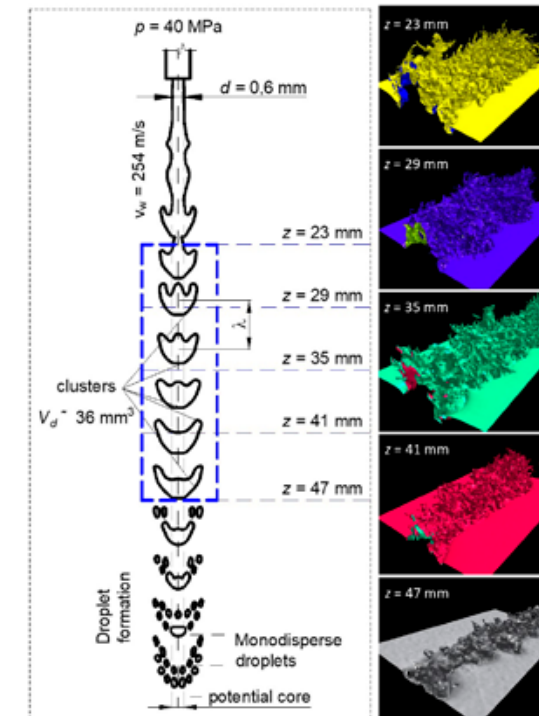


Fig. 1

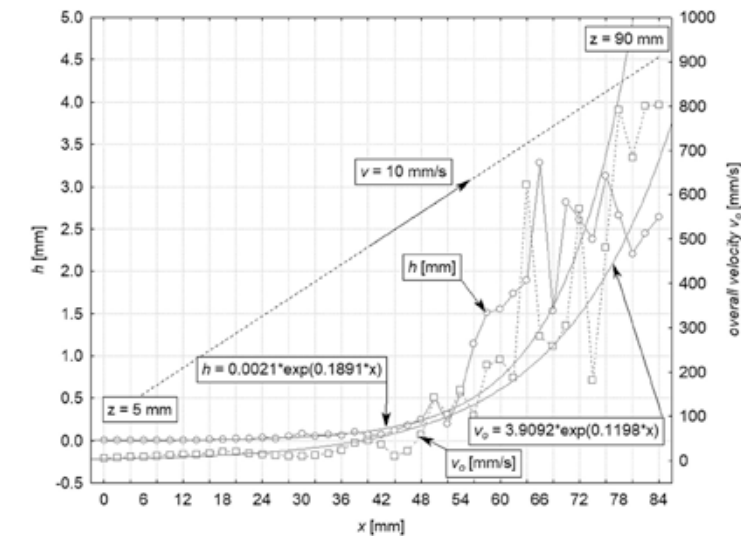


Fig. 2

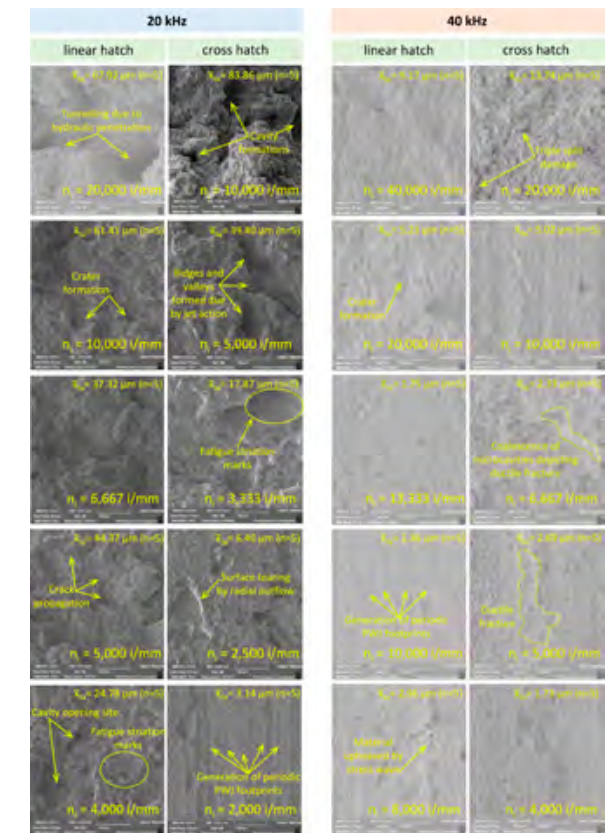


Fig. 4

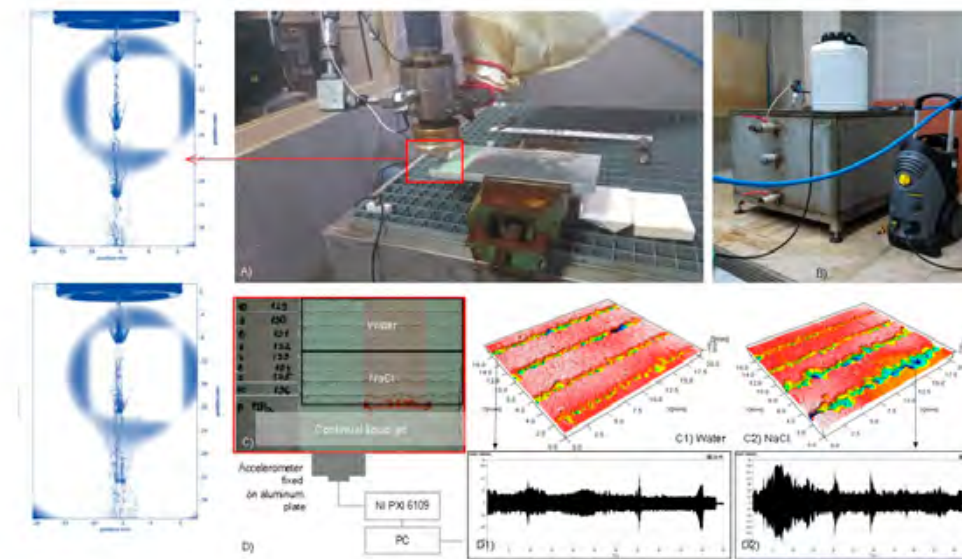


Fig. 3

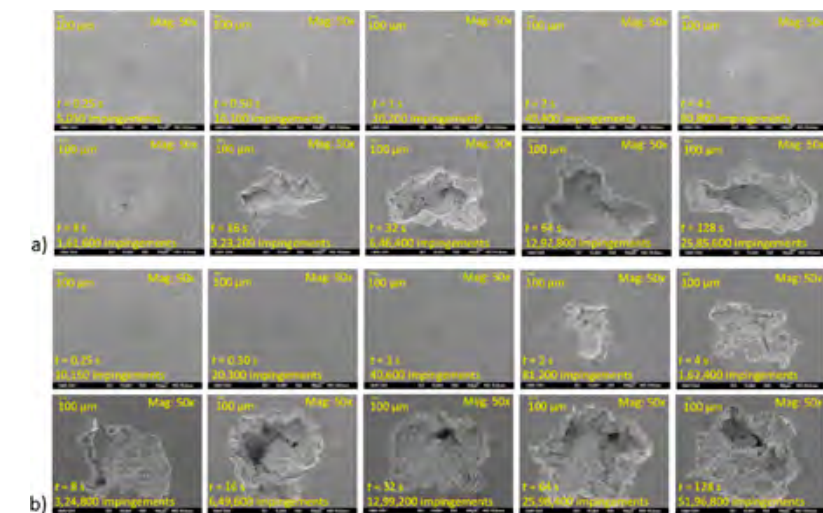


Fig. 5



## Tribological properties of 2D materials and related nanocomposites

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### Participating organisation

Slovak Academy of Sciences, Institute of Electrical Engineering

Institute of Physics, Slovak Academy of Sciences

Slovak Academy of Sciences, Institute of Materials and Machine Mechanics

### Term of solution

08/2018 – 10/2022

### Budget from agency

249 599 €

### Project ID

APVV-17-0560

### Research subject

It is estimated that tribological effects (friction and wear) account for up to 23% of global energy consumption. Advanced low-friction coatings, also known as solid lubricants, are widely used to reduce these effects. A variety of solid-state lubricants such as TiN, TiC, and graphite are used in modern technology. Recently, the use of 2-dimensional (2D) materials, i.e., layered materials with atomically thin layer thicknesses, has been intensively investigated. 2D materials have several advantages compared to traditional coatings, such as extremely low friction, impermeability, and resistance to oxidation. However, there is still a lack of industrially applicable technologies for the preparation of 2D materials over larger areas as well as a deeper understanding of the mechanical properties of 2D materials for their use in low-friction coatings.

### Aim of the research

The project aimed to develop technologies for the preparation of 2D materials and investigation of their frictional properties on micro and macro scales in order to develop ultrathin low friction coatings. In the area of growth technology, we mainly focused on techniques used for sulfurization and selenization and chemical vapor deposition (CVD) for the preparation of transition metal dichalcogenides (MoS<sub>2</sub>, MoSe<sub>2</sub>, PtSe<sub>2</sub>, and others) on large-area substrates. The main goal was to develop a friction force microscopy (FFM) technique using atomic force microscopy (AFM) at the micro-scale to gain a deeper understanding of the 2D material-substrate interaction. The most suitable technologies were then selected for transfer to practically applicable substrates.

### Achieved results

The implementation of the project contributed to the development of 2D material layer deposition technology using sulphurization and selenization with controlled orientation of the flakes in respect to the substrate surface in the case of ultrathin MoS<sub>2</sub> and PtSe<sub>2</sub> layers. Through systematic investigation, we identified the conditions that led to the growth of horizontally or vertically aligned flakes of these

materials with respect to the substrate, which has a significant impact on their tribological properties. It also contributed to the development of the deposition of ultrathin MoS<sub>2</sub> layers deposited by CVD. In addition, we have studied the preparation of ultrathin layers of Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> Mxenes prepared using a modified Langmuir-Schaefer (LS) method. These materials have gained significant interest from the scientific community just during the project implementation and we have investigated their tribological properties beyond the originally stated objectives.

We have intensively investigated the nanotribological properties of mono- (ML) and few-layer (FL) thin films of 2D materials. The focused was given to the effect of angular anisotropy of frictional forces between the AFM tip and the flakes of ML and FL MoSe<sub>2</sub> layers grown by CVD. We further investigated the friction force variations of FL MoS<sub>2</sub> layers with similar surface topography but different orientation with respect to the substrate, where we observed distinctly different tribological behaviours of vertically and horizontally oriented MoS<sub>2</sub> flakes at both micro- and macro-levels. We investigate the nanotribological properties of ML and FL MXenes based on Ti<sub>3</sub>C<sub>2</sub>T<sub>x</sub> deposited by the modified LS method on SiO<sub>2</sub>/Si substrate. We observed excellent lubrication properties of these films and showed that the frictional force of the monolayers is higher compared to the bilayer and trilayer films. By an original methodology, we determined the coefficient of friction (COF) of the investigated Mxene films.

We have also transferred technology of ultrathin coatings to industrially used steel substrates. It was shown that ultrathin (a few nm) Mxene coatings in combination with a softer steel substrate significantly reduces friction force compared to that of the bare substrate in both air and vacuum.

### Benefits for practise

We have demonstrated deposition of thin films of MoS<sub>2</sub>, MoSe<sub>2</sub> and PtSe<sub>2</sub> on large-area substrates with controlled orientation of the crystalline microflakes. We have observed that ultrathin Mxene coatings combined with softer steel substrates are useful in a variety of environments (low pressures). Finally, we identified a possible use of ultrathin coatings based on 2D materials for microactuator devices operating in both air and vacuum, such as STM microscopes.

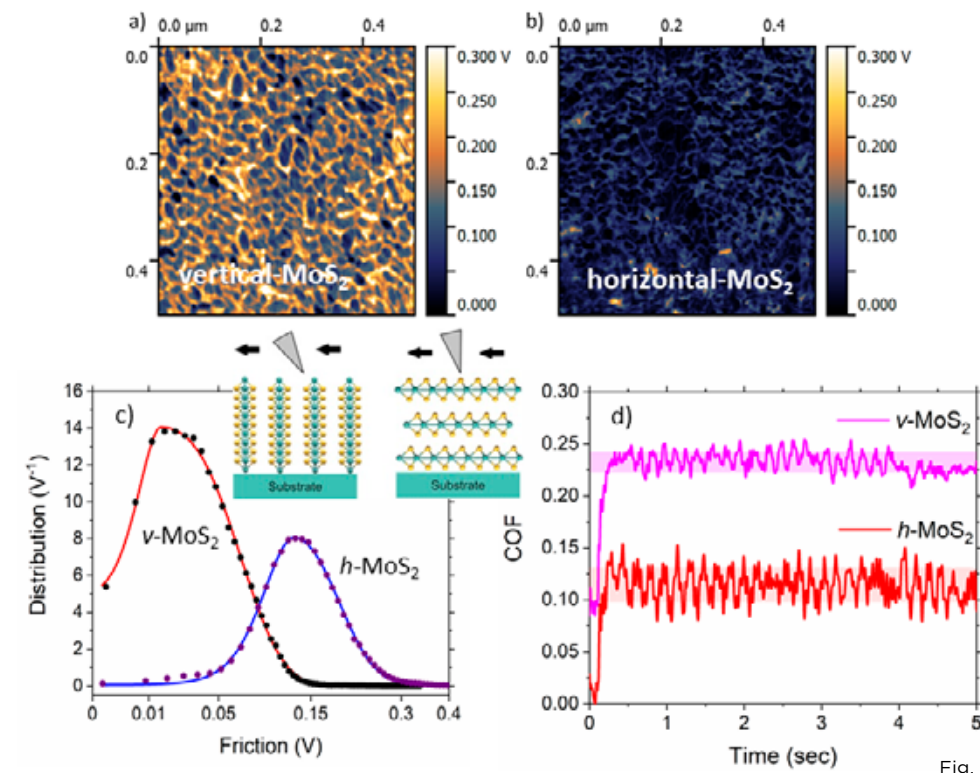


Fig. 1

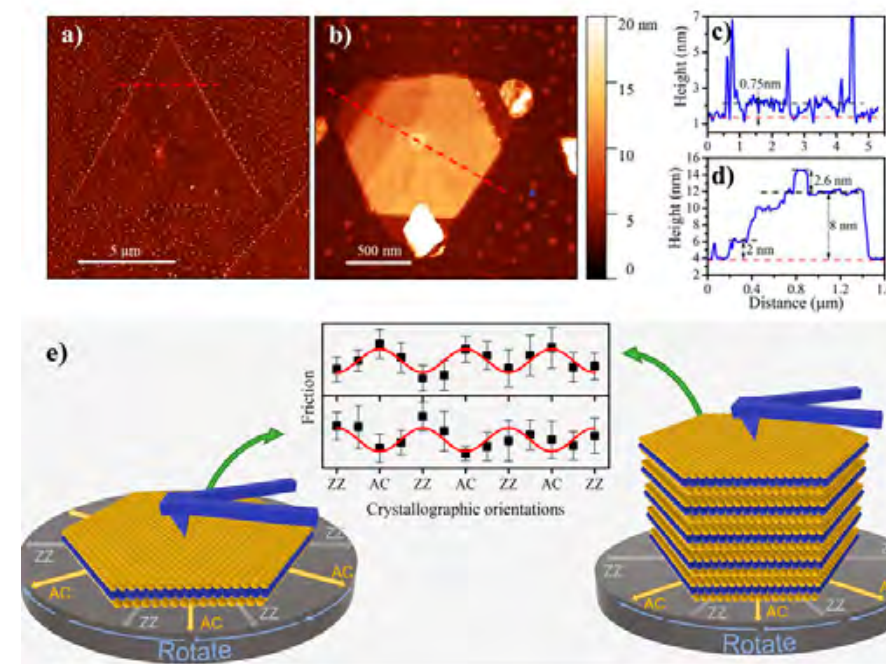


Fig. 2

Fig. 1 / Micrographs of frictional forces measured on ultrathin MoS<sub>2</sub> layers with vertically (a) and horizontally (b) oriented flakes in respect to the substrate surface, and the resulting distribution of frictional forces (c) determined from (a) and (b). (e) Comparison between COF measured on the same samples using a tribometer (pin-on-disk).

Fig. 2 / (a) Topology of monolayer (ML, a) and few-layer (FL, b) MoSe<sub>2</sub> films grown by CVD measured by AFM and height profiles measured along the dashed lines (c, d). (e) shows the measured angular anisotropy of the frictional forces in different directions marked in the schematic images of the measured samples.

Fig. 3 / Illustration of the friction force and adhesion trends of FL PtSe<sub>2</sub> flakes. The friction is highest for vertically oriented flakes, decrease for horizontally oriented flakes, and are lowest for better crystallized flakes.

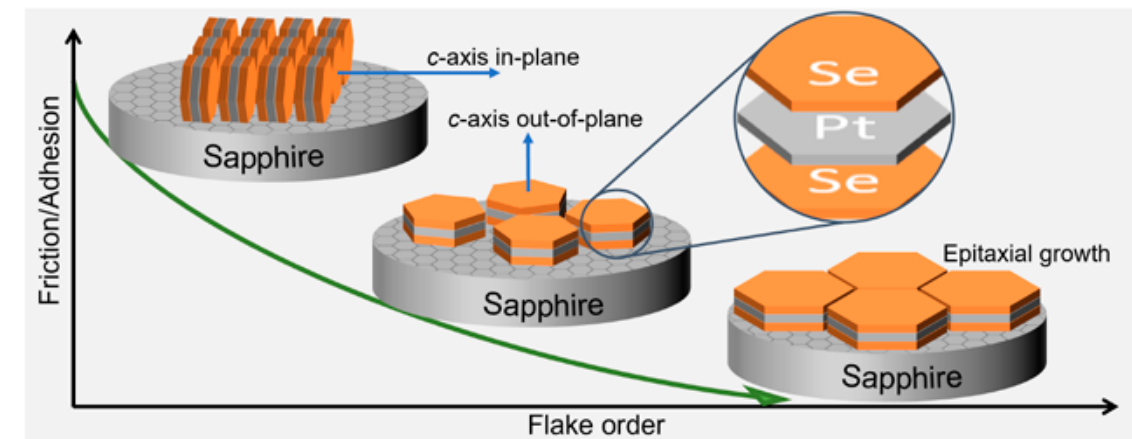


Fig. 3



# Research of roofing with integrated function of heat exchanger

## Research subject

The project RoofFoam aims to develop an outdoor heat exchanger providing efficient and environmentally attractive acquisition of the required heat from the environment, resp. removal of excess heat into the surroundings of the buildings. Because it is the heat of a low-temperature potential, which is due to the alternation of day and night cycle available around the building in practice for most of the year, it may be proposed a system in combination with a suitable seasonal storage of heat (e.g. base plate of the house) to ensure the thermal comfort in a residential area. It requires no electricity supply resp. heat from the combustion of fuel for most of the year.

## Aim of the research

The main objective of the project is research on the possibility of using an aluminium foam as a new type of large-scale roofing with an integrated heat exchanger, which is able effectively to obtain low potential heat from the surroundings of building and transfer it through the liquid heat transfer fluid to the interior of the building. The same roofing system will simultaneously be able to dissipate excess heat accumulated in the building to its surroundings during cooler summer nights. Considering the current technical possibilities of short-term heat accumulation to interior ceiling panels, the objective of this R&D project was to achieve significant cost savings to ensure sufficient thermal comfort in residential and non-residential spaces during cold winter as well as hot summer days without the need to use current conventional air conditioning equipment and heating technologies.

## Achieved results

The thermophysical properties of the proposed thermally active roofing were thoroughly tested in real conditions corresponding to winter and summer operation in a mild climate zone on prototypes produced as part of the project RoofFoam solution (Figs. 1 and 2). The thermophysical

properties of aluminium foam panel samples with dimensions of 600 × 600 × 11 mm and subsequently also of three prototypes of the developed roofing were examined in a climatic chamber intended for modelling the synergistic phenomena of heat transfer, water vapour diffusion and air filtration (Figs. 3 and 4). The results of tests of the ability of a roofing with an integrated function of a heat exchanger to absorb solar radiation proved the suitability of using the proposed concept in order to reduce the costs of construction and operation of future energy-independent houses and buildings covered with sloping roof coverings.

## Benefits for practise

The systems that use the possibility of accumulating heat obtained from solar radiation, especially during hot summer days, in a thermally active base plate or in heat reservoirs built into the ground in close proximity to buildings are known in construction practice. Systems that would be able to obtain energy in the form of heat at a lower temperature on a large scale from the entire surface of the sloping roof of buildings with low costs, and at the same time, if necessary, to remove unwanted heat to the surroundings of the building in the summer, have not been used yet. A roof covering was developed during solution of RoofFoam project, that uses the unique ability of aluminium foam to ensure very efficient heat transfer between the surface of the roof cladding and the liquid heat transfer medium. Based on a thorough analysis of the results of experimental measurements of the thermophysical properties of three prototypes of the developed roof cladding with an integrated function of the heat exchanger, the use of the proposed concept in construction practice can be expected in the near future. The use of developed roofing in the construction of new buildings with nearly zero energy consumption would lead to cost savings to ensure sufficient thermal comfort in both residential and non-residential spaces during cold winter as well as hot summer days. This would reduce the cost of energy consumption when using current conventional air

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**Term of solution**  
08/2018 – 12/2021  
**Budget from agency**  
250 000 €  
**Project ID**  
APVV-17-0580

conditioning equipment and heating technology. The successful future commercialization of the developed thermally active roofing in construction practice can be expected primarily to reduce the costs of construction and operation of future energy autonomous houses and buildings.



Fig. 1

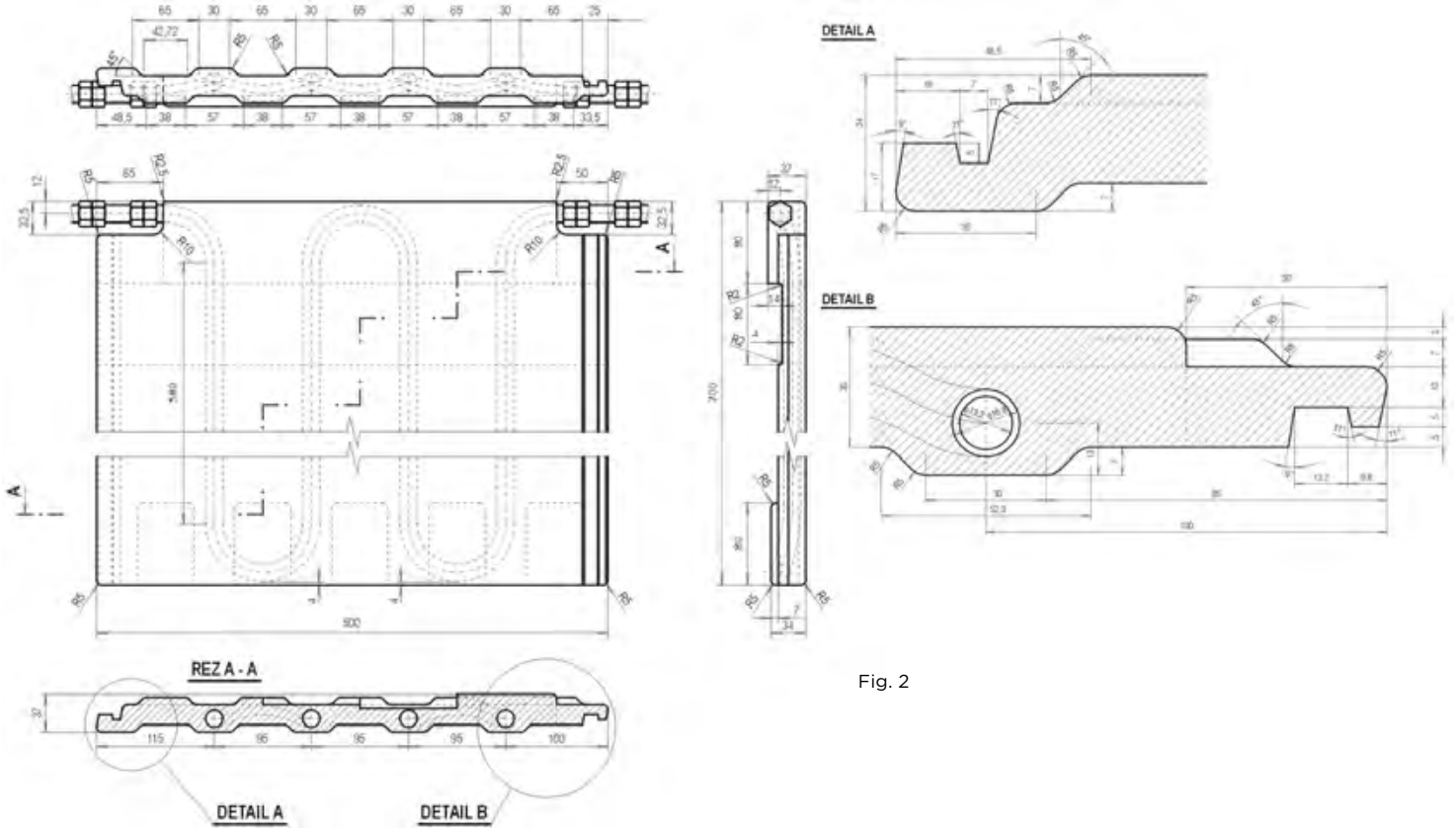


Fig. 2

Fig. 1 / Prototype of one tile of thermally active roof covering with dimensions of 700 × 500 × 37 mm made as a monolithic casting of foam aluminium (the image on the left shows a view of the prototype tile from the exterior).

Fig. 2 / The structural design of one of the three developed prototypes of a thermally active roof cladding made of aluminium foam, whose thermophysical properties were thoroughly examined in real conditions corresponding to climatic conditions in a moderate climate zone.

Fig. 3 / Climatic chamber for modelling the synergistic phenomena of heat transfer, water vapour diffusion and air filtration (a), view of the tested sample of the aluminium foam panel with the dimensions 600 × 600 × 11 mm in the climatic chamber from the interior (b) and exterior (c) side.

Fig. 4 / Thermal image of two prototype tiles of a thermally active roof covering during testing in a climate chamber simulating real weather conditions during summer season.

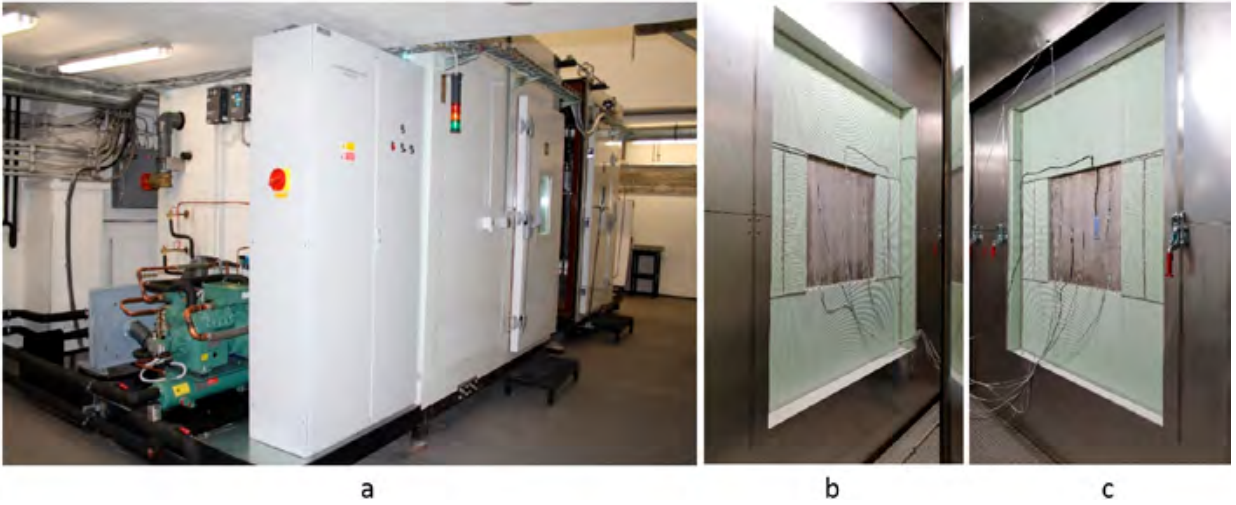


Fig. 3

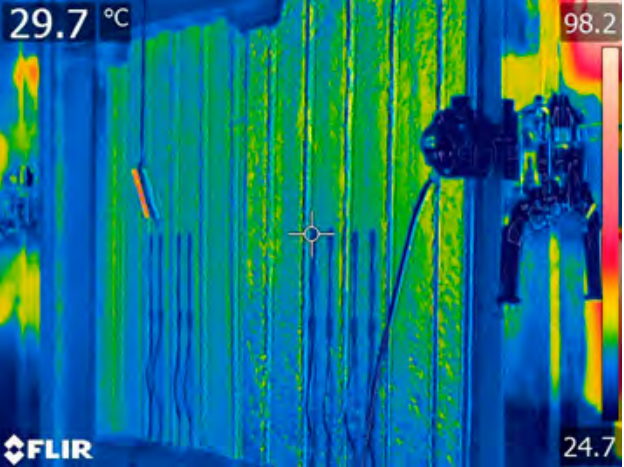


Fig. 4



## Urgent Computing for Exascale Data

## Research subject

The ability to use exascale systems (systems working with data in the order of exabytes) to support crisis decision-making depends critically on the ability of supercomputing centers to implement urgent computing as a new mode of operation. As a conceptual basis, we define urgent computing as a paradigm offering technical and organizational approaches that enable the rapid redirection of IT, software and data and computing resources towards a new problem in order to provide relevant computing resources for its solution in predictable, usually short time periods. Urgent computing is becoming a service provided by Europe's top research computing centers as well as smaller and more flexible local computing centers. This has the dual benefit of immediately providing the societal benefits of using the best performing systems (at any time) and the subsequent ability to optimize the design of future operational centers supporting emergency computing.

## Aim of the research

The goal of the project was to merge service-oriented architectures, cloud computing technologies and semantic web technologies, which can provide a platform with unique advantages - interoperability, scalability and understanding of services and data. By applying semantic web technologies to web services, we have provided machine-processable descriptions of data exchanged between services as well as the services themselves. A clear definition of standards in web services made it possible for us to handle ontologies defining the semantic concepts of services. Using the cloud as the underlying infrastructure ultimately brought scalability. Publicly available electronic services were the target area of the project. They include a whole range of very different actors - providers and clients. Digital agendas are being implemented across Europe to facilitate the transition of pan-European public administration from the old bureaucratic paradigm to a modern service-oriented policy.

## Achieved results

The research of the project was focused on three basic directions: advanced methods of data-centric computing, containerization of software modules and use of cloud infrastructure and fast balancing of resources assigned to computing tasks. During the project, research was carried out in all three of these areas. The key parts of the architecture for urgent computing were designed, which were then described in detail. The proposed architecture was validated on real exa-scalable cloud applications. A cloud service was designed, implemented and verified for collecting data from users in real time into information channels, which can be further aggregated, statistically and graphically analyzed and subsequently evaluated. The intelligent management of distributed data was explored - such a method of data processing enables the use of a pan-European research infrastructure and meets the requirements of European research communities.

### Benefits for practise

The designed and validated system for processing large data sets with the possibility of urgent use of computing resources for solving urgent computing tasks is particularly beneficial in the field of response to crisis events, for example, in modeling the consequences of natural disasters and finding appropriate responses to them. At the same time, the created system allows methodically, automatically, to collect and analyze large amounts of data from many providers. The used methods of semantic description of the used web services will enable data centers to improve the provided services and to connect them to extensive infrastructures of a higher order. The use of modern methods of working in a cloud environment, especially containerization, gives the possibility to use all achieved project results and implemented software parts in a modular and scalable manner.

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**Term of solution**  
08/2018 – 12/2020

**Budget from agency**  
200 000 €

**Project ID**  
APVV-17-0619



# Development of REBCO superconductors for biomedical applications

## Research subject

Materials research of superconductors

## Aim of the research

The main goal of the project was the research and development of REBCO (especially YBCO, GdBCO and SmBCO) bulk single-grain superconductors (BSS) with high critical current density and trapped magnetic field at temperatures lower than liquid nitrogen temperature. The detailed objectives were focused on:

- Optimizing the time-temperature growth parameters of bulk REBCO crystals with selected dopants or with the addition of nanofibers.
- Characterization of the influence of preparation and doping parameters on the structure and microstructure of prepared REBCO BSS.
- Characterization of the relationship between the microstructure of prepared REBCO BSS and their microscopic and macroscopic superconducting properties.
- Optimization of the composition, preparation parameters and superconducting properties of REBCO BSS in order to achieve high values of trapped magnetic field and levitation force.
- Protection of original research results by patent applications and publication of results in high-quality international journals.

## Achieved results

We prepared YBCO, SmBCO and GdBCO BSS using the TSMG (Top Seed Melt Growth) and TSIG (Top Seed Infiltration Growth) methods. Phase transitions, phase composition, structure and microstructure in the studied systems with selected dopants were characterized by thermal analysis, optical and electron microscopy and X-ray diffraction analysis. We characterized the microscopic superconducting properties (critical temperature, critical current density and its dependence on the magnetic field) based on magnetization

measurements from 4.2 K to 77 K. Macroscopic superconducting properties (trapped magnetic field, levitation force) were measured at a temperature of 77 K and at a temperature below 77 K in collaboration with the University of Caen Normandy. In this research, we also collaborated with the University of Cambridge, SJTU Shanghai, SIT Tokyo and CAN Superconductors CR.

We were the first to show that the added CeO<sub>2</sub> suppresses the substitution of barium by gadolinium in the crystal lattice of the Gd(Ba<sub>1-y</sub>Gd<sub>y</sub>)<sub>2</sub>Cu<sub>3</sub>O<sub>x</sub> compound and thus increases the critical temperature to the superconducting state and regulates the concentration of nanoscale pinning centers of magnetic flux lines. The found effect is the subject of a patent application and opens up new possibilities for optimizing the superconducting properties of LREBCO BSS (LRE - light rare earths).

We have developed a new technology for the production of GdBCOAg BSS with the addition of nanocrystalline BaCeO<sub>3</sub>, which is protected by a patent application. Bulk crystals prepared by this technology grow in air without the need to use a controlled atmosphere. At the same time, the crystals will outgrow the entire sample, saving on expensive raw materials.

At the cooperating institution (IMR SAS), polymer fibers containing selected cations were prepared using the electrospinning method, and the heat treatment process was optimized with the aim of removing organic components and the formation of oxides. We added TiO<sub>2</sub> nanofibers to the GdBCO system and prepared BSS.

The results of the study of the influence of the addition of nanocrystalline BaCeO<sub>3</sub> on the refinement of the pinning centers of magnetic flux lines in the form of non-conducting YBaCuO<sub>5</sub> particles showed that even low concentrations of the addition ensure the submicron size of the particles, which leads to a significant increase in the values of the trapped magnetic field.

### Principal investigator

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### Applicant organisation

Slovak Academy of Sciences, Institute of Experimental Physics

### Participating organisation

Slovak Academy of Sciences, Institute of Materials Research

### Term of solution

08/2018 - 12/2022

### Budget from agency

249 686 €

### Project ID

APVV-17-0625

## Benefits for practise

The results we achieved in the framework of the project can be applied in the production of REBCO BSS. In the field of high-current electrical engineering, BSS are used in the form of superconducting permanent magnets for the construction of rotating electric machines, frictionless bearings, levitation transport devices, inertial energy reservoirs, devices for magnetic transport of drugs, wastewater treatment, and the like. As part of the project, we developed a new technology for the production of GdBCOAg BSS with the addition of nanocrystalline BaCeO<sub>3</sub>, which is protected by a patent application. Using this new technology, we produced GdBCOAg BSS and provided them to Cryosoft, s.r.o. Košice, to the implementer of the project results, which will use them in the development of biomedical applications in cooperation with the Institute of Medical and Clinical Biophysics, LF UPJŠ Košice.

We developed cooperation with CAN Superconductors s.r.o. the manufacturer of REBCO BSS. Joint research was mainly focused on GdBCOAg and EuBCOAg BSS. Here, we performed a comprehensive microstructure analysis on GdBCOAg and EuBCOAg BSS with an artificial hole system. We came to the conclusion that the most significant positive effect on the increase of the trapped magnetic field is the reduction of the porosity of the studied MMS. The results will be applied in the production of REBCO BSS in CAN superconductors and contributed to obtaining a new APVV project, the results of which will be implemented in CAN Superconductors.



Fig. 1

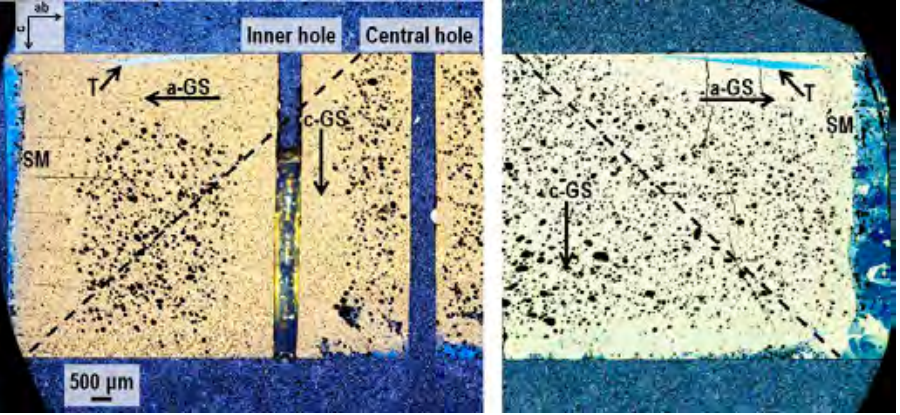


Fig. 2

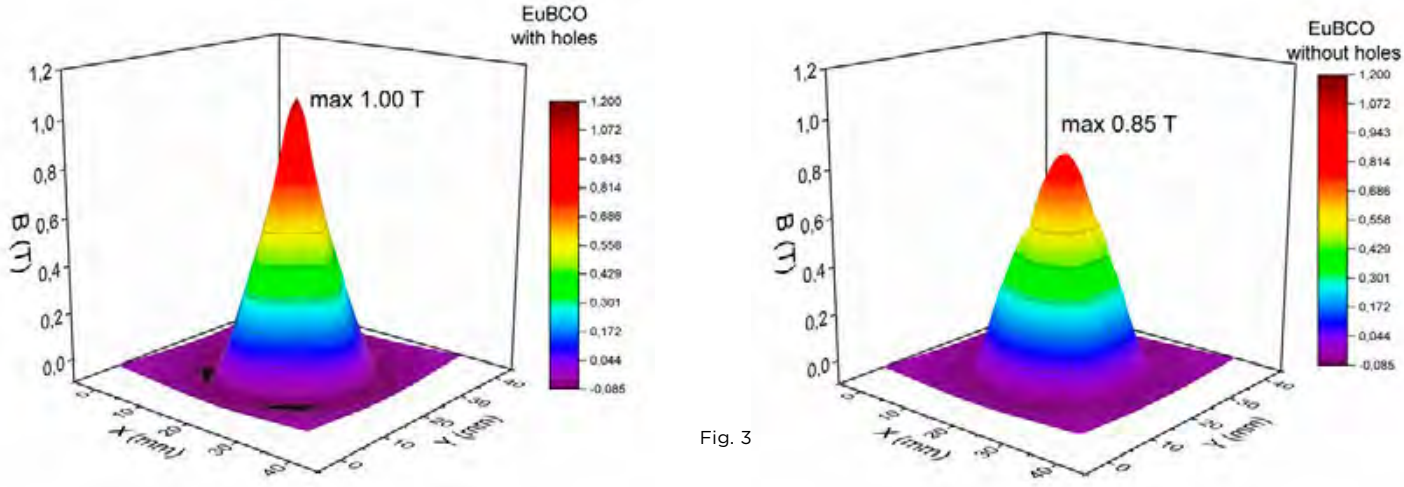


Fig. 3

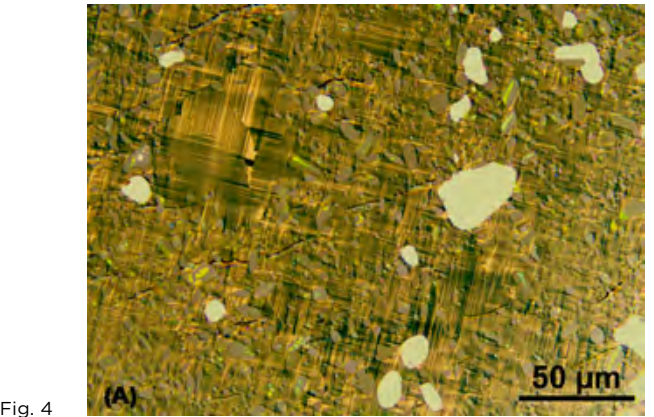
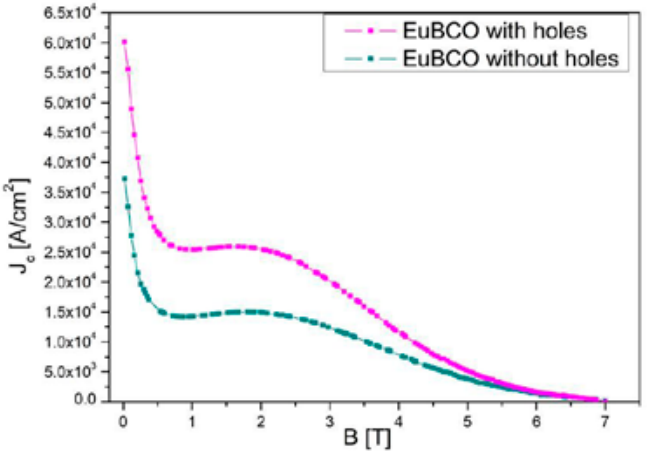


Fig. 4

Fig. 5

# MEDICAL SCIENCE





## Pulmonary surfactant as a modulator of body's response to endotoxin exposure: effects and mechanisms

### Research subject

Pulmonary surfactant is a lipoprotein complex present in the alveoli and airways; it reduces surface tension and prevents the lung collapse. The pulmonary surfactant may under certain circumstances be inactivated by endotoxin (lipopolysaccharide, LPS) from Gram-negative bacteria membranes, which may lead to respiratory failure. The project was to contribute to the understanding of the role of surfactant in the lung local defensive mechanisms. The effect of LPS on the respiratory system was studied in a complex way, by modelling on animals, by testing on smooth airway muscle and in alveolar epithelial cell cultures. Mechanisms of surfactant vs. LPS interaction was studied in a pulsating bubble surfactometer, changes of fluidity by fluorescent spectroscopy and structural changes by small angle (SAXD) and wide angle (WAXD) X-ray diffraction. The visualization of the structural changes at cellular level was performed by X-ray cryo-tomography. The results obtained by wide range of experimental methods allow to create a holistic picture of the effect of endotoxin on the respiratory system, its interaction with surfactant, and new treatment options.

### Aim of the research

Project was divided to several phases. The common denominator was the interest in the deep analysis of the conditions associated with the inactivation of the pulmonary surfactant when the endotoxin enters the body through the respiratory system or the bloodstream, and the possibility to alleviate the lung injury by administration of exogenous surfactant alone or in combination with another pharmacotherapy.

We also intended to analyse the effect of endotoxin on various structures of respiratory system (alveolar epithelium, endothelium of pulmonary capillaries and airway smooth muscle) and to find out the role in this is played by pulmonary surfactant.

### Achieved results

Clinically relevant models confirmed the suitability of exogenous surfactant and verified combinations with N-acetyl cysteine, NAC and polymyxin B, PxB. Original results were obtained on the effect of LPS on cells of the alveolo-capillary membrane. Long-term cultivation of A549 cells could promote a more ATII-like phenotype and could be more suitable model for ATII cells, especially for studies dealing with surfactant production. The studies focused on the relaxing effect of surfactant on the airway smooth muscle (ASM) confirmed the involvement of leukotriene and histamine receptors. Atomic force microscopy revealed that the EP4 receptor for relaxing prostaglandin PGE2 may be involved in ASM relaxation by surfactant through the interaction of the surfactant with the airway epithelium. At the same time, physical-chemical studies monitored mutual interactions of exogenous surfactant with other drugs and biologically significant molecules. Interactions at the molecular level for the potential use of exogenous surfactant as a drug carrier for intratracheal administration were clarified. Interactions of exogenous surfactant exposed to LPS with selected drugs (PxB, NAC) were also studied. Physical-chemical studies suggest the therapeutic benefit of enriching exogenous surfactant with low PxB content. NAC does not evoke structural changes of surfactant, in turn NAC has a stabilizing effect on the structure of surfactant in the fluid state at low content (< 20 wt%).

### Benefits for practise

Conditions associated with inactivation of the body's own pulmonary surfactant, such as acute respiratory distress syndrome (ARDS)/acute lung injury (ALI), have a significant inflammatory component and are associated with high morbidity and mortality. A better understanding of the pathophysiological mechanisms and early treatment of ARDS can improve the survival of patients with severe lung damage, and the results of the project can serve as a basis for planning further preclinical and clinical studies to assess the effect of treatment on severe lung damage. Critically

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**Term of solution**  
08/2018 - 11/2022  
**Budget from agency**  
249 560 €  
**Project ID**  
APVV-17-0250

ill animals on mechanical ventilation as well as double lung injury (hyperoxia and lipopolysaccharide) are models that are little used, although they more closely approximate the multifactorial cause of ARDS in patients. The scientific contribution of the project lies in the original results obtained in experiments on animals, tissues, cells and physical-experimental studies. The social benefit is also in the involvement of young scientists, PhD students, diploma students, as well as undergraduate students in the framework of student scientific activity.

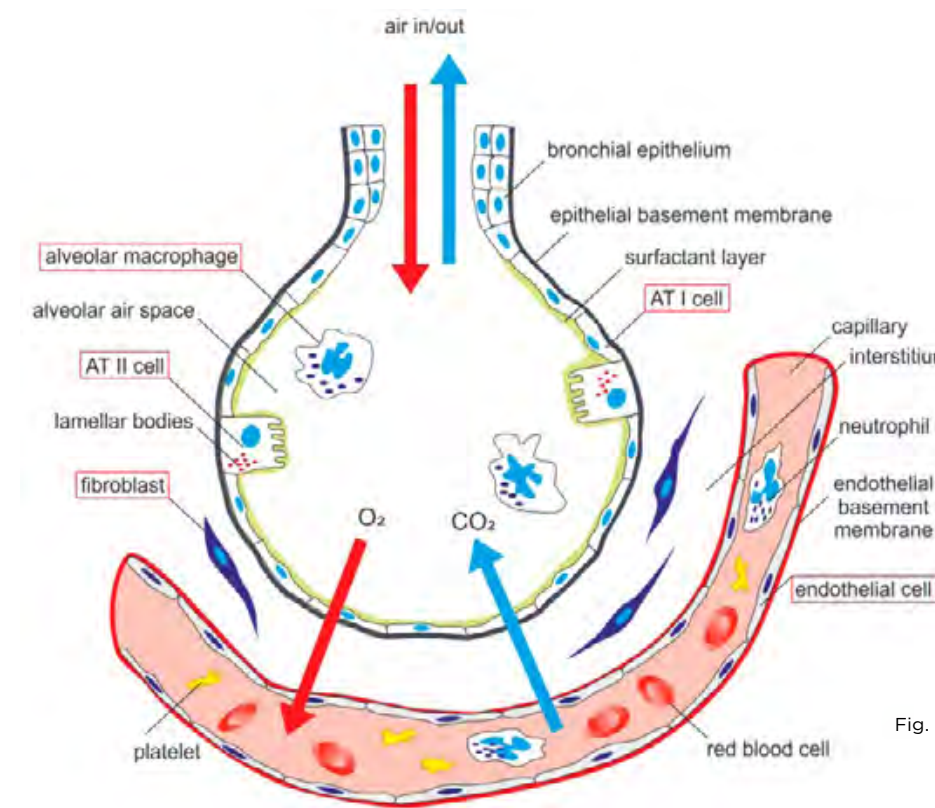


Fig. 1

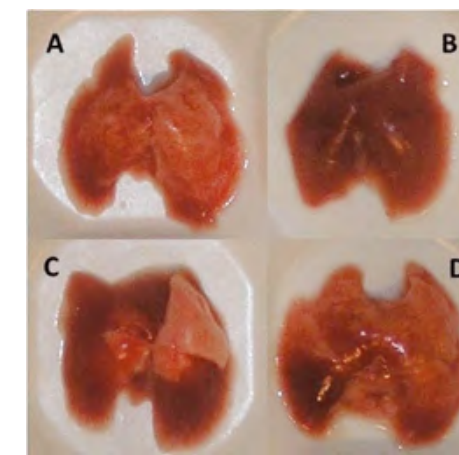


Fig. 4

Fig. 1 / Diagram on pulmonary cells related to alveolar-capillary membrane which may come into contact with lipopolysaccharide (from Nova et al., IJMS 2019)

Fig. 2 / Insertion of airway smooth muscle strip into the chamber with the subsequent possibility to test substances (from dissertation thesis of J. Hanusrichterova).

Fig. 3 / Small-angle X-ray scattering (SAXS) patterns of modified porcine surfactant (PSUR); PSUR and lipopolysaccharide (LPS) 5 %; PSUR and LPS 10 % incubated for 2 hours; PSUR/LPS 10 % and polymyxin B (PxB) 2 %; PSUR/LPS 10 % and PxB 3 % at 37 °C. Wide-angle X-ray scattering (WAXS) patterns of PSUR, PSUR/LPS 10%, PSUR/LPS 10 % and PxB 3 % (37 °C) (from Kolomaznik et al., IJMS 2018).

Fig. 4 / Macroscopic appearance of the lungs in pre-term newborn rabbits after administration of saline and surfactant (A), lipopolysaccharide (LPS) and no further treatment (B), LPS and surfactant (C), and LPS and surfactant with polymyxin B (PxB) (D) (Čalkovská et al., Sci Rep 2021).



Fig. 2

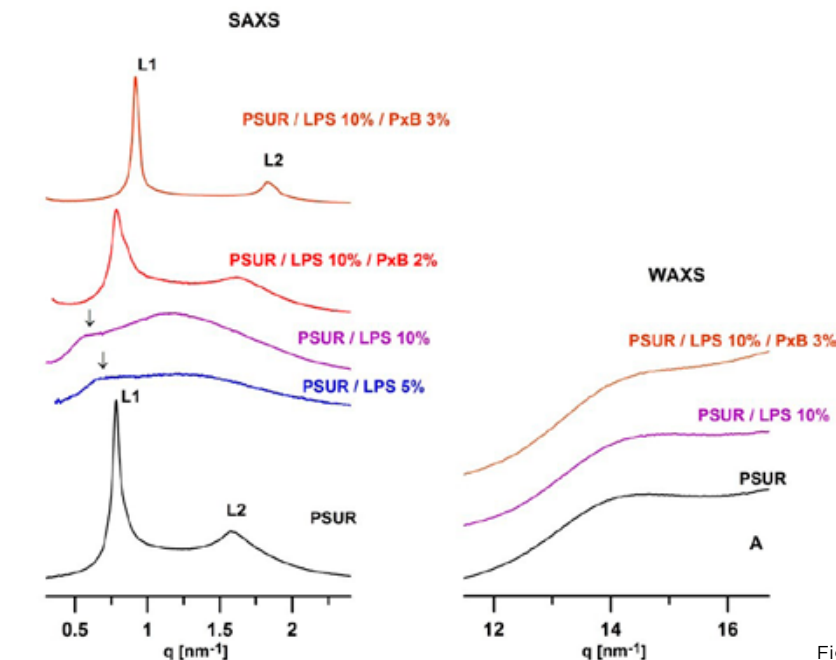


Fig. 3



# Targeting DNA methylation by epigenetic editing and its implementation into personalised diagnostics and therapy of uveal Melanoma

## Research subject

Malignant uveal melanoma (UM) ranks as the most prevalent primary intraocular tumor. The primary cause of mortality lies in metastatic dissemination, affecting nearly half of all patients. Given the restricted availability of treatments for advanced disease stages, a majority of patients survive less than 12 months following a metastasis diagnosis. In tandem with extensively studied genetic abnormalities, such as chromosome 3 monosomy, amplification of chromosome 8 long arm, and mutations in the BAP1 and SF3B1 genes, epigenetic alterations can substantially impact metastatic risk. The disruption of DNA methylation, a principal mechanism governing gene expression, stands as a crucial factor in UM prognosis. A better understanding of epigenetic processes and signaling pathways that elevate the metastatic risk for UM patients holds the potential for uncovering novel therapeutic targets and could pave the way for more effective treatment strategies. The implementation of sensitive techniques for the detection of UM-specific markers within patients' peripheral blood (liquid biopsy) could empower the personalization of therapeutic interventions.

## Aim of the research

The main project aim was to identify DNA methylation alterations associated with an elevated metastatic risk and introduce sensitive techniques for their detection in the peripheral blood of UM patients. Subsidiary objectives encompassed 1) discerning distinct methylation patterns in patients' tumors through comprehensive genome-wide analysis, 2) selection of signaling pathways and candidate genes relevant for hematogenous metastasis, 3) the increase of analytical sensitivity in the detection of tumor-specific methylation markers in peripheral blood, and 4) the development of suitable preclinical models for testing therapeutic efficacy.

## Achieved results

At the genome-wide level, we confirmed extensive gene expression reprogramming in high-risk tumors (Fig. 1) (Clin Transl Med, doi: 10.1002/ctm2.1317). Within the differentially expressed genes, we also identified 60 epigenetic modifiers—proteins pivotal in regulating DNA methylation, histone modification, and chromatin remodeling. Tumors carrying a heightened metastatic risk exhibited 44,398 differentially methylated CpG dinucleotides, predominantly marked by hypomethylation. Guided by our integrative analysis outcomes, we selected 9 prognostic markers boasting remarkable sensitivity and specificity (Fig. 2), thereby holding significant promise for clinical application. We introduced diverse methodologies for detecting circulating tumor cells and circulating tumor DNA in patients' peripheral blood (IJMS, doi:10.3390/ijms21249651). Integral to the project, we successfully developed a patient-derived xenograft (PDX) model, further characterized at a whole-genome level. A pilot single-cell analysis of chromatin accessibility was conducted on PDXs derived from both primary tumors and metastases. The successful therapeutic strategy, tested on the PDX models and primary cultures derived from patient tumors, involves gene therapy facilitated by exosomes (Fig. 3). These extracellular vesicles were comprehensively characterized concerning their biological activity, tumor-targeting efficacy, and therapeutic potential (IJC, doi:10.1002/ijc.33188; IJMS, <https://doi.org/10.3390/ijms241612957>).

Collectively, driven by the project's achievements, we authored 8 papers published in journals indexed in the Current Contents Connect database (cumulative IF 45). Our findings were shared at numerous scientific conferences, and we prepared a book publication for the professional community. The project fostered the successful defense of 2 diploma theses and 2 dissertations.

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**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
249 000 €  
**Project ID**  
APVV-17-0369

## Benefits for practise

Overall, our study provides compelling evidence for the substantial role of DNA methylation in UM progression by regulating the expression of genes involved in critical biological processes such as immune evasion, calcium homeostasis, adhesion, and migration. Importantly, we demonstrate that the DNA methylation status of carefully selected CpG sites has the potential to serve as reliable prognostic biomarkers, underscoring the clinical relevance of DNA methylation analysis in UM. By leveraging the power of epigenetic profiling, we can gain a powerful tool for patient stratification, which can aid in personalized therapy and ultimately lead to improved outcomes. Pending in-depth validation of its in vivo effectiveness and safety, the tested gene therapy approach exhibits substantial therapeutic promise.

Fig. 1 / Evaluation of DNA methylation deregulation and whole-genome analysis results in 25 UM tissues. A) Methodological procedures employed. B) Volcano plot illustrating gene expression differences in high-risk versus low-risk UMs. C) Extend of DNA methylation variances in the 5000 most differentially methylated CpGs.

Fig. 2 / Validation of whole-genome analysis outcomes across an extended cohort of 58 patients by pyrosequencing. A) DNA methylation values of selected genes. B) Analytical sensitivity and specificity assessment. C) Correlation with survival outcomes.

Fig. 3 / Methodological framework for developing exosome-mediated therapeutic approach. Primary tumor cells undergo transduction with the yCD:UPRT gene, whose product metabolizes the non-toxic pro-drug 5-Fluorocytosine (5FC) into the toxic chemotherapeutic agent 5-Fluorouracil (5FU). Exosomes produced by transduced cells possess the capacity to metabolize 5FC into 5FU, resulting in the inhibition of tumor cell viability.

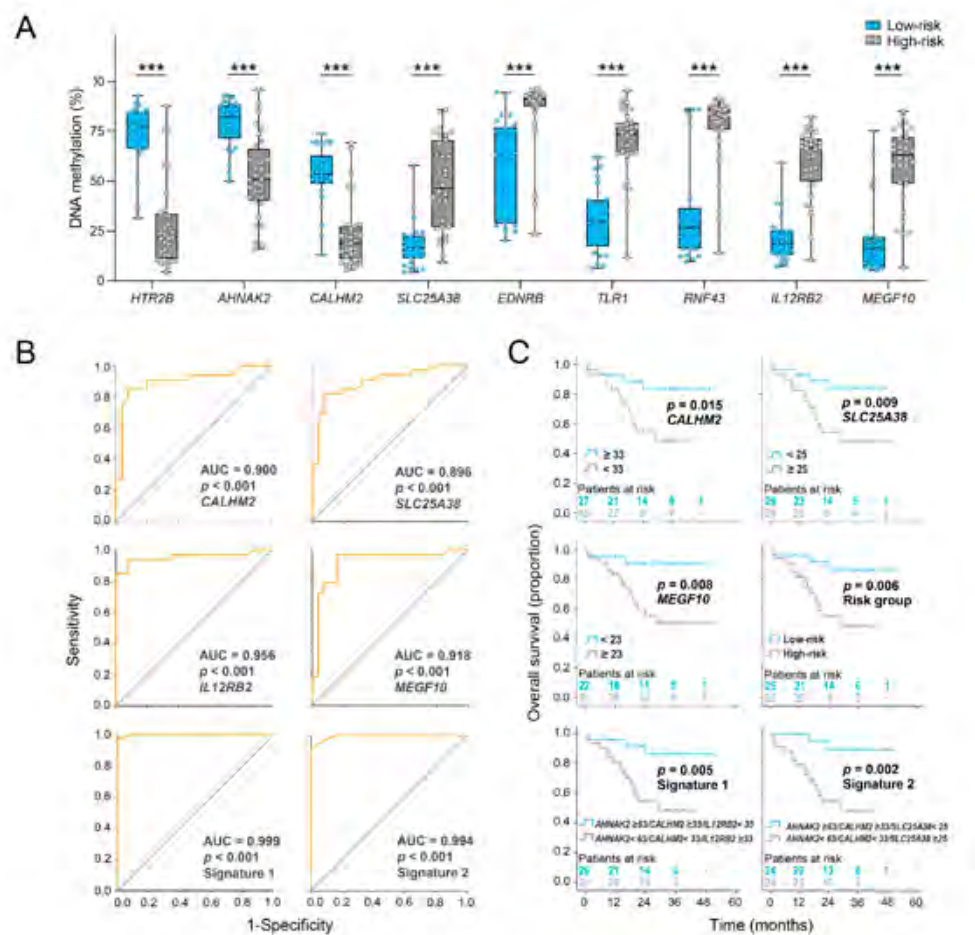
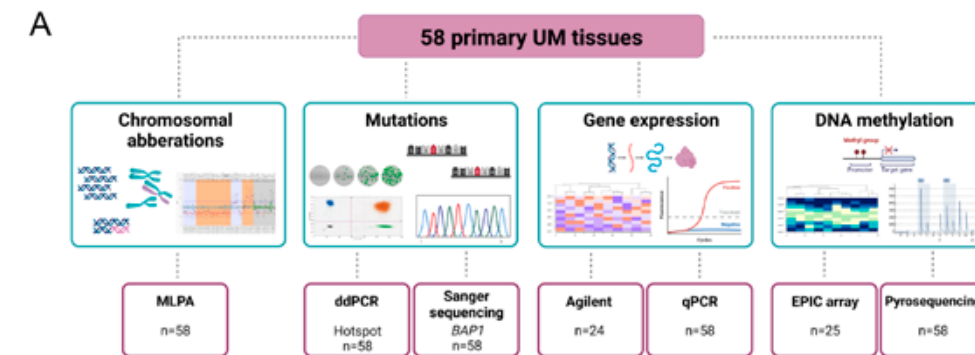


Fig. 2

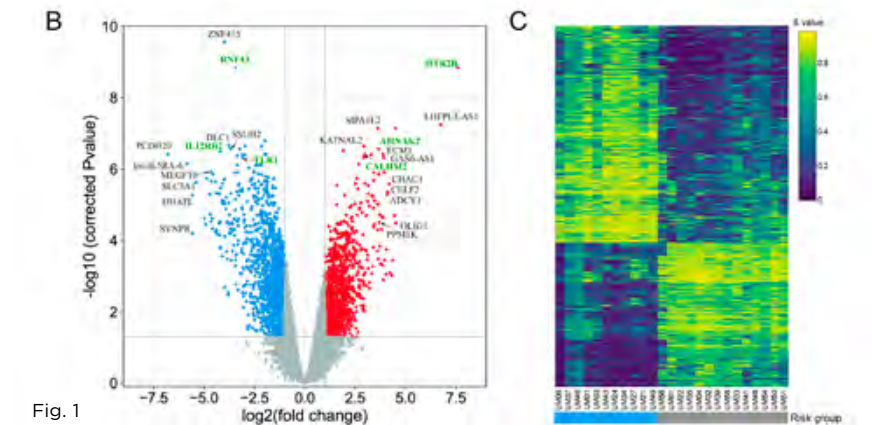


Fig. 1

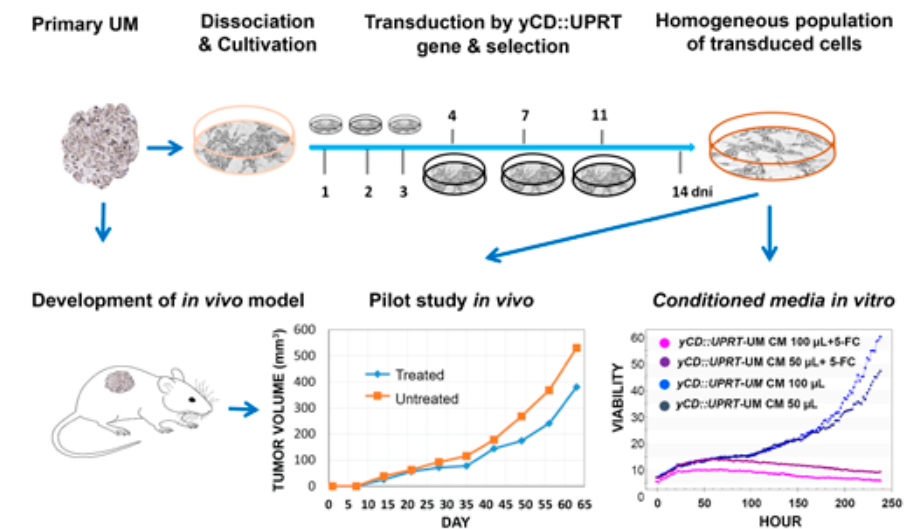


Fig. 3



## Novel small molecules and bioactive nanoparticles for therapy of inflammatory and degenerative diseases of bones and joints

### Research subject

The project follows on from the significant results obtained during the solution of the project APVV-0516-12, which was completed on October 30, 2017. Part of these results of basic research, as well as the synthesised compounds characterized and tested within it, form the basis for the applied research project and developments in the field of compounds with antimicrobial, anti-inflammatory effects and self-aggregating properties as well as systems containing stabilized nanoparticles. In cooperation with medical groups, the research aimed to influence some degenerative diseases of the locomotor system, primarily on joints, bones and cartilage. It was found that some functional groups allow cells to stick to collagen, while others help the crystallization of calcium. A structure that meets all these requirements in one molecule has been developed and can self-organise to aid in treating osteoporotic changes. The key structures, however, are Au and Ag nanoparticles dispersed by gemini cationic surfactants (GCT).

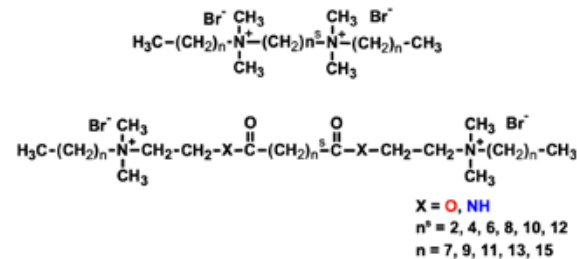
### Aim of the research

- Transferring the results of basic research into practice
- Test the use of compounds with synergistic antimicrobial and anti-inflammatory effects
- Prepare and test such small molecules and nanoparticles that would be suitable for the treatment of particular bone and joint diseases
- Create a preparation with biological activity specifically targeted at the tissues mentioned above (with a dominant regenerative effect on articular cartilage)
- Create a preparation that, at the same time, remains in contact with the target tissue at the point of application, thereby utilizing its maximum effectiveness
- The effort to create a preparation with biological activity, with good affinity to bone tissue, penetration through bone tissue, with sufficient retention at the site of administration (assuming minimal side effects and low toxicity for the organism)
- Increase the quality of life of affected patients

### Achieved results

Exceptional results with a significant potential benefit in the treatment of inflammatory and degenerative joint diseases have been achieved in two areas of Ag and Au nanoparticle research:

- we prepared Ag and Au nanoparticles (Fig. 1) stabilized by GCT



### Structure of GCT used as nanoparticle stabilizers

used stabilizers influenced the size of the formed aggregates (Fig. 2)

- we prepared highly stable nanoparticles (compared to those without stabilizers), and their stability was confirmed by the plasmon resonance effect (Fig. 3)
- the antimicrobial activity of Ag nanoparticles demonstrated the synergistic effect of Ag nanoparticles and stabilizer
- the cytotoxicity of nanoparticles was dependent on the structure of the stabilizer (Fig. 4); the most suitable were those stabilized by GCT with a short connecting chain
- tests of biological activity demonstrated a significant effect of anti-arthritis activity on model animals, manifested by their increased quality of life (Fig. 5).

Three patent applications dealing with Au and Ag nanoparticles stabilized by GCT are also extremely important project results. Preparations containing Au also received a media

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### Participating organisation

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Comenius University Bratislava – Faculty of Natural Sciences

### Term of solution

08/2018 – 11/2022

### Budget from agency

250 000 €

### Project ID

APVV-17-0373

response, and research in this area represented by a patent application (PP 57-2022) concerning Au nanoparticles became the winner of the competition “Technology Transfer in Slovakia 2022” in the category “Innovations” traditionally announced by CVTI SR. As part of the solved project, patent application PP 120-2022 focused on the biological effect of Ag nanoparticles and international patent application PCT/SK2023/050011 was filed.

### Benefits for practise

The prepared stabilized Au and Ag nanoparticles showed good antimicrobial activity and represent the basis for the preparation of drugs with high efficiency in anti-inflammatory therapies of the musculoskeletal system. In addition to the anti-inflammatory effect, dispersed Au nanoparticles also have chondroprotective activity; they can activate the proliferation of chondrocytes and repair articular cartilage affected by inflammation and degeneration. Dispersed Ag nanoparticles have an anti-inflammatory effect as well as antimicrobial activity and have proven to be suitable in the treatment of inflammatory diseases of both soft and hard tissues. Both types of patented nanosystems are characterized by a unique and valued dual effect.

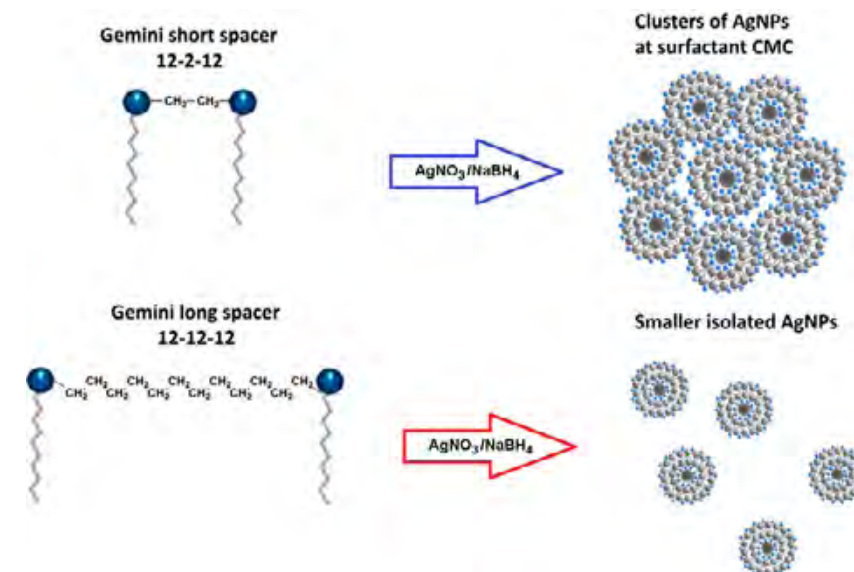


Fig. 1

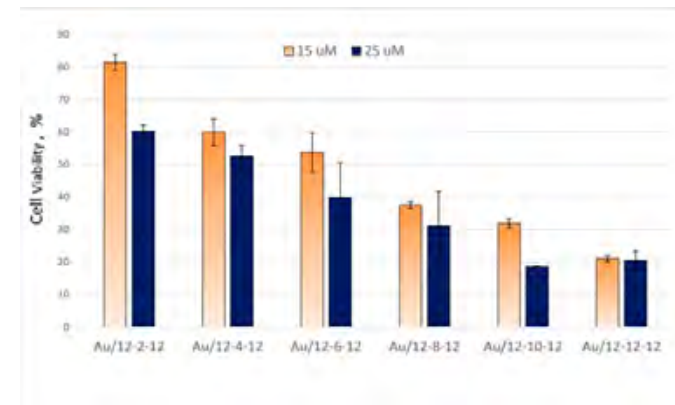


Fig. 4

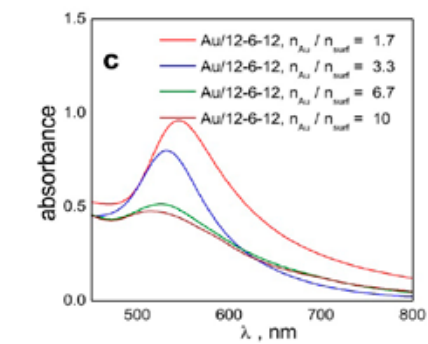


Fig. 3

Fig. 1 / Schematic representation of the formation of Ag nanoparticles. Similarly, Au nanoparticles were prepared from  $HAuCl_4$

Fig. 2 / Electron microscopic photographs of Au nanoparticles stabilized by GCT with different lengths of the connecting chain and without stabilizer

Fig. 3 / Graphic representation of the plasmon resonance effect of Au nanoparticles stabilized by a 12-6-12

Fig. 4 / Dependence of the cytotoxic activity of Au nanoparticles depending on the used stabilizer 12-X-12

Fig. 5 / Anti-arthritis action of Au nanoparticles stabilized by the 12-2-12. The experiment was carried out on rat. The pictures show the left paws of rats: a) a control paw without arthrosis; b) a paw on which arthrosis was experimentally induced, the image shows swelling (red arrow); c) a paw with experimentally induced arthrosis treated with Au nanoparticles stabilized 12-2-12, the image does not show persistent swelling, which was also manifested by the loss of lameness in the given limb

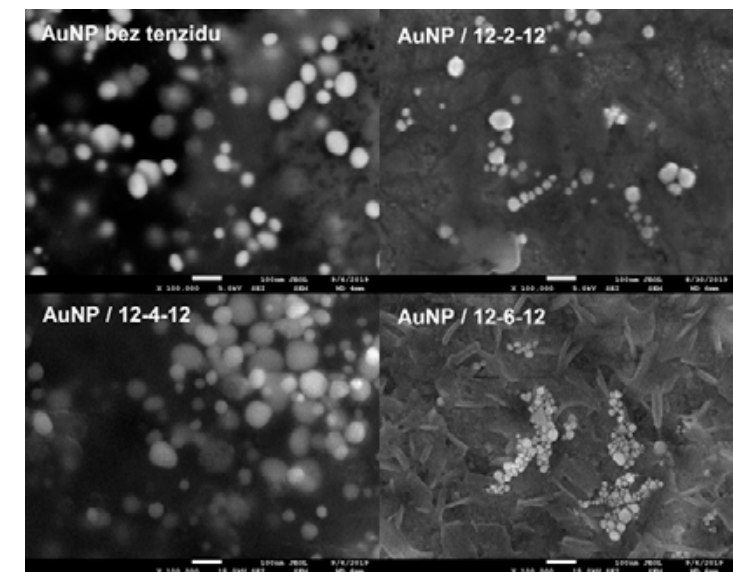


Fig. 2

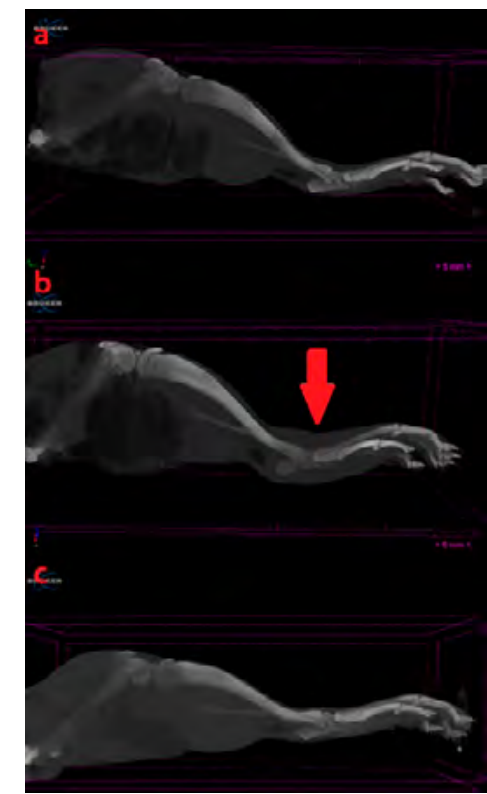


Fig. 5



## Turning cisplatin-resistant testicular germ cell tumors into a curable disease

### Research subject

Mechanisms of response of testicular germ cell tumours (TGCT) to cisplatin (CDDP)-based therapy.

### Aim of the research

The aim of the project was (i) to determine the difference in mRNA and miRNA expression between CDDP-sensitive and CDDP-resistant TGCT cell lines (to select mRNA and miRNA candidates for further analysis and to verify their clinical relevance), (ii) to analyse the possibility of epigenetic regulation of the selected candidates, (iii) to correlate the mRNA level with the protein level for the selected candidate mRNAs, (iv) to correlate the level of endogenous DNA damage with genome instability in TGCT patients, and (v) to decipher the role of the XPA protein level in predicting treatment outcome in TGCT patients.

### Achieved results

After translation into clinical oncology, the results obtained during the project implementation can potentially increase curability of TGCT patients by means of ensuring the curability of patients with poor prognosis as a consequence of high risk of refractoriness or relapse of the disease. We have found that the DNA damage level in chemotherapy-naïve TGCT patients inversely correlates with prognosis. Therefore, we proposed that the DNA damage level may serve as an independent prognostic factor in this malignancy. If combined with the International Germ Cell Cancer Collaborative Group (IGCCCG) prognostic classification, the level of endogenous DNA damage provides the added prognostic value. Furthermore, we revealed that the DNA damage level inversely correlates with haematological toxicity in TGCT patients who received first-line chemotherapy. The level of endogenous DNA damage also independently correlates with the number of some specific subpopulations of immune cells, such as NK (natural killer) cells, CD16-positive dendritic and regulatory T cells. By correlating the number of individual subpopulations of immune cells with clinical parameters, we disclosed that the level of neutrophils, eosinophils, type 2

dendritic cells, lymphocytes and cytotoxic T lymphocytes is significantly associated with progression-free survival (PFS), while the level of neutrophils and non-classical monocytes and the total number of lymphocytes is associated with overall survival (OS) of TGCT patients. We also showed that prognosis of TGCT patients inversely correlates with the expression level of the key proteins of nucleotide excision repair pathway, primarily the XPA protein. Increased XPA expression, predicting a worse prognosis, was found in the non-seminomatous histological subtype, IGCCCG poor prognosis group, increased S stage, as well as the presence of lung, liver, and non-pulmonary visceral metastases. In clinical stage I (S-CS I) seminomas, we identified 64 proteins that associate with process of rete testis invasion (RTI). Of these, 14-3-3 $\gamma$ , ezrin, filamin A, parkinsonism-associated deglycase 7 (PARK7), vimentin and vinculin proteins were validated in a cohort of S-CS I patients. We found that expression of the PARK7 and filamin A proteins reduces the risk of RTI, while the expression of 14-3-3 $\gamma$  increases it. We identified genetic biomarkers in TGCT cell lines that associate with response to CDDP. 281 genes were differentially expressed in CDDP-resistant compared to CDDP-sensitive TGCT cell lines. DNMT3L, GAL, IGFBP2, IGFBP7, LITD1, NANOG, NTF3, POU5F1, SOX2, WNT6, ZFP42, ID2, PCP4, SLC40A1 and TRIB3 genes showed the highest expression change when all CDDP-resistant TGCT cell lines were paired with all CDDP-sensitive lines. The products of the identified genes are pluripotency factors or are involved in processes such as cell metabolism, proliferation or migration. We proposed that, after clinical validation, these genes could serve as prognostic biomarkers for the early detection of CDDP response in TGCT patients.

### Benefits for practise

The obtained results represent novel original findings that have potential to contribute to new directions, innovations and concepts in the field of clinical oncology in TGCT patients. Above all, they might be applicable for early

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250 000 €  
**Project ID**  
APVV-17-0384

stratification of TGCT patients and identification of patients with a poor prognosis. The obtained results could also contribute to the development of new therapeutic strategies, since targeting of the studied factors and mechanisms could improve the prognosis of relapsed and refractory TGCT patients.

Fig. 1 / Differentially expressed genes in CDDP-resistant TGCT cell lines were compared with CDDP-sensitive H12.1 cell line. Volcano plot comparisons of mean log2-FC of gene expression between H12.1D and H12.1 (A), 1411HP and H12.1 (B) and 1777NRpmet and H12.1 (C) cell lines. Overlap of all three CDDP-resistant TGCT cell lines vs H12.1 (D).

Fig. 2 / Kaplan-Meier estimates of PFS (A) and OS (B) stratified by IGCCCG risk group and % DNA in tail. Both PFS and OS were significantly decreased in intermediate and poor risk patients having DNA damage over 6.34 % in contrast to all other groups ( $p < 0.001$  for both PFS and OS).

Fig. 3 / Immunohistochemistry of expression of 14-3-3 $\gamma$ , filamin A and PARK7 in RTI-negative (upper panel) and RTI-positive (bottom panel) S-CS I patients. Original magnification 40 $\times$ .

Fig. 4 / Flow cytometry gating strategy used for immunophenotyping selected leukocyte subpopulations in TGCT patients.

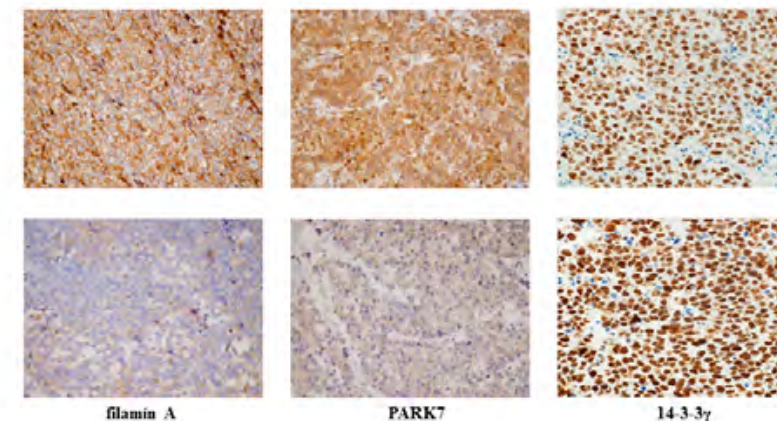
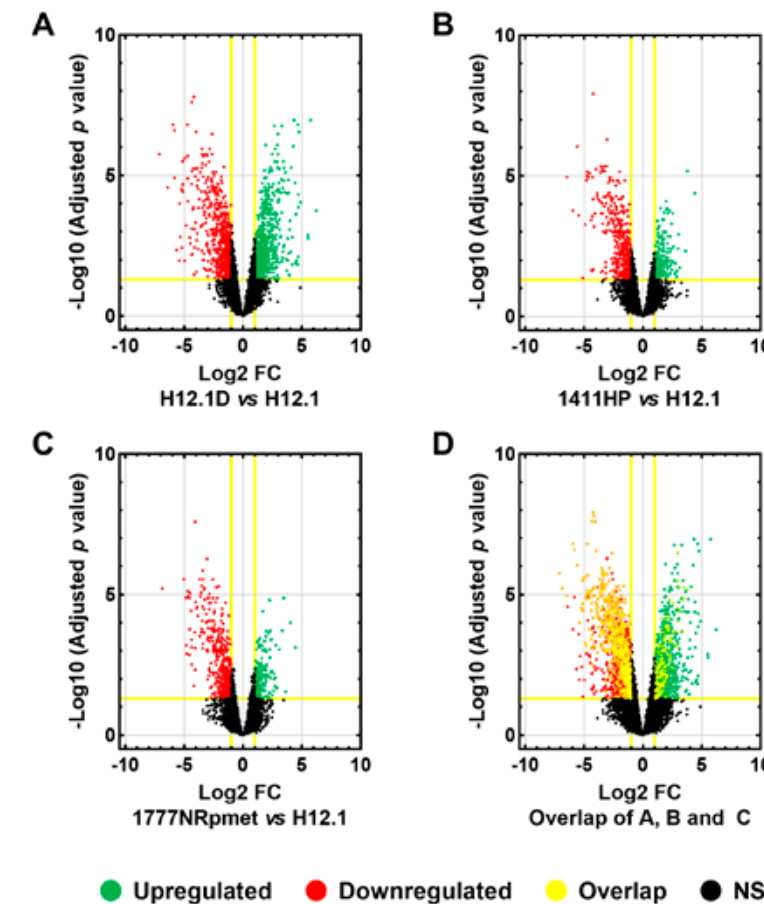


Fig. 1

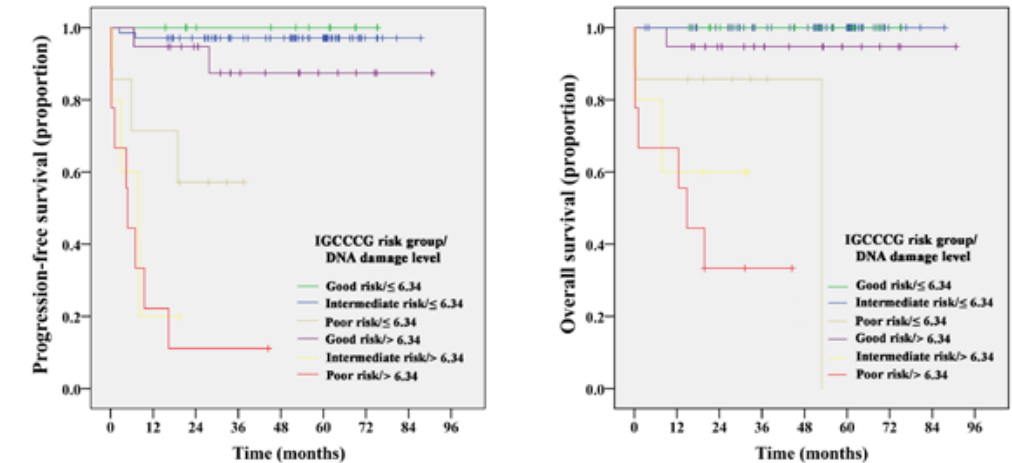
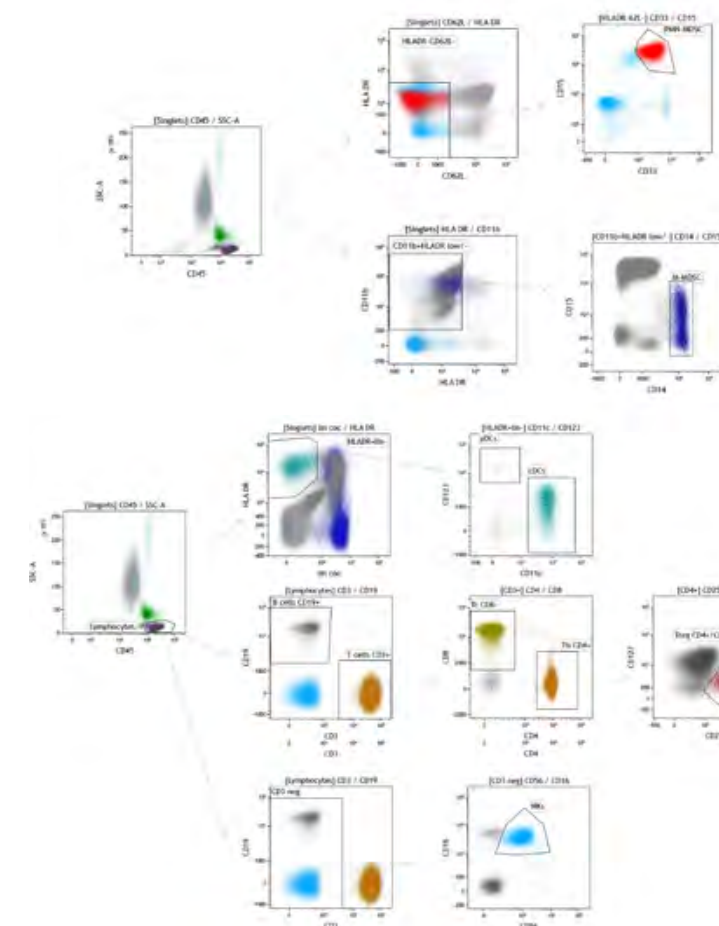


Fig. 2





# AGRICULTURAL SCIENCE





Protection of endangered  
Slovak livestock breeds in ex  
situ conditions

Research subject

Protection of the animal genetic resources has an impact on the present and also future life quality and important effect on the food safety. An effective cryopreservation of biological material from certain species of livestock is not yet fully mastered. The related issues are reduced viability and quality of frozen/thawed livestock sperm, embryos and stem cells. The aim of the submitted project is to optimize the methodologies for obtaining, cryopreservation and quality evaluation of spermatozoa, embryos and stem cells of farm animal breeds that are endangered or at risk based on monitoring. These breeds are pinzgau cattle, two rabbit breeds (holic blue and slovak grey-blue rex) and one sheep breed (original valachian). Obtained results allow to extend the animal gene bank, established prespectively at NPPC Research Institute for Animal Production Nitra in collaboration with Slovak University of Agriculture in Nitra, for cryopreserved biological material.

Aim of the research

The aim of the submitted project is to optimize the methodologies for obtaining, cryopreservation and quality evaluation of spermatozoa, embryos and stem cells of farm animal breeds that are endangered or at risk based on monitoring. These breeds are pinzgau cattle, two rabbit breeds (Holic blue and Slovak grey-blue Rex) and one sheep breed (original valachian). Obtained results allow to extend the animal gene bank, established prospectively at the NPPC, Research Institute for Animal Production Nitra in collaboration with Slovak University of Agriculture in Nitra, for cryopreserved biological material.

Achieved results

Optimization of cryopreservation methods (equilibration time of ram sperm before freezing - ram sperm, application of Ficoll as a cryoprotective substance - rabbit sperm, flow cytometry - indicate of stem cell quality, ..... ) made it possible to successfully freeze the monitored reproductive biological material of Slovak national livestock breeds. The result is a high progressive motility of 85% of sperm and stem cells (90%) after thawing, which is one of the important factor in assessing sperm and stem ceels quality. Methods such as CASA, flow cytometry, or the use of electron microscopy have allowed us to more accurately evaluate the quality of fresh and thawed sperm and stem cells. All analyzed Slovak national breeds in the project are cryoprotected in the form of frozen sperm or stem cells and stored in a gene bank at the NPPC VÚŽV Nitra. The samples were also registered in an international database (www.cryoweb.com). We met the planned goals, including outputs, within three years of the solution.

Benefits for practise

Despite the nature of the project - basic research, the output for practice is specifically frozen samples of sperm and stem cells of Slovak national breeds (rabbits, rams, chickens) for the purposes of the national gene bank of the Slovak Republic, all samples are registered in international database (www.cryoweb.com).

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**Term of solution**  
08/2018 – 06/2021  
**Budget from agency**  
249 684 €  
**Project ID**  
APVV-17-0124

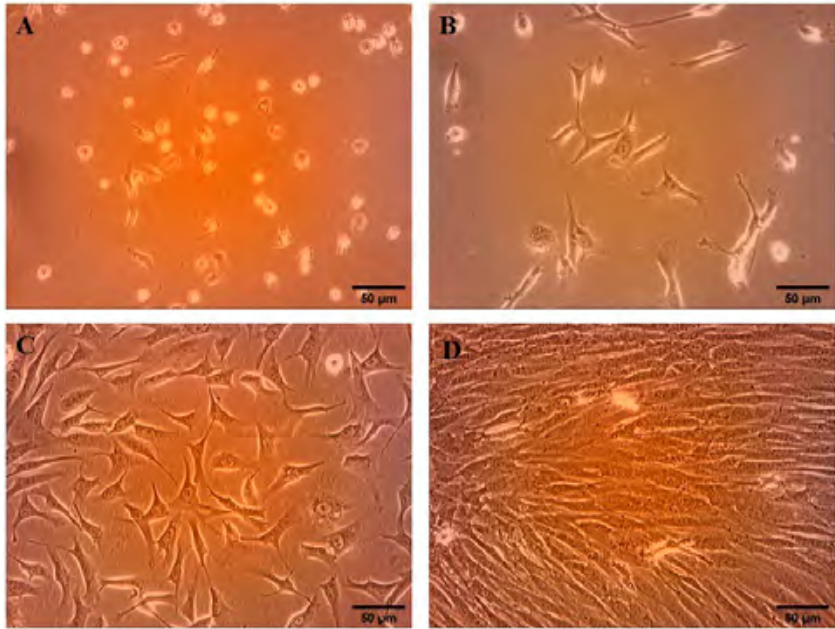


Fig. 1

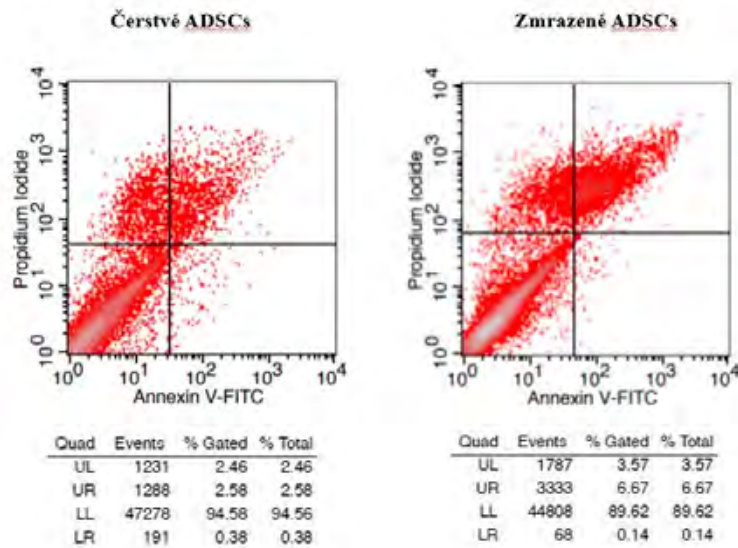
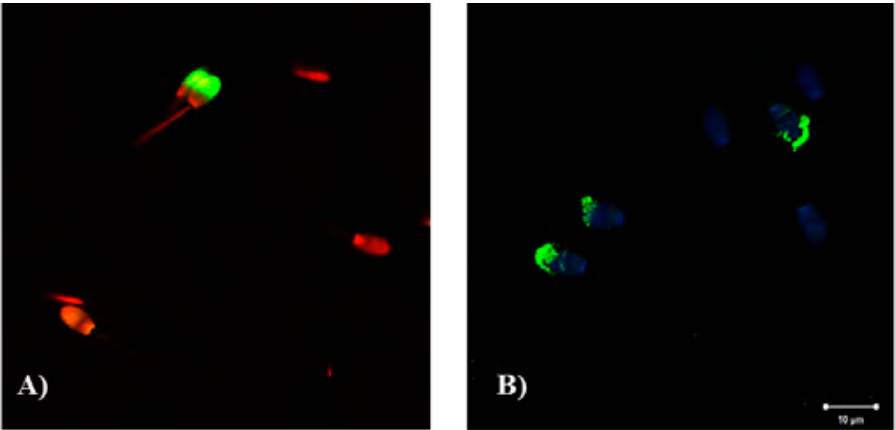


Fig. 3



B) Detekcia ROS pozitivnych spermii

B) Detekcia ubiquitinovanych spermii

Fig. 2



Fig. 4

Fig. 1 / Morphology of ADSCs cells. (A) 24 hours after isolation, cells begin to adhere, showing a spherical shape. (B) 72 hours after isolation, the cells are grouped into small colonies, the cell shape changes to spindle-shaped. (C) 4 days after isolation, confluence is approximately 50–60%, cells show a fibroblast-like shape. (D) 7 days after isolation, cells reach 90–100% confluence. We observe a continuous monolayer of cells. (Magnification 20x; scale bar = 50 µm).

Fig. 2 / Illustrative shot from confocal microscopy of ram spermatozoa

Fig. 3 / Representative view of cell viability assessment by flow cytometry

Fig. 4 / The original Valaška (Valachian sheep)



## Potential of silicon for mitigation of arsenic and antimony toxicity in agricultural crops

### Research subject

Contamination by antimony (Sb) and arsenic (As) represents a serious environmental problem in countries with high level of industry and agriculture, but also in Slovakia, due to intensive mining in the history and storage of As-enriched fly-ash from coal burning. Therefore, the sites contaminated by these elements can be found across the whole Slovakia, from Malé Karpaty Mountains, Horná Nitra region, Liptov region to surroundings of Košice city in Eastern Slovakia. Although active mining of Sb ores was stopped already at the end of the 20<sup>th</sup> century, there are still some residuals in the country, like old mining heaps and waste deposits. These sites serve as source of contamination and represent a serious threat for mankind living in the surrounding. Both As and Sb are non-essential for living organisms, including plants. Despite of this, plants can take up and accumulate these elements in relatively high concentrations in their organs. On the other hand, we know that one of the possible solutions to ameliorate the toxicity of some heavy metals (e.g. cadmium) in plants might be silicon (Si) application. Despite intensive research in the last years there was still only limited knowledge about the effect and phytotoxicity of As and Sb, as well as interaction of toxic (As, Sb) and beneficial (Si) metalloids in plants what was the research topic of this project.

### Aim of the research

The main aim of the proposed project was to understand the mechanism of the interaction of beneficial element silicon with toxic, for plants non-essential elements (arsenic and antimony) during growth and the development of selected cultural and important agricultural crops.

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**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
250 000 €  
**Project ID**  
APVV-17-0164

### Achieved results

Within this project we have performed a whole spectrum of experiments with various crops and important plants grown in a plethora of experimental conditions. This effort brought a number of valuable new knowledge, most of which were already published as twelve original manuscripts and review papers, or as presentation on domestic and international conferences. As main findings we consider valuable knowledge about negative influence of antimony and arsenic on the plant biomass, chlorophyll synthesis and photosynthetic apparatus, as well as antioxidant response of plants that are exposed to stress caused by toxic doses of these non-essential metalloids. Understanding of the toxic influence of arsenic and antimony was necessary for optimal application of silicon and study of their interaction. In respect to fulfil the aims of the project, we succeed to compare the phytotoxicity of As and Sb with effects of other toxic elements and heavy metals. Additionally, we fulfil the mosaic of missing knowledge about toxicity of As and Sb on growth and development of various important crops and cultural plants, like maize, sorghum, wheat, tobacco, mung bean, poplar or *Arundo donax*. One of the interesting findings was identification of mechanisms of Si uptake and deposition in date palm root tissues. We obtained unique results about specific tissue localisation of Si within so called „stegmata“ cells, that are closely associated with sclerenchyma. We also performed experiments dealing with Si transport proteins LSi and their role in Sb uptake to roots. Last but not least, we found out some answers to questions related with the engagement of Si in individual physiological and biochemical processes in plants exposed to toxic elements, and partially we proved the reliability of Si application to agricultural plants grown in contaminated substrates from Slovakia.

### Benefits for practise

The results of the project can be used in basic research and development, as well as in education during student's experiments and theses, and in praxis. Obtained results about toxic effects of arsenic and antimony and possibilities of their alleviation by silicon can be used in crop production, suitable plant hybrids and varieties selection and protection against abiotic stress. The results might be useful also for production of safer food and alimentary products as well as in evaluation of negative influence of abiotic stresses, mainly metals and metalloids on individual components of the environment.

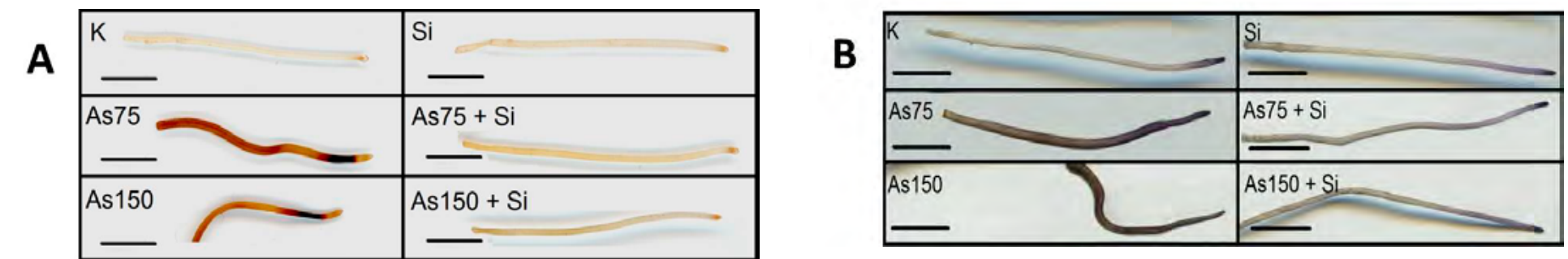


Fig. 1

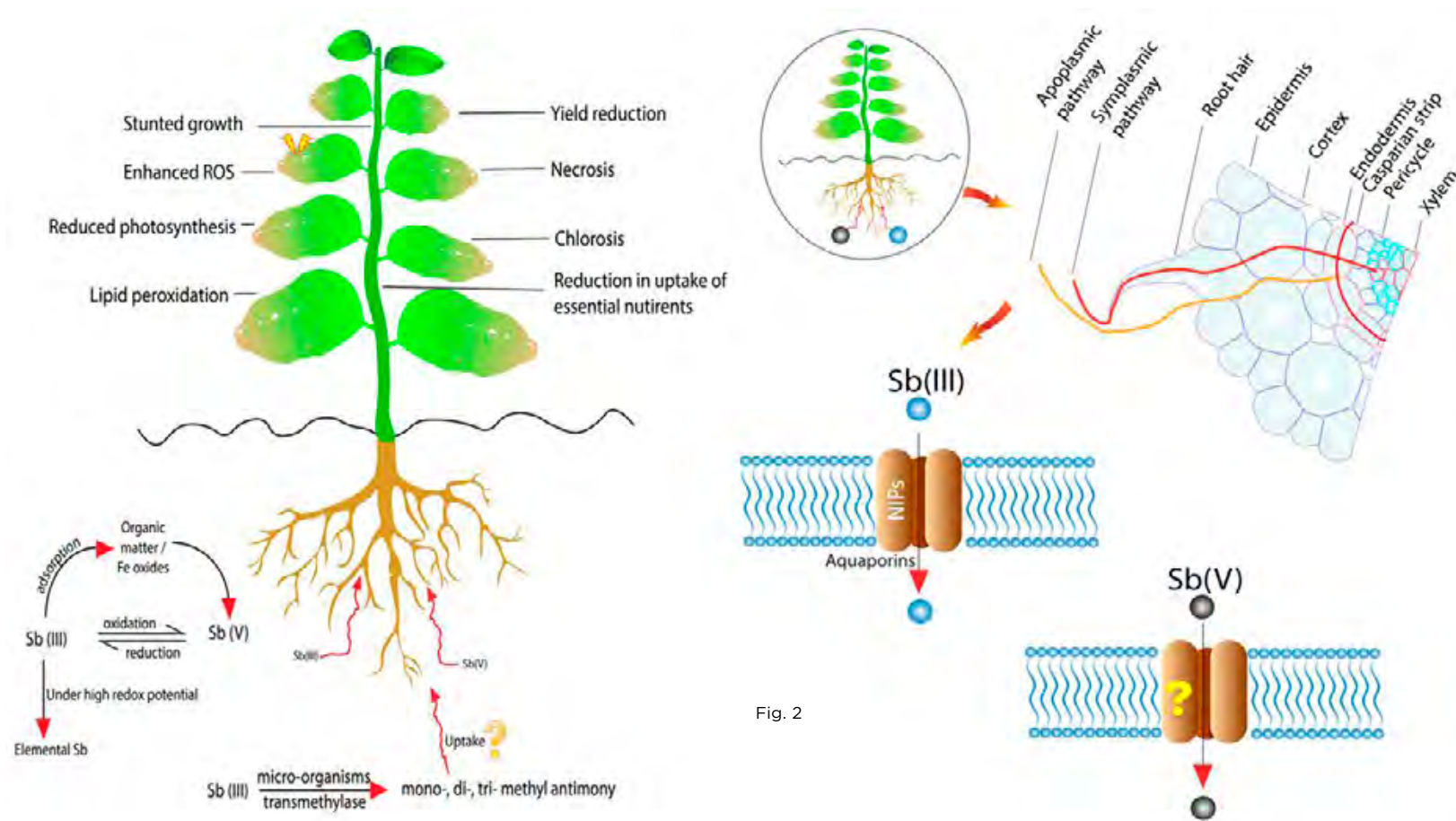


Fig. 2

Fig. 1 / Histochemical visualisation of hydrogen peroxide (A) and superoxide (B) in maize roots grown in control conditions and with presence of As and Si.

Fig. 2 / Mechanisms of antimony uptake by root cells and tissues and its negative effects on growth and development of plants (according to Vidya et al., 2022).

Fig. 3 / Silicon phytoliths in leaves of *Arundo donax* visualised by scanning electron microscopy (A) coupled with EDX analysis (B).

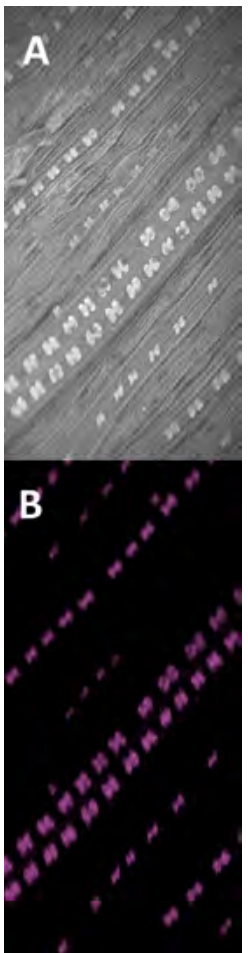


Fig. 3



## Bioactive compounds of sea-buckthorn and their application in functional foods

### Research subject

The project was focused on identification, characterization of the stability of bioactive compounds of sea buckthorn (*Hippophae rhamnoides*) and their application in functional foods. The applied research included activities ranging from the cultivation of sea buckthorn, through the use of by-products of its processing to the production of innovative types of food products with sea buckthorn. The project was implemented at the NPPC Food Research Institute in cooperation with the Faculty of Chemical and Food Technology of the Slovak Technical University in Bratislava and with partners from the practice PD Tvrdošovce, Celpo, s.r.o., Očová and Mlyn Kolárovo, a.s.

### Aim of the research

Input raw material of sea buckthorn fruits of the Leikora variety from the sea buckthorn orchard of PD Tvrdošovce was characterized in detail during 3 seasons (2018-2021). On the basis of the analysis of the content of biologically valuable components (vitamins, flavonoids, polyphenols and other components with antioxidant effect) and morphological and sensory parameters, the different stages of ripeness were characterised and compared, which were the basis for recommendations for harvesting and subsequent processing of the fruit. Particular attention was paid to the possibilities of using the pomace - by-products of sea buckthorn juice production, which are a valuable source of bioactive substances.

### Achieved results

Dried sea buckthorn pomace has been applied to fortify cereal products, which are a common and popular food for various groups of consumers. New formulations for cereal products with enhanced nutritional value have been developed, in which the content of biologically valuable components during processing and storage has been characterised. Composite flour blends consisting of cereal, pseudocereal and legume sources with the addition of finely ground dried sea buckthorn have been used to prepare new products (breads, cakes, biscuits and puffed snacks) with an increased

content of fibre, protein, carotenoids, rutin, vitamins and other health-promoting components. The products were characterised in terms of quality, nutritional value and the presence of bioactive compounds, but also in terms of the content of contaminants produced by baking the products. Sea buckthorn pomace was found to be an exceptional source of health-promoting bioactive compounds but, on the other hand, also a significant potential source of the undesirable potentially carcinogenic acrylamide. Therefore, as a next step, an innovative method of enzymatic pretreatment of sea buckthorn pomace and flours with asparaginase was proposed, which led to the effective elimination of the formation of undesirable process contaminants during baking, while the benefits derived from sea buckthorn were preserved. A similar acrylamide elimination principle was applied to the nutritionally valuable cereals (oats and rye) used for heat-processed products with long shelf-life.

### Benefits for practise

Methods of obtaining raw materials with low disposition for the formation of acrylamide were applied for as utility models at the Industrial Property Office of the Slovak Republic and as a European patent application. During the project, 9 scientific publications in foreign and domestic impacted journals were published with a total of 203 citations, 29 papers in professional journals and proceedings in Slovakia, 27 papers at foreign conferences published in proceedings, 2 registered utility models in the Slovak Republic, 1 European patent application, 5 new products, 1 validated technology, 10 diploma and 3 doctoral theses were realized, 2 doctoral positions were created, 5 electronic documents were published, 15 popularization activities were organized, 5 applications for new projects were submitted within the Slovak Republic, 3 of which were supported, 4 applications for international COST projects, 2 of which were supported, and other forms of international cooperation and cooperation with the business sector were realized. The team of NPPC VÚP researchers led by Ing. Zuzana Ciesarová, PhD. together with the project implementer Celpo, s.r.o., Očová,

#### Principal investigator

Ing. Ciesarová Zuzana, PhD.

#### Applicant organisation

National Agricultural and Food Centre  
- Food Research Institute

#### Participating organisation

Slovak University of Technology in Bratislava  
- Faculty of Chemical and Food Technology

#### Term of solution

08/2018 – 12/2021

#### Budget from agency

247 724 €

#### Project ID

APVV-17-0212

won the Award for Technology Transfer in Slovakia 2020 in the Innovation category. For their systematic approach to technology transfer, they were nominated in the category Innovator also in 2021.

#### Key publications:

1. Ciesarová, Z. et al., Food Research International. 133, (2020), 109170. doi: 10.1016/j.foodres.2020.109170. IF: 4.972.
2. Kreps, F. et al., Food Packaging and Shelf Life. 29, (2021), 100739. doi: 10.1016/j.fpsl.2021.100739. IF 6.429.
3. Ciesarová, Z. et al., Food Chemistry. 365 (2021), 130491. doi: 10.1016/j.foodchem.2021.130491. IF 7,514.
4. Ciesarová, Z. et al., Foods 12 (2023), 3170. <https://doi.org/10.3390/foods12173170>. IF 5,42.

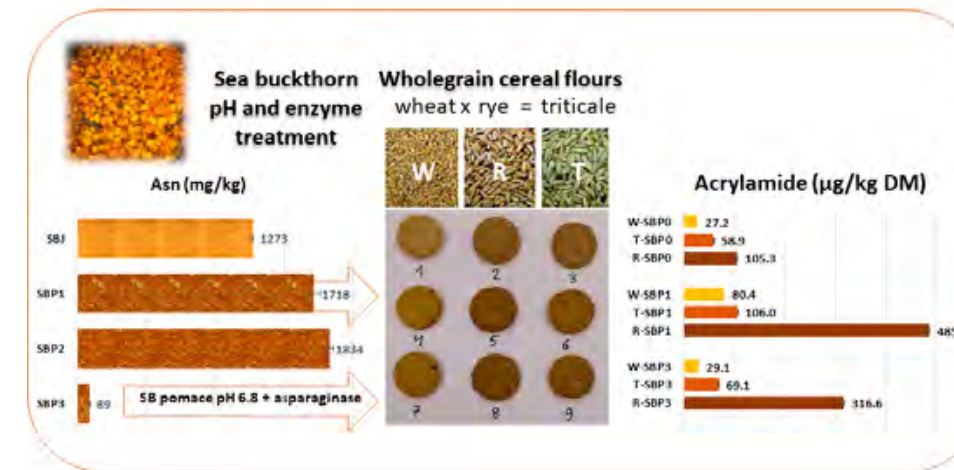


Fig. 1

## Intellectual property protection



Fig. 2



Fig. 1 / Graphical abstract FOODS\_2023: Innovative fortified sea buckthorn biscuits with reduced acrylamide level. Published in Ciesarová, Z.; Kukurová, K.; Jelemenská, V.; Horváthová, J.; Kubincová, J.; Belovič, M.; Torbica, A. Asparaginase Treatment of Sea Buckthorn Berries as an Effective Tool for Acrylamide Reduction in Nutritionally Enriched Wholegrain Wheat, Rye and Triticale Biscuits. Foods 2023, 12, 3170. <https://doi.org/10.3390/foods12173170>. Impact factor: 5,42.

Fig. 2 / COINTT Award 2020 for Technology Transfer in Slovakia in the category of Innovation

Fig. 3 / Sea buckthorn orchard in PD Tvrdošovce

Fig. 4 / Production of innovative puffed snacks in CELPO, s.r.o. Očová



Fig. 3

Fig. 4



## Testing novel policies and business models for provision of selected forest ecosystem services

### Research subject

The ecosystem services provided by forests and forestry include the benefits to biodiversity conservation, water production and protection, human well-being, or climate change adaptation and mitigation. A lot of attention is paid to the importance of the topic of forest ecosystem services and their optimal utilisation in relation to the needs of society. The main objective of the research project was to test, through case studies using available data and methodological approaches, the possibility of developing new policies and business models to support the provision of selected forest ecosystem services.

### Aim of the research

Strategic project objective was to contribute to the sustainable development of the Slovak Republic by increasing incentives for the provision of forest ecosystem services (FES). The main objective of the project was to use case studies to develop new policies and business models to strengthen policy coordination for timber production, biodiversity conservation, carbon sequestration, recreation and water-related FES. At the same time, the aim was to present, in collaboration with the outcomes users, research results and the possibilities of the chosen research approach in arguing with other experts and raising public awareness of FES.

### Achieved results

Based on a literature review on the links among different policies, business models and FES provision, appropriate testing approaches were selected in the case studies. The case studies were selected based on collaboration with the end users of research results and they represented regions with different priorities and requirements for FES (Forest District Bratislava, municipal forest Banská Bystrica and Tatras National park –Štrbské pleso area). Using suitable research methods, the available data on the natural environment, forest condition and current forest management, forecasts of forest management in the region were made according

to the selected FES priorities. The FES priorities were determined in a participatory manner in collaboration with various actors/interest groups in the case study region. The results of the modelling of management change (timber production constraints) were translated into payments for FES (PES). PES were proposed to compensate for the losses of timber production revenues. Testing of the feasibility and acceptance of management change at the case study level was carried out in the regions for all selected FES based on the priorities identified by the actors. Acceptance testing of the proposed PES led to a preference for public schemes in all regions. The synthesis of the results allowed design of better policy coordination for the provision of FES and better acceptance of forest management changes. The research results have been published in 11 peer-reviewed articles, 2 books. Dissemination of results consisted of international collaboration, 5 popularization activities and more education activities. More than 160 participants had possibility to visit various events, including non-formal education in practice and formal education at the university.

### Benefits for practise

Project results contributed to the development of the new policy mechanisms and business models for better use of FES in Slovakia. Cross-sectoral measures to promote PES have been proposed as part of the participatory process of developing the new National Forest Programme. At the regional level, the possibility was presented to prepare a regional support scheme across all affected sectors and actors (Bratislava case study), or to coordinate activities to strengthen the fulfilment and use of FES in public policy measures of the municipality (Banská Bystrica case study, and Tatras case study). Communication and dissemination activities took place throughout the duration of the project, but were significantly affected by the Covid-19. Some activities took place online, what allow their recording and further sharing. Planned outcomes of project were met or exceeded in every indicator. Activities to share the results continue beyond the project timeline through the project website <http://www.ipoles.sk/testpesles/> and international collaboration.

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National Forest Centre  
**Participating organisation**  
Technical University in Zvolen – Faculty of Forestry  
**Term of solution**  
08/2018 – 12/2021  
**Budget from agency**  
249 899 €  
**Project ID**  
APVV-17-0232



Fig. 1 / TestPESLes project logo

Fig. 2 / Participatory workshop with stakeholders in Banská Bystrica

Fig. 3 / Management change option in the Banská Bystrica municipal forests according to the priorities of interest groups

Fig. 4 / The design model of payments for ecosystem services (PES)



Fig. 3

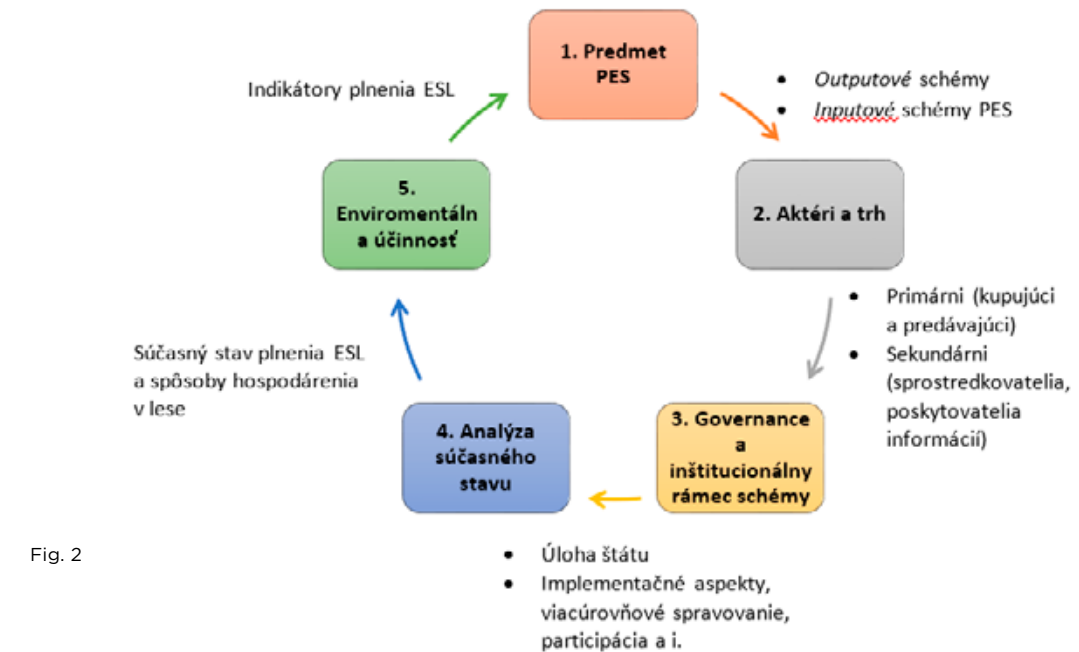


Fig. 2



Fig. 4



## Assessment of recent changes and trends in agricultural landscape of Slovakia



**Principal investigator**  
RNDr. Halada Ľuboš, CSc.  
**Applicant organisation**  
Slovak Academy of Sciences, Institute of Landscape Ecology  
**Participating organisation**  
Constantine the Philosopher University in Nitra  
**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
240 223 €  
**Project ID**  
APVV-17-0377

### Research subject

The main project motivation was insufficient knowledge of recent changes in the agricultural landscape (AL) and their impact on nature and society, despite the key role of AL in food production, ecosystem services provision, and environment of a significant part of the Slovak population. We need improve identification of the spatial operation of these changes, the regularities of their distribution, quantification of their extent, intensity and impact on functions and ecosystem services of AL, prediction of the future development of AL and its impact on the structure and functions of AL. The project focused on these issues.

### Aim of the research

The project main objective was to assess the extent and spatial distribution of recent changes in the use of the Slovak agricultural landscape, their trends and impacts on the main functions of the agricultural landscape and the ecosystem services dependent on them. Sub-objectives:

- To develop a comprehensive system of methods, procedures and indicators for the detection, mapping and analysis of recent changes in the use of Slovak AL at local and national levels;
- To assess the spatial distribution and extent of significant changes and processes and their impact on the performance of AL functions and ecosystem services;
- Propose measures, tools and procedures for informed and participatory decision-making and planning for sustainable use of AL at national and local levels.

### Achieved results

The project main outcome is a comprehensive assessment of the changes in AL use in Slovakia after 1990 - their extent, trends, distribution, impacts on landscape functions and provision of ecosystem services. The original features of the project are a complex approach involving both natural and socio-economic factors, emphasis on internationally established indicators use, development trends analysis,

formulation of possible future scenarios, linking of several spatial levels, and stakeholder involvement.

In the first phase, we assessed the drivers, pressures and indicators of AL change in the international and national context. At the national level, we evaluated AL change, interpreted them as a processes, and evaluated the ecosystem services provided by AL. At the local level, we analysed the status and changes of AL in seven case studies in different landscape types. The result is landscape ecological studies for each area with comprehensive information applicable for planning their further development. The final phase focused on interpretation, generalisation of results and proposals - besides comparing national and local trends, we formulated proposals and measures for further development of Slovak AL.

The results of the project are 13 Current Contents and 15 other peer-reviewed papers, 1 scientific monograph abroad, initiation of 14 national and international projects, various forms of international cooperation a number of other activities. The results and outputs of the project made it possible to achieve the main objective and three sub-objectives.

### Benefits for practise

**Science and research:** The project has identified and addressed several topical issues that require the development of new assessment methodologies for, e.g. impact of global megatrends on AL, environmental impacts of changes in AL use, changes in ecosystem services, negative impacts of urbanisation, consequences of climate change, natural resources degradation. The used methods contribute to further research in ecology, environmental science and agriculture. The project has improved participatory research methods, important for successful involving stakeholders in research.

**Education and training:** The monograph "A Catalogue of Ecosystem Services in Slovakia" (Springer 2020) and the forthcoming university textbook "Agricultural Landscape of Slovakia" will serve as a didactic tool at universities, but also as a source of knowledge for further research, planning and decision-making processes.

**Practical application:** The results can be used at the national level, e.g. during the evaluation of the Strategic Development Plan of Slovakia and the development of a new plan, for the formulation of priorities and measures of the Common Agricultural Policy. They can also be used for the preparation of regional and local strategic and planning documents, as well as for the environmental assessment of AL. Users can be municipalities, professional organisations for nature and landscape protection, agriculture, projecting institutions, but also farmers, NGOs, local action groups, etc.

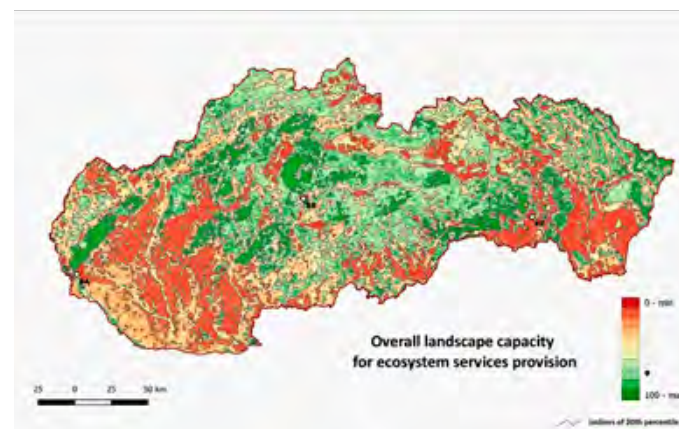
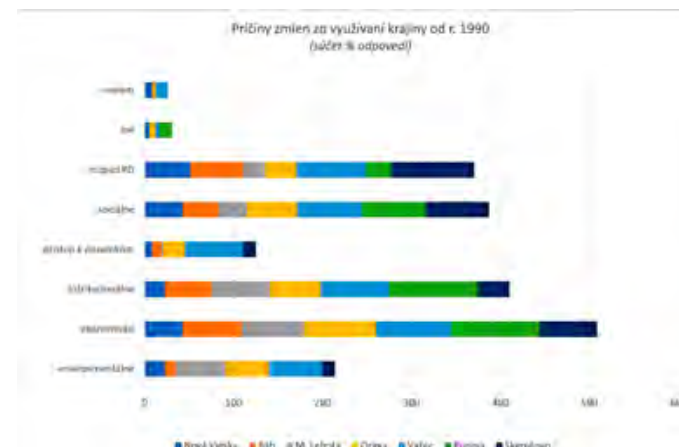
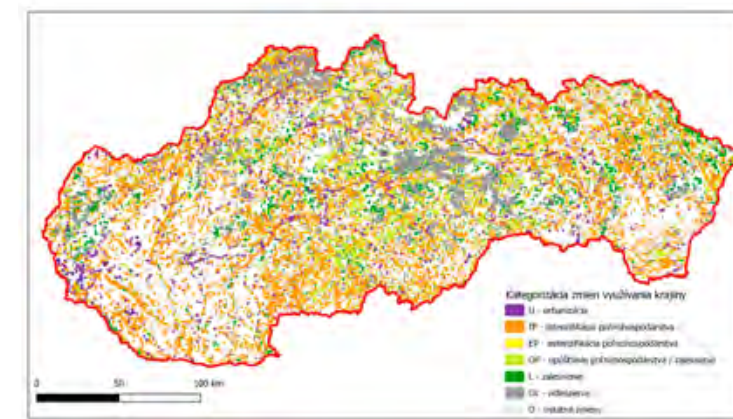


Fig. 1

Fig. 2

Fig. 3



Fig. 4

Fig. 5



# SOCIAL SCIENCE





## Constitution of liberal-democratic state and radicalization of political culture

### Research subject

This project explored how the constitutions of liberal democratic states can respond to the radicalisation of political culture that is rising in both transitional and advanced democracies. The project compared the institutions of so-called militant democracy with a benevolent approach to political radicalism. In particular, the research focused on the two central institutes of militant democracy - repression of hate speech and dissolving political parties. It subjected these institutes to a normative analysis, examining their compatibility with freedom of expression and political competition.

### Aim of the research

In the first phase of the project, the research was oriented towards describing the problem under study, i.e., identifying symptoms and causes of radicalisation of political culture. In the second phase, the research focused on framing, analysing and defending selected solutions to the problem under study. The research team compared American and European approaches, repressive and non-repressive means of protecting democracy. It looked for room for constitutional-conforming restrictions on freedom of expression and democratic political competition.

### Achieved results

In the first phase of the project, the research was oriented towards describing the problem under study, i.e., identifying symptoms and causes of radicalisation of political culture. In the second phase, the research focused on framing, analysing and defending selected solutions to the problem under study. The research team compared American and European approaches, repressive and non-repressive means of protecting democracy. It looked for room for constitutional-conforming restrictions on freedom of expression and democratic political competition.

**Principal investigator**  
doc. Mgr. Káčer Marek, PhD.  
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Trnava University in Trnava – Faculty of Law  
**Term of solution**  
08/2018 – 06/2022  
**Budget from agency**  
157 124 €  
**Project ID**  
APVV-17-0056

### Benefits for practise

Several of the project's conclusions can be used as a criterion for selecting public policies or as a guide for their design in the legislative process. Some findings can also address interpretive problems arising in the prosecution and punishment of hate speech and in the dissolution of political parties.



Fig. 1



Fig. 2



Fig. 3



Fig. 4



Fig. 5

Fig. 1 / Human Dignity: A Philosophical and Legal Reflection - a cover of the monograph

Fig. 2 / Material Core in Slovak Constitutional Law - a cover of the monograph

Fig. 3 / Restricting Freedom of Expression in a Radicalizing Society - a cover of the monograph

Fig. 4 / Parliamentary Culture - a cover of the proceedings

Fig. 5 / Dissolution of Political Parties as a Manifestation of Militant Democracy - a cover of the proceedings



# Promotion of Reading Literacy in Mother Tongue and Foreign Language

## Research subject

The subject of the research was the development of reading literacy by supporting text understanding in native and foreign languages through an intervention, specifically the Reading Comprehension Intervention Program (IP). The intervention consisted of stimulating predictor (attention, memory, perception, cognitive structuring, inferential thinking, divergent thinking, tolerance of ambiguity, critical thinking), working with a text (linear and non-linear text, extensive and intensive reading) and developing reading strategies. IP was designed with the intention of helping teachers in preparing students to understand the text.

## Aim of the research

The main goal of the project was the development and validation of IP for mother tongue and foreign languages (FL) based on the determined reading comprehension predictors. The goal reflected several aspects: sociological, linguistic, methodological and application with regard to the mother tongue (Slovak - SL, Hungarian - HL) and FL (English - EL, German - GL, French - FL and Spanish - SpL). Comprehension of the text read in the mother tongue was verified at primary and lower secondary schools - PS (4th and 7th grade). Comprehension of the text read in a FL was verified at upper secondary schools - SS (3rd grade), for EL also at PS. The proficiency level in different FLs according to the CEFR was also taken into account - A2 and B1 for EL (1<sup>st</sup> FL) and A2 for the other (2<sup>nd</sup>) FLs.

### The research was carried out on 3 levels:

- development and validation of a tool for testing reading comprehension in mother tongue and FLs,
- determining predictors of reading comprehension,
- development and verification of IP modules.

Primary and secondary schools (more than 40) all over Slovakia participated in the research.

## Achieved results

In the 1st stage of the research, a tool for measuring reading comprehension was created and validated. The researchers prepared a battery of research methods and investigated predictors of reading comprehension. It turns out that latent variables characterizing the student's family background (emotional-communication environment, cultural capital of the family) appear as the strongest sociological predictors, tolerance of ambiguity (complexity and novelty factors) and the need for structure (desire for structure factor) as the strongest cognitive-personality predictors in EL, FL and SpL, lexical and grammatical competence, language and sociolinguistic competence as language predictors in GL, SL and HL.

Based on the predictors of reading comprehension, IP was developed and verified. It appears that the intervention aimed at developing text comprehension in EL, GL and SpL supported pupils' reading comprehension, the effect of IP as well as the tendency to increase comprehension and the bond strength was manifested. In secondary vocational schools, the increase in understanding in GL was statistically significant, but the increase trend and the bond strength did not show. In FL, both the effectiveness of IP and classical teaching was found, but the sustainability and tendency of the understanding increase was manifested only with pupils who completed IP. The effect of IP was also identified in primary and lower secondary schools in EL, SL and HL. In some groups, it was found that students need a longer period of time to work with the intervention.

The scientific presentation of the project results was carried out through publishing papers in WoS or Scopus journals (more than 20), in Slovak and foreign scientific and professional journals (more than 25), conference proceedings (more than 35), monographs (6) and textbooks (10). The project results were presented at scientific events in Slovakia and abroad (PT, ES, DE, UZ, RU, Brazil, and others), in various educational institutions. The organization of an international

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Constantine the Philosopher University in Nitra  
**Term of solution**  
08/2018 - 12/2022  
**Budget from agency**  
200 000 €  
**Project ID**  
APVV-17-0071

conference was also a significant project result. Students (especially PhD ones) were widely involved in the project, they analyzed the research results in their theses (including 8 PhD ones).

## Benefits for practise

The results of the project were applied in the educational process at primary and secondary schools and HEI. 9 IP modules were developed and verified: EL-2, GL-1, FL-1, SpL-1, SL-2 and HL-2. The IP modules are published in textbooks. IP modules are also used in the economic sphere, as IP prepares employees for communication in a FL in various work fields. Furthermore, dozens of teachers from all over Slovakia were trained in the application of IP.



Fig. 1



Fig. 2



Fig. 3



Fig. 4

Fig. 1 / Reading Comprehension Intervention Program Workshop for teachers of Slovak language

Fig. 2 / Application of Reading Comprehension Intervention Program for Slovak language in primary education - example of teacher work with pupils

Fig. 3 / Workshop of the research team

Fig. 4 / Selected set of textbooks of the Reading Comprehension Intervention Program



# Generating scientific information to support labour market policy making

## Research subject

Generating scientific information to support labour market policy-making

## Aim of the research

The project's main objective is to support the creation of labour market policies through the creation of relevant scientific information. This objective was, in line with the project proposal, fulfilled in two areas/project activities:

- II. Evaluating the impact of active labour market policy (ALMP) measures
- II. Modelling labour supply using a microsimulation model

## Achieved results

Within the project, impact studies of individual APTP measures in Slovakia were developed. Specifically the REPAS training programme, Graduate Practice, Activation Works and Activation Works in the form of voluntary service. The identification of effects related to participation in these measures on the labour market success of the participants uses administrative data provided by the Central Office of Labour, Social Affairs and Family (ÚPSVaR).

This project activity also produced automated reports assessing the impacts of a total of ten APTP measures based on a sample of participants from 2017. The reports are generated automatically based on data from the Office for Employment and Social Affairs and the database of labour market policies administered by the European Commission.

The effectiveness of the measures is defined by the impact on the absence from the unemployment register. It is quantified by a quasi-experimental approach, comparing the outcomes of participants and an ex-post-selected control group over a period of three years after participation in the measure.

In addition to the applied outputs, articles in this thematic area of the project have been published in scientific journals, namely the Journal of Applied Econometrics, The Econometrics Journal, and Econometrics and Statistics.

The second activity involved the development of the dynamic microsimulation model SLAMM. It is a model of Slovak labour supply, which allows the simulation of the development of labour supply in a detailed breakdown by gender, age, education, or labour market status. It is a tool for modelling the impact of ageing on the labour market.

The documentation of the model has been published in the journal of the International Mycosimulation Society. Several applications of the model have also been published. Scientific articles have been published in impacted journals, namely Eastern European Economics, International Journal of Microsimulation, International Journal of Comparative Sociology, and Economic Journal.

## Benefits for practise

In addition to the automated reports mapping the effectiveness of the APTP measures, the project also produced more detailed impact studies of the individual measures/programmes. For example, in the evaluation of REPAS, we designed the methodology and estimated the effectiveness based on a request from the Institute of Social Policy of the Ministry of Labour, Social Affairs and Family (ISP). The results were published in the ISP study "Kto chce zať, musí siasť", also as part of a scientific article in the international impacted journal Labour.

On the basis of the request of the project partner, the Central Office of Labour and Social Affairs (ÚPSVaR), a methodology for evaluating the performance of regional Labour Offices was developed.

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Slovak Academy of Sciences, Institute of Economic Research  
**Participating organisations**  
Comenius University Bratislava – Faculty of Philosophy  
Matej Bel University in Banská Bystrica – Faculty of Natural Sciences  
**Term of solution**  
08/2018 – 12/2021  
**Budget from agency**  
160 000 €  
**Project ID**  
APVV-17-0329

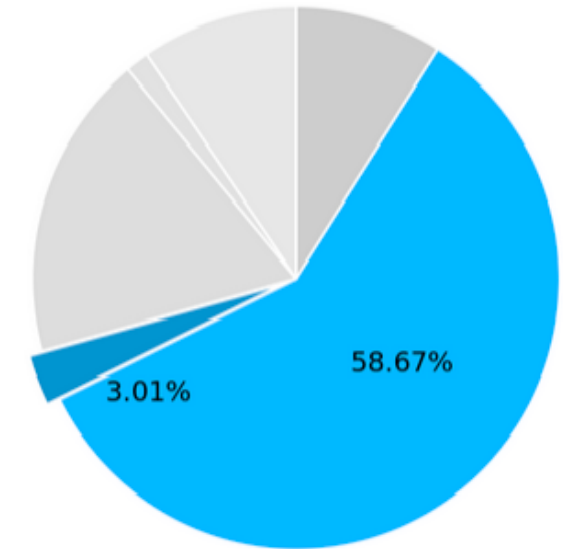
In the case of the development of microsimulation models, two versions of the microsimulation model were also used in the framework of cooperation with the decision-making sphere. The model was used to generate predictions at the request of the Value for Money Unit in the production of the 'Employment and Wages in Public Administration' expenditure reviews. A second, longer-term, collaboration was established with the Institute of Education Policy at the Ministry of Education, Science Research and Sport (IVP), where the project researchers developed a microsimulation tool to predict student numbers and teacher demand at the regional level. The forecast results were published in the IVP commentary "Forecasting the number of students and teachers by district by 2030". The project investigators also provided training on the microsimulation model to ensure its use by IVP staff even after the end of the project.

Fig. 1 / Sources flowing to the Graduate practice during 2017  
Source: Labour Market Policy Database/graphs from automated reports

Fig. 2 / Proportion of participants and control group outside the registered unemployed UoS (proxy for employment rate)  
Source: ÚPSVaR/graphs from automated reports

Fig. 3 / Long-term development of labour supply in Slovakia  
Source: Eurostat / EUROPOP / SLAMM model

## Participants



## Classification of LMP and measure

- Direct job creation
- Employment incentives
- Employment incentives: Support for graduate work experience
- Sheltered and supported employment and rehabilitation
- Start-up incentives
- Training

## Expenditure

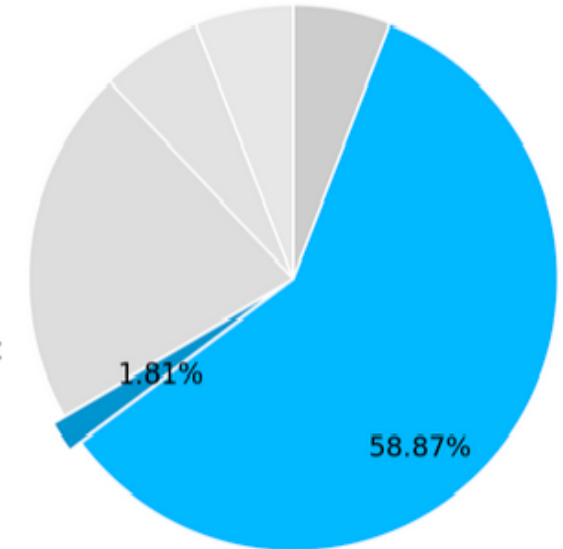
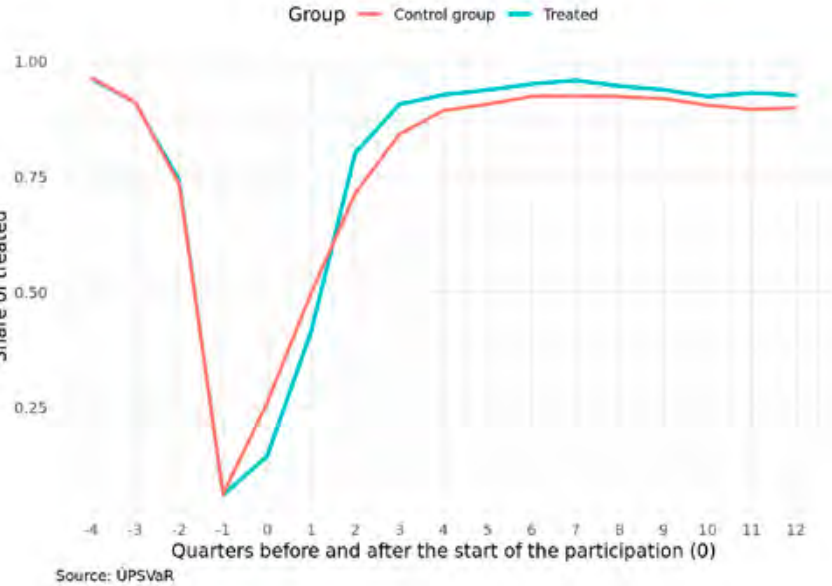


Fig. 1



Source: ÚPSVaR

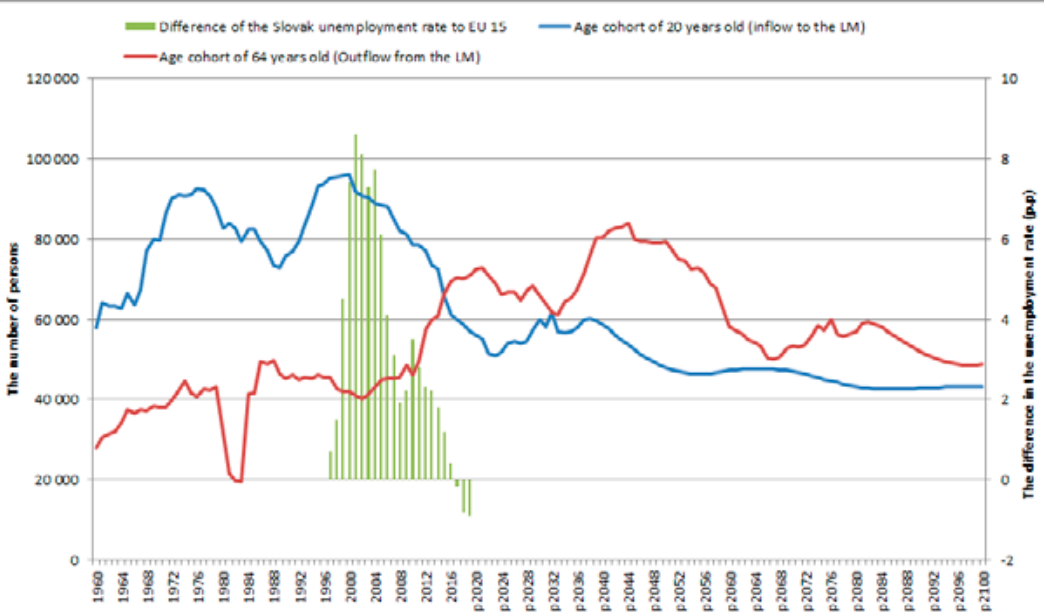


Fig. 2

Fig. 3



## Human Rights and Ethical Aspects of Cyber Security

### Research subject

The scientific research activity carried out within the project focused on the issue of information and cyber security, which represents an important public interest not only at the national, but also at the European level. The importance of the investigated issue is constantly confirmed by the increasing number of cyber-attacks leading to security incidents affecting not only the state and its services, but also the lives of ordinary citizens. The difficulty of the researched area led to the creation of a research team composed of experts from the fields of law, informatics and mathematical statistics, the aim of which was to provide an interdisciplinary and comprehensive view on information and cyber security and its legal regulation.

### Aim of the research

The defined objectives of the project included the creation of a human-rights and ethical framework for preventive, reactive and research activities in the field of information and cyber security, as well as determining the extent of the impact of the human-rights and ethical framework on operational and research activities in the field of information and cyber security.

### Achieved results

The results achieved by the research team consist in the assessment of the legal and ethical aspects of security awareness creation, the scope and legitimacy of monitoring cyber security threats through security devices, testing cyber security vulnerabilities of information systems, as well as creating team cooperation in the area of sharing cyber security incidents and other data (preventive activities). In relation to the actual solution of cyber security incidents (reactive activities), the researchers focused on the issues of storing data on cyber security incidents and the possibilities of their analysis considering the need to protect the individual from the infringement of their rights in the cyber environment. In this context, the possibility of active defence against the

cyber security attack perpetrator was investigated, including the implementation of digital forensic analysis. At the same time, the impact of the given environment on statistical methods, machine learning methods and deep learning data analysis as regards research and operational activities in the field of cyber security was analysed. Considered were also the issues regarding the necessity of anonymization, or pseudo-anonymization of data, use of data obtained as part of operational activities in the scope of research activities, etc. Moreover, for the purpose of quantifying the influence of the human-rights and ethical framework on the effectiveness of operational and research activities in the field of cyber security, the informativeness of the collected data for cyber security was compared from a statistical and economic point of view, and the information losses related to data that cannot be collected and analysed considering the human-rights and ethical reasons was examined.

### Benefits for practise

The results achieved within the project have significant application potential in several areas due to the high topicality of the investigated issue:

1. In the further scientific research of the legislation on cyber security, which, due to its nature, can be expected to be amended in the future;
2. In the application practice – a specific form of project results application is visible in the operational activities of the governmental unit CSIRT.SK and the academic cyber security team CSIRT-UPJS. A particularly significant application output is also the contribution of the research team to the discussion on the amendment of the legislation, the Act No. 69/2018 Coll. on cyber security, for which an expert opinion was drawn up representing an expert evaluation of the draft of the submitted amendment, which was provided to the legislator for assessment as part of the ongoing legislative process;

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Pavol Jozef Safarik University in Kosice  
**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
209 708 €  
**Project ID**  
APVV-17-0561

3. In the pedagogical process, primarily by including different cyber security topics in teaching, e.g. within the subject Introduction to the Law of Information and Communication Technologies taught at the Faculty of Law, as well as by the organization of special educational events, which include Summer School of Cybercrime regularly organized by members of the research team which focuses on students of law and computer science from both Slovak and Czech universities with the aim to create a space for student cooperation in solving technical and legal problems from the field of cyber security;
4. In the popularization of the topic in professional and lay public at various events.

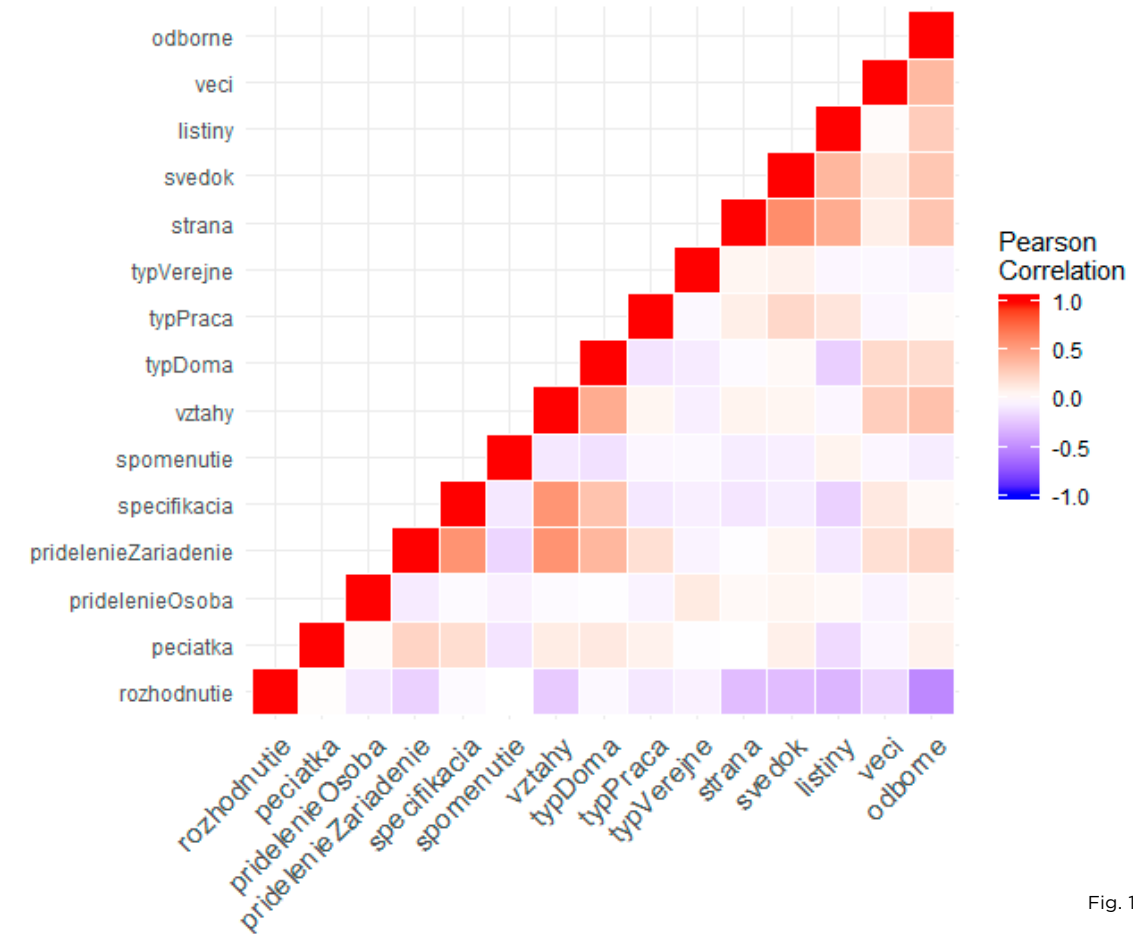


Fig. 1 / Analysis of judicial decisions including IP addresses as digital evidence in criminal proceedings. As part of the project, the researchers focused on court decisions considering IP addresses as a digital evidence in criminal cases. The results of their efforts were published in the international journal Forensic Science International: Digital Investigation. Fig. displays the so-called heatmap describing the relationship between individual attributes of court decisions.

Fig. 2 / Summer School of Cybercrime 2020. The Summer School of Cybercrime was organized as a part of the project uniquely combines the field of information and cyber security and criminal and IT law. The summer school is focused on solving cyber incidents and investigating cybercrime. Within the project, it served as a space for moving the project results into the educational process.

Fig. 3 / Project researchers at the Transforming Privacy Law into Practice workshop held in Oxford.



Fig. 2



Fig. 3



## Improvement of effectiveness of legal regulation of public procurement and its application within EU law context

### Research subject

A substantial part of public investment is spent through public procurement (around EUR 2 trillion per year, representing 14% of the EU GDP), as high-quality public services depend on modern, well-managed, and efficient procurement. Improving public procurement can yield big savings: even a 1% efficiency gain could save €20 billion per year. The public sector can also use procurement to boost employment, growth, and investment, and to create an economy that is more innovative, resource and energy-efficient, and socially inclusive.

Three key areas of application problems in different stages of public procurement processes (preparation, procurement, execution of order, control, and review mechanisms) have been identified.

### Aim of the research

The main objective of the project was to provide concrete proposals of the improvement of legislation in the sphere of public procurement for application practice and therefore based on the results of research to provide framework and concrete legislative proposals in the sphere of legislation of public procurement in the Slovak Republic, as well as the European Union legislation.

### Partial objectives were to provide proposals and recommendations in three basic areas of questions:

1. the competitive basic documents and the competition conditions,
2. market distortions caused by bodies governed by public law
3. procedures in public procurement.

The complementary objective was to identify the failures of the current Slovak legal regulation and the European Union public procurement law.

### Achieved results

The aim of the research was fulfilled by the following sponsors:

#### A. Proposals de lege ferenda

- (a) in the report to the Office for Public Procurement
- (b) in the individual publications which were annexed to the report and which were published within the project

#### B. Commenting on legislative proposals during the project.

Under the first sub-objective, draft contract models have been developed. Under the second sub-objective, a proposal of guidelines on state aid and public procurement has been drafted. Within the third sub-objective, a number of works were published with de lege ferenda proposals concerning procedures in public procurement, independence of the Office for Public Procurement and the Antimonopoly Office of the Slovak Republic, application of the principles of public procurement, the relationship between antitrust and public procurement, environmental and social aspects of public procurement and participation of small and medium enterprises in public procurement, the legal regulation of the register of public sector partners, the effectiveness of sanctions and the legal consequences of breaches of public procurement rules, as well as the submitted comments on the legislative proposals. This part of the research also addressed issues raised by the COVID-19 pandemic.

### Benefits for practise

The research team of the project prepared a reviewed research report for the Office for Public Procurement (ÚVO), which represents a summary of the key findings during the project.

The report provides proposals for better regulation of various aspects of public procurement, to prepare draft methodologies for evaluating the relationship between state aid in public procurement and contractual models that can help contracting authorities in defining certain types of contracts.

### Principal investigator

doc. JUDr. Blažo Ondrej, PhD.

### Applicant organisation

Comenius University Bratislava – Faculty of Law

### Term of solution

08/2018 – 12/2021

### Budget from agency

170 550 €

### Project ID

APVV-17-0641

The report focuses on two aspects of the evaluation of current legislation and de lege ferenda proposals, i.e. the specific regulation of the register of public sector partners and secondary policies in public procurement (with a special emphasis on green public procurement). Finally, it focuses on draft guidelines for contracting authorities, specific guidelines on the relationship between public procurement and state aid, as well as contractual terms.

Based on the agreement between the ÚVO and the Comenius University Bratislava, Faculty of Law, the latter committed, inter alia, to develop precise proposals for better regulation in the field of public procurement for application practice, and thus on the basis of research results to provide framework and concrete proposals in the field of public procurement regulation in f the Slovak Republic, as well as the legal regulation of the EU, within the special report for the ÚVO or in a set of articles and other scientific works and presentations within the conferences, and the Office for Public Procurement committed ensuring their use in practice in its field of application, while respecting the applicable legislation within its activities.

Fig. 1 / Cover of monograph "Sekundárne ciele verejného obstarávania" [Secondary Goals of Public Procurement]

Fig. 2 / Cover of monograph "Harmonizácia pravidiel verejného obstarávania v práve medzinárodného obchodu" [Harmonization of Public Procurement Rules in International Trade Regulation]

Fig. 3 / Excerpt from the press release on cooperation between the Faculty of Law of Comenius University and the Office for Public Procurement. Source: TASR: <https://www.teraz.sk/slovensko/verejne-obstaravanie-sa-od-jesene/342248-clanok.html>

Fig. 4 / Cover of "Peer-reviewed research policy paper for public administration" submitted to the Office for Public Procurement



Fig. 1

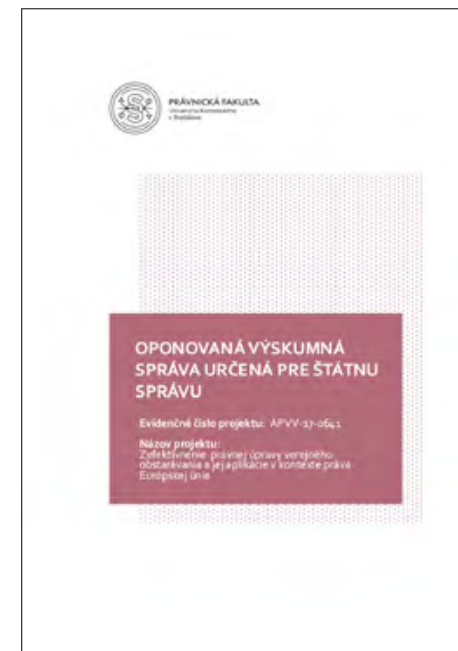


Fig. 2



Fig. 2



Fig. 3



# HUMANITIES SCIENCE





# Commentary on the Book of Psalms II and III

## Research subject

The project consisted in the creation of a scholarly commentary on the Book of Psalms that included translations of the Psalms from the Hebrew original and from the Greek translation (the Septuagint), philological and textual notes on each translation, contemporary scholarly commentary, rabbinic commentary, patristic commentary and classical spirituality commentary on individual verses and expressions, along with an analysis of the form, genre and structure of a given psalm and the theological, liturgical and pastoral application of each psalm. The project output will be applied in schools with a focus on theology and religious education as educational material, in churches and religious institutions for spiritual and cultural enrichment, and as a basis for the study of Semitic languages, classical philology, Slovak philology, ancient and medieval history, as well as philosophy and theology.

## Aim of the research

The goal of the project was to translate and comment on individual psalms from a linguistic, theological and pastoral viewpoint, such that both scholars and the general public could better understand them. The result of this scholarly-research activity comprised translations of psalms from the Hebrew original and from the Greek translation (the Septuagint), philological and textual notes on each translation, contemporary scholarly commentary, rabbinic commentary, patristic commentary and classical spirituality commentary on individual verses and expressions, along with an analysis of the form, genre and structures of the given psalm and the theological, liturgical and pastoral application of the psalm.

## Achieved results

Over four years, members of the research team published 8 monographs and 17 studies in domestic and foreign current journals, and in cooperation with Slovak Radio, interviews in the form of applied outputs were released on 2 CDs.

Members of the APVV-Commentaries on the Psalms team established two new research teams based on cooperation on this project, and they formulated two new projects which were submitted for evaluation in the APVV. The project's applied outputs have appeared over time in media such as Slovak Radio, TV Lux, Rádio Lumen, Rádio Mária and others. In addition, an important connection of the project with the ongoing project of Jewish-Christian dialogue in Slovakia was shown. In 2017, the project was awarded the Dominika Tatarka prize and in 2023 the Fides et Ratio prize.

## Benefits for practise

The project output should be applied as basic educational material in schools with a focus on religious education, but also in church and various denominational religious institutions for scholarly, spiritual and cultural enrichment, should also be a basis for the study of Semitic languages, classical philology, Slovak philology, ancient history, philosophy and theology, and last but not least, for the support of ecumenical and interreligious dialogue. The entire project ran with the expected continuity in the dialogic form of pluralistic thinking and the formation of a unified lexicon and confessional expressions in the spirit of ecumenism. The commentaries will with time become a compulsory part of the formative curriculum of future representatives of both the Catholic and Protestant churches, i. e. priests, pastors, catechists, seminarians and formation leaders, including from the side of the Jewish faith, i. e. rabbis. The addressed theologians of Christian denominations count on these commentaries when they begin the work of creating new dogmatic treatises that would be based on these latest scholarly knowledge.

**Principal investigator**  
ThLic. doc. Lichner Miloš, PhD.  
**Applicant organisation**  
Trnava University in Trnava – Faculty of Theology  
**Term of solution**  
08/2018 – 12/2022  
**Budget from agency**  
200 000 €  
**Project ID**  
APVV-17-0001



Fig. 1

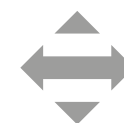


Fig. 2

Fig. 1 / Handing over the first part of the commentary to the Pope. St. to Father František

Fig. 2 / A series of commentaries on the Old and New Testaments





SLOVAK RESEARCH  
AND DEVELOPMENT  
AGENCY

|                     |   |
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