



# Research Innovations Technologies 2022

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Warsaw University  
of Technology



# INTRODUCTION

The “Research Innovations Technologies 2021” catalogue is the next edition of the publication presenting the technological offerings of the Warsaw University of Technology (WUT). It is aimed at the business community and entrepreneurs looking to improve their competitive potential on the market by using innovative solutions developed by scientists.

The Warsaw University of Technology is home to a large number of robust and young, but also highly experienced research teams. The diversity of the technologies showcased in this Catalogue provide ample proof of the Warsaw University of Technology’s huge potential to cooperate with business.

Each item, in addition to a description of the technology itself, also contains information on the current technology readiness level (TRL), which makes it possible to determine the stage of its development and the expenditures still needed to see it through to implementation. In addition, the provided description of market maturity facilitates estimating the innovation and implementation potential of the presented technologies.

Feel invited to approach the Warsaw University of Technology to take advantage of our technological offerings.



**PROFESSOR ADAM WOŹNIAK, PHD, DSC**  
**VICE-RECTOR FOR DEVELOPMENT**



# HOW TO READ THE LABELS



## TECHNOLOGICAL LEVEL

the level of advancement of a technology is defined using the technological readiness level (TRL):

- 1 starting scientific research
- 2 finding potential applications
- 3 proof-of-concept study
- 4 laboratory verification
- 5 tests in simulated real-world conditions
- 6 prototype tests in close real-world conditions
- 7 prototype tests in operating conditions
- 8 demonstration of the final form of the technology
- 9 technology ready for implementation



## COMPETITION

the number of entities on the market providing similar solutions as WUT



## MAIN USERS

type of entities being the potential target group of the solution provided by the team



## MARKET MATURITY

the level of market maturity

# DISCOVER WUT'S SOLUTIONS

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# DISCOVER WUT’S SOLUTIONS

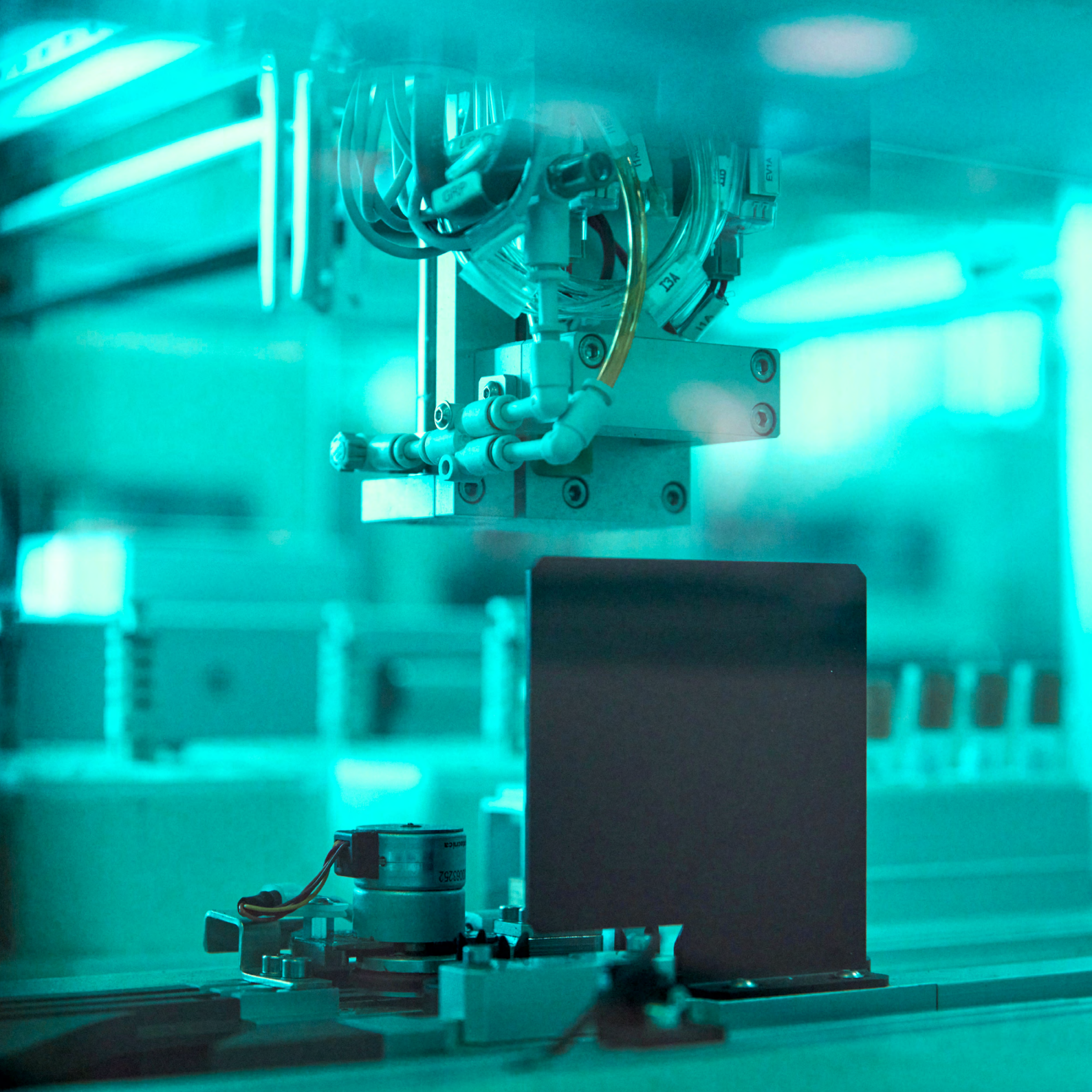
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**ENGINEERING**

# MECHANICAL OSCILLATOR FLOW METER

This solution is a product innovation.

Applications

Mechanical oscillator flow meters are designed for the measurement of liquids and gases. They have been widely tested under industrial conditions, for such liquids as cold and hot water, paraffin, aviation fuel, sewage (pre-treated), liquid sulphur and other liquids present in the technological processes of the chemical and food industries. They are also widely used in the measurement of gases and gas mixtures, such as air, oxygen, nitrogen, acetylene, hydrogen. In special versions, they are used for a non-standard liquids, such as liquid nitrogen, oxygen, liquefied natural gas, biogas.

How it works?

The mechanical oscillator flow meter consists of a flow meter, the size and measuring range of which depends on the diameter of the pipeline and the universal signal booster. The liquid flowing through the flow meter is split by the flow splitter into two flows, which act on the oscillator, which features self-aligning bearings. The oscillator has a magnet attached to it, which, as it vibrates with the oscillator, induces an alternating electromotive force in the inductor located on the outside of

Technology creators:

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- » Maciej Szudarek, PhD (Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)
- » Grzegorz Rosłonek, PhD (PGNiG S.A.)
- » Adam Bogucki, PhD (PGNiG S.A.)
- » consortium: PW, PGNiG S.A., Centralne Laboratorium Pomiarowo-Badawcze (Central Laboratory for Measurement and Research)

the body. Volume flow rate is determined on the basis of the frequency of the impulse signal coming from the flow meter.

Basic metrological parameters

Thanks to the special structure of the bearings, which largely allows self-cleaning, the flow meter sensor is resistant to mechanical pollution. Uncertainties of measurement depend on the diameters of the sensor and the measured liquid, as well as the desired ranges. 0.5-1.5% for liquids and 1.5 to 2-times higher for gases. With the non-linearity correction function, it is possible to reduce uncertainties to 0.3%.

Features which make this solution stand out from competing solutions

- universality – the flow meter has been tested in both high and low temperature conditions,
- durability – the proposed solution features a knife bearing, which provides higher durability than the sensitive bearings of turbine flow meters,
- price – structural simplicity could translate into affordable price when compared to the competition.



TECHNOLOGICAL LEVEL

stage 5: TRL 7-9



COMPETITION

strong competition (a large number of entities)



MAIN USERS

large enterprises international corporations



MARKET MATURITY

the market is at a mature stage of development



# ANGULAR MICRO-DISPLACEMENT SENSOR

## How it works?

Two-beam interferometers, in which the incoming beam is first split into two beams running along the two arms of the device, are widely known. The laser beam in each interferometer arm is usually directed through several reflecting surfaces to the other (outgoing) beam splitter. This beam splitter then combines both beams to cause their interference. If the beam entering the interferometer (i.e. the beam falling on the incoming beam splitter) is deflected by a small angle in the interferometer plane, and there is the same number of reflections in both interferometer arms (in general, if there is an even or odd number of reflections in both arms), then the two interfering outgoing beams become deflected by the same angle and in the same direction, without impacting the interference effect in the form of the analysed interference pattern, which is advantageous in interferometric systems that count the moving fringes.

## Features which make this solution stand out from competing solutions

The creators of the discussed sensor have proven (the description can be found in scientific publications) that if the number of beam reflections in both arms of the interferometer differs by an odd number, then the incoming beam deflection will cause the deflection of

## Technology creator:

- » prof. Marek Dobosz, PhD, DSc  
Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)

interfering beams by the same angle value, but in opposite directions. This way, the interference angle changes, causing a change in the period of the observed interference fringes. The creators of the sensor have developed a photodetection system and algorithms for the analysis of signals from individual photodetectors, to determine the change of period of the fringes and to convert it into a change in the interference angle, and eventually into a change in the angular position of the incoming interferometer beam.

The creators suggested a remarkably simple technical implementation of the said method in the form of an integrated optical system consisting of a single beam splitter cube with two prisms fixed to it with an adhesive, a rectangular one and a corner cube one. Thanks to this structure, an exceptional sensitivity to the angle deflections of the laser beam has been achieved with minimal size of the measuring system. The developed angular micro-displacement sensor is a globally unique device in terms of its manner of operation and metrology and utility parameters in a selected plane.

## Application

Sensor models were created for measurement in a single plane and three-dimensional measurement versions, and versions for use in a stabilisation system for beam axis direction were evaluated.

## Basic features and metrological parameters

- The sensor features both firmware and software.
- Its advantage is small size, 50x35x30 mm (with electronics).
- The sensor is characterised by an extremely high resolution of up to 25 nrad. The accuracy is  $\pm 0.5 \mu\text{rad} \pm 0.005 \alpha$  ( $\alpha$  – the measured angle). The measuring range is ca. 360  $\mu\text{rad}$ .



## TECHNOLOGICAL LEVEL

stage 4: TRL 4-6



## COMPETITION

no competition



## MAIN USERS

small and medium-sized enterprises



## MARKET MATURITY

the market is being created



# LASER DIODE INTERFEROMETRIC MEASUREMENT SYSTEM

Interferometer system units constitute one of several optical configurations that allow the measurement of linear and angular displacements. While these configurations are widely known and used in coordinate metrology, thanks to the use of a small-diameter beam (4 mm), the size of the components of the measurement system are about twice smaller than in commercially available devices. The developed measurement system allows the verification of positioning and rotational errors of coordinate machines, CNC machines and all devices performing precise movements. The system contains: a laser head with an interference-stabilised laser diode, optical measurement units, fringe counting and interpolation circuit card, environmental compensator, software, mechanical mounting and adjusting units.

### How it works?

A beam emitted by the laser head is introduced into the measurement interferometer unit, in which one of the elements is a measuring reflector. After reception in the head by the photodetection system, the interference signal is converted into appropriate electrical signal, which is then passed to the meter and interpolator system, which in turn converts it into information about reflector displacement. This information is provided to the user on a personal computer.

### Technology creator:

- » prof. Marek Dobosz, PhD, DSc  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)

### Features which make this solution stand out from competing solutions

The developed laser head feeding the measurement interferometer is a completely original device containing a number of patented solutions, which uses an affordable laser diode as a light source. To stabilise the laser frequency (which is necessary for measurement purposes), the creators developed a new method involving the use of light interference generated as a result of reflections of the beam going through an optical wedge made of a specially selected material. The laser head also includes an innovative system developed by the creators for receiving interference fringes with a finite period using a small-sized integrated photodetector. It consists of 13 photo sensors appropriately distributed with the use of new signal processing algorithms, which ensures that the measurement error is minimised.

### Basic metrological parameters

- The measuring ranges of linear and angular displacements are 3.5m and  $\pm 5^\circ$ , respectively.
- The maximum resolutions of linear and angular displacements are 0.3nm and 0.5", respectively.
- Relative vacuum wavelength instability over 8h: ca.  $5 \cdot 10^{-8}$  (average relative displacement).
- Relative measurement uncertainty for linear displacements: 10-6.



### TECHNOLOGICAL LEVEL

stage 3: TRL 1-3  
stage 4: TRL 4-6



### COMPETITION

little competition



### MARKET MATURITY

the market is being created



# MECHANICAL TESTING USING MINIATURE SPECIMENS

What is it about?

The concept is a process innovation involving conducting a research procedure to determine the mechanical properties of structural materials present in a limited volume which precludes the preparation of specimens with standard-compliant sizes.

Another application area of miniature specimens is in situations where tests must be non-destructive to (or have a minimal destructive effect on) the analysed device or structure. In such cases, a small amount of the material can be collected and is sufficient to carry out mechanical tests using miniature specimens and determine the mechanical properties of the material of the device or structure in a non-destructive manner (having a minimal destructive effect).

Technology creators:

- » prof. Zbigniew Pakieła, PhD, DSc
- » Rafał Molak, PhD
- » Tomasz Brynk, PhD
- » Barbara Romelczyk-Baishya, MSc
- » Kamil Majchrowicz, MSc
- » Monika Wieczorek, MSc

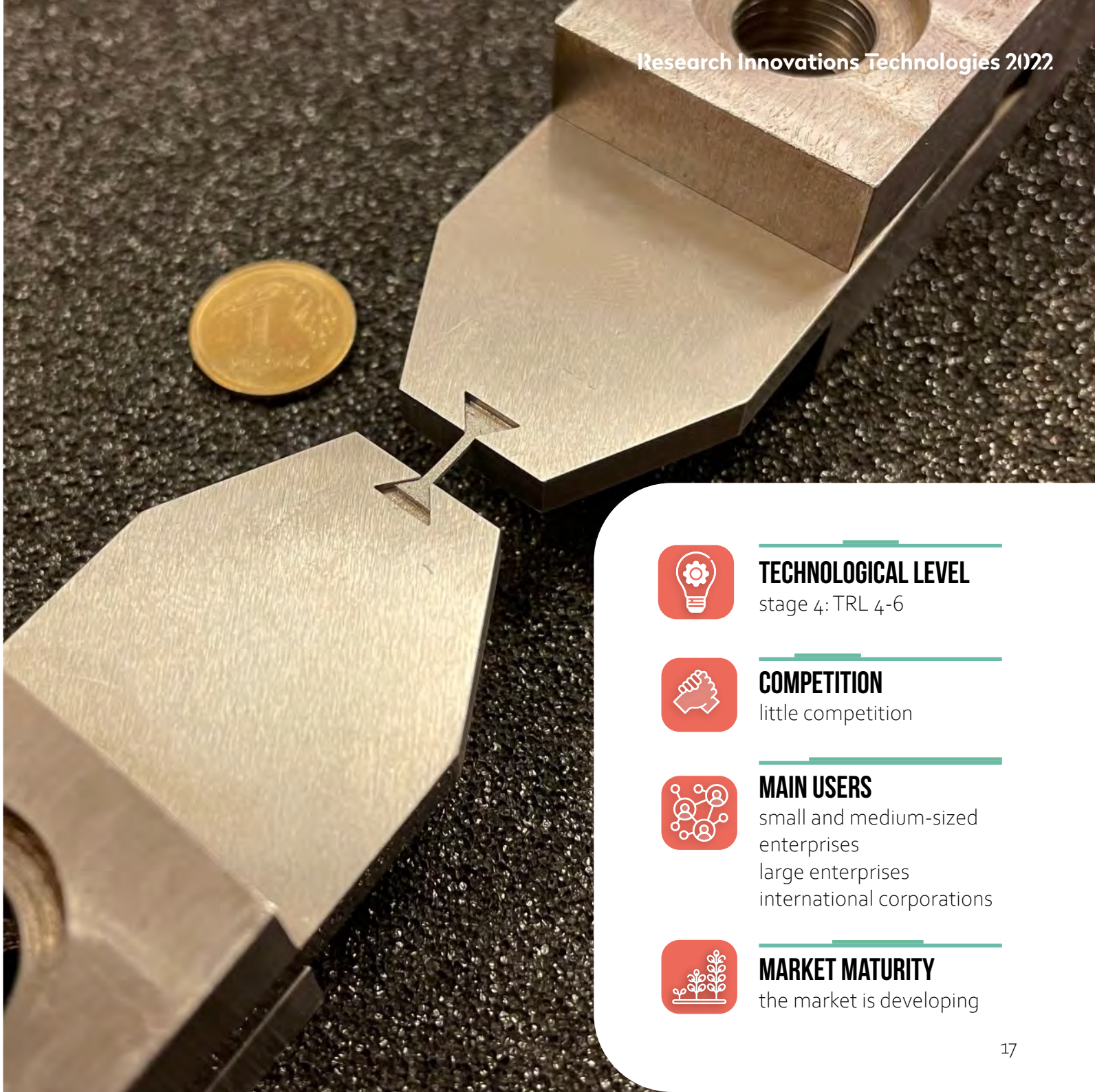
(Division of Materials Design, Faculty of Materials Science and Engineering, WUT)

Application

This method allows determining the mechanical properties of materials that may be collected in a very limited amount from an operating installation or materials which are available for testing only in low volumes. Potential users include the chemical and petrochemical, power, aerospace, automotive and nuclear industries and science laboratories developing new materials.

Features which make this solution stand out from competing solutions

This solution facilitates determining the mechanical properties of materials available in limited quantities. The typical procedures used in practice and provided by laboratories are based on the requirements set out in standards, which require a relatively high specimen volume.



TECHNOLOGICAL LEVEL

stage 4: TRL 4-6



COMPETITION

little competition



MAIN USERS

small and medium-sized enterprises  
large enterprises  
international corporations



MARKET MATURITY

the market is developing



# GAN-ON-SI HEMT POWER AMPLIFIERS FOR AVIONICS SYSTEMS

A trend to move away from gallium arsenide to wide-bandgap semiconductors has long been observed in the production of transistors and integrated circuits for radar systems. Currently, it is known that the GaN HEMT technology will form the basis for manufacturing active microwave devices for radiolocation. For various reasons, the predominant substrate for GaN epitaxy in GaN-based high-power microwave devices is SiC. However, devices of this type are very expensive.

### What is the innovation?

An alternative solution involves GaN HEMT transistors on silicon wafers, which can be purchased for half the price. Currently, the GaN on Si technology is rarely used in GaN HEMT production for RF and microwave applications. Our solution also covers the construction of power blocks, which provides polarisation signals for GaN/Si microwave transistors and controls amplifier operation. The units contain high-performance AC/DC and DC/DC converters based on GaN/Si HEMT transistors, which allow power supply from AC 110-230V and DC 24-30V).

### Technology creators:

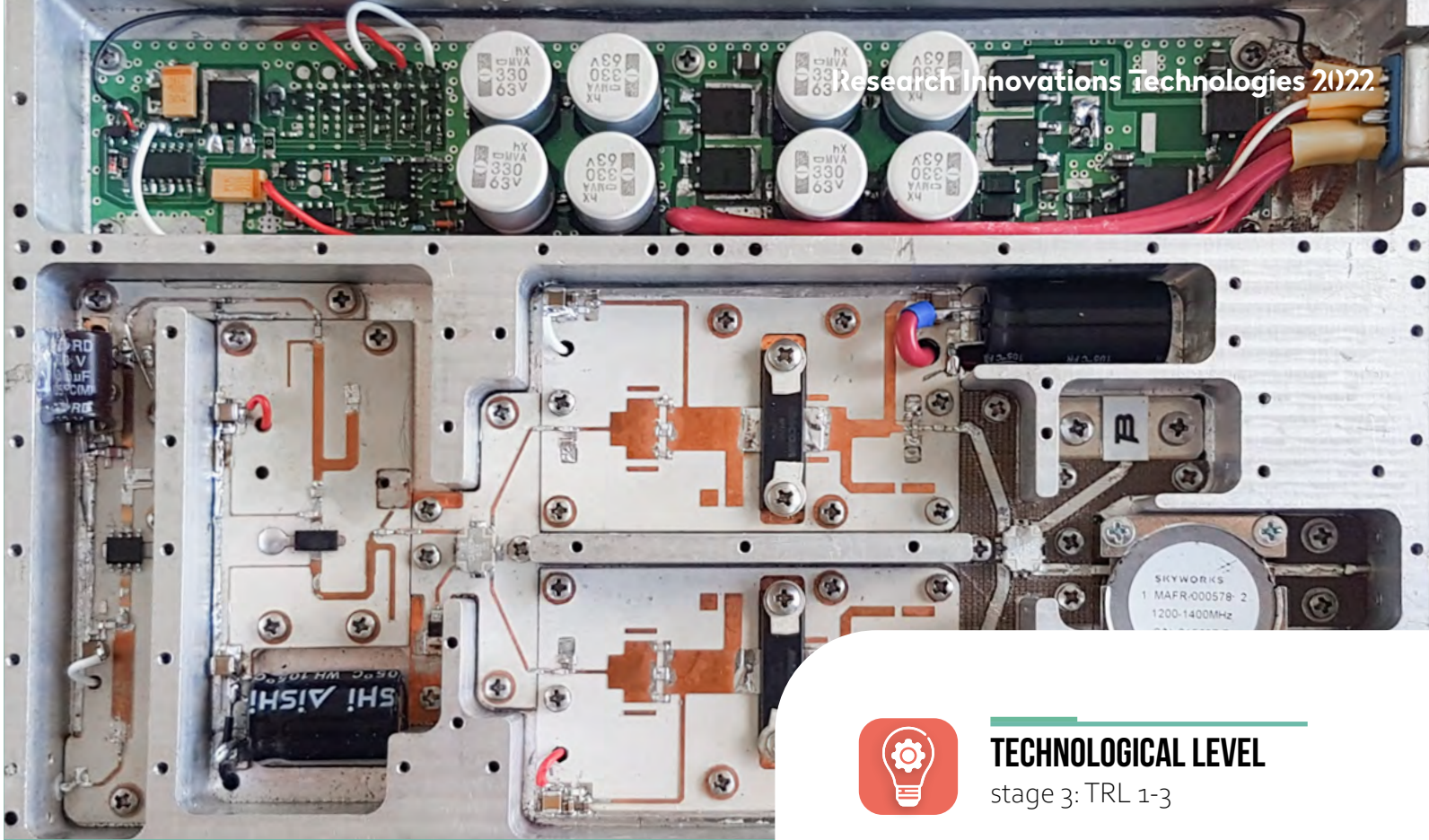
- » Wojciech Wojtasiak, PhD, DSc, Associate Professor (Institute of Radioelectronics and Multimedia Technology, Faculty of Electronics and Information Technology, WUT)
- » Daniel Gryglewski, PhD (Institute of Radioelectronics and Multimedia Technology, Faculty of Electronics and Information Technology, WUT)

### Application

The primary idea is to use a more affordable GaN/Si technology in less demanding systems (with lower power density requirements). Such systems include secondary surveillance radars, including IFF and DME subsystems. The idea is justified by low operating frequencies up to 3.5 GHz and pulse operation with a small duty cycle.

### Features which make this solution stand out from competing solutions

The main innovation of the amplifier involves the use of more affordable GaN transistors on an Si substrate in the structure of power amplifiers (to be used in less demanding systems). However, the application of this solution requires consideration during the circuit design dynamic temperature distributions of active elements. The channel temperature value under normal operating conditions of the transistor significantly affects its performance.



Firstly, the transistor life span is reduced when operating at channel temperatures close to the maximum allowable value. Secondly, the parameters of the transistor (both DC and RF) indicate a significant dependence on the temperature of its active region. The results indicate that the use of this GaN "on" Si transistor for the production of microwave power amplifiers is economically viable.



**TECHNOLOGICAL LEVEL**  
stage 3: TRL 1-3



**COMPETITION**  
no competition



**MAIN USERS**  
small and medium-sized enterprises  
large enterprises



**MARKET MATURITY**  
the market is at a mature stage of development



# ELECTRIC DRIVE SYSTEM WITH A SWITCHED RELUCTANCE MACHINE

The work conducted by a team from the Faculty of Electrical Engineering of the Warsaw University of Technology as part of the TECHMATSTRATEG project entitled "Technologies of semiconductor materials for high-power and high-frequency electronics" allowed the development of an electric drive system with a switched reluctance machine (SRM) based on transistors made of gallium nitride (GaN). The team developed a complete power electronic converter along with a dedicated control system.

## How it works?

This solution involves providing a special reference signal to the phase current control system of the machine. The signal is selected in such a way as to compensate torque ripples in the system. The reference signal shape is calculated in real time using a multi-resonant current controller in the angular velocity control loop. The innovation involves a different approach to sampling parts of the machine angular velocity controller connected with the multi-oscillation controller. In the developed approach, sampling of the

## Technology creators:

- » Krzysztof Jackiewicz, MSc  
(Institute of Control and Industrial Electronics, Faculty of Electrical Engineering, WUT)
- » Bartłomiej Ufnalski, PhD, DSc  
(Institute of Control and Industrial Electronics, Faculty of Electrical Engineering, WUT)

multi-oscillation controller has been synchronised with the angular position of the machine shaft. This solution allows an effective reduction of torque ripples and angular velocity of a drive system in both steady and dynamic states. An additional advantage is that the operating effectiveness is independent of operating conditions, which allows the use of this solution in variable-frequency drives.

The SRM is made of electrical steel and copper winding located solely on a stator, which makes it inexpensive to produce, simple and, as a result, extremely durable and resistant to damage. The SRM does not contain a mechanical commutator or moving parts other than bearings. No rare-earth elements are required to produce the SRM, which makes it more attractive in the context of the rare-earth-free concept. The structure of the SRM and the converter makes it possible to continue operation even if the winding is partly damaged. The SRM is characterised by a high torque overload factor.

## Broad application

Drives based on the SRM can be used in electric vehicles, belt conveyors, pump and fan drives, as well as in places with special requirements, such as explosion hazard areas, completely submerged areas or elevated temperature areas.

## Features which make this solution stand out from competing solutions

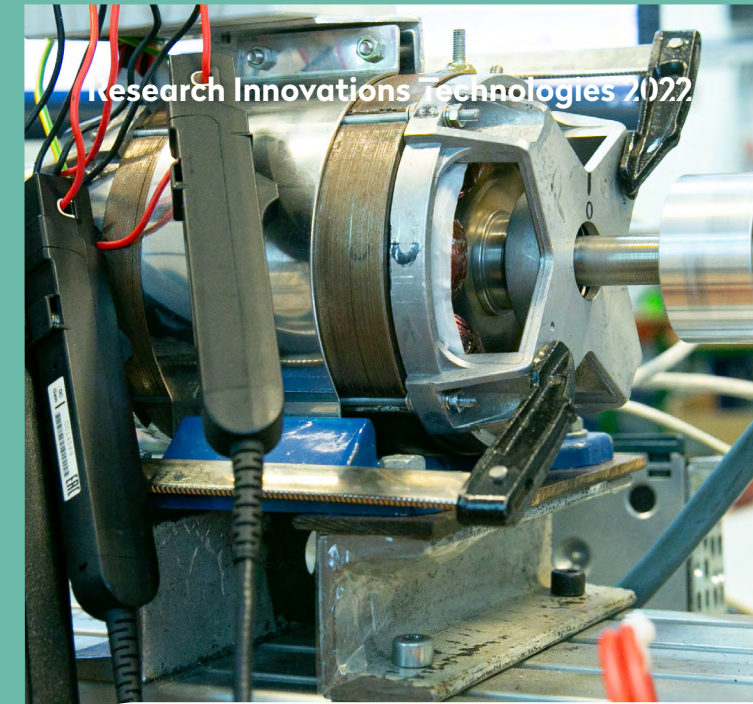
A traditionally controlled SRM is characterised by a significant torque ripple level, which results in excessive noise and vibration, reducing the life span of the whole device. Research work made it possible to develop a control system that dramatically reduces torque ripple. It is particularly noteworthy that the developed solution involves the appropriate control of the machine's phase currents, and does not require any physical intervention in the drive system.

## Opportunities

The SRM is characterised by:

- simple, durable and affordable structure,
- capability to operate under special conditions (no permanent magnet or sparking components),
- high torque overload factor.

An innovative control algorithm allows a significant reduction of the disadvantageous properties of the SRM involving torque ripples. The developed control system is an invention and is currently patent pending (application No. P.432816).



## TECHNOLOGICAL LEVEL

stage 5: TRL 7-9



## COMPETITION

not defined



## MAIN USERS

small and medium-sized enterprises  
large enterprises  
international corporations



## MARKET MATURITY

the market is at a mature stage of development



# IMPROVING THE USE VALUE OF WOOD THROUGH INTERGRATION WITH ELECTRONICS

Europeans value wood products, and Poland is one of the leading manufacturers in Europe. Poland has high-quality raw material, in quantities which meet market needs, and we can manage wood in a reasonable way. Despite huge progress in material engineering which has taken place over hundreds of years, wood is still one of the main building materials used in structural elements and finishing works. Manufacturers of windows, furniture, doors, or floors value such properties of wood as durability, heat properties, and effects on acoustics. What if we provided one more functionality to this material?

## What is it about?

The technology being developed allows the increase in its value by integrating electronics based on carbon nanomaterials. This idea was born at the Faculty of Mechatronics of the Warsaw University of Technology. Integrating wood with electronics has become a factor which can boost the attractiveness of wood.

The subject-matter of the invention includes functional wood-based materials or pure wood integrated with recyclable electronic components based on carbon nanomaterials – graphene (Gr) and carbon nanotubes (CNTs).

## Technology creators:

- » Agnieszka Łękawa-Raus, PhD, Eng.  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)
- » Damian Łukawski  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)
- » Alina Dudkowiak  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)
- » Prof. Małgorzata Jakubowska, PhD, DSc, Eng.  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)
- » Daniel Janczak, PhD, Eng.; Tomasz Bohun  
(Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, WUT)

## How it works?

A simple and inexpensive way to give wood-based composite materials additional functionalities, such as built-in physical condition detection, or the possibility to control temperature, for example, will find application in smart buildings, interior design and furniture production.

The addition of a new functionality is likely to result in creating a range of new products for the construction industry, such as self-drying or self-heating structural and interior-design elements, construction panels for smart buildings which provide information about the condition of the structure, e.g. the condition of pressure values, humidity, or fire hazards, etc.

## Features which make this solution stand out from competing solutions

- the technology will allow the extended functionalities of wood as a structural and finishing material,
- structural wood or wood for finishing purposes will be equipped in a physical condition detection system, e.g., long-term stress,
- the possibility to control the condition of wood, e.g. temperature or humidity,
- the possibility to respond to sudden threats, e.g. fire or flooding.



## TECHNOLOGICAL LEVEL

stage 4: TRL 4  
(completed)



## COMPETITION

no competition



## MAIN USERS

large Polish and international enterprises



## MARKET MATURITY

the market is being created



# NANOSTAL – A NEW GENERATION OF HEAT TREATMENT OF STEEL

The developed, innovative process consists of a formation of nanocrystalline structure in steel using phase transformations taking place during a properly designed heat treatment. Conventional heat treatment of steel consisting of martensitic quenching and tempering does not allow obtaining high strength of steel without reducing its ductility. The process, developed by scientists in the NanoStal team overcomes this contradiction, allowing to achieve both high strength and high ductility of steel, as well as increased resistance to cracking. The nanocrystalline structure improves also a number of service properties, which extends the lifetime and operational safety of steel products.

The unique properties of nanostructured steel come from its microstructure which consists of alternately arranged layers of bainitic ferrite and austenite of nanometric thickness. A ductile austenitic phase and the lack of cementite precipitates contribute to the increase of ductility and fracture toughness. Carbon-supersaturated bainitic ferrite and strong grain refining of both phases ensure high strength of nanostructured steel.

## What is the process of nanostructuring of steel?

The nanostructuring process involve the following stages: austenitisation, cooling to the lower temperature range of the bainitic transformation, isothermal holding at this temperature and cooling down to room temperature.

## Technology creators (NanoStal team):

- » Wiesław Świątnicki, PhD, DSc, Associate Professor
- » Emilia Skołek, PhD, Eng.
- » Adam Gołaszewski, MSc, Eng.
- » Szymon Marciniak, MSc, Eng.
- » Krzysztof Wasiak, MSc, Eng.
- » Kamil Wasiluk, MSc, Eng.

(Division of Surface Engineering, Faculty of Materials Science and Engineering WUT and NanoStal Sp. z o.o.)

The duration and temperature of individual stages of the process depend on the chemical composition of steel and austenitisation conditions. For that reason the heat treatment parameters are precisely selected on the basis of experimental phase transformation diagrams for a given type of steel, taking into account specific requirements related to the final properties of treated element.

Scientists from the NanoStal team developed several variants of the nanostructuring process, i.e., two-step bainitizing, as well as complex heat treatments, including Q&P, B-Q&P, B-Q&T, which use the following stages: nanobainitizing (B), martensitic quenching (Q), partitioning (P) or tempering (T).

Hybrid treatment methods have also been developed, combining nanostructuring processes with surface engineering(carburizing, nitriding, boronizing). They allow to combine the high hardness of the surface layer (up to 1500HV) and the advantages of the nanocrystalline core of steel element.

The developed technologies are the outcome of research conducted at the WUT Faculty of Materials Science and Engineering (WIM), and demonstrate a technology readiness level (TRL) of 4 to 6. In order to implement the technology in industrial practice scientists from WIM, together with the Applied Research Institute - Warsaw University of Technology (IBS PW), established the NanoStal sp. z o.o. company which tests and refines the technologies at TRL 6 and 7.

Nanocrystalline steel is not only characterised by high strength and crack resistance, but also by:

- reduced frictional wear,
- increased fatigue strength,
- reduced quenching distortion of steel elements during heat treatment.

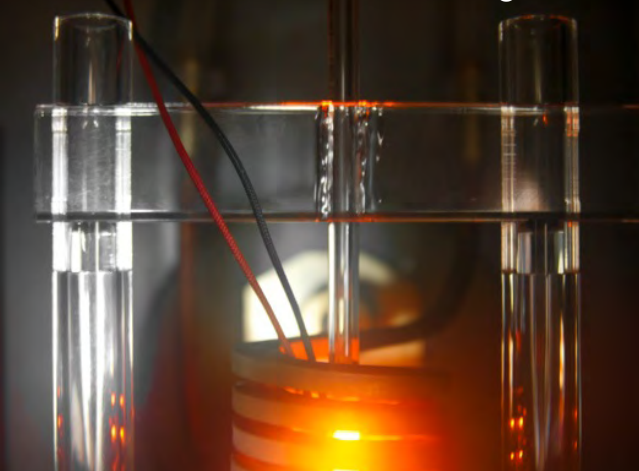
The implementation of new technology in the production cycle in an industrial enterprise is facilitated by the following factors:

- the nanostructuring process can be performed in heat treatment furnaces available on the market,
- the process is conducted on ready-made component of any shape and size, without changing the remaining phases of the production cycle,
- nanostructuring can be applied for numerous standard steel grades.

## Application

Steel subjected to nanostructuring receive unique properties, impossible to obtain with the use of conventional heat treatment technologies. In collaboration with manufacturers representing various sectors, NanoStal co. produced a number of prototype structural elements and tools using this new technology, e.g.

- gears for high-load planetary gear systems used in mining. The works were performed as part of IE OP application project called "Nano4Gears". High-load gears are very demanding elements. They must have a durable, and crack resistant core transmitting load and a very hard and wear resistant surface. The gears manufactured in the new technology are characterised by higher resistance to tooth breakage than the ones manufactured with the use of conventional technologies,
- coining punches which are subject to high and cyclic loads. Such punches emboss coin images on thousands of metal discs. If their lifetime is short, it can result in production downtime and the need to provide new tools. Nanostructural steel punches are characterised by a longer lifetime, and also allow the elimination of harmful chromium (VI) coatings, and to replace them with safe nitrided surface layers,
- long-life concrete bolts,
- knives and blanking dies with increased wear resistance,
- stamping dies characterised by high dimensional stability.



**TECHNOLOGICAL LEVEL**  
from TRL 4 to TRL 7



**COMPETITION**  
low competition



**MAIN USERS**  
micro-enterprises, small  
and medium-sized enterprises  
large companies  
international corporations



**MARKET MATURITY**  
the market is at a mature  
stage of development



# SYSTEM OF OPTIMIZATION AND DESIGN IN AEROSPACE — SODA

In terms of individual analyses, there are numerous computational tools for designing aerial vehicles, but they are not connected into a coherent design and optimisation system.

### Competition

There are only a few research projects (members of the Team participated in one of them) in the field of integrated design and optimisation intended for specialised support for aerial vehicles and one commercial solution dedicated for aerospace applications. Numerical tools of this type are also used by the major aerospace companies, such as Airbus, Boeing, Lockheed-Martin, Northrop Grumman, which do not share their software. Only the US company DARcorporation provides its clients with such solutions.

### Demand

The rapid development of the unmanned aerial vehicles sector holds promise for potential market interest in this type of product.

### Technology creators:

- » prof. Tomasz Goetzendorf-Grabowski, PhD, DSc  
(Institute of Aeronautics and Applied Mechanics, Faculty of Power and Aeronautical Engineering WUT)
- » Jacek Mieloszyk, PhD  
(Institute of Aeronautics and Applied Mechanics, Faculty of Power and Aeronautical Engineering WUT)

### What is the innovation?

The presented solution involves the creation of an integrated system for the design and optimisation of aerial vehicles.

The team has long been working on numerical tools for designing and optimising aerial vehicles, which are successfully used in its own projects. Currently, individual elements of the system, as well as example integrations, are available. However, expenditures for tighter system integration, creating a user-friendly interface and detailed user documentation are still needed.

### Features which make this solution stand out from competing solutions

In a lot of cases, the analyses used for design and optimisation in the WUT team are more advanced than the competing solutions.



### TECHNOLOGICAL LEVEL

stage 5: TRL 7-9



### COMPETITION

little competition



### MAIN USERS

natural persons  
microenterprises  
small, medium-sized and large enterprises  
international corporations



### MARKET MATURITY

the market is developing

# DIGITAL RAILWAY. DIGITAL TWIN OF AN ETCS APPLICATION

“Digital railway” is a framework project – an initiative responding to the digitalisation processes in rail traffic control, which can be observed at the European level (e.g. the Digital Rail for Germany programme). The main driver of these processes is the implementation across Europe of the automatic train control system ERTMS/ETCS as a significant element of the interoperability of the European railway system.

What is it about?

A Digital Twin is a representation of a real-world system in virtual form, which involves data structures and algorithms.

It consists of three fundamental elements:

- the space of the real-world system,
- the space of digital representation,
- a link ensuring data flow between both spaces.

The real-world system is equipped with sensors, recorders, which collect information on its status and the events occurring within it. Via a data link, the collected information reaches the digital twin, where it is gathered. It describes both the current state and the history of operation of the real-world system. The algorithms implemented by the digital twin environment process the accumulated data using simulation and data analysis techniques. The foreground knowledge obtained on the real-world system then comes back to its space, where it is used for optimising selected aspects of its structure and operation.

Technology creator:

» Andrzej Kochan, PhD  
(Centre for Transport Certification, Division of Traffic Control and Transport Infrastructure, Faculty of Transport, WUT)

How it works?

The Digital Twin of the ETCS application (CBAE) creates a digital representation of the real-world system installed on the railway line. It constitutes the main component of CBAE infrastructure, which is accompanied by CBAE monitor components and the Virtual Laboratory. The monitor allows ongoing analysis of the represented system, while the Virtual Laboratory is a space for conducting research on the real-world system. At the Virtual Laboratory, thanks to the use of an innovative design method, virtual prototyping, the user can quickly and interactively create various ETCS application configurations, which are verified in terms of design principles in real time. The constructed models can be further tested by simulating operating scenarios, which is the second major service provided by the Virtual Laboratory. Operating scenarios are well established in the railway industry as a method of verifying the correctness of cooperation between the ETCS system elements and its environment. This functionality makes it possible to verify and validate the real-world system, which is impossible using dynamic tests and real-world trains. All configuration and operational data appearing in the CBAE infrastructure are recorded in the archive, which is a source of information for analyses that provide new knowledge about the real-world system.



Application

In recent years there has been a noticeable increase in interest in the digital twin concept. Gartner, a leading research and consulting company, has referred to the digital twin as one of the ten most important strategic technological trends in 2019. At the same time, Grand View Research forecasts that the DT market will reach the value of USD 27.06 billion by 2025, which is roughly a tenfold increase over 2017's USD 2.26 billion.

The solution is intended for the transport industry and is in the early implementation stage.

Features which make this solution stand out from competing solutions

The concept presented by our team combines knowledge of information technologies with the knowledge of a transport engineer, including a designer, producer and user, as well as expert in the formal and legal domain.



TECHNOLOGICAL LEVEL

stage 2: finding potential applications



COMPETITION

little competition



MAIN USERS

large companies  
international corporations



MARKET MATURITY

the market is at a mature stage of development



# MINIATURE RADAR SYSTEM FOR DETECTION, TRACKING, AND IMAGING

The industrial revolution taking place in front of our eyes has brought into our lives a multitude of sensors whose goal is to automatically detect changes to the surroundings. In order to ensure safe transport, the traffic of various transport modes is thoroughly monitored - including both vehicles driven by people and unmanned vehicles. Sensors are also used for other purposes, e.g. to measure contestants' results during a sports event, or to visualise the course of team games. Various types of electronic solutions are applied to this end, and the most popular one is monitoring with the use of optical or thermal imaging cameras. The weak point of traditional optical solutions is their susceptibility to the time of day and weather conditions, and no possibility to measure direct distance and speed. Radar sensors remove these limitations. The contemporary scale of the integration of electronic systems allows us to offer miniature devices with a growing number of capabilities, at lower prices.

What is it about?

XY-Sensing Sp. z o.o., a spin-off company established at the Warsaw University of Technology, addresses today's challenges and caters for the needs of the market, through its miniature radar (12cm x 15cm x 6cm) operating

Technology creators:

- » Piotr Samczyński, PhD, DSc, Eng., Associate Professor (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Prof. Krzysztof Kulpa, PhD, DSc, Eng. (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Jacek Misiurewicz, PhD, DSc, Eng., Associate Professor (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Mateusz Malanowski, PhD, DSc, Eng., Associate Professor (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Damian Gromek, PhD, Eng. (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Krzysztof Stasiak, MSc, Eng. (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » XY-Sensing Sp. z o. o. (WUT's spin-off)

in two ISM bands. The device can detect, track, and provide an image of objects within the range of hundreds of meters as well as sub-meter resolution. XY-Sensing was founded by scientists from the Faculty of Electronics and Information Technology, dealing with radiolocation for over thirty 30 years. The offered solution allows work in difficult weather conditions, and is characterised by low weight - only 0.5 kg, and low power demand - below 40 Watt. The parameters facilitate automated and simultaneous detection and imaging to numerous objects on a continuous basis. The developed miniature radar sensor is currently at the final testing phase. Technological Readiness Level 9 has been achieved, which means that it is ready to use.

The system, consisting in a miniature radar head, additionally allows access to raw radiolocation data, which improves its feasibility in educational applications.

Application

The offered radar sensor may be used in numerous industries, i.a. automotive industry, military sector, or in transport or sports infrastructures.

Example usage:

- detection of small flying objects,
- protection and monitoring of critical infrastructure,
- detection of changes to building infrastructure (monitoring of bridges/buildings),
- traffic monitoring, detection of approaching vehicles, adaptive traffic-light system control,
- safe level crossings - detection of approaching train
- radar imaging,
- "Sense and Avoid" applications.

The most important features which make this solution stand out from competing solutions

- miniature size,
- low power consumption,
- direct measurement of distance and speed,
- operation in all weather conditions.



**TECHNOLOGICAL LEVEL**  
stage 4: TRL 9



**COMPETITION**  
low competition



**MAIN USERS**  
small and medium-sized enterprises, large companies  
international corporations  
non-governmental organisations  
central and local government bodies, EU authorities



**MARKET MATURITY**  
the market is developing





**MEDICINE**

# MATERIALSCARE — 3D PRINTING IN MEDICINE

3D printing of personalised medical instruments. 3D printing has transformed the quality and the process of treatment of humans by providing new medical instruments to doctors, and implants to patients.

## What is it about?

MaterialsCare designs and manufactures personalised medical instruments used for optimising surgical procedures. Virtual planning of operations on the basis of computed tomography imaging facilitates the production of personalised instruments using the 3D printing method.

Surgical templates designed and produced by MaterialsCare improve the accuracy of facial bone reconstruction while the time of the surgical procedure is shortened. The scope of resection of soft tissue and bones, and the precise location of dental implants is defined on the basis of imaging tests during a consultation with a surgeon.

## Application

The most frequent surgical procedures using the support of virtual planning and surgical templates include mandibular reconstruction and orthognathic surgery. Our portfolio also includes the planning of eye socket reconstruction surgeries or the reconstruction of temporomandibular joints. The implemented projects are most of all aimed to serve patients – to improve the effects of surgical treatment, increase precision of matching bone splinters, which contributes to a better quality of life after the treatment is completed.

## The team working on the project:

- » Bartłomiej Wysocki, PhD, Eng. (legal and financial aspects)
- » Agnieszka Chmielewska, MSc, Eng. (CAD)
- » Paweł Pacek, MSc, Eng. (production and sterilisation)
- » Maciej Rysz, MD, PhD (medical consultations)
- » Prof. Wojciech Świążkowski, PhD, DSc, Eng. (scientific consultations)
- » MaterialsCare Sp. z o.o.



Surgical templates, individually designed and produced by MaterialsCare, allow the performance of bone cuts in the planned location and under the right angle. By using a set of try-in models for tumour resection and adjustment of bones with which the mandible is to be reintegrated, it is possible to match bone elements like a key to a lock. Virtual planning of surgical procedures, supported by surgical templates, reduces the risk of human error.

Other types of personalised medical instrumentarium include matrices for the personalised shaping of titanium mesh or phantoms used for the bending of titanium plates or micro-plates. It is also possible to plan and print 3D objects which facilitate bone positioning during operations – dilation and shift of the jaw/mandible.

## How it works?

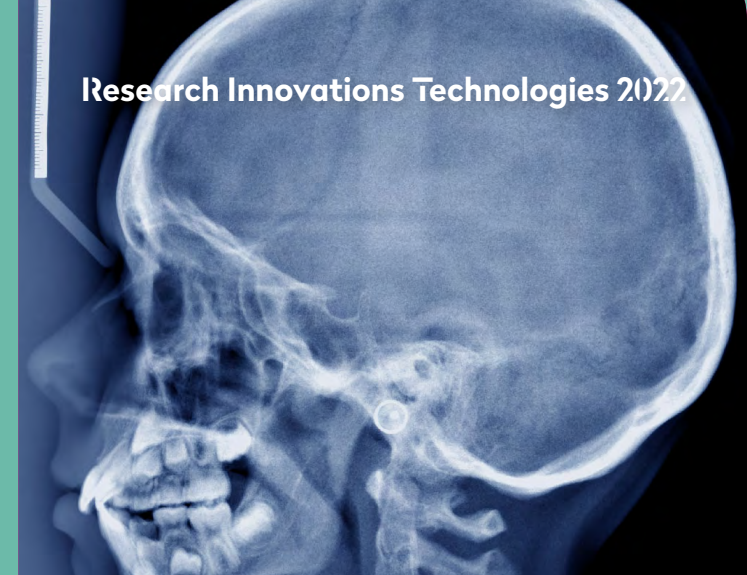
Personalised medical instrumentarium is produced with the use of the 3D print method based on light-cured resins with a CE marking. Materials used by MaterialsCare may be sterilised in an autoclave.

Bone resections are performed using standard surgical tools under an appropriate angle, and consistent in cut planes with the models produced on the basis on virtual planning of surgical procedures. Virtual operation assistance based on physical models contributes to improved facial symmetry, and better final functional and aesthetic effects in patients.

Based on the comparison of the results of surgical procedures conducted with the use of standard methods, and computer-assisted procedures, it can be said that the team is able to achieve better outcomes in nearly every aspect. The increased costs of virtual planning and models are in a large extent mitigated by the reduced duration of procedures and less complications. The advantages of computer-assisted operations have contributed to a substantial increase in the popularity of this type of procedures worldwide.

## MaterialsCare proposal for medicine

- Preparation of virtual and physical pre-operative models,
- 3D printing of templates for surgery, with particular attention to maxillofacial surgery,
- Design and characterisation of polymer and metal materials for medical purposes,
- Veterinary implants produced with the use of 3D printing technology based on plastic materials and titanium,
- R&D cooperation on medical and veterinary projects with the use of 3D printing.



## TECHNOLOGICAL LEVEL

stage 5: TRL 8



## COMPETITION

low competition



## MAIN USERS

public healthcare sector  
private clinics  
individuals



## MARKET MATURITY

the market is developing



# TECHNOLOGY FOR THE PRODUCTION OF NEW GENERATION TITANIUM IMPLANTS

What is it about?

It entails the development of a unique technology for the production of new generation titanium implants used for fixating bone fractures, in which the key element is the production of biocompatible fixation plates and rods made of pure titanium (Ti-CP) used for the reconstruction of bones, with the use of the unique and innovative method of explosive working. Thanks to the applied technology, the developed medical products will be characterised by a unique biocompatibility, no alloy elements, high mechanical strength, and reduced weight. The use of titanium (Ti-CP) in which strength properties will be obtained without the need to use alloy elements, is due to reduce the costs of materials thanks to eliminating the need to use expensive, deficit and cytotoxic elements, such as aluminium, niobium, tantalum or zirconium, which will at the same time improve the performance properties such as biocompatibility. The increased strength obtained by way of explosive working will contribute to the reduced diameter of bolts, and thus the holes drilled in bones, needed to fix the implants. This will minimise bone damage and improve its stability and regeneration speed, where temporary implants are used.

Technology creators:

- » Michał Gloc, PhD, Eng.  
(Division of Materials Design, Faculty of Materials Science and Engineering, WUT)
- » Sylwia Przybysz-Gloc, PhD, Eng.  
(Institute of High Pressure Physics, Polish Academy of Sciences - PAS)
- » Marcin Wachowski, PhD, Eng.  
(Faculty of Mechanical Engineering - Military University of Technology)

Accelerated osseointegration process (connection between the implant and the bone) reduces the risk of septic inflammation (bacterial infections) which may occur during or after the implantation procedure.

How it works?

Pure titanium is not characterised by high strength. Its strength is lower than, for example, that of surgical steel. Titanium can be strengthened by way of plastic working. Explosive working is currently one of the most modern and innovative metal working methods used in practice. This innovative technology allows obtaining materials with unique properties, both in terms of strength and resistance to degradation. The unique nature of the solution consists in the development of pure titanium (Ti - CP) explosive working method, aimed at obtaining a material which has a much higher mechanical strength than the currently used alloys. This will allow the elimination of currently used alloy additives used with pure titanium, such as aluminium (6%), niobium (5%) or zirconium (2%) which, while stabilising the  $\beta$  phase, reduce the biocompatibility, which is essential in the said applications.

Application

Planowane je zastosowanie rozwiązania w medycynie. Plans have been made to apply the solution in medicine. Literature on the subject reports numerous cases of allergic reactions to titanium implants; nonetheless, we need to take into account that implanted materials are not made of pure titanium, but of an alloy of numerous metallic elements. The quality of the materials which are currently used in medicine creates a need to refine the biomaterials in use today, and to make attempts to introduce new materials into medical practice. By inserting an implant into human organism, it is assumed that it will fulfil its function in a long-term perspective. A good fixation of the bone with an implant, an appropriate implant shape, the load taking into account the stress distribution at the contact point of the implant and the bone tissue, and the provision of a rigid fixation of the implant in the bone for the entire period it is placed in the organism, will facilitate the creation of such conditions as the ones which accompany normal bone fracture healing process.

Features which make this solution stand out from competing solutions

The solution consists in the development of technology for the production of biocompatible implants worked with the use of explosive methods. This unique technique allows the production of formed isotropic materials with excellent strength parameters. The explosive method is a relatively simple, inexpensive and fast metal working method. The development of pure CP titanium working technology will facilitate the production of working-strengthened plates and rods made of pure titanium. The proposed development activities allowed the selection of optimum explosive working parameters, needed to produce biocompatible and durable components with a high mechanical strength, which will initially be used in veterinary practice, and ultimately in humans.



**TECHNOLOGICAL LEVEL**  
stage 5: currently TRL 6



**COMPETITION**  
low competition



**MAIN USERS**  
individuals  
small and medium-sized enterprises, large companies  
international corporations



**MARKET MATURITY**  
the market is developing

# VIDO — DIAGNOSTICS AND TREATMENT OF VISUAL IMPAIRMENTS

Accurate examinations, automated selection of vision correction methods and testing of new solutions, without the costly production of trial glass or contact lenses – these are just a few of the advantages of a device which is the focus of works as part of the VIDO project. Project called "VIDO – Improving the quality of vision through dynamic optics" is financed by the National Centre for Research and Development as part of the LIDER IX programme (LI- DER/15/0061/L-g/17/NCBR/2018 in the period between 1 January 2019 and 31 December 2022.

What is it about?

The objective of the project is to create a device which will be able to provide new data, and transform the effects of patient examination process, without any perceptible modifications made to testing. The device automatically and extremely accurately "measures" the eye, and then generates any kind of a corrective device on a special display, virtually placing it in or on the eyeball. Patients will be able to see as if they were wearing a given device, but the need to produce and apply the actual device is eliminated at this stage. For instance, before a surgery, the doctor will be able to demonstrate several options to the patient, helping them with the decision about the treatment method.

Application

Virtual corrective lenses will not only allow the optimisation of cost-intensive technological production processes, but are also likely to greatly facilitate clinical trials prior to the approval of actual devices for use,

The team working on the project:

- » Karol Kakarenko, PhD, Eng.  
(The Faculty of Physics, WUT, project leader, module constructor, and vision optics expert)
- » Izabela Ducin, PhD, Eng.  
(Faculty of Physics, WUT, projection systems expert)
- » Anna Byszewska, MD, PhD  
(Department of Ophthalmology, Military Institute of Medicine in Warsaw, human-subject research expert)
- » Jan Bolek, MSc, Eng.  
(Faculty of Physics, WUT, automation and robotics expert)
- » Dariusz Parzych, MSc  
(Centre for Innovation and Technology Transfer Management of the Warsaw University of Technology, market research and commercialisation expert)
- » Krzysztof Petelczyc, PhD, Eng.  
(Faculty of Physics, WUT, promotion expert)

especially given that some solutions, once verified using our device, might not qualify for the implementation stage at all. The outcomes of the works are to support ophthalmologists and patients, and facilitate scientific and industrial research.

The marketing of the device will allows the production of personalised correction devices, without the need to rely on already produced lenses. The solution will also contribute to conducting scientific research, and to extending its range. It will also be possible to check whether accurate vision correction will be accepted by the patient's brain.

The scholars devote a lot of attention to adapting the devices to the needs expressed by the recipients – mainly ophthalmologists and medical companies.

This has already been demonstrated by the composition of the team whose members include, i.a., an ophthalmologist, an IT expert, an optician, a psychologist, and a business analyst. Some functionalities of the device will be more useful in clinical ophthalmology while others in technological laboratories. However, with a view to optimising the price of the finished device, and thus improving its availability, we are considering the possibility to limit certain features for specified recipients. The authors also try to ensure that the equipment will not considerably differ in terms of size and operation from the solutions known to potential users. The first business partners are already expressing their interest in cooperation. The VIDO project team is working in the new Perception Research Laboratory, which is a joint project of the Physics Department and the Research and Analysis Department of the Centre for Innovation and Technology Transfer Management.

Features which make this solution stand out from competing solutions

At present, none of the devices present on the market offer all the capabilities arising from the project implemented by the scientists from the Faculty of Physics. However, they are aware of the market competition. That is why the project team monitor customer needs and functionalities of commonly available solutions on an ongoing basis. In particular, they pay special attention to the Spanish VAO device, created under the direction of Prof. Pablo Artal, as the one that most resembles their project. The difference is that the said device works in a closed field, which means that the patient looks at optotypes with digits and letters displayed on screen. With the device we are developing, we want patients to see a broad field, not just the optotypes, but also their natural surroundings. This way, it will be possible to test near and distance vision in real-life conditions. The fundamental value of the device will be that it will integrate multiple functionalities into a single algorithm. Most of those functionalities already exist in the form of separate devices. In our opinion, however, their full potential will not be achieved until they are combined in a single system. Moreover, the dynamic generator of corrective devices will be a certain innovation.



TECHNOLOGICAL LEVEL  
stage 2: Proof of concept



COMPETITION  
high competition



MAIN USERS  
everyone – starting from individuals who will be tested with the use of the device, to corporations which can purchase production rights



MARKET MATURITY  
the market is developing



# ARTIFICIAL BLOOD VESSELS

## What is it about?

Scientists have been working on coronary vessel grafts aimed to replace defective vessels. The objective is the most accurate possible recreation of natural vessels, so scholars seek inspiration in their structure. And it is a complex one. It includes several layers which will be reconstructed one by one from synthetic polymer materials.

## Features which make this solution stand out from competing solutions

The project can be distinguished by the fact that the last layer, the one to have direct contact with blood, will resemble the natural structure, as it will be covered by cells taken from the patient.

## Application

It is a response to an actual need expressed by medical circles. At present, by-pass grafts are used in the case of coronary occlusion. A blood vessel is taken from one of the patient's other body parts, most often from the lower leg, and a bypass is formed between the aorta and the coronary artery. Thanks to this the obstructed artery section is bypassed, and blood is transported to the heart. However, such procedures are not always possible.

Large-diameter vascular prostheses have been successfully used in medicine for some time. However, the demand for small-diameter vessel implants, up to 4-5 mm (such as coronary vessels) with a sufficient degree of biocompatibility, has not been met yet.

## Technology creators:

- » Beata Butruk-Raszeja, PhD, Eng. (project leader, Division of Biotechnology and Bioprocess Engineering, Faculty of Chemical and Process Engineering, WUT)
- » The team:
  - Prof. Tomasz Ciach, PhD, DSc, Eng.,
  - Iwona Łopianiak, MSc, Eng.,
  - Michał Wojasiński, PhD, Eng.,
  - Aleksandra Kuźmińska, MSc, Eng. (Division of Biotechnology and Bioprocess Engineering, Faculty of Chemical and Process Engineering, WUT)
  - Paulina Trzaskowska, PhD, Eng. (Centre for Advanced Materials and Technologies CEZAMAT)

This gap may be filled by products developed as a result of the completed studies.

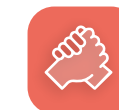
## The strengths of the technology

- small internal diameter (2-5 mm) allowing the use of the prosthesis as a substitute for coronary vessels,
- mechanical parameters resembling the parameters of human blood vessels,
- the external surface coated with nanofibres characterised by appropriate layout and size – ensuring proper environment for the growth of smooth muscle cells and recreation of the outer surface of blood vessels,
- the interior surface is covered with selective biomolecules - ensures high hemocompatibility of the prosthesis and allows self-healing of the endothelium layer.



## TECHNOLOGICAL LEVEL

stage 4: TRL 4-6,  
intellectual property:  
domestic patent protection,  
patent No. 238765



## COMPETITION

high competition



## MAIN USERS

small and medium-sized  
enterprises, large companies,  
international corporations



## MARKET MATURITY

the market is developing



# AN INTEGRATED CIRCUIT TO MONITOR HUMAN HEALTH

What is it about?

The BioSoC chip integrates systems that monitor physiopsychic parameters, such as heart electrical activity (ECG), electrical activity of muscles (EMG), body temperature, stress level (skin resistance) and breath rate. This technology allows the monitoring of health state parameters in humans under dynamic conditions, e.g., a pilot flying a plane, a train driver, a tram driver, a bus driver or a lorry driver, excavator or crane operators on construction sites.

Features which make this solution stand out from competing solutions

The system facilitates the collection of information, its analysis and interpretation with the use of a single chip. This solution is unique at a global scale.

Technology creators:

- » Witold Pleskacz, PhD, DSc, Eng., Associate Professor (project leader on the part of WUT, Institute of Microelectronics and Optoelectronics, Faculty of Electronics and Information Technology, WUT)
- » Project Consortium: Institute of Medical Technology and Equipment, Military Institute of Aviation Medicine, Warsaw University of Technology, Institute of Electron Technology, FONON Sp. z o.o.

Application

Thanks to the above features, it creates a perfect basis for the construction of technological solutions for the mobile device market (e.g., in telemedicine), and for the rapidly developing wearables market.



TECHNOLOGICAL LEVEL

stage 4: TRL 4-6



COMPETITION

high competition



MAIN USERS

small and medium-sized enterprises



MARKET MATURITY

the market is developing



# A BIO-IMPLANT TO REGENERATE BONE TISSUE

## What is it about?

The developed technology consists in the production of bio-implants which support the regeneration and recreation of bone defects in humans and animals. The material for bio-implants and the production method were developed as part of the project. Moreover, the proposed concept was tested as part of research conducted on small and large animal models.

## How it works?

The developed bio-implant was made of a composite material which includes a biodegradable polymer, and a bioceramic which is naturally present in human bones. After the implant is placed in the affected area, it allows the patient's bone tissue to grow, and after a specified time, the bio-implant is subject to degradation and absorbed. The bone-loss area is ultimately filled with fully regenerated bone tissue.

## Technology creators:

The team is managed by

- » Prof. Wojciech Świąszkowski, PhD, DSc, Eng.  
(Faculty of Materials Science and Engineering, WUT)

## Features which make this solution stand out from competing solutions

The advantage of the Bio-implant production technology over the existing bone grafting methods is the possibility to produce personalised and complex shapes made of bioactive material. The bio-implant is characterised by an openwork internal structure which allows the bone tissue to form across the entire implant. Another strength is the increased elasticity of the implants in relation to ceramic fillers in the form of blocks. The advantage over bone grafting materials in the form of a granulate is the fact that the Bio-implant is a finished product which does not require forming during the implantation procedure, shortening the surgical procedure time.

## Implementation

A spin-off company called MaterialsCare was established in August 2015 at the Warsaw University of Technology to deal with the implementation and commercialisation of research results.



## TECHNOLOGICAL LEVEL

stage 5: TRL 7



## COMPETITION

low competition



## MAIN USERS

large enterprises  
international corporations



## MARKET MATURITY

the market is being created

# THE PRODUCTION OF A DYNAMIC SUBSTITUTE FOR CANCELLOUS (SPONGY) BONE

The standard treatment of bone defects involves the performance of an autogenous bone graft to initiate the regeneration of damaged tissue. Grafts contain bone-forming elements, such as osteoblasts, stem cells, extracellular matrix, and growth factors. The aforementioned treatment method is equally common and full of threats – it carries the risk of infection in the graft area, bleeding or nerve damage. The application of bone substitutes, whose implantation additionally promotes bone growth, is a state-of-the-art solution. The dynamic substitute for spongy bone, developed by scientists from the Department of Chemistry and Polymer Technology at the Faculty of Chemistry at the Warsaw University of Technology, is a response to these emerging needs (intellectual property rights: patent No. PL 236858, patent No. PL 236857, patent No. PL 236111).

## How it works?

The obtained implant is flexible and elastic, unlike the scaffold formed using a popular emulsion templating and porogen leaching (often NaCl) method, or the 3D printing method.

## Technology creators:

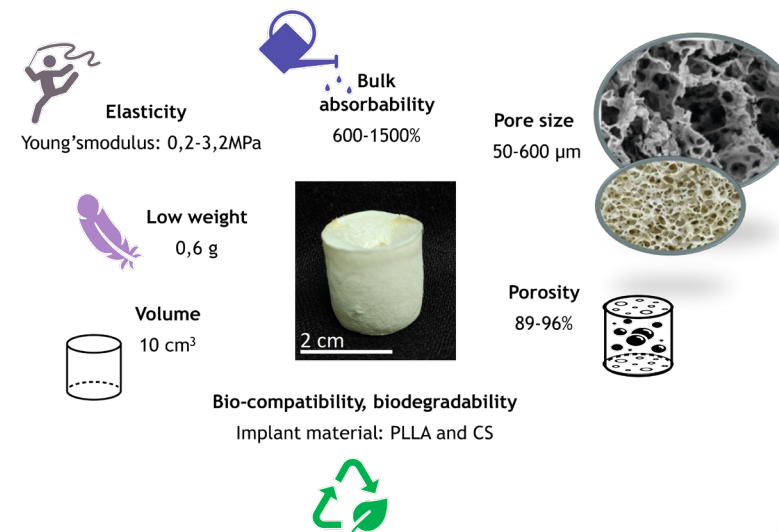
- » Agnieszka Gadomska-Gajadhur, PhD, DSc, Eng.  
(Department of Chemistry and Polymer Technology, Faculty of Chemistry WUT)
- » Paweł Ruśkowski, PhD, Eng.  
(Department of Chemistry and Polymer Technology, Faculty of Chemistry, WUT)

Thanks to this, it is possible to obtain an implant which is resistant to crumbling under pressure, and easy for surgeons to trim freely directly in the operating room. The bone substitute is to constitute a carrier for platelet rich plasma, which is known to induce tissue formation in the process of spongy bone regeneration.

## Application

The method for the production of a dynamic substitute for spongy bone may be used in medicine, i.e., by hospitals, private orthopaedic clinics, or research centres. The method is based on materials which are approved for use in medicine. The polymer is metabolised by living organisms to non-toxic degradation products, so it does not accumulate in the organism. It is possible to apply this bone regeneration method without the risk of rejection (as the host's plasma is used).

## BIOACTIVE SPONGY BONE SUBSTITUTE - PROPERTIES



## The most important features of the solution include:

- non-toxicity toward bone cells, and bone marrow,
- biodegradability of the implant eliminates the need for re-operations in order to remove it,
- the flexibility of the implant allowing the adjustment of its size and shape during the procedure in the operating room.
- appropriate internal morphology allowing the injection of platelet-rich plasma, containing bone growth factors, despite the hydrophobic nature of the implant material,
- high porosity, ranging from 90 to 96% allowing uninterrupted migration of nutrients and cell metabolites.



## TECHNOLOGICAL LEVEL

stage 4: TRL 4



## COMPETITION

small competitions,  
no such products on the  
commercial market



## MAIN USERS

private and public sector  
private clinics and public hospitals



## MARKET MATURITY

the market is being  
created



# T-SKIN — DETECTION OF SKIN CANCER

The development of non-destructive testing of materials with the use of terahertz (THz) radiation has contributed to the search for compact optical systems. In the light of current research findings, it is assumed that one of the key issue is the development of diffractive optics solutions for this radiation range, which is the main objective of the T-SKIN project. The project is financed by the National Centre for Research and Development as part of the Lider IX programme (LIDER / 11/0036 / L-9/17 / NCBR / 2018).

What is it about?

The key objective of the project is to use THz radiation for skin imaging purposes, including the option to identify neoplastic tissues. An optical system has been designed for terahertz radiation which allows the differentiation of healthy skin and neoplastic tissue. It is an innovative method for the detection of skin cancer.

Features which make this solution stand out from competing solutions

Compared with the currently applied dermatoscopes, the use of THz radiation is a seemingly a more expensive solution. However, the automated testing procedure and the use of special properties of THz radiation would allow the replacement of a dermatology specialist with an automated system operated by a technician, which in turn is due to significantly reduce the costs of diagnostic tests.

Technology creators:

- » Agnieszka Siemion PhD, Eng. (project leader)
- » Izabela Ducin, PhD, Eng.
- » Piotr Sobotka, PhD, Eng.
- » Mateusz Surma, MSc, Eng. (Division of Optics and Photonics, Faculty of Physics, WUT)
- » Paweł Komorowski, PhD, Eng.
- » Elżbieta Czerwińska, MSc, Eng.
- » Michał Walczakowski, MSc, Eng. (Institute of Optoelectronics, Military University of Technology - MUT)

Given that, without the need to wait for a doctor's appointment, patients would be able to receive initial information whether a given lesion might pose a threat and whether it requires further medical consultation.

How it works?

The device is based on optical modules with diffraction structures.

The solution which entails the application of compact diffractive optics might be designed and produced for further system configurations depending on the potential intended use, and, what is more, it is not limited to Terahertz radiation bandwidth only – which makes it an attractive solution also for visible radiation bandwidth, infra-red radiation, millimetre waves, or ultraviolet bandwidth.

Thanks to the application of a multifunctional module with diffraction structures, it will be possible to design a compact device operating in a reflective configuration which will ultimately allow the real-time testing of patients.



Thanks to the applications of optical system accumulating the signal on detectors, it is possible to use cheaper detectors, available on the commercial market, which do not require operation in low temperatures, which will contribute to the elimination of the need to use a cryostat and to the construction of a compact system.

Application

The possibility to build a compact device with the use of components available on the market gives hope for a prompt practical application of the solution.



**TECHNOLOGICAL LEVEL**  
stage 4: TRL 4



**COMPETITION**  
very low competition



**MAIN USERS**  
international corporations  
central and local government bodies  
EU authorities



**MARKET MATURITY**  
the market is being created

# POCT (POINT-OF-CARE TESTING) DEVICES AND AUTOMATED DIAGNOSTIC TESTS

By way of combining the ideas, achievements, and technologies developed by experts from several teams representing CEZAMAT, the Faculty of Chemistry, and the Faculty of Electronics and Information Technology at WUT, it is possible to provide products for broadly understood medical diagnostics which are innovative at the European scale. Two large-scale research projects, ImDiag and ImGen, are devoted to the development of state-of-the-art solutions in the sphere of automated diagnostic tools. The projects are being implemented as part of two consortia, i.e., ImDiag – WUT, Screenmed, and the Łukasiewicz Industrial Chemistry Institute (2018-2022); and ImGen – Screenmed, WUT and National Institute of Public Health/National Institute of Hygiene (2019-2022).

## What is the ImDiag project about?

The project concerns the development of the structure and production technology of miniature diagnostic devices for innovative medical technologies allowing the determination of various analytes (including disease biomarkers and other biological specimens) with the use of electrochemical analysis cassettes. The project fits in the civilizational trend of the development of medical diagnostics, allowing the performance of sensitive and accurate diagnostic tests, in the circumstances where instant results are needed, for instance where human life is at threat due to a myocardial infarction, a general inflammation or the spread of microorganisms through the circulatory system.

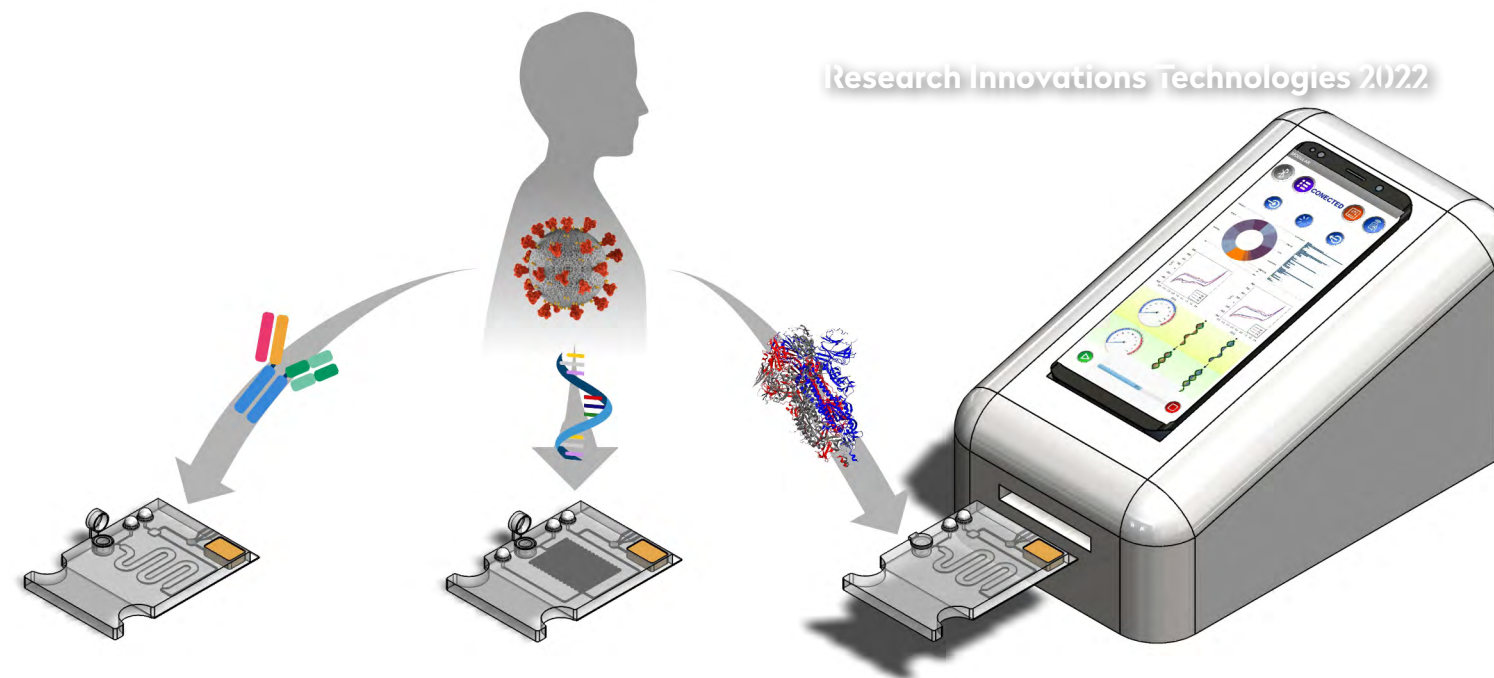
## Technology creators:

- » Prof. Elżbieta Malinowska, PhD, DSc, Eng. (project leader, Centre for Advanced Materials and Technologies CEZAMAT, Department of Medical Biotechnology, Faculty of Chemistry, WUT)
- » Prof. Zbigniew Brzózka, PhD, DSc, Eng.,
- » Mariusz Pietrzak, PhD, DSc, Eng., Associate Professor,
- » Marcin Drozd, PhD, Eng.
- » Robert Ziółkowski, PhD, Eng. (Department of Medical Biotechnology, Faculty of Chemistry, WUT)
- » Jerzy Weremczuk, PhD, DSc, Eng. (Institute of Electronic Systems, Faculty of Electronics and Information Technology)
- » Krzysztof Różanowski, PhD, Eng.,
- » Katarzyna Tokarska, PhD, Eng.,
- » Kamil Żukowski, PhD, Eng. (Centre for Advanced Materials and Technologies CEZAMAT)

## What is the ImGen project about?

The project involves the development of the structure and production technology of miniature diagnostic devices for the detection of SARS-CoV-2 virus as part of POCT procedures. Its main objective is to develop innovative SARS-CoV-2 (infection) rapid detection technology or the rapid detection of anti-SARS-CoV-2 antibodies (past infection) in biological specimens.

The product caters for an urgent epidemiological need – the construction of low-cost diagnostic devices allowing the performance of sensitive and accurate diagnostic tests in the conditions which require immediate results directly at the point of care, in the POCT mode, as screening tests in workplaces or distributed testing stations.



The devices designed as part of the project might constitute the basis for a universal tool for the diagnostics of infectious diseases other than COVID-19, with the use of both immunosensor and gene-sensor platforms.

## Application

The technologies have the potential to support the diagnostic products market in the sphere of self-testing and POCT, and to be used in non-specialised testing centres (out-patient clinics, care centres, distributed testing stations).

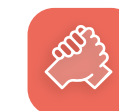
## Features which make this solution stand out from competing solutions

The proposed solutions might contribute to a significant reduction of diagnostic testing costs (in some cases, a visit to an outpatient clinic would not be required). What is important, they are likely to play an increasingly important role as an aid in the prompt application of effective treatment procedures, which in turn would improve their results (significant from patients' perspective), and due to the reduction of healthcare expenditures (no need for hospital treatment, long-term therapies and potential rehabilitation).



## TECHNOLOGICAL LEVEL

stage 4: TRL 4-6



## COMPETITION

no data



## MAIN USERS

outpatient clinics, care centres  
distributed testing stations



## MARKET MATURITY

the market is developing



# POLY(GLYCEROL SUCCINATE) PRODUCTION METHOD

## What is it about?

Invention (PL 238248) concerns the poly(glycerol succinate) production method. It is a new polyester which may be applied in the form of a biomaterial, a drug carrier or a cell scaffold in tissue engineering. The material is built of substances which are naturally present in the organism, and for that reason, neither the polymer nor its degradation products are toxic. Succinic acid is present in the Krebs cycle, a rapid metabolic pathway occurring in every living cell. Glycerol is a component of cell membranes. Moreover, glycerol constitutes a substantial waste product in the production of biodiesel, so the possibility to manufacture a valuable product is an attractive option for the industry.

## How it works?

Our invention thoroughly describes the stoichiometric ratio of substrates, the temperature, and the duration of the reaction. What is more, the invention also includes a detailed description of the purification process. The described processes do not require any complex apparatus, and are consistent with the Green Chemistry principles.

## Technology creators:

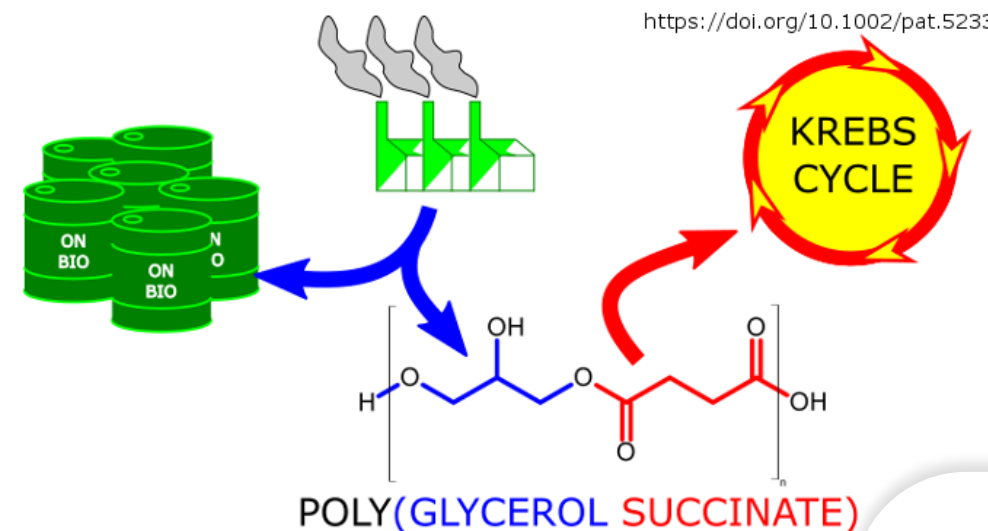
- » Agnieszka Gadomska-Gajadhur, PhD, DSc, Eng.
- » Paweł Ruśkowski, PhD, Eng.
- » Michał Wrzecionek, MSc, Eng.  
(Department of Chemistry and Polymer Technology, Faculty of Chemistry WUT)

The outcome is the production of cheaper, and at the same time better biomedical materials, i.e., implants characterised by improved assimilation in tissue engineering, bone fixation devices (bolts and plates) with a reduced risk of inflammation, the production of new coatings for medical device sensors.

## Application

Poly(glycerol succinate) can be used for soft tissue regeneration, i.e., heart tissue, vascular tissue, nervous tissue and cartilage. It can also be used for eye retina regeneration, and in the healing of perforated tympanic membrane. It may serve as a surgical sealant during surgical procedures. In addition, due to the relatively short degradation time, it may be used as a biocompatible API carrier. The coating of the contact surface of biomedical sensors is a completely new application of the polyester.

Given its intended use, the invention should be seen as an interesting proposal mainly for companies manufacturing biomedical polymers. On the other hand, the treatment of glycerol, which is waste generated in the course of biodiesel production, makes the proposed solution an attractive option also for refining businesses.



## Features which make this solution stand out from competing solutions

The process for the production of poly(glycerol succinate) has been optimised, resulting in a mathematical model which demonstrates the impact of reaction parameters on the properties of the product. The authors are able to obtain a product of specified properties (esterification degree, molar mass, the degree of branching), tailored to market needs. The material can be further modified with a view to obtaining new properties.



## TECHNOLOGICAL LEVEL

stage 4: TRL 4



## COMPETITION

no competition



## MAIN USERS

self-employed individuals and micro enterprises  
small and medium-sized enterprises, large companies, international corporations



## MARKET MATURITY

the market is being created



**CHEMISTRY**



# BIOCIDAL NANOCOMPOSITE PARTICLES WITH A BROAD SPECTRUM OF ACTION

## What is the innovation?

Nanocomposite particles are nanomaterials characterised by unique bioactive and biocidal properties. This solution is provided in the form of a dry nanopowder or as nanocolloidal systems in various solvents. The nanocomposite particles were developed at the Faculty of Materials Science and Engineering of the Warsaw University of Technology and deployed to production by the spin-off company ADJ Nanotechnology Sp. z o.o., which specialises in developing, large-scale production and distribution of bioactive nanocomposite powders for use as raw materials in the production of self-sterilising materials. It is a product innovation.

## Main features

The developed biocidal nanocomposite particles are fully effective and, which is particularly important, not only as a raw material, but thanks to exceptional dispersity, also after modifying other materials and coatings. This facilitates the use of protected products in places particularly exposed to the spread of disease-causing microbes. Numerous tests and analyses have also proven that, in contrast to free nanoparticles, nanocom-

## Technology creators:

- » Agnieszka Jastrzębska, PhD, DSc, University Professor (Division of Ceramic Materials and Polymers, Faculty of Materials Science and Engineering, WUT)
- » prof. Andrzej Olszyna, PhD, DSc (Division of Ceramic Materials and Polymers, Faculty of Materials Science and Engineering, WUT)



posite systems are safe for the environment, while retaining excellent self-sterilising properties. This means that the functional properties of new nanoproducts also include improved end user safety.

## Features which make this solution stand out from competing solutions

The nanomaterial manufacturing process at ADJ Nanotechnology is highly innovative. This is due to: simple concept, flexible production and a virtually unlimited combination of possible chemical compositions of the manufactured nanoproducts. The technology used in in-house manufacturing provides high flexibility in selecting raw materials for synthesis and the process itself can be called one-pot bottom-up. This facilitates obtaining nanopowders with unique chemical compositions and properties.



Other loose materials can also be introduced into the reaction mixture, which are then covered with nanoparticles with a composition matching the substrates contained in the mixture. This results in the formation of a hybrid nanostructure with a chemical composition and parameters that can be easily adjusted to the specific requirements of end users. The obtained nanoproducts can be called "tailor-made" and having unique functional features. The only limitations are the imagination of nanostructure creators, the need to ensure specific functionalities, and, obviously, costs.



**TECHNOLOGICAL LEVEL**  
implementation



**COMPETITION**  
little competition (no more than several entities)



**MAIN USERS**  
natural persons  
microenterprises  
small and medium-sized enterprises  
international corporations



**MARKET MATURITY**  
the market is developing

## 3D PRINTING INK USED IN REACTIVE INKJET PRINTING TECHNOLOGY

The most popular 3D printing methods available on the market include fused deposition modelling (FDM), selective laser sintering (SLS), selective laser melting (SLM) or stereolithography (SLA), but due to the need of heat treatment of the materials used, their physical properties deteriorate.

### How it works?

Reactive inkjet printing is a novel printing method. Printing is based on a chemical reaction between two or more ink ingredients. Droplets of substrates collide in the air, and are further applied in the location where they build up the printed item. The subject of the solution is the composition of the ink which guarantees instant reaction and high efficiency without the need to use any catalysts or high temperatures.

### Application

The application of the proposed ink ingredients (poly-ester resin and a hardening agent) includes the incremental production of items with specified geometry.

The proper selection of substrate ratio by generating droplets of specific size, allows the printing of biocompatible materials characterised by good mechanical properties.

### Technology creators:

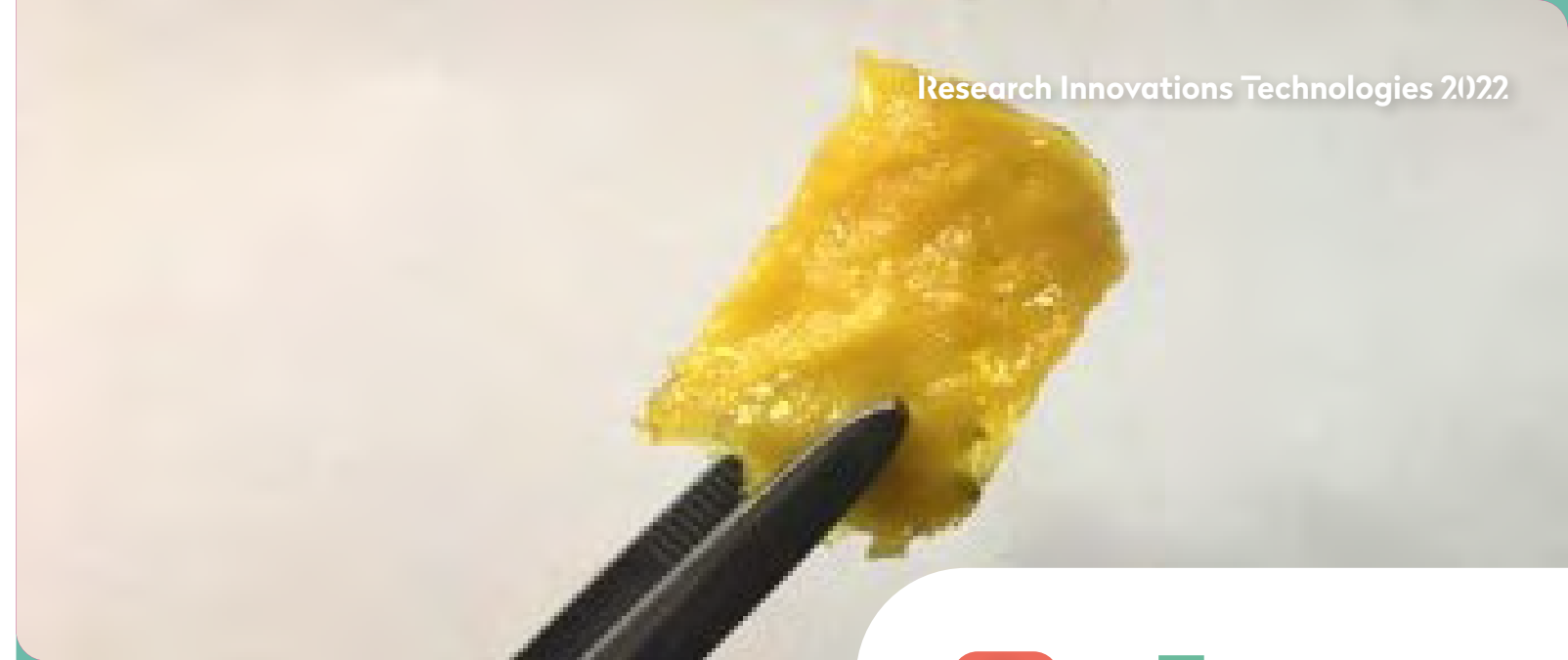
- » Agnieszka Gadomska-Gajadur, PhD, DSc, Eng.
- » Paweł Ruśkowski, PhD, Eng.
- » Michał Wrzecionek, MSc, Eng.
- » Krzysztof Kolankowski, MSc, Eng. (Department of Chemistry and Polymer Technology, Faculty of Chemistry, WUT)

A structure resembling rubber is created, and by annealing the printed item, it is possible to control its final tautness. Both materials are of natural origin, and no waste is generated in the course of the reaction between them.

### Features which make this solution stand out from competing solutions

Reactive inkjet printing is a technology which is still not widespread on the global market. It is used by a few teams, and their equipment includes laboratory-scale printers. Printing with the use of the proposed ink may contribute to the rapid development of this field of science, allowing large-scale research into the process, and ultimately the use of the ink by major processing companies to print large-size items.

The composition of the ink guarantees the creation of biocompatible and biodegradable products characterised by good mechanical properties.



### The most important advantages of the solution

- high reaction efficiency and speed,
- no need to use a catalyst,
- no need to use and evaporate solvents – the substrates may be used in a pure form,
- no gas is released in the course of the reaction, and no foaming takes place in the product, which is the most frequent defect of the known ingredients,
- no by-products are generated in the course of the reaction.



### TECHNOLOGICAL LEVEL

stage 3: TRL 3



### COMPETITION

no competition



### MAIN USERS

self-employed individuals and micro enterprises  
small and medium-sized enterprises, large companies, international corporations



### MARKET MATURITY

the market is being created



# ULTRASONIC ATOMIZER

## RESEARCH PLATFORM — REPOWDER

The rePowder technology was created for the purpose of research in the course of preparing a doctoral dissertation on the 3D printing of metallic glasses. It facilitates accelerating research on new materials for 3D printing.

How it works?

The device produced by the Amazemet company can atomize any material in any form, even in very low quantities of several grams. In addition, this technology is designed with more than atomization in mind. The rePowder platform can also be used for alloying, homogenisation and moulding of metallic materials regardless of composition. Thanks to the modular build and a number of developed feeders, the feedstock can be in any form – from wire or rod to powder, and failed prints or production waste, which can be recycled this way. In combination with other metal 3D printing devices, the device allows achieving closed-loop production.

Technology creators:

- » Łukasz Żrodowski  
(Division of Structural and Functional Materials, Faculty of Materials Science and Engineering, WUT)



Application

This technology is the ideal solution for research units dealing with the development of new metallic materials. The produced powder is of high quality due to its extremely high sphericity, which enhance materials flowability, a very low level of foreign pollutants, including oxidation, and narrow particle size distribution.

Features which make this solution stand out from competing solutions

In contrast to widely known gas atomization, rePowder does not use high-pressure gas for atomization, but ultrasound. The melted material is fed to the element vibrating with ultrasonic frequencies and sprayed on its surface and is then set in the protective atmosphere of the working chamber, forming perfectly spherical powder particles. Melting may be performed directly using a plasma torch, allowing the processing of high-alloy materials or using induction to prevent the loss of elements with a low vapour pressure.



**TECHNOLOGICAL LEVEL**  
stage 5: TRL 7-9



**COMPETITION**  
little competition  
(no more than several entities)



**MAIN USERS**  
small and medium-sized enterprises  
large enterprises  
international corporations  
Universities and Research Institution



**MARKET MATURITY**  
the market is developing

# AUTOMATED SUPPORT DISSOLUTION AND SURFACE FINISHING STATION – SAFEETCH

An important element of the metal additive manufacturing process is the necessary postprocessing of the print. The removal of scaffold structures and smoothing surface using traditional methods is highly time-consuming and may be responsible for as much as 70% of the overall product cost.

## What is it about?

safeEtch is a patented ultrasonic-chemical technology introducing a support dissolution method into the world of metal printing. safeEtch facilitates the removal of all supports without any mechanical processing, while smoothing out surfaces even in the most inaccessible corners. Using a technology that dissolves supports makes it possible to apply a completely new approach to designing elements, with the complete use of the chamber volume, by stacking elements on top of each other.

The principle of operation is based on the chemical dissolution of a thin layer of material using a specially-designed mixture of acids and an additional mixing effect caused by ultrasound.

## Technology creators:

- » Łukasz Żrodowski (Division of Structural and Functional Materials, Faculty of Materials Science and Engineering, WUT)

**AMAZEMET**

- » associated technologies: :  
MaterialsCare Sp. z o.o.  
- postprocessing of metallic scaffold structures produced using the SLM (selective laser melting) technology

This effect makes it possible to appropriately stimulate the reaction and take advantage of beneficial cavitation phenomena, and facilitates the flow of the solution into every crevice of the detail. As a result, the print is free of supports, features smooth surfaces thanks to the removal of non-dissolved powder particles, and retains sharp edges.

## Application

The features of the process make it a particularly good fit for the industrial production of titanium elements and implants manufactured using additive technologies and for automating postprocessing in metal 3D printing.

This technology is used by the MaterialsCare company to remove non-dissolved powder particles in additively manufactured titanium implants used in veterinary medicine.



## Features which make this solution stand out from competing solutions

This solution significantly differs from the currently used techniques. In the case of mechanical processing, the process of finishing elements is long and expensive, particularly for components with complicated geometry.

With regard to electropolishing, each element must be connected to a power source, which also reduces production capacity and makes it impossible to process several elements in one go.

In contrast to electropolishing, the safeEtch technology for dissolving support structures and surface finishing allows retaining the sharp edges of the processed elements and ensures a high level of accuracy in relation to the CAD model after the cleaning process.



## TECHNOLOGICAL LEVEL

stage 5: TRL 7-9



## COMPETITION

little competition  
(no more than several entities)



## MAIN USERS

small and medium-sized enterprises  
large enterprises  
international corporations



## MARKET MATURITY

the market is developing



# MICROBIOLOGICAL COSMETIC MATERIALS

We can observe a growing demand for natural cosmetic substrates. They may be used as fragrance, preservatives or active substances. The increased interest on the market results from the greater public awareness both in the context of environmental and health-related aspects. To cater for the expectations of customers, manufacturers are developing new technologies with a view to obtaining non-synthetic substrates used in the production of cosmetics and skin-care products.

## What is it about?

Skin disorders, such as acne or atopic dermatitis, affect a considerable proportion of the population. There are no perfect solutions, and the products available on the market are associated with unpleasant smell and stains on clothes, and, if that was not enough, they contain artificial preservatives. Two natural products, rose fragrance (2-phenylethanol, 2-PE) and a bio-ferment containing 1.5-3% 2-PE, obtained in the course of a biotechnological process, might be the answer.

Both products are obtained in the course of the production of 2-PE – alcohol characterised by a rosy fragrance and bactericidal and fungicidal action confirmed by the results of numerous research, which in natural conditions is present in plant essential oils.

The developed solution is an alternative to the traditional chemical synthesis methods or extraction from flower petals.

## Technology creators:

- » Jolanta Mierzejewska, PhD, DSc  
(Department of Pharmaceutical and Cosmetic Biotechnology, Faculty of Chemistry, WUT)
- » Karolina Drężek (nee Chreptowicz), PhD, Eng.  
(Department of Pharmaceutical and Cosmetic Biotechnology, Faculty of Chemistry, WUT)

The method of extraction from plant material is very expensive. In turn, during chemical synthesis, exerting substantial environmental impact, harmful by-products are generated. The scientists developed a biotechnological method with the use of yeast, which allows obtaining a natural product in the course of a process designed with the natural environment in mind.

## How is it created?

The rose fragrance produced at the WUT comes from the fully natural 2-PE biosynthesis process, by way of biotransformation of L-phenylalanine (a natural amino acid) with the use of baking yeast, *Saccharomyces cerevisiae*. The bio-ferment is a fermented food-grade rapeseed oil, obtained in the course of microbiological production coupled with the production of the rose fragrance. The fermentation process results in the production of, i.a., unsaturated free fatty acids (Omega-3, -6, -9), acetic acids displaying bactericidal, fungicidal, and brightening effects, and 2-PE (1.5-3%) which is the source of a pleasant rosy fragrance, also acting as a preservative. The outcome of the fermentation process is the creation of a natural mixture which is much better absorbed by the skin than crude rapeseed oil.

## Features which make this solution stand out from competing solutions

The innovative feature of the solution is the application of a microbiological production of unique cosmetic materials with the use of yeast, which is considered a substance of natural origin. There are formally no enterprises in Poland which produce cosmetic materials from yeast, or they have not demonstrated their presence on the market yet. Therefore, there is a niche for the development of this type of technology. Also, we can observe a steady increase in the consumer interest in cosmetic products which are free from chemically synthesised substances, and have effective skin care and anti-ageing action.

Both products manufactured at the WUT, the rose fragrance (2-PE) and the bio-ferment are natural substances. 2-PE may be used to perfume and stabilise cosmetics. The bio-ferment containing 1.5-3% 2-PE, due to the presence of Omega-3, -6 and -9 unsaturated fatty acids, is perfect for the production of cosmetics having regenerative, lubricating, moisturising and anti-ageing properties.

## Application

According to Global Markets for Flavour, the value of the global aroma and fragrance market was estimated at USD 27bn in recent years. According to forecasts, it will amount to over USD 31bn in 2022, with an average growth rate of over 6%. In turn, as per the Global Aroma Chemicals Market, it is estimated that the global aroma chemicals market is due to increase by approx. 5.5% in the years to come.

Polish cosmetic industry is ranked as the 6th largest cosmetic industry market in Europe. The value of the cosmetic market oscillated around PLN 23bn between 2016 and 2017. It is estimated that natural cosmetics account for approx. 10% of the market, and their sale is growing. Moreover, Polish cosmetic companies are turning to the production of bio-cosmetics in an increasing extent.

Both products have successfully passed microbiological, physiochemical, and dermatological tests, and have been used in the formulas of cosmetics manufactured by SENKARA and SOHO cosmetics, Polish companies whose products are available on the domestic market.



## TECHNOLOGICAL LEVEL

stage 4: TRL 9

Intellectual property: patent  
No. PL234032B1



## COMPETITION

low competition on the Polish market, 2-3 entities on the European market



## MAIN USERS

micro enterprises



## MARKET MATURITY

the market is developing

# TECHNOLOGY FOR AMBER WASTE MANAGEMENT

Baltic amber is a well-known brand all over the world, mainly as a jewellery material mined in Poland, Ukraine, and Germany. However, only a part of the material can be used for the production of jewellery. Out of 200 tonnes of amber mined globally, about 70% become waste after separating the gemstones, half of which is fit for use in the cosmetic industry following appropriate procession (extraction/solution) and characterising. The annual potential of the market is estimated at PLN 70 millions. It is possible to obtain 175-700 tonnes of extracts for cosmetic production out of the 70 tonnes of amber waste available each year. Despite a ban on the exports of amber material from Russia, the jewellery market specialising in amber processing has not experienced any downturn. On the contrary, huge interest and exports of amber to China has resulted in the recovery of the industry.

**What is the solution about? Application**

There are "materials of amber origin" present on the cosmetics market, but, according to our findings, they contain marginal quantities of amber ingredients (amber dust) or do not contain them at all. We have developed a technology for the processions and usage of amber waste, and we explored the possibility to prepare a range of cosmetic raw materials and cosmetics containing products of amber origin, and distinguished by specified healing properties.

**Technology creators:**

- » Prof. Ludwik Synoradzki, PhD, DSc, Eng. (Faculty of Chemistry, WUT)
- » Sławomir Safarzyński, PhD, Eng. (Faculty of Chemistry, WUT)
- » Agnieszka Sobiecka, PhD, Eng. (Faculty of Chemistry, WUT)
- » Halina Hajnowicz, MSc, Eng. (Faculty of Chemistry, WUT)
- » Anna Jerzak, MSc, Eng. (Faculty of Chemistry, WUT)
- » Marcin Koziorowski, MSc (Faculty of Chemistry, WUT)

**What is it about?**

According to own studies (including extraction with the use of various organic solvents, with 8-96% efficiency), we were able to confirm the presence of several dozen compounds in amber, described in literature, including, i.a. fenchone, fenchol, camphor, isoborneol, borneol, bornyl formate, succinic acid, and methyl bornyl succinate, methyl isobornyl succinate, as well as pimaric acid, abietic acid, dihydroabietic acids and their esters. We have shown that amber can react with some solvents, e.g. alcohols and anhydrides. Thanks to this it is possible to solve it completely or partially and prepare concentrates which are fit for application in cosmetics.

**How it works?**

- We have confirmed that the obtained cosmetics have advantageous properties, e.g., they improve the hydration of stratum corneum of the epidermis, disinfect, show soothing and anti-inflammatory properties, and, what is important, have no adverse effects.
- Providing a new natural raw material (with a scientifically verified composition and well-tested positive action) to the cosmetic industry has the potential to constitute significant advantage over competitive proposals. The value of the cosmetic market in Poland amounted to nearly PLN 20 bn in 2017.

**Features which make this solution stand out from competing solutions**

- no such products on the market,
- the availability of a valuable and inexpensive raw materials,
- scientifically proven action of identified ingredients,
- the technology can successfully be implemented at an industrial scale,
- the product contributes to the withdrawal of amber waste used for the manufacturing of counterfeit amber from the market – environmental protection and legal regulations,
- high marketing added value resulting from the products associations with history, and equating such products with high quality and value.



**TECHNOLOGICAL LEVEL**

stage 4: TRL4 completed (searching for an enterprise to enter the TLR 5 phase)



**COMPETITION**

low competition



**MAIN USERS**

self-employed individuals  
micro-enterprises  
small and medium-sized enterprises, large companies



**MARKET MATURITY**

the market is developing



# SMART FLUID — SHEAR THICKENING FLUIDS

Smart Fluid SA is a young and rapidly growing spin-off company dealing with the development and implementation of state-of-the-art protective materials based on shear thickening fluids (STF). This company was established on the foundations of knowledge and experience gained as part of the research conducted at the Faculty of Chemistry and the Faculty of Materials Science and Engineering of the Warsaw University of Technology since 2009. The objective of Smart Fluid is to lead to the commercial use of the Smart Fluids and Gels being developed.

How it works?

STF technology is based on the step change to viscosity, which can be observed as a shift from the liquid state to the solid state. On impact (application of force) STF harden within milliseconds, and become a protective shield which disperses the impact force.

It is a reversible process – directly after the impact, the material behaves like a Fluid or Gel again, it is ready to accept another blow directed at the same point.

Shear thickening fluids may be used as fillers, e.g. in various types of protective pads. It is only one of numerous application possibilities. A wide experience of the company in designing the properties of STF guarantees their effective and reliable action, depending on the demand and use conditions.

Technology creators:

» Smart Fluid SA

Application

Innovative and flexible STF materials may be used in sports equipment (protectors, vibration absorbers), in protective clothing for motorcycle drivers, in ballistics (stab- and bullet-proof vests) or in the automotive sector as an element of car seats and child safety seats, providing protection in the case of an accident or absorbing vibrations.

Smart Fluid also developed a technology allowing STF immobilisation in the form of thin layer of Gel. The applied solution prevents the Gel from falling down vertical surfaces, allowing the maintenance of protective properties related to the shear thickening phenomenon. Smart Fluid has reached the stage of developing product prototypes and searching for commercial partners.

Features which make this solution stand out from competing solutions

The solutions applied by Smart Fluid are innovative and stand out among the solutions currently available on the market, in particular,

- in ballistics – there is no similar product which would reduce injuries and would be so flexible, comfortable and thin as SCG (Smart Ceramic Gel); the existing solutions are thicker or rigid – and there are only few injury-reducing products (LFT, ATF, thick foam),

- in the sphere of sports protective equipment – there is no product of similar flexibility and degree of protection combined with such small thickness, which would be able to improve users' safety and use comfort (similar products are made of other materials – d3o, sastec, koroyd, polyanswer, EVA foam, g-form, poron, ect.),
- in the sphere of vibration isolation – there is no product based on STF – constant-viscosity fluids are currently used, but they are several times more expensive than STF,
- as regards the shear thickening properties – the current market proposal does not provide for viscosity change similar to the one obtained by the Smart Fluid Team (only 2 other companies in the world sell STF).

The company was awarded numerous prizes for the development of the solutions, i.e., a honourable mention at the Polish Product of the Future 2016 competition, honourable mention in the category of START-UP as part of Innovation Initiator Newsweek 2017, the Grand Prix of the Prime Minister, the Audience Award at the Impact'17 congress, Gold Medal during the „2018 Taiwan Innotech Expo Invention Contest” for a prototype of a vibration isolator based on shear thickening fluids to protect buildings against seismic shocks, or the Silver Medal during the 46 International Exhibition of Inventions Geneva 2018” for sports protective equipment based on the shear thickening fluid technology.



TECHNOLOGICAL LEVEL

TRL – 8,  
Manufacturing Readiness Level (MRL) – 5



COMPETITION

ballistics – low competition,  
sports protective equipment – high competition,  
vibration isolation – high competition,  
shear thickening properties – low competition



MAIN USERS

ballistics – special forces, armed forces and law-enforcement bodies;  
sports protective equipment – professional and amateur athletes;  
vibration isolation – manufacturers of shock absorbers for cars, aircrafts and motorcycles, together with the protection against earthquake vibrations for buildings, bridges, etc.;  
shear thickening properties – scientists



MARKET MATURITY

ballistics – market at a mature stage of development;  
sports protective equipment – market at a mature stage of development;  
vibration isolation – the market is developing;  
shear thickening properties – the market is being created





**ECOLOGY**



# SMART PARTICULATE MATTER SENSOR

Advanced life forms on the surface of the Earth are represented by aerobic organisms, which would not have emerged without the characteristic Earth's atmosphere. If it is polluted by particulate matter or liquids it becomes atmospheric aerosol, which is toxic for humans. The chemical composition of the atmosphere is becoming increasingly complex as a result of human activity. In recent years, it has become clear that air quality has a decisive influence on human well-being, health, work performance and even length of life.

## What is it about?

The widespread presence of chronic respiratory diseases, asthma, or cancer, is being increasingly associated by the public with pollution. Central and local governments are pressed to take action. The ones who have the best network of sensors will be the first to acquire detailed knowledge of the sources of the problem.

For that reason, we have been working on air quality measurement methods at the Institute of Theoretical Electrical Engineering and Information Measurement Systems for several years, which resulted in a new "smart particulate matter sensor." It is an attractive solution in terms of costs.

## It consists of:

1) a measurement chain based on the optical method together with a gas test chain developed using the 3D print method,

## Technology creators:

- » Bogdan Dziadak, PhD, Eng.  
(Institute of Theoretical Electrical Engineering and Information Measuring Systems, Faculty of Electrical Engineering, WUT)
- » Łukasz Makowski, PhD, Eng.  
(Institute of Theoretical Electrical Engineering and Information Measuring Systems, Faculty of Electrical Engineering, WUT)

2) an electronic sensor module based on an amplified photodiode,

3) a microprocessor module based on a 32-bit microcontroller in the ARM architecture which joins all the components and controls the light source.

The measurement chain, the microprocessor control unit and software were developed in full at the Warsaw University of Technology. The prototype was tested in laboratory conditions, simulating real-life conditions, while the readings were verified against the reference calibrated sensor in calibration laboratories.

## Application

"The smart particulate matter sensor" may be introduced to the consumer market, where the awareness of air pollution issues has been considerably raised. There is also a growing readiness to incur costs with a view to providing protection against threats related to smog. In a similar scenario, the device can be offered to public institutions, such as communes, city offices, care and education establishments, healthcare centres, which have certain responsibilities towards their residents.

## A wide range of possibilities

The sensor is a tool thanks to which it is possible to develop another product which is much more attractive for other types of customers. The said product entails data and conclusions drawn from the analysis of such data, which we are striving to achieve by extending the device with a communication module to connect it to the network in the IoT model. It is possible to consider time series predictions here, which is exactly what the Institute's neural network experts are dealing with.

The provision of access to the data free-of-charge or in connection with the existing website will allow the collection of significant marketing data about the preferences and interests of persons living in places related to sensor location. Together with other data sources it may prepare the ground for the development of comprehensive business strategies in the sphere of consumer market (products associated with health or healthy lifestyle).

Moreover, it is possible to develop long-term statistical characteristics of air quality for selected locations, which may be of interest to companies operating in the insurance or healthcare sectors (poor air quality means higher disease risk), or the building industry (clean air means a more attractive housing offering).

The implementation of the solution, which is vital for social reasons, should constitute an important element of building a positive brand and company image, which allows such entities to create additional value.



## TECHNOLOGICAL LEVEL

stage 4: TRL 5  
(tests have been performed in near real-life conditions and in real-life conditions; the particulate matter sensor has been recently verified by the technology creators through comparison with calibration stations)



## COMPETITION

low competition



## MAIN USERS

non-governmental organisations, central government, local governments, individuals



## MARKET MATURITY

the market is developing

# HABITARS — REMOTE SENSING FOR ECOLOGY

How can we efficiently monitor natural habitats, including NATURA 2000 network habitats? By using various remote sensing and geographic information system technologies in an integrated manner. Thanks to such combinations, we can objectively and repetitively assess the condition of protected areas and valuable habitats and plant species, and monitor the threats they may be exposed to, including the risk of secondary succession.

What is it about?

As part of the HabitARS project, implemented by a large-scale consortium, an innovative methodology was developed to support the monitoring of non-forest habitats in the Natura 2000 network with the use of state-of-the-art remote sensing technologies. The team of scientists from the Warsaw University of Technology was responsible for the preparation of the methodology aimed at identification and monitoring of secondary succession of trees and shrubs - one of the threats to Natura 2000 habitats.

How it works?

In Poland the succession process has been exacerbating since the 1990s, which is related to the successive resignation from running agricultural activities in some regions of the country. It has resulted in a substantial transformation of, for example, meadows, due to the irreversible change to the species composition as a result of the extinction of valuable native species.

Technology creators:

- » Katarzyna Osińska-Skotak, PhD, DSc, Eng., Associate Professor (Leader) (Department of Photogrammetry, Remote Sensing and Spatial Information Systems, Faculty of Geodesy and Cartography, WUT)
- » Aleksandra Radecka, MSc, Eng.
- » Wojciech Ostrowski, MSc, Eng.
- » Krzysztof Bakula, PhD, Eng.
- » Łukasz Jełowicki, MSc, Eng.
- » Konrad Górski, MSc, Eng.
- » Jakub Charyton, Eng.

The developed succession identification methodology uses aerial data - hyperspectral imaging which, thanks to the recording of hundreds of spectral bands, allows the detection of species, and laser scanning (ALS) which facilitates the production of a 3D digital surface model.

By using machine learning methods, big data, and landscape metrics, the developed procedure has been automated in a large extent.

As a final result, the data on the spatial extent of trees and shrubs is generated, separating forest areas from trees and shrubs entering habitat areas (posing a potential threat), together with their species composition.

As part of the next stage, also fully automatic, the level of secondary-succession threat for a given area or habitat is defined. It allows a fast survey of the area in terms of the potential progression of the succession process, thanks to which it may be a significant support in the decision-making process concerning protective measures. In addition, the team developed a procedure for the use of archival photogrammetric data, including aerial photographs, for the purpose of defining the dynamics of the succession process.

Such knowledge allows the forecasting of what may happen, and how fast it may happen, if no preventive measures are undertaken.

Application

The results of the R&D works can be used by the General Directorate for Environmental Protection, Regional Directorates for Environmental Protection, national and landscape parks, universities, non-governmental organisations, and investors.

The methodology has been implemented and is one of the services provided by the project leader – MGGP Aero Ltd. Similar solutions, following their adaptation to the requirements and needs of other users, may also be successfully implemented in other institutions.

Features which make this solution stand out from competing solutions

The proposed solution utilises state-of-the-art remote sensing technologies (hyperspectral imaging and airborne laser scanning) allowing an automated monitoring of tree and shrub succession to agricultural land and to areas which are valuable from the nature conservation perspective.



**TECHNOLOGICAL LEVEL**  
stage 4: TRL 6



**COMPETITION**  
low competition



**MAIN USERS**  
non-governmental organisations  
central government bodies  
local government



**MARKET MATURITY**  
the market is developing



# REWARD — REMOVAL OF DETERGENTS FROM WATER

In industrial laundries, as much as 10 litres of water and 6 g of detergents are used to wash every 1 kg of dry textiles. In laundries which wash 15 tonnes of textiles every day (especially hotel and hospital bedding, work and hospital clothes), daily water consumption may be as high as 150 thousand litres and the amount of detergents (washing, softening, bleaching) used is about 90 kg. This creates a large volume of waste water contaminated by these chemicals, but also by anything that was present on the washed textiles.

## What is it about?

REWARD – a project of a Polish-German consortium, which brings financial savings and reduces environmental pollution by closing the water loop in laundries. The team developed a method of reclaiming most of the water used for washing, which can return to the process at the pre-wash stage.

## How it works?

Due to using this technology, a waste water stream is generated that is only a fraction of the original one – only 10–20 thousand litres per day instead of 150 thousand. This demonstrates clear environmental benefits. Membrane filtration uses self-developed micro-/ultrafiltration membranes with openings only fractions (even hundredth) of a micrometer in size. Water flows through the membrane along with dissolved compounds, including detergents.

## Technology creators:

- » Maciej Szwaś, PhD, DSc, Eng., Associate Professor (Chair of Integrated Processes Engineering, Faculty of Chemical and Process Engineering, WUT)
- » Daniel Polak, MSc, Eng. (Chair of Integrated Processes Engineering, Faculty of Chemical and Process Engineering, WUT)

It stops objects larger than membrane holes, especially particulates forming dirt, as well as fats and proteins forming micelles with detergents. Dipole induction is a method known mainly in the metallurgical industry and involves applying an electric charge to particulates (textile fibres or dirt particles), due to which they form bigger agglomerates, which facilitates their stopping on the membrane.

The project involved tests under real-life conditions. Additional tests, conducted according to the German standards of the laundry industry, demonstrated that washing quality did not decrease with the application of regenerated water when compared to the quality where unmodified water was used.

## Features which make this solution stand out from competing solutions

In Poland there are only a few manufacturers of installations using membranes. Obviously there are many more such manufacturers in Europe, but no more than 30 of them have a significant position.

However, the essence of the technology is the modified membrane, and only members of the project consortium have the knowledge related to it. This technology is perfected and proven under real-life conditions, which makes it ready for implementation.



## TECHNOLOGICAL LEVEL

stage 5: TRL 9, ready for implementation the technology is perfected and proven under real-life conditions



## COMPETITION

low competition



## MAIN USERS

large companies  
industrial laundries, laundry chains  
car wash chains



## MARKET MATURITY

the market is at a mature stage of development

# GRAPHENE INFRARED RADIATION SHIELDING

What is it about?

Scientists from the Faculty of Chemical and Process Engineering of the Warsaw University of Technology use graphene oxide and graphene-derived compounds to prepare new materials for infrared radiation shielding. The team's objective was to create a material which would form a barrier against both the entry and release of heat. The developed materials are composites.

How it works?

The materials are produced on the basis of polymers (currently two types). The filler materials used include graphene materials with the addition of metal oxides, e.g. titanium oxide. This combination guarantees effective shielding. Graphene materials are added to absorb radiation, and metal oxides are intended to disperse it.

Features which make this solution stand out from competing solutions

Window foils that protect from radiation are already offered on the market. However, the materials developed by scientists from the Warsaw University of Technology are a viable alternative to compete with them. In order to reduce the temperature by a few degrees Celsius, manufacturers add 5% of filler.

Technology creators:

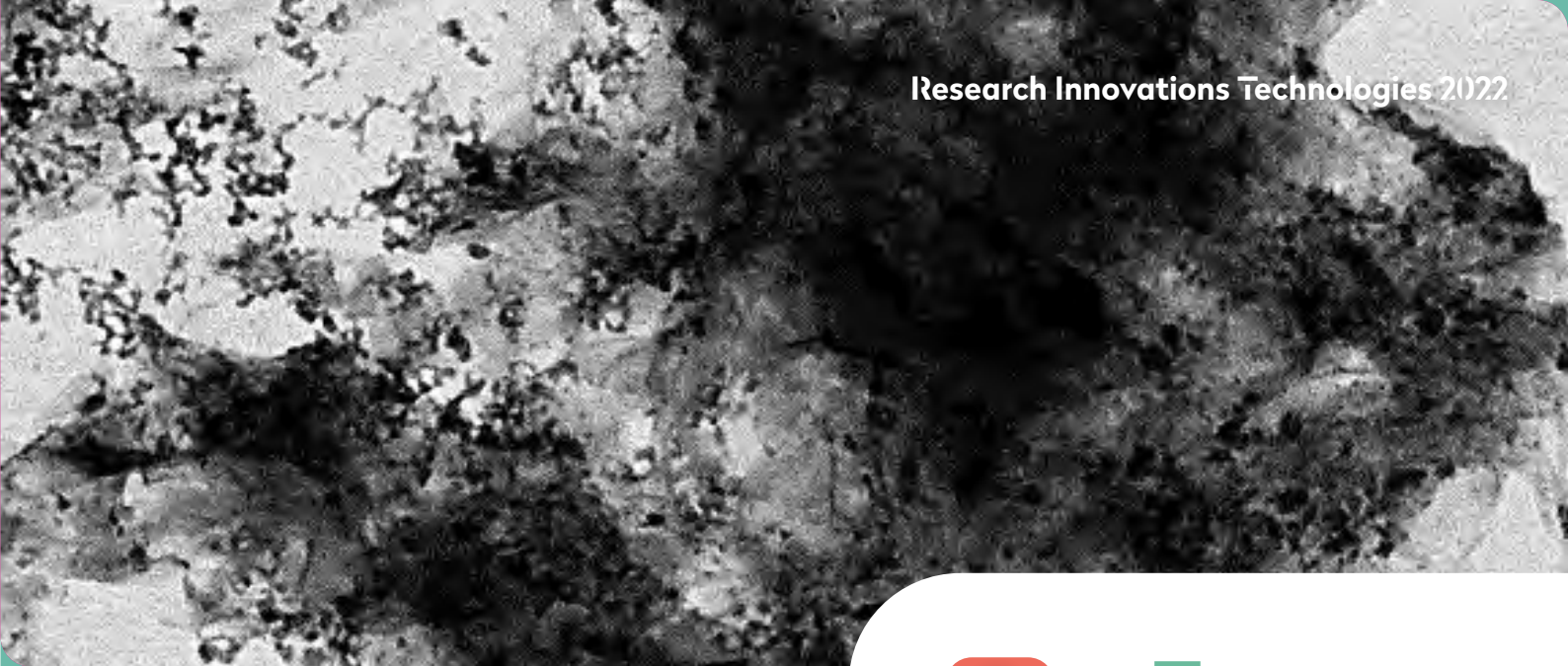
- » Marta Mazurkiewicz-Pawlicka, PhD, Eng. (Graphene Laboratory, WUT, Faculty of Chemical and Process Engineering, WUT)
- » Artur Małolepszy, PhD (Graphene Laboratory, WUT, Faculty of Chemical and Process Engineering, WUT)
- » Leszek Stobiński, PhD, DSc (Graphene Laboratory, WUT, Faculty of Chemical and Process Engineering, WUT)
- » The project was implemented in cooperation with Tatung University from Taiwan and the University of Warsaw (Faculty of Physics)

The scientists obtained similar results after adding 0.1% of filler, i.e. 50 times less. Currently, the team is focused on materials, not specific applications.

Application

Potential applications immediately come to mind and may include windows, but also exterior walls, and even fabrics – such materials would protect against losing heat in the winter and from overheating in the summer.

For buildings and vehicles this could be an alternative to air conditioning, which is widespread these days. Air conditioning involves very high energy consumption. The more we want to change the temperature in relation to the natural temperature of a given room, the more energy is needed. Any less energy-consuming assistance would result in budget savings and environmental benefits.



Looking to the future

Scientists from the Warsaw University of Technology conducted tests with promising results, but a number of issues must still be tested in more detail. This concerns, among other things, the behaviour of polymers under UV radiation, elevated temperature and modified humidity. It is also important to test the already developed solutions both in various conditions and over a longer period.



**TECHNOLOGICAL LEVEL**  
stage 3: TRL 3



**COMPETITION**  
high competition



**MAIN USERS**  
natural persons  
small and medium-sized enterprises  
large enterprises



**MARKET MATURITY**  
the market is developing



# SAFEDAM — PREVENTION OF FLOOD HAZARD

What is it about?

This solution involves advanced technologies to assist the prevention of flood-related hazards.

The objective of the SAFEDAM project is to create a system for monitoring levees using an unmanned, non-invasive aerial measurement platform for scanning from a low altitude, with additional use of aerial and satellite images.

How it works?

The system uses multi-source photogrammetry data. It allows taking advantage of data from a satellite altitude – optical, within the visible light spectrum, as well as near infrared and radar data. With regard to aviation techniques, the data used include both photogrammetry data from the national resource and data obtained from UAV platforms developed under the project. Low-altitude data include data from a lightweight aerial scanner, multispectral imaging data and thermal data.

Technology creators:

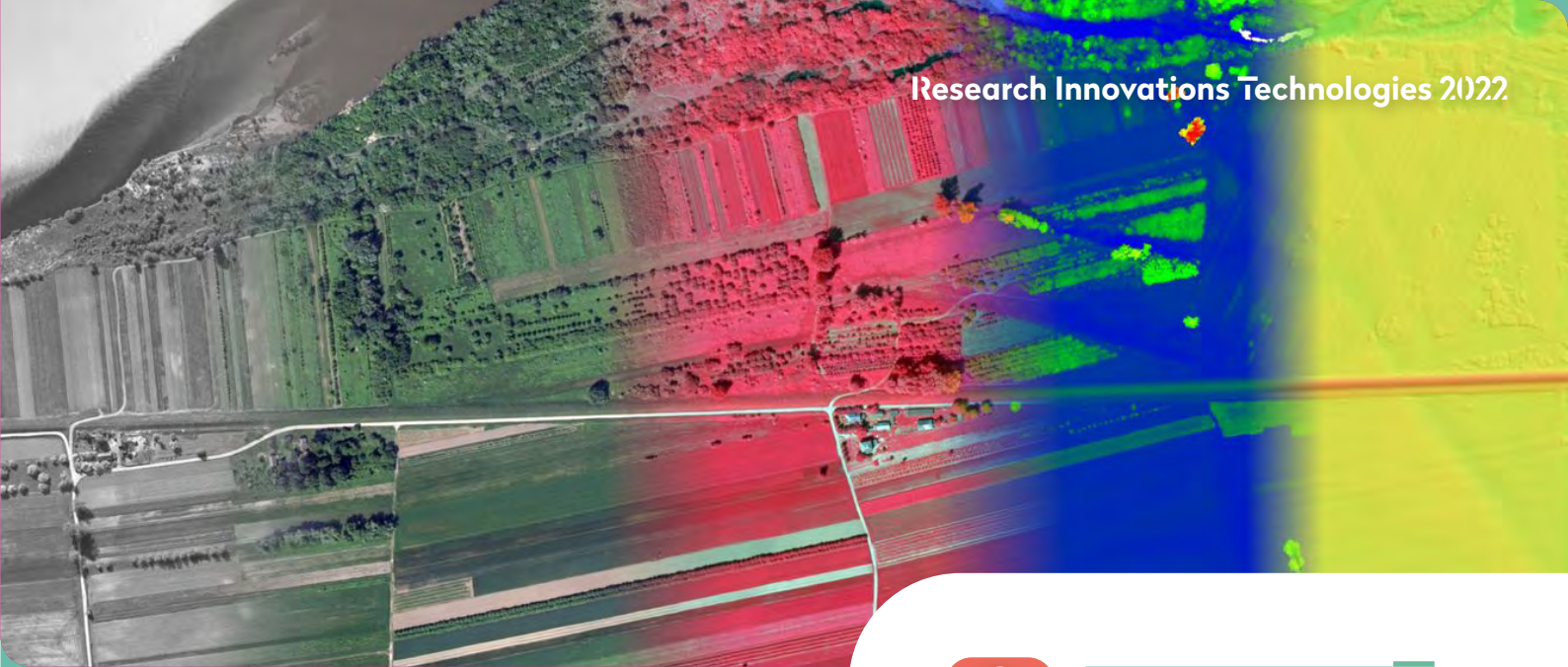
- » Krzysztof Bakula, PhD, Eng.
- » Wojciech Ostrowski, MSc, Eng.
- » Magdalena Pilarska-Mazurek, MSc, Eng.
- » Adam Salach, MSc, Eng.
- » Katarzyna Osińska-Skotak, PhD, DSc, Eng., Associate Professor
- » Project Manager: Prof. Zdzisław Kurczyński, PhD, DSc, Eng. (Department of Photogrammetry and Remote Sensing)

Application

Harnessing multi-source data facilitates the assessment of levee condition and detection of potential changes that may be present in both the preventive and interventional system configurations.

The system allows expert and automatic 3D data analysis, which is required for the work of flood infrastructure managers and crisis management bodies.

The SAFEDAM system also allows geoparticipation in the monitoring of levees. Its implementation facilitates effective management of flood risk and the whole system complements the existing domestic flood protection projects.



Features which make this solution stand out from competing solutions

System inThe SAFEDAM information technology system is a unique platform processing and managing geospatial data for flood risk management connected with monitoring levees using state-of-the-art remote sensing techniques. The system takes advantage of multi-sensor unmanned aerial platforms for detecting damage, as well as data from the geodesy and cartography resource, and also geoparticipation involving the public in notifying alerts connected with the state of flood infrastructure.



**TECHNOLOGICAL LEVEL**  
stage 5: TRL 9



**COMPETITION**  
no competition



**MAIN USERS**  
national and local authorities  
large enterprises



**MARKET MATURITY**  
the market is being created

# ICESURFER — PROTECTION OF SURFACES FROM ICING

The subject matter tackled by the project creators is extremely serious. Deposited and accumulated ice may be deadly in many areas of our lives. The risk additionally increases when icing forms on the aerodynamic surfaces of aircraft or wind turbines on important power plant components moving at high speeds.

What is it about?

The IceSurfer project is aimed at developing a technology for producing icephobic (preventing ice formation) surfaces for use in elements made of polymer composites. This is particularly important for the said aircraft components, wind turbine blades and devices providing electric power to houses and flats. The project "ICE-phobic SURfaces for components based on polymER composites - IceSurfer" is financed by the National Centre for Research and Development under the programme LIDER IX, No. LIDER/16/0068/L-g/17/NCBR/2018.

How it works?

The project assumes modifying the protective layer used for composite coating (gel-coat) in a way that prevents ice from sticking to it or delays the nucleation of ice crystals for as long as possible.

Technology creators:

- » Rafał Kozera, PhD, Eng. (Leader)  
(Faculty of Materials Engineering, WUT)
- » Bartłomiej Przybyszewski, MSc, Eng.  
(Faculty of Materials Engineering, WUT)
- » Katarzyna Żołyńska, MSc, Eng.  
(Faculty of Materials Engineering, WUT)
- » Bogna Sztorch, PhD  
(Centre for Advanced Technologies,  
Adam Mickiewicz University in Poznań)
- » Michał Gloc, PhD, Eng.  
(Faculty of Materials Engineering, WUT)
- » Szymon Tofil, MSc, Eng.  
(Faculty of Mechatronics and Mechanical  
Engineering, Kielce University of Technology)

The modified layer is meant to have lower ice adhesion properties, which will make it easier to remove from the surface. Scientists synthesise various additives intended to modify the properties of the external composite layer. For this purpose, they use nanoparticles and apply chemical and laser modifications. The project assumes the introduction of changes in the gel-coat production process, so that they acquire the desired properties from the start. The secondary objective is to use this solution in already produced and used elements. In such cases, specially modified paints will be applied.

Features which make this solution stand out from competing solutions

The technology being developed by a team of scientists may be a perfect alternative to the currently used ways of managing surface icing.

These methods are usually harmful to the environment and expensive, while reducing material durability. Manual ice removal is based on using chemical agents, which destroy the structure of elements and penetrate to the air and soil. In addition, solutions using electric power for de-icing require very high power, which not only negatively affects the environment and is inefficient, but is also becoming increasingly uneconomical. A similar solution is being developed in multiple centres, but it is difficult to find a solution that eliminates the disadvantages of e.g. silicon, which, while meeting the key criteria, is not useful due to its limited resistance to erosion factors. Clearly, it must be remembered that the protected elements are subject to extreme mechanical and thermal loads and operate on a non-stop basis, which creates favourable conditions for highly intensive surface degradation.

How it works?

The developed solution might have a very wide range of applications, but under the IceSurfer project the team of scientists is focused on wind turbines. Tests will also be conducted in an icing wind tunnel and in real-life conditions. In addition, scientists can recreate accelerated degradation under weather conditions.



TECHNOLOGICAL LEVEL

stage 4: TRL 5



COMPETITION

no competition



MAIN USERS

small and medium-sized enterprises  
international corporations  
non-governmental organisations



MARKET MATURITY

the market is developing



# STREAMLINING PROCESSES



# FAST AND ACCURATE DETECTION OF HIDDEN INFORMATION SOURCES IN A COMPLEX NETWORK

We have developed a very fast and accurate algorithm for detecting primary sources of information propagation in complex networks.

## What is it about?

The method is based on the gradient analysis of network location positions, which may be sources of the signal. The algorithm operates on the basis of the maximum likelihood method and can indicate the most likely source of information having very limited input data about the presence of this information in the network. This means that to find the origin of information, it is not necessary to track its entire route, which is often impossible. To run the algorithm requires only a few to a dozen or so observations (node-time pairs) and knowledge of the connections within the network.

## Technology creators:

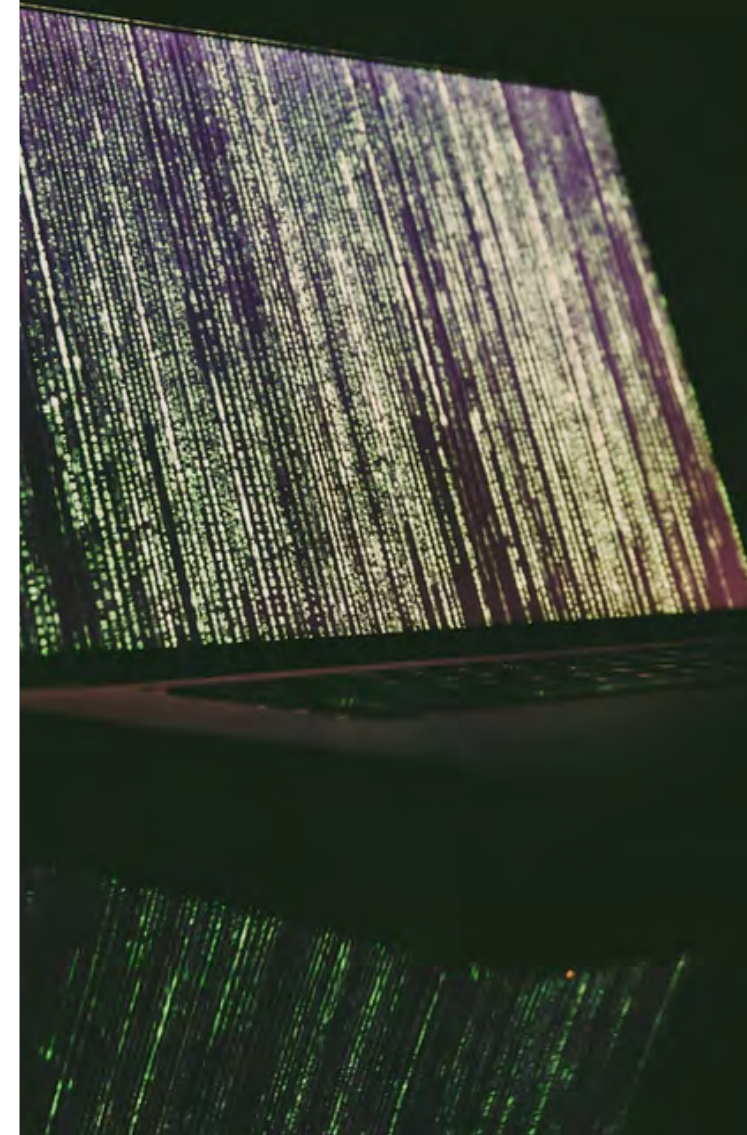
- » Prof. Janusz Hołyst, PhD, DSc  
(Center of Physics in Economics and Social Sciences, Faculty of Physics, WUT)
- » Robert Paluch, PhD  
(Center of Physics in Economics and Social Sciences, Faculty of Physics, WUT)
- » Krzysztof Suchecki, PhD  
(Center of Physics in Economics and Social Sciences, Faculty of Physics, WUT)

## Features which make this solution stand out from competing solutions

The advantage of this method is its low computational complexity and the resulting speed, which makes it possible to find sources even in networks composed of millions of nodes.

## Application

An example application can be locating the centre of an epidemic (with localities as nodes) or an undisclosed source of fake news (with social media users accounts as nodes).



## TECHNOLOGICAL LEVEL

stage 1: idea/concept



## COMPETITION

little competition



## MAIN USERS

small and medium-sized enterprises



## MARKET MATURITY

the market is developing



# GTS-LOG: MODULE FOR EFFICIENT TIME SERIES CREATION FROM TEXT LOGS USING GPU

In many computer systems, elements of distributed infrastructure report their state to the central monitoring location in the form of text log entries. Such logs may contain billions of entries, which must be processed into numerical information and recorded in a time series database in real time. This is usually handled by distributed processing systems based on the map-reduce method, which provide good scalability to multiple machines, making it possible to reach the required performance.

What is it about?

The use of our module for efficient time series creation from text logs using GPU (GTS-LOG) allows eliminating complex and expensive architecture to obtain the required performance on a single machine equipped with a processing unit. This solution leads to obvious savings on energy consumption, space and personnel costs. Our solution has been tested on a real-world case in an industrial-like environment, where it has proven its extremely high performance which greatly exceeds that of other solutions of its type. In particular, the system can adapt textual data and IP addresses and pair numbers with a performance of up to tens of millions of matches per second.

Technology creators:

- » Krzysztof Kaczmarek, PhD (Department of Information Processing Systems, Faculty of Mathematics and Information Science, WUT)
- » Stanisław Piotrowski, MSc (WUT)
- » Artur Niewiadomski, BEng (WUT)

Processing entire lines of text logs can be performed at 10 million lines per second on a single GPU. The system's architecture is designed in such a way that its performance may increase with multiple GPUs installed on a single machine.

Application

The GTS-LOG module can be used in every place where the processed data is collected in the form of text logs, whereas the format of these logs is of minor importance. The greatest advantage of the system is its speed, which means that it will be especially helpful for applications where real-time data processing is required, in monitoring systems, IoT, telecommunications, content distribution, etc.

Features which make this solution stand out from competing solutions

GTS-LOG has a broad range of configuration options for various file fields in the Apache Log format and an extremely high textual data processing speed.



**TECHNOLOGICAL LEVEL**  
stage 4: TRL 4-6



**COMPETITION**  
little competition



**MAIN USERS**  
large companies



**MARKET MATURITY**  
the market is at a mature stage of development

# BALTICLSC: COMPUTATION POWER FOR SMES

Scientists and businesspeople from eight states of the Baltic Sea Region are implementing the project BalticLSC (Baltic Large-Scale Computing), which is meant to improve the effectiveness of using high computing power. Warsaw University of Technology is the consortium leader. The project's objective is to support innovative activities, particularly among small and medium-sized enterprises, but also to use the computing power surplus of large companies. According to a report by PRACE (Partnership for Advanced Computing in Europe), the European Union loses 2–3% of its GDP every year due to delays in using modern computation methods. In the countries of our region these indicators are even worse. Thanks to BalticLSC, the situation is starting to improve.

What is it about?

The project creators focus on three main areas – providing computing power to those who need it, indicating the areas, where this power could significantly improve the competitiveness of companies, and managing excess power to the benefit of suppliers. The BalticLSC system would allow the creation of an appropriate network of connections.

Application

Businesses and institutions, which do not have sufficient knowledge about large-scale computation and access to high computational power will be given tools which facilitate defining problems and an infrastructure that accelerates obtaining the results needed.

Technology creators:

- » Michał Śmiałek, PhD, DSc, Eng.  
(consortium coordinator and project creator)
- » Kamil Rybiński, PhD, Eng.
- » Krzysztof Marek, MSc, Eng.
- » Radosław Roszczyk, PhD, Eng.
- » Marek Wdowiak, MSc, Eng.
- » Bartosz Sawicki, PhD, DSc, Eng.

(Faculty of Electrical Engineering WUT)

Businesses with appropriate hardware that has been used in a limited way will also take advantage of the system. The available computing potential will be offered to others.

As a target, BalticLSC also assumes the development of a business model that will ensure the effective use of the system. The project's outputs will not be solely commercial. It is expected to include a variety of financing methods and support non-profit organisations and public administration bodies. It will also be open to cooperation with new companies and institutions.

How it works?

A computer can generate a specific number of computing operations per second. This number is defined as its computing power. An "ordinary" computer can compute several to more than a dozen threads at the same time, while for supercomputers this number reaches hundreds and even thousands. Computers can also be joined into clusters and extended ad infinitum. It is this ability to join computers that will be the power of the consortium led by the Warsaw University of Technology. The consortium is composed of universities and institutes from Sweden, Latvia, Germany, Denmark, Lithuania, Finland and Estonia.

Scientists from the WUT are responsible for the coordination of all project works. They are also developing the software.

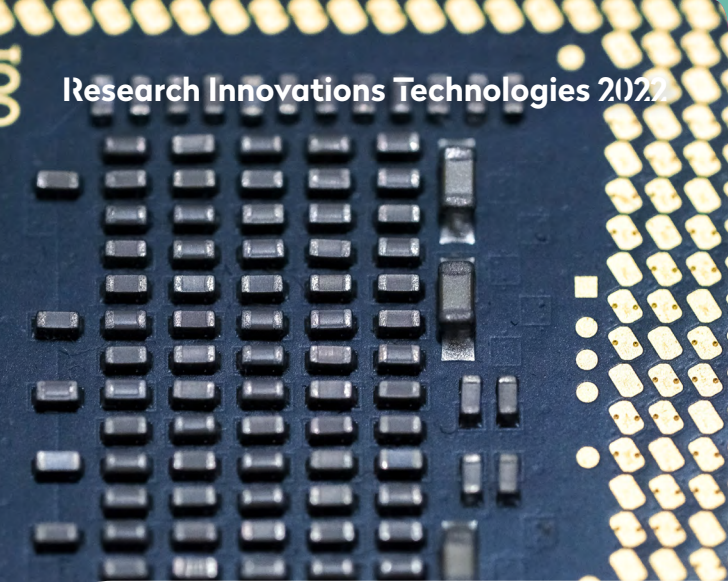
The challenge is to design the software in a way that allows it to make computations on thousands or millions of computers at the same time, which the project creators call parallelisation.

Application in practise

An example application is described in the following case study. A shipyard is designing a new yacht hull and the engineers are setting the optimisation parameters and checking their values in simulation programmes. For example, a narrow hull is found to be fast but unstable, and a wider one is more stable, but also slower. As there are thousands of parameters, there are also millions of cases to compute. Under traditional conditions, simulating all the variables would take weeks or even months. Thanks to BalticLSC it is possible to compute many different variants at the same time. It is enough to upload the task and it will be sent to the available computers, which will compute the solution within a few hours. No experience in large-scale computations or even programming skills will be needed to use the system, as this aspect will be handled by the project team members. The project has use cases in classical engineering, but also in such popular fields as data mining, machine learning and big data.

Features which make this solution stand out from competing solutions

The BalticLSC system is distinguished by its low-code approach to creating computation applications, which significantly accelerates the process of moving from concept to implementation. Access to and management of large-scale computing resources is available with an easy-to-use web portal. At present, no other system with similar features has been identified. There are numerous HPC (high performance computing) and cloud computing solutions, but they do not have the features provided by our system (access for SMEs, low-code approach, etc.).



TECHNOLOGICAL LEVEL

stage 4: TRL 4-5, the technology has been validated in laboratory and near real-world environment



COMPETITION

no competition there is no known system with similar properties



MAIN USERS

SME micro-enterprises small research centres



MARKET MATURITY

the market is being created (computing resources marketplace using the low-code approach)

the market is at a mature stage of development (the market for access to HPC services is mature)



# IMPROVING PRODUCTION PROCESS EFFICIENCY USING MATHEMATICAL MODELLING

The presented solution concerns the mathematical modelling of production processes and constitutes an innovative approach to improving the efficiency of production processes using computer programs.

What is it about?

As part of its operations, the Team focuses on:

- developing mathematical models of processes, including simulation models using the available information technology tools,
- developing dedicated algorithms for optimising processes using selected information technologies for their implementation,
- conducting computation or simulation experiments on the developed models and algorithms, as elements assisting in making business decisions,
- implementing the obtained results in enterprises and organisations.

Technology creators:

- » Cezary Szwed, PhD  
(Department of Production, Processes and Project Management, Faculty of Management, WUT)
- » Justyna Smagowicz, PhD  
(Department of Production, Processes and Project Management, Faculty of Management, WUT)

In addition, the Team carries out work which involves the following:

- constructing models of business processes using the simulation approach for managing these processes,
- constructing models of critical processes in enterprises and organisations to prepare contingency plans.

Features which make this solution stand out from competing solutions

The innovative nature of the operations results from the application of frontier information technologies for the complete digitalisation of the studied processes, including production processes. The tools used assist in the construction of adequate simulation models and optimisation algorithms for solving production problems.

Application

The proposed approach may be used in the management of production, logistics and services, enhancing business processes and maintaining their continuity. It can be used in both discrete and continuous processes, e.g. in the energy sector.



**TECHNOLOGICAL LEVEL**  
stage 1: idea/concept



**COMPETITION**  
little competition



**MAIN USERS**  
small and medium-sized enterprises



**MARKET MATURITY**  
the market is developing



# HERITAGE IMAGING — AUTOMATING 2D/3D DIGITISATION

## What is it about? Features which make this solution stand out from competing solutions

Heritage Imaging is a spatial documentation of cultural heritage objects. The automation and objectification of the process of three-dimensional documentation of historic objects at high resolution is still an unsolved problem. In the light of the emerging needs, both in Poland and abroad, our automated solutions are an attractive alternative to manual processes in which the system operator must manipulate the object or 3D scanner by hand to capture the whole surface of complex objects.

## How it works?

The project creators use computer-controlled manipulators, such as industrial robot arms, linear tables and turntables to automate the measurement sequences performed from multiple directions.

In most cases, the measurement technique used involves scanners with structured light developed at the Faculty of Mechatronics of the Warsaw University of Technology. These devices are specifically adapted to the 3D scanning of surfaces of historic objects which are sensitive to both the amount of energy and its spectrum.

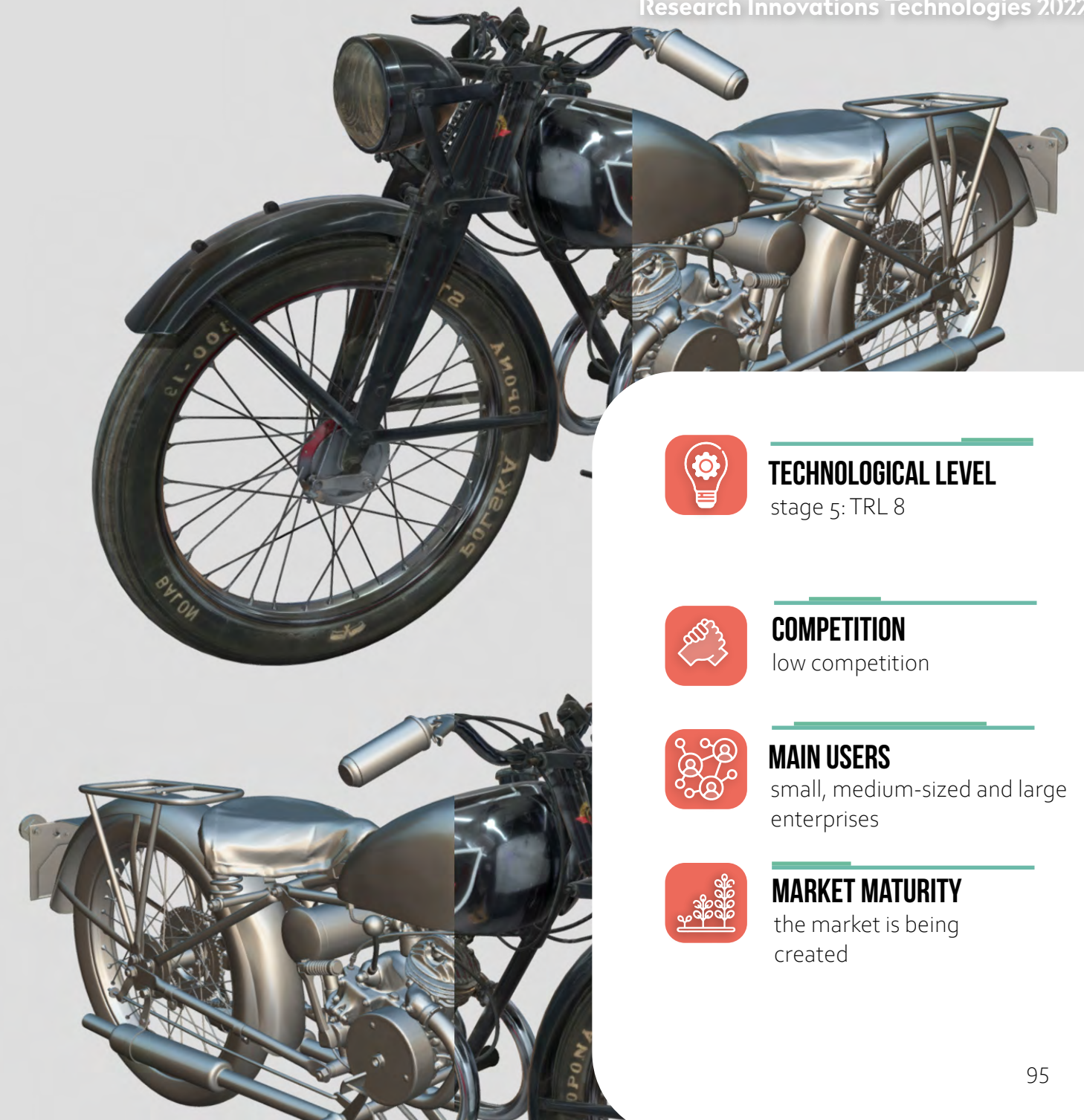
## Technology creators:

- » Prof. Robert Sitnik, PhD, DSc, Eng. (Institute of Micromechanics and Photonics, Faculty of Mechatronics, WUT)
- » Eryk Bunsch, Master of Fine Arts (certified art restorer, Faculty of Conservation and Restoration of Works of Art, Academy of Fine Arts in Warsaw)
- » Heritage Imaging Sp. z o.o.

## Application and services

The project creators can also provide comprehensive support for digital documentation processes of cultural heritage objects, using both 2D and 3D techniques, starting from the project planning stage, through implementation, to archiving and assistance in using results. The team also has experience in planning 2D and 3D digitisation processes, taking into account such elements as:

- creating strategies of digitisation activities for cultural institutions,
- determining the technical requirements that meet the assumed project objectives for different recipients (art conservation, education or promotion departments)
- specifying the requirements regarding the accuracy of the obtained measurement data and quality control methods,
- monitoring the process of producing digital documentation at all stages (measuring, data processing, developing presentation models and archiving).



## TECHNOLOGICAL LEVEL

stage 5: TRL 8



## COMPETITION

low competition



## MAIN USERS

small, medium-sized and large enterprises



## MARKET MATURITY

the market is being created



# INTERNET OF THINGS — FROM PHOTOS TO CUSTOM CLOTHING

With each year, an increasing number of people order products online. However, ordering perfectly fitting clothes without leaving your home is quite a challenge. For many people it is difficult to find suitable clothing. This is due to various reasons, either on their part, or independent of them.

## What is it about?

The proposed technology will allow them to easily choose clothes fit for their body and physical features. The automatic measurement of the human body on the basis of its photographs is possible by using advanced 2D/3D image information processing, machine learning algorithms and trained neural networks.

## How it works?

The metric correctness of the obtained dimensions is ensured by a mobile calibration scale against which the user takes photographs. The required measurements are made on the basis of correlations of shape indicators applied to 2D photographs with the actual dimensions obtained from a database of human body 3D scans.

## Technology creators:

- » Łukasz Markiewicz, MSc, Eng.  
(Institute of Micromechanics and Photonics, Faculty of Mechatronics, WUT)
- » Prof. Robert Sitnik, PhD, DSc, Eng.  
(Institute of Micromechanics and Photonics, Faculty of Mechatronics, WUT)

## Application

This solution is addressed at large enterprises selling clothes online. This tool could lead to reduced consumption in the clothing industry, resulting in lower use of the produced materials that have a considerable effect on the natural environment. A direct benefit for clothing companies will also be a reduction in the number of products returned, lower logistics costs and increased brand confidence. Consumers will be able to minimise the number of thrown away and ill-fitting clothes.

## Features which make this solution stand out from competing solutions

Measurements on the basis of a photograph of a person against a special pattern background. The measurement accuracy of a 3D scanner in every home.



## TECHNOLOGICAL LEVEL

stage 4: TRL 4-6



## COMPETITION

high competition  
distinguished by a unique  
approach to measuring



## MAIN USERS

large enterprises selling clothes  
online



## MARKET MATURITY

the market is developing

# SUSTAINABLE INDUSTRY 4.0 — ADVISORY MODEL

The research involves developing a model which describes the relationships between Industry 4.0 and sustainable development.

**What is it about?**

This model can be used as a basis for providing advisory services involving organisational diagnosis and identification of specific areas of improvement connected with sustainable development and the tools and technologies of Industry 4.0 which may contribute to this improvement, along with a detailed evaluation of the suggested changes in the financial, environmental and social contexts.

In addition, the conducted analysis will make it possible to identify the best practices and, if needed, provide a programme for implementing the selected elements of the model.

**Technology creators:**

- » SUSTAIN 4.0 Research Group  
(Institute of Production Systems Organization,  
Faculty of Mechanical and Industrial  
Engineering, WUT)

**Application**

It is expected that the parties interested in using the model will include both industrial enterprises and service providers, as well as public administration bodies responsible for promoting and developing the Industry 4.0 concept and sustainable development in Poland.

**Features which make this solution stand out from competing solutions:**

- speed of service,
- flexibility of operation,
- highest quality of services,
- availability of the team.



**TECHNOLOGICAL LEVEL**  
stage 1: Idea/concept



**COMPETITION**  
little competition



**MAIN USERS**  
small and medium-sized enterprises  
large enterprises  
international corporations



**MARKET MATURITY**  
the market is developing





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