Lodz University of Technology

JASTRZĄB
Porozumienie Centrów Badawczych Bezpieczeństwa i Obronności Cywilnych Uczelni Technicznych

AREAS OF COMPETENCE AND DEVELOPMENT WORKS

FOR STATE DEFENSE AND SECURITY APPLICATIONS



September 2026

Dear Readers

We invite you to explore the updated catalogue of technologies developed at Lodz University of Technology and intended for rapid deployment in support of national security and defence. These technologies have been selected from among the many practical outputs of the research currently conducted at our University. They demonstrate strong potential for implementation and may be applied as dual-use solutions.

The technologies presented are aligned with the objectives set out in the document Priority Directions for Scientific Research in the Ministry of National Defence for 2021–2035, published by the Innovation Department of the Polish Ministry of National Defence. They address the needs of the Polish Armed Forces in strengthening national research capabilities and developing advanced technologies for national security.

The current geopolitical situation calls for an intensified search for new and innovative technologies, particularly disruptive technologies that may find applications in the defence sector. Such technologies are developed not only at military research centres, but also at civilian research institutions. For this reason, in 2022, Lodz University of Technology established the Defence and Security Research Centre, with a mission to bring together the University's research groups around issues related to defence and security in the broadest sense.

The significant research and scientific potential of civilian technical universities in the field of dual-use technologies has also encouraged other academic institutions to strengthen their cooperation within the "Jastrząb" Alliance of Research Centres for Defence and Security Technologies of Civilian Universities of Technology. The Alliance currently brings together seven universities: Bialystok University of Technology, Poznan University of Technology, Lodz University of Technology, Rzeszow University of Technology, Silesian University of Technology, Kielce University of Technology, and Warsaw University of Technology.

The purpose of the "Jastrząb" Alliance is to integrate interdisciplinary research groups from different academic centres and to promote new, innovative and breakthrough solutions in the fields of defence and security. The initiative remains open to all civilian universities of technology in Poland. Lodz University of Technology has the honour of chairing the "Jastrząb" Alliance during the current term of office.

By placing this catalogue in your hands, we hope to establish new and develop existing forms and areas of cooperation in research and development, both through bilateral relations and within the framework of the "Jastrząb" Alliance. Such cooperation is intended to facilitate rapid deployment of dual-use technologies developed in Poland and based predominantly on Polish engineering expertise, which should make a significant contribution to strengthening the country's defence capabilities.

We invite you to explore the catalogue and join us in cooperation.



prof. dr hab. inż. Krzysztof Jóźwik
Rector of Lodz University of Technology

Table of contents

Textiles and textronics

1. SPARTAN Personalized protective clothing system with active heating 6
2. Textronic clothing with integrated toxic substance detection sensors 7
3. Hybrid yarn for protection against electromagnetic radiation 8
4. 3D composite fire barrier 9
5. Textile impact barriers for critical infrastructure protection 10
6. Textile charger for electronic devices 11
7. Smart adaptive camouflage for military concealment systems 12
8. Functional textiles using physical vapour deposition (PVD) technology 13
9. BioProtect textiles – eco-friendly insectrepellent textiles for health protection and user comfort 14
10. Fire-resistant and thermal insulation biocomposites from renewable natural fibres 15

Optoelectronics

11. Low-power infrared systems for remote applications 16
12. Infrared systems for remote gas detection and identification 17
13. Infrared systems for non-destructive testing of composites and multilayer structures 18
14. VCSEL arrays for LiDAR and spatial scanning systems 19
15. VCSEL emitters for optical communications and data transmission 20
16. Anti-reflective coatings for optical systems 21
17. Thermal imaging system for monitoring and diagnosing military vehicle braking systems 22

Electromagnetism - shelding and detection

18. Hybrid textile FSS structures for characterizing electromagnetic radiation absorption 23
19. Textile antennas for communication systems 24
20. Thin-film composites for electromagnetic shielding 25
21. Textile – polymer electromagnetic radiation shielding materials 26

Unmanned systems

22. LUMI_DROP – autonomous mini-UAV swarm deployment system 27
23. Variable-pitch propeller drive for VTOL unmanned aerial vehicles 28
24. Drone interceptor – low-cost high-speed UAV platform for airspace defence 29
25. Modular gripper for unmanned aerial vehicles 30
26. Multi Domain Tracking and Localization System (MDTLS) 31
27. Enhanced Vision Localization – advanced vision localization system 32
28. Oil-free blower for fuel cell systems and aircraft air systems 33

Advanced new materials and coatings

29. High-strength surface layers for precision mechanical components 34
30. Elastomer seals for dry-running applications 35
31. Fire- and heat-resistant rubber products 36
32. Low-friction coatings for unmanned aerial vehicle engines 37
33. Parylene coatings for electronics protection 38
34. Rubber for arctic applications 39
35. Wear-resistant surface layers for armament components and drive systems 40
36. Hardened surface layers for high-load gears and drive systems 41

Biomedical engineering and biotechnology

37. Wound dressing materials for battlefield trauma care 42
38. Bioactive coatings for textile materials 43
39. VR system supporting post-traumatic stress disorder (PTSD) therapy 44
40. Effervescent orodispersible tablets containing green coffee, providing prolonged stimulation and supporting concentration 45
41. Tea resin concentrate for functional beverages 46
42. Platform for probiotic and postbiotic formulations 47

1. SPARTAN Personalized protective clothing system with active heating

K22 – Department of Microelectronics and Computer Science

Challenge
Prolonged exposure to low temperatures and adverse weather conditions can impair personnel's psychophysical performance. Maintaining optimal thermal comfort is crucial for the safety and effectiveness of task performance.

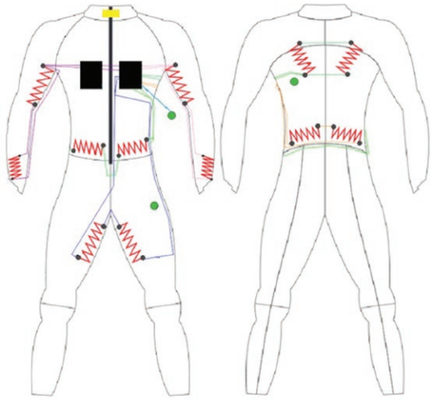
Technology overview
SPARTAN is a personalized protective clothing system with active heating and intelligent temperature management. It automatically adjusts heating parameters to environmental conditions and the user's needs, supporting task performance in demanding environments.

Key advantages of the technology
- Intelligent temperature control
- Automatic adjustment of heating parameters to operating conditions
- System personalization based on the user's needs
- Integration with a mobile app and smartwatch
- Use of artificial intelligence to support system management
- Technology validated under real-world operating conditions

Current technology readiness level
TRL 9 – The technology has been deployed and validated under real-world operating conditions for mountain rescue teams. It is ready to be adapted for additional user groups.

Implementation potential
The technology enables active heating systems to be integrated into specialized protective clothing and tailored to the requirements of uniformed and emergency services.

Developed by
Department of Microelectronics and Computer Science at Lodz University of Technology, in cooperation with the Central Institute for Labour Protection – National Research Institute and PSA Małachowski.



General layout of the system components.



Outer suit.



Mobile app (with an artificial intelligence module) for controlling the heated clothing.

2. Textronic clothing with integrated toxic substance detection sensors

I41 –Institute of Architecture of Textiles

Challenge
Personnel operating in environments where toxic substances may be present require rapid and continuous information about emerging hazards. Conventional detection systems typically require users to carry additional equipment, potentially restricting users' mobility.

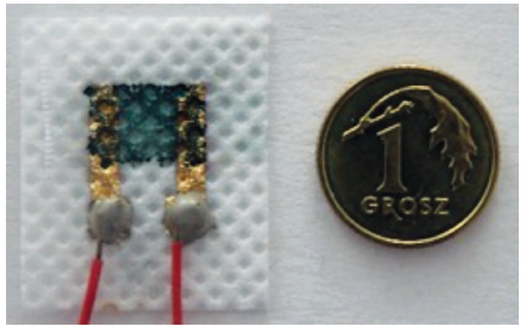
Technology overview
The technology integrates chemical sensors into protective clothing, enabling real-time monitoring of the presence of toxic gases and vapours from organic liquids. The technology ensures continuous monitoring of environmental conditions without the need for additional measuring instruments.

Key advantages of the technology
- Integration of sensors into protective clothing
- Continuous monitoring of the operating environment
- Detection of toxic gases and vapours from organic liquids
- Integration with monitoring and alarm systems
- Ergonomic design that does not compromise user comfort

Current technology readiness level
TRL 4 – The technology is currently undergoing laboratory testing. TRL 7 is expected to be achieved following the development and validation of a prototype.

Implementation potential
The technology enables sensors to be integrated into protective clothing and equipment used by uniformed and emergency services.

Developed by
Institute of Architecture of Textiles, Lodz University of Technology.



Example of a gas sensor fabricated using digital printing.



Prototype workwear with replaceable sensor and electronic circuitry.

3. Hybrid yarn for protection against electromagnetic radiation

I42 – Textile Institute

Challenge

Electromagnetic radiation can interfere with electronic devices and communication systems, reducing their reliability in both civilian and military applications, which creates a need for materials that provide effective protection against electromagnetic radiation.

Technology overview

The technology involves the development of a hybrid yarn based on a fancy-yarn construction concept, designed for manufacturing fabrics that protect against electromagnetic radiation. The solution enables the use of different weft structures to enhance the electromagnetic shielding effectiveness of fabrics.

Key advantages of the technology

- Novel hybrid-yarn concept based on a fancy-yarn construction
- Ability to engineer fabrics using various weft arrangements
- Shielding effectiveness of up to 69 dB at 370 MHz
- Electric charge induction detected only at 30 MHz
- Effectiveness confirmed by laboratory testing

Current technology readiness level

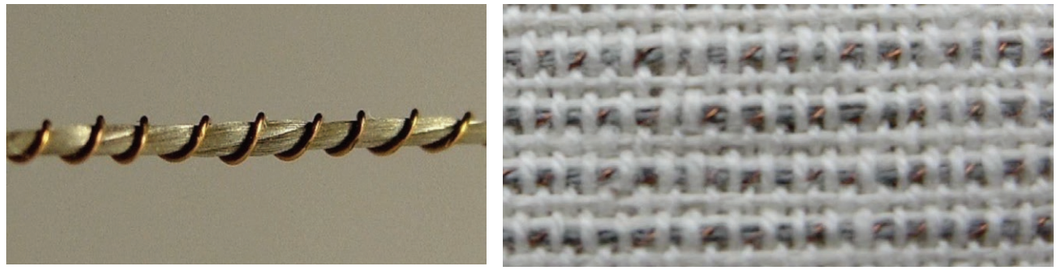
TRL 7 –A technology prototype has been developed and validated under laboratory conditions. The target technology readiness level is TRL 9.

Implementation potential

The technology enables the production of fabrics with shielding properties for use in protective clothing and other applications where protection against electromagnetic radiation is required.

Developed by

Textile Institute, Lodz University of Technology.



Hybrid yarn for electromagnetic induction.

Textiles and textronics

4. 3D composite fire barrier

I42 – Textile Institute

Challenge

Effective protection against the spread of fire requires solutions that not only provide a barrier against flames but also actively support fire suppression. This is particularly important for protecting infrastructure and public facilities, as well as for military and emergency response applications.

Technology overview

The technology comprises a composite fire barrier based on a 3D spacer fabric with a sandwich structure. The barrier incorporates channels for transporting a fire-extinguishing agent and an activation system triggered when a fire hazard is detected. The solution combines the function of a passive fire barrier with an active system that limits the spread of fire.

Key advantages of the technology

- 3D spacer fabric with a sandwich structure
- Integrated channels for transporting a fire-extinguishing agent
- Automatic activation of the fire suppression system upon hazard detection
- Resistance to temperatures exceeding 1,200°C
- Structure designed for integration with an active fire suppression system

Current technology readiness level

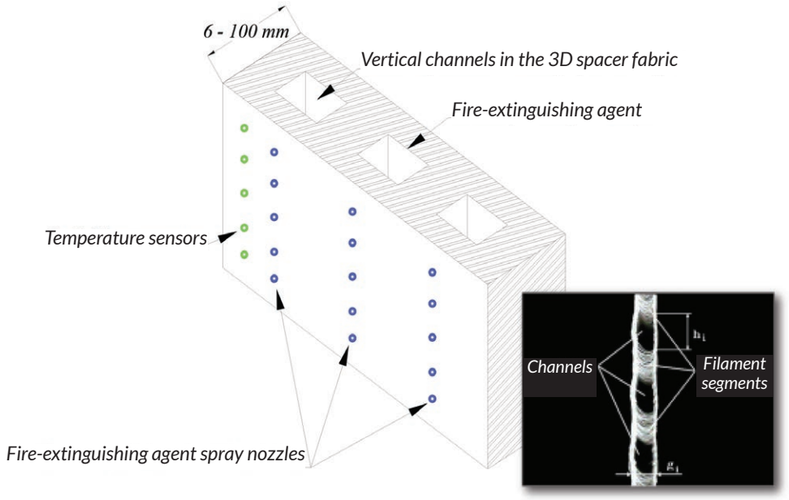
TRL 3 – The research project has been initiated. TRL 4 is expected upon completion of the first stage of research.

Implementation potential

The technology enables the development of lightweight, mobile fire barriers for protecting infrastructure and temporary facilities, as well as for establishing safety zones during emergency response and military operations.

Developed by

Textile Institute, Lodz University of Technology.



Conceptual diagram of an active 3D textile fire barrier.

5. Textile impact barriers for critical infrastructure protection

I42 – Textile Institute

Challenge
Modern threats to critical infrastructure and military and civilian facilities require new solutions capable of mitigating the effects of impacts from vehicles and airborne objects, including unmanned aerial vehicles (UAVs).

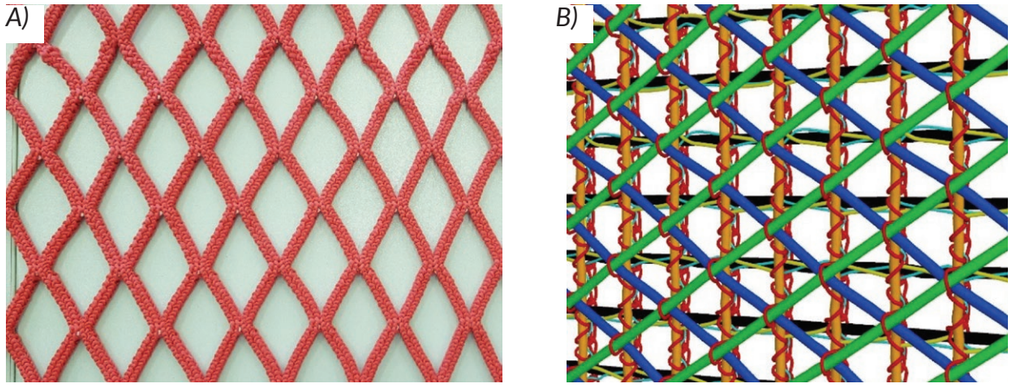
Technology overview
The technology comprises multilayer impact barriers made from textile nets manufactured using yarns and ropes. Their multilayer structure enables the barriers to absorb impact energy effectively, providing a lightweight alternative to conventional steel barriers.

Key advantages of the technology
- Multilayer structure made from knitted textile nets
- More than seven times the dynamic strength of steel mesh
- Capacity to absorb impact energy of up to 7,000 kJ
- Ability to stop a 10-tonne vehicle travelling at 120 km/h
- Resistance to chemical and biological corrosion

Current technology readiness level
TRL 3 – The research project has been initiated.
TRL 4 is expected upon completion of the first stage of research.

Implementation potential
The technology enables the development of lightweight protective barriers to protect critical infrastructure and military and civilian facilities against impacts from vehicles and unmanned aerial vehicles.

Developed by
Textile Institute, Lodz University of Technology.



Examples of mesh impact barrier structures:
A) a physical barrier with a biaxial reinforcement system,
B) a barrier with a quadriaxial reinforcement system.

6. Textile charger for electronic devices

I42 – Textile Institute

Challenge
The growing number of portable electronic devices and personal electronic equipment is driving the need for independent power sources that reduce reliance on conventional batteries and portable rechargeable batteries.

Technology overview
The technology uses a textile structure made from a hybrid yarn combining a ferromagnetic element with an electrically conductive yarn, enabling electrical energy to be harvested through electromagnetic induction. Energy can be obtained both from electromagnetic fields in the surrounding environment – including GSM, Wi-Fi and radio transmitters – and from an electromagnetic field generated by the movement of permanent magnets integrated into the user's clothing or equipment.

Key advantages of the technology
- Hybrid yarn combining a ferromagnetic element with an electrically conductive yarn
- Energy harvesting from electromagnetic fields present in the surrounding environment
- Energy harvesting from the user's movement using permanent magnets
- Integration into the user's clothing and equipment
- Power supply for portable electronic devices without conventional batteries or power banks

Current technology readiness level
TRL 4 – A prototype textile charger was developed, and the feasibility of achieving the specified functions under laboratory conditions was confirmed.

Implementation potential
The technology enables textile energy-harvesting systems to be integrated into the user's clothing and equipment, providing power for portable electronic devices and personal electronic equipment.

Developed by
Textile Institute, Lodz University of Technology.

7. Smart adaptive camouflage for military concealment systems

K41 – Department of Mechanical Engineering, Informatics and Chemistry of Polymer Materials

Challenge

Conventional camouflage relies on static patterns that become less effective under changing conditions and against modern reconnaissance and detection systems. Developing materials capable of adaptively changing their optical properties could significantly improve concealment effectiveness and user safety.

Technology overview

The technology enables the production of camouflage materials capable of changing colours in response to UV radiation and temperature. This effect is achieved by combining conventional textile-dyeing methods with a layered printing technique using screen printing and photochromic and thermochromic pigments.

Key advantages of the technology

- Adaptive adjustment of camouflage to changing environmental conditions
- Improved concealment effectiveness and maintenance of a tactical advantage in dynamic operational environments
- Reduced risk of detection by modern reconnaissance systems

Current technology readiness level

TRL 3 – The research project has been initiated. TRL 5 is expected upon completion of the first stage of research, followed by TRL 7 after prototype development and field-testing.

Implementation potential

The technology enables the development of adaptive camouflage materials for military clothing and specialized garments used by uniformed services.

Developed by

Department of Mechanical Engineering, Informatics and Chemistry of Polymer Materials, Lodz University of Technology.



A soldier wearing a camouflage uniform in a forest environment and an example of colour changes in photochromic-pigment-coated textiles following exposure to different doses of UV radiation.

8. Functional textiles using physical vapour deposition (PVD) technology

I42 – Textile Institute

Challenge

The diverse structures of textile materials – determined by product type, weave, areal density and raw material composition – affect the ability to produce continuous and stable functional thin films. Developing a technology capable of effectively applying coatings to materials with different structures is essential for the advancement of modern textile products.

Technology overview

The technology enables textile materials to be functionalized through the deposition of thin films using physical vapour deposition (PVD) methods, particularly magnetron sputtering. The solution under development can confer electrically conductive, electromagnetic shielding, and antimicrobial properties on textiles, and enable their use as heating elements or sensors.

Key advantages of the technology

- Application of functional thin films without significantly affecting the performance characteristics of textile materials
- Ability to provide textile materials with new functionalities
- Use of a single technology to produce materials with various functions
- Broad applicability in smart textiles, protective clothing, wearable electronics and technical textiles

Current technology readiness level

TRL 2 – The solution relies on existing research infrastructure and the team's experience in applying conductive coatings to textile materials using physical vapour deposition methods, including magnetron sputtering. Further work is going to focus on defining process parameters for different types of textile materials and developing and validating functional textile prototypes.

Implementation potential

The technology could be used in the production of smart textiles, protective clothing, wearable electronics, medical devices, technical textiles and components for the automotive and aerospace industries.

Developed by

Textile Institute, Lodz University of Technology.

9. BioProtect textiles – eco-friendly insect-repellent textiles for health protection and user comfort

I42 – Textile Institute

Challenge

During military operations, fieldwork, and outdoor activities users are exposed to mosquito bites, which reduces comfort and may increase the risk of mosquito-borne diseases. Repellents applied directly to the skin require frequent reapplication and provide protection for a limited period. There is a need for textiles that offer long-lasting repellent properties integrated directly into garments.

Technology overview

The technology functionalizes fibres in polylactic acid nonwovens using advanced carriers for active substances, enabling controlled release of a natural mosquito repellent. The technology enables active substances to be incorporated into the structure of a biodegradable nonwoven fabric and gradually released during use.
The developed prototype is intended primarily for protection against mosquitoes. The technology can be applied in textile garment components, providing convenient protection without the need to apply repellents directly to the skin.

Key advantages of the technology

- Laboratory-tested mosquito-repellent action
- Controlled release of the active substance
- Extended duration of the repellent efficacy compared with traditional repellents
- Reduced need for frequent application of repellents to the skin
- Possible integration into textile garment components
- Possible adaptation for protection against other insects, subject to further testing

Current technology readiness level

TRL 6 – A prototype textile solution for protection against mosquitoes has been developed. Further work includes expanding the scope of testing, confirming efficacy under field conditions, evaluating the durability of the repellent efficacy during use and scaling up the process of incorporating the active substance into the nonwoven structure.

Implementation potential

The technology could be used to produce clothing and protective textile components for soldiers and uniformed services personnel, workers in agriculture, forestry, environmental protection and infrastructure construction, tourists and travellers, trekking, camping, and fishing enthusiasts, other individuals spending extended periods in areas with high mosquito activity. Subject to further research, the solution could also be adapted to provide protection against other insect species.

Developed by

Textile Institute, in cooperation with an international insect-rearing laboratory.

10. Fire-resistant and thermal insulation biocomposites from renewable natural fibres

I41 – Institute of Architecture of Textiles

Challenge

The growing demand for materials produced from renewable resources is driving the search for solutions that combine a reduced environmental impact with specialized performance properties. A particular challenge is the development of lightweight biocomposites that use natural fibres while providing fire resistance, thermal insulation, and adequate mechanical strength.
Such materials could replace conventional components in applications including aircraft structures, vehicles, construction, and drone components such as motor covers used during firefighting operations.

Technology overview

The technology involves the development of biocomposites based on renewable natural fibres such as flax, hemp, and wool. Appropriate selection of fibres, matrix materials and production processes makes it possible to obtain materials with enhanced fire resistance and thermal insulation properties without additional chemical modifiers.
The solution is intended for applications which require lightweight structural materials with high performance parameters, including components for unmanned aerial vehicles used in firefighting operations.

Key advantages of the technology

- Provides fire resistance, thermal insulation, and good mechanical properties while remaining lightweight
- Uses renewable natural fibres
- Reduces need for chemical modifiers
- Aligned with circular economy principles and recycling potential

Current technology readiness level

TRL 3 – A preliminary biocomposite concept has been developed and its key properties have been confirmed through material testing. The next stages are going to involve prototype development, validation, and application testing, leading towards TRL 7.

Implementation potential

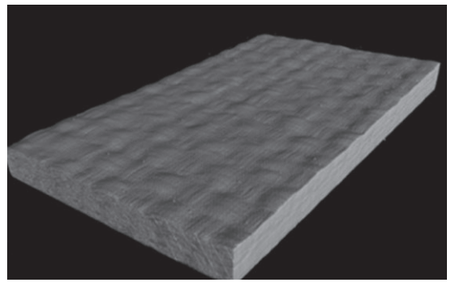
The technology could be used in the aerospace sector and unmanned aerial systems, including components for drones deployed in firefighting operations. It also has potential applications in the transport, automotive, and construction industries, as well as wherever lightweight materials with high fire resistance, thermal insulation properties, and good mechanical performance are required.

Developed by

Institute of Architecture of Textiles,
Lodz University of Technology.



Drone motor cover.



Composite reinforced with natural fibres.

11. Low-power infrared systems for remote applications

I23 – Institute of Electronics

Challenge
Infrared systems used on remote and autonomous platforms must provide high sensitivity and resolution while minimizing power consumption, weight, and size. This is particularly important for unmanned platforms, where the available energy directly affects mission duration.

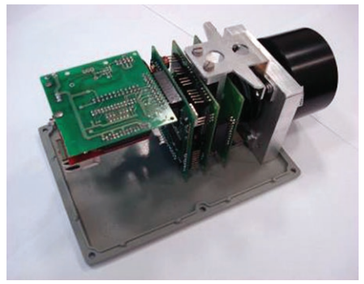
Technology overview
The technology comprises low-power infrared systems designed for integration with unmanned platforms. The solution provides the required sensitivity and resolution of radiometric systems while reducing power consumption and maintaining a low-weight and compact device size.

Key advantages of the technology
- High sensitivity and resolution with reduced power consumption
- Lightweight and compact design suitable for integration with unmanned platforms
- Interoperability with other detection systems
- Resistance to mechanical loads and damage

Current technology readiness level
TRL 5 – Thermal imaging cameras and pyrometric systems have been developed for applications including medical examinations, non-destructive testing, and gas detection. The systems use quantum and bolometric detectors – including MCT, VOx, and a-Si detectors – and offer resolutions of up to 640 × 480 pixels.
The electronics, optics, software and mechanical components require adaptation for defence and security applications.

Implementation potential
The technology enables the development of low-power infrared systems for unmanned platforms, remote observation systems, and specialized detection systems.

Developed by
Institute of Electronics, Lodz University of Technology.





Thermal imaging cameras (VOx, a-Si) developed at the Institute of Electronics, Lodz University of Technology.





12. Infrared systems for remote gas detection and identification

I23 – Institute of Electronics

Challenge
Rapid detection of toxic and explosive gas leaks is essential for the protection of critical infrastructure and the safety of emergency response and military operations. Remote hazard detection reduces risks to personnel and improves the effectiveness of monitoring in hazardous areas.

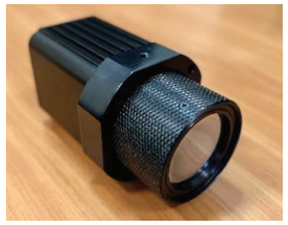
Technology overview
The technology comprises infrared systems using spectrometric imaging with interference filters for the remote detection and identification of selected gases in the infrared spectral range of 3–16 µm. The solution employs VOx bolometric detectors and cooled detectors operating in the MWIR and LWIR bands, enabling gas identification based on their characteristic spectral signatures.

Key advantages of the technology
- Remote gas detection without direct access to the source of a leak
- Identification of selected toxic and explosive gases
- Integration with mobile unmanned platforms
- Improved safety during operations conducted in hazardous areas

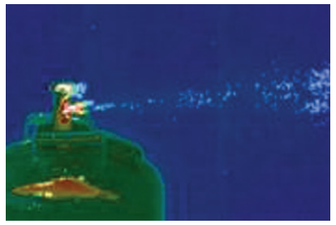
Current technology readiness level
TRL 5 – A 640 × 480 VOx bolometric thermal imaging camera operating across the 3 – 16 µm wavelength range has been developed together with dedicated software. The technology requires further software adaptation and field testing.

Implementation potential
The technology enables the development of mobile remote gas detection systems for unmanned platforms and systems for monitoring critical infrastructure, industrial facilities, and hazardous areas.

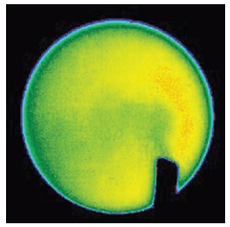
Developed by
Institute of Electronics, Lodz University of Technology.



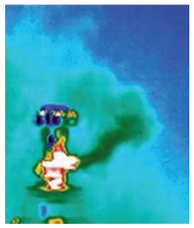
VOx3-16 µm camera



Propane butane



Carbon dioxide



Ammonia

Wideband thermal imaging camera (VOx, 3–16 µm) developed at the Institute of Electronics, Lodz University of Technology, with examples of gas detection.

13. Infrared systems for non-destructive testing of composites and multilayer structures

I23 – Institute of Electronics

Challenge

Assessing the technical condition of composites and multilayer structures requires methods capable of detecting internal defects without damaging the inspected object. Rapid diagnostics are particularly important for structures used in industry, defence and security systems, e.g. bulletproof vests, helmets, etc.

Technology overview

The technology uses thermographic non-destructive testing to detect defects, delamination, and material non-uniformities. Analysis of temperature changes over time, performed using a sensitive thermal imaging unit and dedicated software, allows for the evaluation of the condition of materials and structures without affecting their integrity.

Key advantages of the technology

- Non-invasive diagnostics of composites and multilayer structures
- Detection of defects that are not visible on the material's surface
- In-service testing without interrupting normal operation
- Diagnostics of moving machine components and personal protective equipment, including ballistic vests

Current technology readiness level

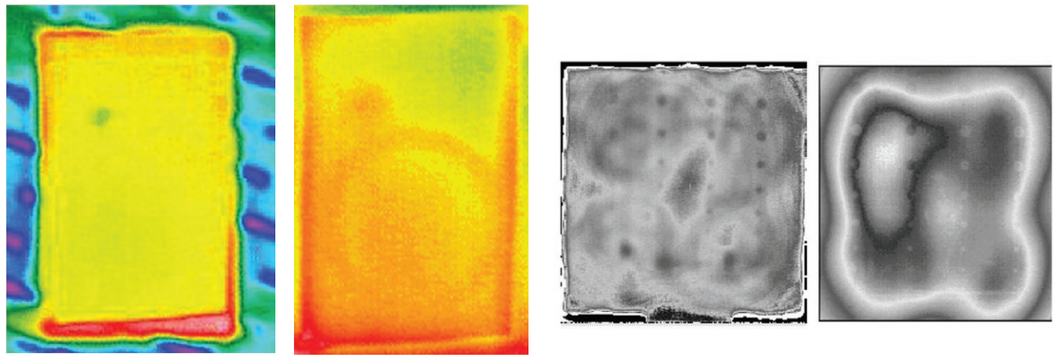
TRL 5 – Thermographic non-destructive testing systems with dedicated software have been developed for various applications such as construction – including critical infrastructure – heritage conservation, and medicine. The technology requires adaptation for defence and security applications.

Implementation potential

The technology can be used for quality control of composites and multilayer structures by manufacturers of military equipment, unmanned vehicles, ammunition, and personal protective equipment.

Developed by

Institute of Electronics, Lodz University of Technology.



Detection of subsurface defects and material inhomogeneities.

14. VCSEL arrays for LiDAR and spatial scanning systems

I71 – Institute of Physics

Challenge

Modern spatial scanning and autonomous perception systems LiDAR require compact, energy-efficient near-infrared light sources that can be easily integrated into measurement and observation devices. A key requirement is the ability to increase optical power without significantly increasing the size of the system.

Technology overview

The technology comprises two-dimensional arrays of semiconductor vertical-cavity surface-emitting lasers (VCSELs) which are a compact source of near-infrared radiation in the 760–1,060 nm wavelength range. Rather than being a complete optoelectronic system, the solution is a key emission component designed for integration with optics, detectors, control electronics, and software supplied by system partners.

Key advantages of the technology

- Miniaturized and energy-efficient light-source design
- Scalable optical power through an increased number of emitters
- Straightforward integration with modern optoelectronic systems
- Development of compact modules for mobile and unmanned platforms

Current technology readiness level

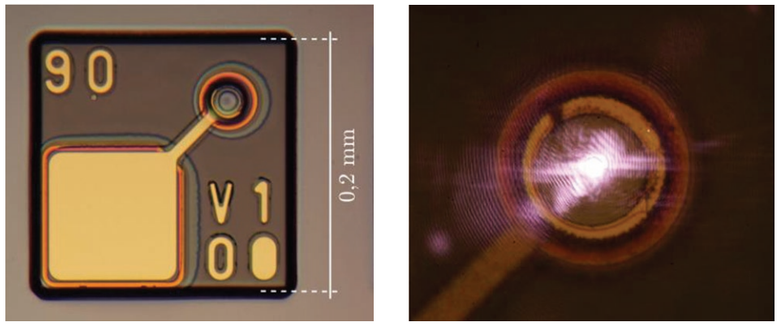
TRL 6 – VCSEL arrays emitting at a wavelength of 850 nm and delivering up to 2 W of optical power have been developed, along with demonstrators operating across the 760–1,060 nm wavelength range. Arrays designed for other wavelengths and higher power levels are currently at TRL 5 – 7.

Implementation potential

The technology could be implemented by manufacturers of LiDAR modules, spatial scanning systems, unmanned platforms, mobile robots, and autonomous systems using near-infrared radiation.

Developed by

Institute of Physics, Lodz University of Technology.



Left: photograph of a single VCSEL laser; right: photograph of the light-emitting area. Emission near the laser action threshold is visible.

15. VCSEL emitters for optical communications and data transmission

I71 – Institute of Physics

Challenge
Modern communication systems require fast and secure data transmission while minimizing device size and power consumption. This is particularly important for mobile and unmanned platforms and autonomous systems.

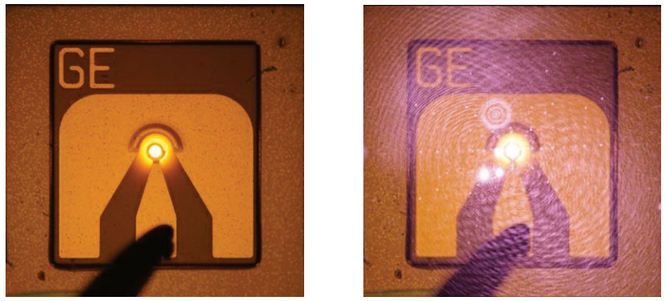
Technology overview
The technology comprises semiconductor vertical-cavity surface-emitting lasers (VCSELs) operating in the near-infrared wavelength range of 760–1,060 nm and designed for optical data transmission. The solution is an emission component intended for integration into optical communication systems, providing high-speed data transmission in a compact, low-power design.

Key advantages of the technology
- High signal modulation frequencies (exceeding 20 GHz)
- Miniaturized and energy-efficient design
- Integration with compact electronics and mobile platforms
- Fibre-optic transmission resistant to electromagnetic interference

Current technology readiness level
TRL 6 – Semiconductor VCSELs operating at a wavelength of 850 nm with efficiencies of up to 40% and output powers of up to 1 W have been developed along with data-transmission laser demonstrators offering a bandwidth of 11 GHz. For selected wavelengths and modulation frequencies exceeding 20 GHz, the technology is currently at TRL 5 – 7.

Implementation potential
The technology could be implemented by manufacturers of optical communication systems, unmanned platforms, satellites, and autonomous systems using optical data transmission.

Developed by
Institute of Physics, Lodz University of Technology.



Photograph of the laser below the lasing threshold (left) and above the threshold (right).

16. Anti-reflective coatings for optical systems

I11 – Institute of Materials Science and Engineering

Challenge
The effectiveness of observation, targeting, and optoelectronic systems depends on maximizing the amount of light transmitted through their optical components. Reflections from optical surfaces cause light losses, reducing image quality and device performance.

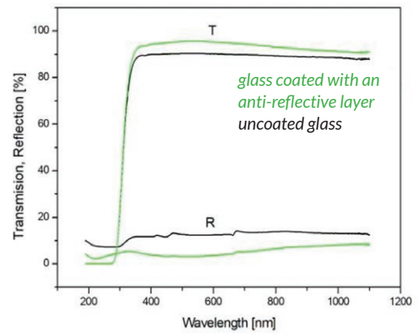
Technology overview
The technology comprises thin-film anti-reflective coatings designed for application to lenses and other optical components. The coatings reduce light losses caused by surface reflections, increasing optical transmission and improving the performance of optical systems.

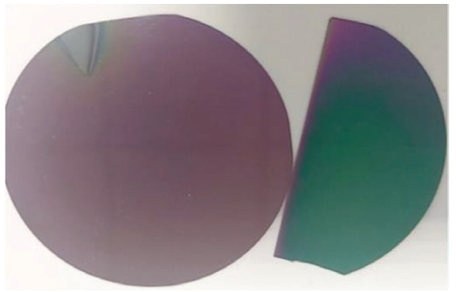
Key advantages of the technology
- Increased light transmission through optical components
- Improved image quality and observation-system performance
- Compatibility with a wide range of optical systems

Current technology readiness level
TRL 6 – A process for applying thin-film anti-reflective coatings has been developed, together with coating designs for optical components. The technology requires industrial implementation for military applications.

Implementation potential
The technology could be implemented by manufacturers of optical systems used in observation, targeting, and optoelectronic equipment.

Developed by
Institute of Materials Science and Engineering, Lodz University of Technology.





Visible-light transmittance (T) and reflectance (R) spectra for uncoated glass and glass coated with an anti-reflective coating. Photographs of coatings deposited on silicon (Si) substrates.

17. Thermal imaging system for monitoring and diagnosing military vehicle braking systems

I82 – Institute of Management

Challenge
Undetected faults in braking systems can lead to vehicle failures, increased operating costs, and risks to user safety. Effective diagnostics means abnormalities are detected before a failure occurs.

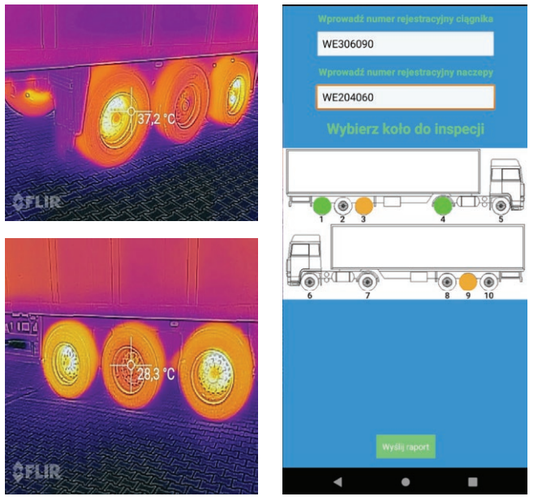
Technology overview
The technology comprises a braking-system monitoring and diagnostic solution that uses thermal imaging cameras to monitor the temperature of vehicle braking components in real time. Data analysis allows the system to detect abnormalities and predict potential faults ahead of their occurrence, which supports maintenance planning, improves vehicle operating safety, and reduces fleet maintenance costs.

Key advantages of the technology
- Ongoing monitoring of the braking system with thermal imaging system
- Early detection of abnormalities and prediction of failures
- Automated data analysis with integration into fleet management systems
- Improved operating safety and reduced vehicle maintenance costs

Current technology readiness level
TRL 7 – The project involves adapting an existing thermal imaging system for braking-system monitoring and diagnostics for use in military vehicles. The baseline solution was previously developed and deployed by a road freight transport operator. Current work focuses on adapting the technology to the requirements of selected military vehicles and validating it under operational conditions.

Implementation potential
The technology can be implemented by manufacturers of specialized and military vehicles and by fleet operators to monitor braking-system condition, plan maintenance, and reduce the risk of vehicle failure.

Developed by
Institute of Management, Lodz University of Technology.



18. Hybrid textile FSS structures for characterizing electromagnetic radiation absorption

I41 – Institute of Architecture of Textiles and I21 – Institute of Automatic Control

Challenge
Continual development of communication systems, radars, electronics, and wireless devices is increasing the level of electromagnetic interference. Applications such as protective clothing, camouflage systems, aviation, and critical infrastructure require electromagnetic waves to be selectively attenuated, transmitted or redirected. At the same time the materials must remain lightweight, flexible, and functional.

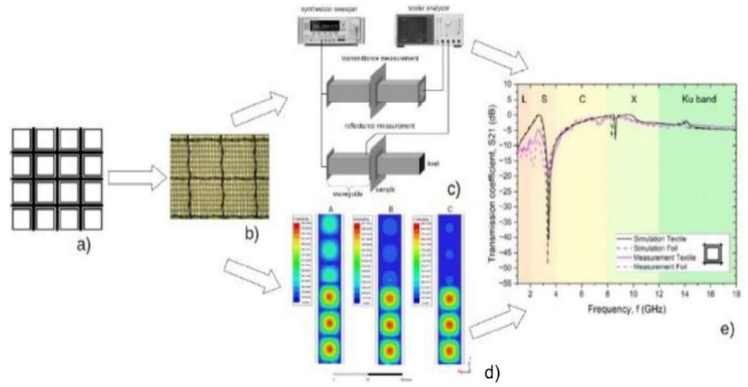
Technology overview
The technology uses textile manufacturing processes – including embroidery, weaving, screen printing and laser cutting to create conductive structures on textile substrates, forming frequency-selective surfaces (FSS). The structures are designed and optimized using numerical simulations before being manufactured and tested experimentally. The solution enables the selective attenuation, transmission or directional reflection of electromagnetic waves.

Key advantages of the technology
- Selective shielding and absorption of electromagnetic waves
- Control over the direction of electromagnetic wave reflection
- Integration of electromagnetic functions into textile materials
- Lightweight, flexible, and scalable solution adaptable to various applications
- Use of widely available textile manufacturing technologies to produce functional structures

Current technology readiness level
TRL 3-4 – FSS structure concepts have been developed, and samples demonstrating partially confirmed effectiveness have been produced. Further work is going to include the development and optimization of prototypes and their experimental validation under conditions representative of real-world use.

Implementation potential
The technology could be used in protective clothing and smart textiles, camouflage and electromagnetic-emission reduction systems, protection of electronic devices against electromagnetic interference (EMI), solutions for the aerospace and space industries, critical infrastructure protection.

Developed by
I41 –Institute of Architecture of Textiles and
I21 – Institute of Automatic Control,
Lodz University of Technology.



Design process for conductive frequency-selective surface structures:
a) structure design;
b) structure fabrication using embroidery, weaving, screen printing or laser cutting;
c) electromagnetic property testing;
d) model testing and simulation;
e) comparison of experimental and simulation results.

19. Textile antennas for communication systems

I23 – Institute of Electronics and I42 – Textile Institute

Challenge

Modern communication systems require lightweight, durable, and flexible antennas that can be integrated into uniforms and personal equipment without compromising ergonomics and mobility. Conventional antennas increase equipment weight and are susceptible to damage when used under demanding conditions.

Technology overview

The technology covers the design, fabrication, and testing of textile antennas intended for integration into uniforms, specialized clothing, and personal equipment. The developed method enables antennas to customized to the requirements of specific applications and evaluated for their electrical and functional performance. The solution can operate with personal communication and positioning systems as well as systems monitoring the user's physiological parameters.

Key advantages of the technology

- Integration of antennas into uniforms and personal equipment
- Lightweight and flexible design
- Increased resistance to in-service damage
- The possibility of integrating concealed communication systems
- Compatibility with positioning and physiological monitoring systems

Current technology readiness level

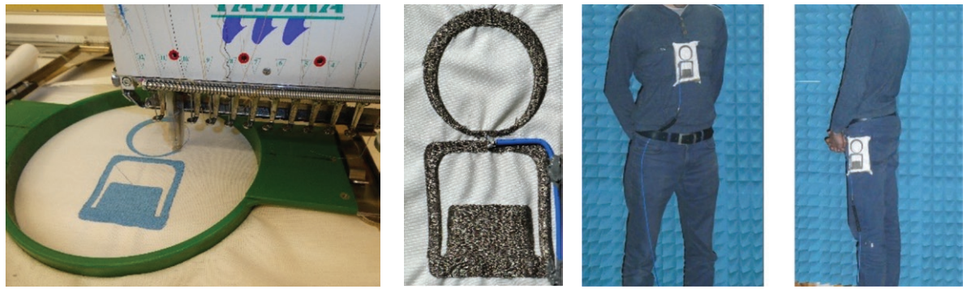
TRL 4 – A method for designing, fabricating, and evaluating textile antennas has been developed, and prototypes have been produced for selected applications. Developing an antenna for a new application requires a dedicated design, prototype development, and evaluation of its radio-frequency performance.

Implementation potential

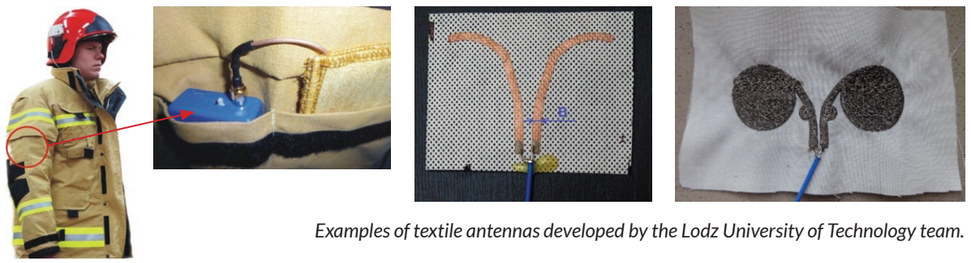
The technology could be implemented by manufacturers of uniforms, specialized clothing, wireless communication systems, and personal equipment for soldiers and uniformed services.

Developed by

Institute of Electronics, Lodz University of Technology
Textile Institute, Lodz University of Technology.



Process of fabricating an example textile antenna at Lodz University of Technology: computerized embroidery, prototype, and measurements on the human body.



Examples of textile antennas developed by the Lodz University of Technology team.

20. Thin-film composites for electromagnetic shielding

I25 – Institute of Mechatronics and Information Systems

Challenge

Electronic devices used in military and industrial systems require effective protection against electromagnetic fields and electrostatic discharge. At the same time, protective materials should withstand environmental factors while remaining thin and lightweight.

Technology overview

The technology comprises thin-film polymer-based composites containing nanomaterials, designed to protect electronic devices against electromagnetic radiation and electrostatic discharge. Selective use of nanofillers enables tailoring the electrical and shielding properties of the layers to the requirements of a specific application.

Key advantages of the technology

- Effective shielding against electromagnetic radiation
- Protection against electrostatic discharge
- Customization of the material properties through the selection of nanofillers
- Minimal weight due to the thin-film design
- Straightforward surface-modification process
- Resistance to environmental factors

Current technology readiness level

TRL 4 – The method for manufacturing thin-film composites has been developed, and one of the resulting materials has been evaluated for electromagnetic shielding effectiveness and electrical conductivity. The next stages are going to include adapting the deposition process to target applications and substrates, followed by testing of shielding effectiveness and resistance to electromagnetic-field exposure.

Implementation potential

The technology could be used to protect electronic devices operating in military systems, industrial environments, and critical infrastructure, wherever there is a need to mitigate electromagnetic radiation and electrostatic discharge.

Developed by

Institute of Mechatronics and Information Systems, Lodz University of Technology.

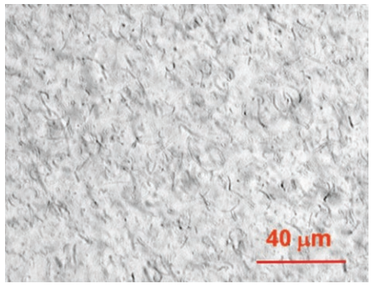


Figure 1. Microscopic image of a polymer film containing a carbon filler.

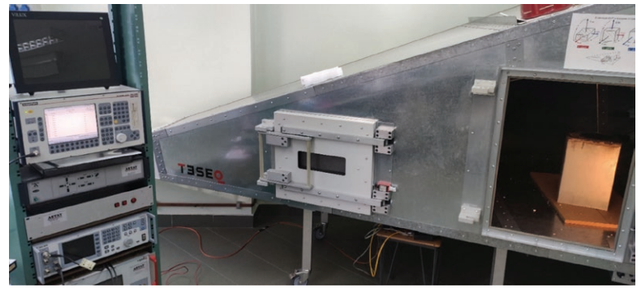


Figure 2. Testing the electromagnetic radiation shielding performance of a prototype composite layer against external sources.

21. Textile – polymer electromagnetic radiation shielding materials

I21 – Institute of Automatic Control

Challenge

The rapid development of wireless electronic equipment and communication systems operating in the GHz frequency range is increasing the exposure of equipment and personnel to electromagnetic radiation. There is a growing need for solutions that provide effective protection, while overcoming the weight and rigidity limitations of conventional metal shielding.

Technology overview

The technology comprises textile – polymer materials designed to shield against electromagnetic radiation (EMR), particularly in the radar frequency range.
The solutions may be based on woven fabrics, knitted fabrics, or nonwovens combined with metals, conductive polymers, and their composites. Manufacturing processes include screen printing, digital printing, and textile finishing processes.
A key feature of the developed materials is the fact that shielding is achieved predominantly through absorption of electromagnetic radiation rather than reflection.

Key advantages of the technology

- the shielding mechanism relies predominantly on radiation absorption
- lightweight and flexible construction compared with conventional metal shielding
- ability to use woven fabrics, knitted fabrics, and nonwovens as substrates
- ability to combine different conductive materials and application methods
- ability to design shielding structures at different levels of the product
- architecture – from fibres and yarns to the finished material

Current technology readiness level

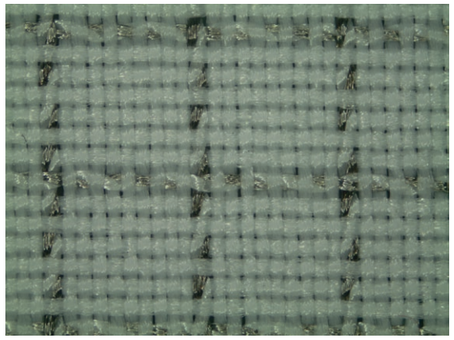
TRL 4 – different variants and prototypes of textile – polymer shielding structures have been completed and their effectiveness has been confirmed in model-based testing conducted at the Military Institute of Armament Technology in Zielonka. Currently, the prototypes are being developed further and the technology is being prepared for production.

Implementation potential

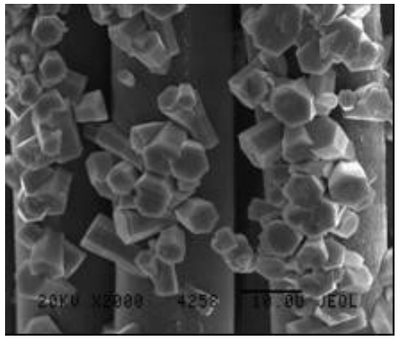
The technology can be used to protect personnel and equipment against electromagnetic radiation, reduce the electromagnetic signature of military equipment, and increase its immunity to electromagnetic radiation. Potential end users include the Air Force, Armoured Forces, Territorial Defence Forces, Border Guard, and Police.

Developed by

Institute of Automatic Control,
Lodz University of Technology.



Fabric with silver-plated conductive threads.



Microstructure of zinc oxide on the fabric surface.

22. LUMI_DROP – autonomous mini-UAV swarm deployment system

I21 – Institute of Automatic Control

Challenge

Modern military, reconnaissance and search-and-rescue missions require the rapid deployment of multiple unmanned aerial vehicles across a wide area. Conventional solutions require each unit to be launched individually, delaying mission commencement and limiting operational range.

Technology overview

The technology comprises an autonomous system for transporting and deploying a swarm of mini unmanned aerial vehicles based on a mothership-drone architecture. The platform transports the mini-UAVs to a designated area and releases them in flight.
Following deployment, the mini-UAVs automatically enter a pre-programmed operating mode and independently perform their assigned tasks without direct operator involvement.

Key advantages of the technology

- Deployment of multiple mini-UAVs, including FPV drones, during a single flight
- Extended operational range through the use of a mothership drone
- Simultaneous access to multiple target locations
- Autonomous mission execution by mini-UAVs following deployment

Current technology readiness level

TRL 5 – A prototype of the LUMI_DROP system has been developed and its operation has been validated under test conditions. Further work is going to focus on increasing the reliability and repeatability of the system's performance under real-world operating conditions.

Implementation potential

The technology could be used by search-and-rescue (SAR) units, uniformed services, emergency medical services and infrastructure protection teams, as well as in systems conducting autonomous missions using UAV swarms.

Developed by

Institute of Automatic Control, Lodz University of Technology.





23. Variable-pitch propeller drive for VTOL unmanned aerial vehicles

I13 – Institute of Machine Tools and Production Engineering

Challenge

Unmanned VTOL platforms require propulsion systems that deliver high efficiency during vertical take-off, hovering, and forward flight. Fixed-pitch propellers achieve peak efficiency only under specific flight conditions and therefore cannot provide optimal performance throughout the entire flight profile.

Technology overview

The technology comprises a propulsion system for VTOL unmanned aerial vehicles using an active or passive variable-pitch propeller mechanism. The solution adjusts the propeller geometry to different phases of flight, improving propulsion efficiency during take-off, hovering, forward flight, and landing. The mechanism can be incorporated into new UAV designs or used to upgrade existing platforms.

Key advantages of the technology

- Improved propulsion efficiency
- Up to a twofold increase in flight speed while maintaining high efficiency
- Operation across a wide range of flight speeds
- Increased rate of climb
- Reduced energy consumption
- Propeller characteristics adaptable to different phases of flight

Current technology readiness level

TRL 6 – A variable-pitch propeller drive has been developed, together with prototypes of active and passive pitch-control mechanisms. The solution has been validated through laboratory testing and integrated into prototype UAVs. The active-mechanism prototype has also been validated under real-world conditions on an in-house-designed VTOL platform, confirming its technological advantages.

Implementation potential

The technology could be implemented by manufacturers of unmanned aerial vehicles and VTOL platforms requiring high propulsion efficiency across different phases of flight. It could also be used to upgrade existing designs.

Developed by

Institute of Machine Tools and Production Engineering, Lodz University of Technology.





24. Drone interceptor – low-cost high-speed UAV platform for airspace defence

I21 – Institute of Automatic Control

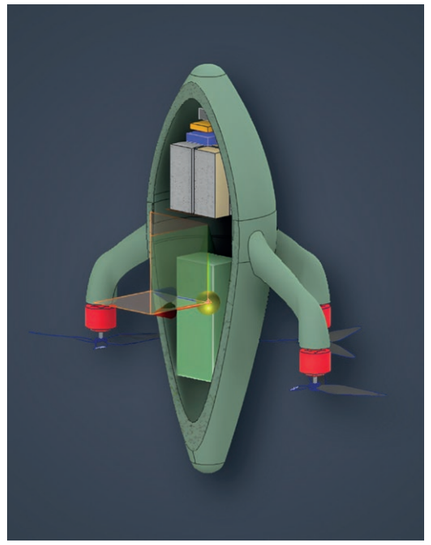
Challenge

Modern air defence systems face a growing threat from low-cost unmanned aerial attack platforms. Countering these threats is often disproportionately expensive, creating a need for fast and affordable interceptor platforms. The technical challenge is to develop a UAV capable of exceeding 300 km/h while maintaining stable control, video transmission, telemetry, and effective component cooling.

Technology overview

The project involves the development of a lightweight UAV with a carbon-fibre frame and an aerodynamically shaped, 3D-printed shell. The platform's shape is optimized using aerodynamic simulations to maximize flight speed and energy efficiency. The drone incorporates low-latency FPV transmission, telemetry, temperature monitoring, and manual or autonomous control.

Integration with a hexacopter acting as a mothership drone enables airborne deployment of the UAV, automatic system activation, and flight stabilization.



Key advantages of the technology

- **Design:** Lightweight carbon-fibre frame with an aerodynamic, 3D-printed shell
- **Control:** Fully autonomous GPS navigation or manual FPV flight using low-latency video transmission
- **Technology:** Cooling system for critical components, real-time telemetry, component temperature monitoring and automatic flight initiation following release from a carrier platform

Current technology readiness level

TRL 3 – A platform prototype has been developed, and the operation of its core subsystems has been verified under laboratory conditions. Further work is going to include flight testing, performance evaluation, mothership-drone deployment trials, and optimization of the structure, propulsion system, aerodynamics, and autonomous functions.

Implementation potential

- Research and testing of high-speed UAVs
- Pilot training
- Dynamic aerial filming
- Development of systems for countering aerial threats

Developed by

Institute of Automatic Control, Lodz University of Technology.

25. Modular gripper for unmanned aerial vehicles

I21 – Institute of Automatic Control

Challenge
Unmanned aerial vehicles are increasingly used to transport small payloads and perform tasks requiring the remote manipulation of objects. Available gripping solutions are typically designed for a single type of payload or a specific platform, limiting their versatility.

Technology overview
The technology comprises a lightweight gripper designed for installation on unmanned aerial vehicles, enabling various types of objects to be picked up, transported, and released. Its design can be adapted to the dimensions and weight of the payload, allowing the solution to be used with different UAV platforms and across various operational scenarios.

The gripper uses a single-degree-of-freedom mechanism that moves a set of passive compliant elements, enabling it to grasp and transport objects of various shapes and dimensions.

All structural components are fully scalable, making it easy to adapt the gripper's geometry to the requirements of a specific application.

Key advantages of the technology
- Gripping and transporting payloads using UAVs
- Modular design allowing the gripper size to be adapted to a specific application
- Low weight that minimizes the impact on flight performance
- Integration with various unmanned platforms
- Simple design facilitating manufacturing and further development

Current technology readiness level
TRL 8 – The solution has successfully completed testing, demonstration, and validation in its intended operational environment. Further work is going to include extensive testing across diverse real-world scenarios, optimization of the production process and preparation of complete technical documentation.

Implementation potential
The technology could be used in emergency response, logistics, inspection, military and reconnaissance operations wherever payloads need to be transported remotely using unmanned aerial vehicles.

Developed by
Institute of Automatic Control, Lodz University of Technology.





26. Multi Domain Tracking and Localization System (MDTLS)

I72 – Institute of Information Technology

Challenge
The rapid development of unmanned aerial vehicles means that conventional detection systems are increasingly proving insufficient. Detecting drones without a typical electromagnetic signature — including fibre-optic-controlled platforms that may remain invisible to conventional counter-UAV systems — presents a particular challenge. Effective solutions are therefore required to detect and track such objects under diverse environmental conditions.

Technology overview
The technology involves the development of the Multi-Domain Drone Tracking System (MDDTS), a multisensor solution for detecting, locating and tracking unmanned aerial vehicles. The system integrates data from acoustic, thermal imaging, infrared and visible-light sensors and uses artificial intelligence algorithms for automated object detection and identification.

The integration of multiple information sources improves drone-detection effectiveness, including for objects that are difficult to detect using conventional methods. It also enables operation at night and under conditions of limited visibility, smoke or fog.

Key advantages of the technology
- Detection and tracking of drones without relying on their electromagnetic signatures
- Integration of data from multiple sensor types within a single system
- Artificial intelligence algorithms for automated object detection and identification
- Effective operation under challenging environmental conditions, including at night and in limited visibility, smoke and fog
- Detection of fibre-optic-controlled drones and other objects that are difficult to identify using conventional methods

Current technology readiness level
TRL 5 – The system concept and solutions for integrating data from multiple sensors have been developed. The next stage will involve building and demonstrating a prototype under conditions representative of real-world operation, leading towards TRL 6.

Implementation potential
The technology could be used in systems protecting critical infrastructure, industrial and logistics facilities and national borders. It could also support the Polish Armed Forces, emergency response services and organizations responsible for securing mass gatherings and events with enhanced security requirements.

Developed by
Institute of Information Technology, Lodz University of Technology.

27. Enhanced Vision Localization – advanced vision localization system

I21 – Institute of Automatic Control

Challenge

Unmanned aerial vehicles typically rely heavily on Global Navigation Satellite Systems (GNSS). However, GNSS signals may be unavailable, obstructed by terrain or deliberately jammed. Loss of access to GNSS can result in accumulating positioning errors, mission interruption and potentially hazardous operational situations.
The challenge is to develop a method that enables a drone to determine its position using visual data without continuous access to satellite navigation signals.

Technology overview

Enhanced Vision Localization (EVL) is a drone geolocation system that uses images from an onboard camera and satellite imagery covering the approximate operating area. The system combines absolute localization with visual odometry, enabling it to determine the drone's geographical coordinates and track its movement between successive position fixes.

The solution builds on the earlier Vision Localizer system, in which absolute position was determined using objects with known coordinates, while drone displacement was calculated using optical flow and ORB features. Ground distances are calculated using ground sample distance (GSD), the camera's optical parameters and flight altitude. Tests conducted using footage from actual flights reconstructed trajectories closely corresponding to those recorded in the onboard logs.

The system uses a specially fine-tuned artificial intelligence model to compare images from the onboard camera with satellite imagery. By recognizing distinctive terrain features, the model determines the drone's position and limits the accumulation of positioning errors during extended GNSS-denied flights.

Key advantages of the technology

- **GNSS-independent operation:** Enables reliable flight in areas where satellite signals are unavailable or disrupted
- **Multi-layer visual localization:** Combines absolute localization, visual odometry and velocity estimation, reducing the impact of errors from individual methods and limiting accumulated drift
- **Image-to-satellite-map matching:** Determines geographical coordinates by comparing onboard camera imagery with distinctive features visible in satellite images

Current technology readiness level

TRL 3 – The system has been verified using data from actual flights under conditions representative of its intended operating environment. Further work will focus on improving localization accuracy and reliability.

Implementation potential

The technology could be used wherever reliable navigation without access to GNSS is required, particularly in military and special operations, search-and-rescue missions, flights in urban environments, infrastructure inspections, and operations inside structures or in areas exposed to satellite-signal interference. The system could also serve as a redundant positioning source, improving the safety of autonomous drone missions.

Developed by

Institute of Automatic Control, Lodz University of Technology.



28. Oil-free blower for fuel cell systems and aircraft air systems

I12 – Institute of Turbomachinery

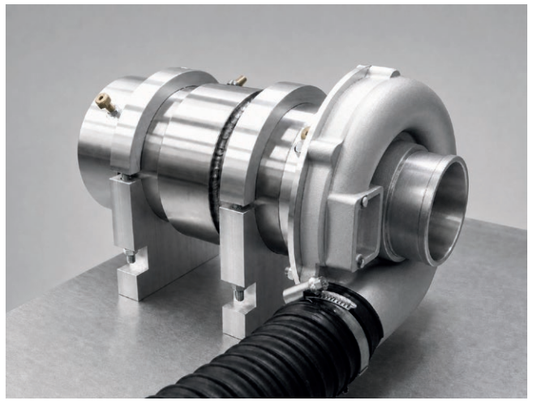
Challenge

PEMFC fuel cell systems and aircraft pressurization systems require a reliable supply of air at the appropriate pressure and flow rate. These applications require oil-free air compression systems that eliminate the risk of component contamination and ensure high operating reliability.

Technology overview

The technology comprises an oil-free blower designed to supply air to proton-exchange membrane fuel cell (PEMFC) systems and aircraft cabin pressurization systems. The device provides the airflow and compression parameters required for efficient and stable system operation. Its oil-free design eliminates the risk of contaminating system components.

A prototype has been developed and achieved the specified operating parameters under laboratory conditions. The technology has also been successfully implemented in fuel cell systems through cooperation with a consortium involving partners from European Union countries.



Key advantages of the technology

- Oil-free design eliminating the risk of system-component contamination
- Stable and efficient air supply for PEMFC systems
- Suitability for installations requiring a clean working medium
- High reliability and simplified device maintenance

Current technology readiness level

TRL 6 – A device prototype has been developed and achieved the specified operating parameters under laboratory conditions. The technology has been implemented in fuel cell systems through cooperation with a consortium involving partners from European Union countries. TRL 9 is expected within two to three years.

Implementation potential

- PEMFC-based power systems
- Propulsion systems for unmanned aerial vehicles intended for long-duration missions
- Propulsion systems for reconnaissance vehicles requiring low noise and heat emissions and a high degree of operational stealth
- Aircraft cabin pressurization systems providing a controlled supply of clean air

Developed by

Institute of Turbomachinery, Lodz University of Technology.

29. High-strength surface layers for precision mechanical components

I11 – Institute of Materials Science and Engineering

Challenge

Modern defence systems and critical infrastructure components require high resistance to wear, fatigue, corrosion, and seizure while maintaining the dimensional stability of the treated components. Conventional surface-hardening methods do not always provide the required combination of performance properties for precision components operating under high loads.

Technology overview

The technology uses the FineLPN low-pressure nitriding (LPN) process, conducted in a controlled gas atmosphere under reduced pressure[1]. The process enables nitrogen to diffuse into the surface layer of steels and special alloys, producing a layer with high hardness, wear resistance, and beneficial compressive stresses.
The developed solutions include selecting process parameters, modelling nitrided-layer growth, and evaluating the operational properties of the treated components. The technology extends the service life and improves the reliability of precision components used in machinery, drive systems, and control systems, while maintaining high dimensional accuracy.

Key advantages of the technology

- High surface-layer hardness
- Increased resistance to abrasive wear and fatigue
- Improved corrosion resistance of selected steel grades
- Minimal distortion compared with processes requiring quenching
- Treatment of precision components with complex geometries
- High process repeatability and control
- Extended service life of safety-critical components

Current technology readiness level

TRL 9 – Process parameters have been developed for selected material groups, and the technology's effectiveness in tailoring the properties of nitrided layers has been validated. The technology is currently used in the machinery industry to manufacture components for agricultural equipment.

Implementation potential

The technology could be implemented in the defence, aerospace, energy, machinery, and automotive sectors. It is particularly suitable for components requiring high wear resistance, while maintaining dimensional accuracy. LPN is especially attractive for precision aerospace and control-system components, where minimal distortion and high dimensional stability are essential.

Developed by

Institute of Materials Science and Engineering,
Lodz University of Technology.

[1] P. Kula, R. Pietrasik, E. Wołowiec. Sposób azotowania narzędzi wykonanych ze stopów żelaza. Patent PL 219125, 2014.



Example of nitrided metal-forming tools.
Source: SECO/WARWICK S.A.

30. Elastomer seals for dry-running applications

I33 – Institute of Polymer and Dye Technology

Challenge

Seals operating in moving friction interfaces require appropriate lubrication, particularly during equipment start-up. Failure of the lubrication system or restricted lubricant delivery can increase friction, accelerate seal wear, and damage the entire mechanism.

Technology overview

The technology involves modifying the surface of dynamic elastomer seals using a high-energy ion beam. The process creates a thin, modified surface layer while preserving the material's flexibility. This layer reduces friction and abrasive wear and, depending on the selected process variant, can also provide hydrophobic properties or improve surface adhesion.

Key advantages of the technology

- Operation of friction interfaces without continuous lubrication
- Reduced risk of damage during start-up or lubrication-system failure
- Increased resistance of seals to abrasive wear
- Preservation of material flexibility following surface modification
- Surface properties tailored to the requirements of specific applications

Current technology readiness level

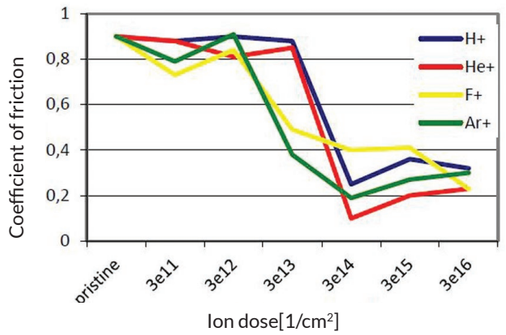
TRL 5 – Various process variants for modifying the surfaces of elastomer seals have been developed and tested. Further work is going to include process optimization and adaptation of the modification parameters to the type of elastomer, seal design, and operating conditions.

Implementation potential

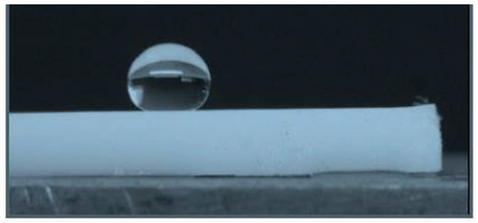
The technology could be implemented by manufacturers of seals, mechanical equipment and propulsion systems operating under challenging lubrication conditions, variable temperatures, vacuum, microgravity or in contaminated environments.

Developed by

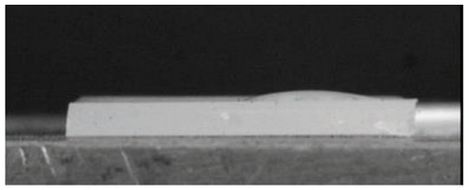
Institute of Polymer and Dye Technology,
Lodz University of Technology.



Effect of ion type and dose on the coefficient of friction of SBR rubber against steel.



Graphitization + surface development.



Oxidation + surface smoothing.

31. Fire- and heat-resistant rubber products

I33 – Institute of Polymer and Dye Technology

Challenge

Rubber components used in vehicles, equipment, and installations exposed to high temperatures should retain their functional properties even during a fire. Conventional rubber materials burn, potentially resulting in loss of sealing integrity, damage to installations, and safety hazards.

Technology overview

The technology comprises rubber products with enhanced resistance to fire and high temperatures, developed by modifying the composition of the rubber compound. The use of specially selected fillers creates a protective ceramic layer when exposed to high temperatures. This layer limits material combustion and reduces the release of volatile combustion products. The solution enables rubber components to remain functional for at least 30 minutes under direct fire exposure.

Key advantages of the technology

- Preservation of rubber-product functionality during fire exposure
- Formation of a protective ceramic layer that limits material combustion
- Reduced release of volatile combustion products
- Application in seals, protective covers, cables, and hoses
- Improved safety of systems operating under fire conditions

Current technology readiness level

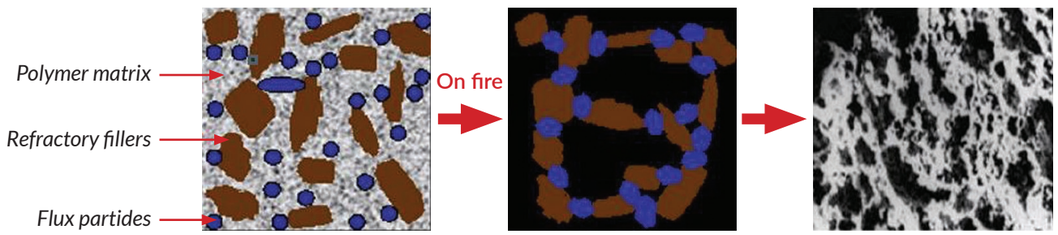
TRL 5 – Material formulations have been developed, and their properties have been verified under laboratory conditions. Further work is going to include optimizing the compound composition and adapting the technology to the requirements of specific applications.

Implementation potential

The technology could be implemented by manufacturers of rubber products used in vehicles, industry, the energy sector, and critical infrastructure wherever components must remain functional when exposed to fire or high temperatures.

Developed by

Institute of Polymer and Dye Technology,
Lodz University of Technology.



Ceramic structure observed by scanning electron microscopy (SEM)

32. Low-friction coatings for unmanned aerial vehicle engines

I11 – Institute of Materials Science and Engineering

Challenge

Small internal combustion engines used in unmanned aerial vehicles generate noise and significant amounts of heat, which increases their acoustic and thermal detectability. Friction also reduces propulsion efficiency and affects fuel consumption and engine durability.

Technology overview

The technology comprises low-friction coatings based on molybdenum disulphide, designed to modify the surface of the moving components of two-stroke internal combustion engines. The coatings reduce friction, enable a lower proportion of oil in the fuel mixture and decrease the engine's operating temperature.
As a result, noise is reduced, and the thermal and acoustic signatures of unmanned aerial vehicles are diminished, making them more difficult to detect.

Key advantages of the technology

- Reduced friction and improved engine efficiency
- Lower engine operating temperature and reduced infrared detectability
- Reduced engine noise
- Lower oil content in the fuel mixture
- Compatibility with lightweight two-stroke engines used in UAVs

Current technology readiness level

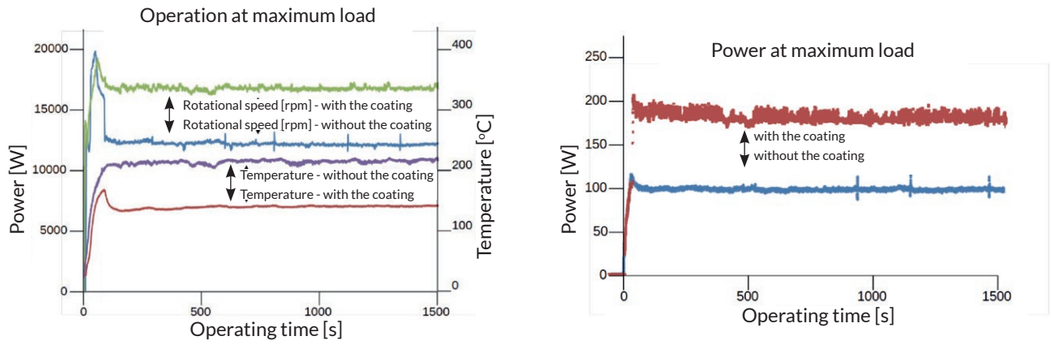
TRL 4 – A process for manufacturing low-friction coatings has been developed and tested under laboratory conditions. The solution has also undergone preliminary validation using small two-stroke model engines, achieving a noise reduction of approximately 5 dB. Further work will include process optimization and validation using the target UAV engines.

Implementation potential

The technology could be implemented by manufacturers of engines for unmanned aerial vehicles and lightweight aerial platforms, particularly in applications requiring reduced acoustic and thermal detectability.

Developed by

Institute of Materials Science and Engineering,
Lodz University of Technology.



Comparison of the operating characteristics of the tested two-stroke engines with and without additional surface treatment in the form of a molybdenum disulfide-based low-friction coating.

33. Parylene coatings for electronics protection

I11 – Institute of Materials Science and Engineering

Challenge

Electronic systems used in field, maritime and industrial environments are exposed to moisture, water, salt spray, and aggressive chemicals. Effective electronics protection requires thin, hermetic coatings that do not compromise the electrical performance or functionality of the protected components.

Technology overview

The technology involves applying thin-film parylene coatings through chemical vapour deposition (CVD) polymerization to protect electronic systems against moisture, gases, and environmental factors.

The process produces a uniform coating of consistent thickness across the entire component surface, including edges, holes, and difficult-to-access areas.

The developed technology also includes a method that significantly improves coating adhesion to most engineering plastics.

Key advantages of the technology

- Effective protection of electronics against moisture, water, and salt spray
- Uniform coating of components with complex geometries, including the interiors of holes and narrow gaps
- Highly effective barrier against gases and water vapour
- Elimination of poor parylene-coating adhesion to most engineering plastics
- Excellent dielectric properties and chemical resistance

Current technology readiness level

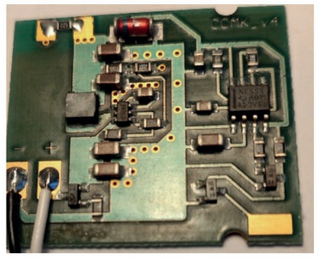
TRL 6 – A process for applying parylene coatings has been developed, and its effectiveness in protecting electronic systems has been validated. Components measuring up to 200 × 280 mm can currently be coated. Further work is going to include expanding the processing system to accommodate larger electronic assemblies.

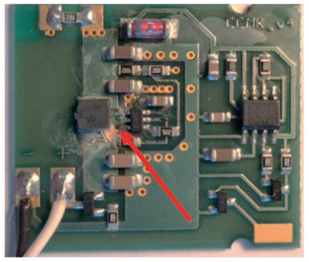
Implementation potential

The technology could be implemented by manufacturers of electronic equipment operating under demanding environmental conditions, including military, maritime, aerospace and industrial applications, and critical infrastructure.

Developed by

Institute of Materials Science and Engineering,
Lodz University of Technology.





DC/DC converter coated with parylene (left) and an uncoated converter (right).
The protected unit remained operational in ice and water at various temperatures for 12 months, while the unprotected unit failed after four days.

34. Rubber for arctic applications

I33 – Institute of Polymer and Dye Technology

Challenge

Most rubber components used in vehicles and equipment lose flexibility as temperatures decrease. Under Arctic conditions, this can cause seals to crack and hoses, and vibration-damping components to stiffen, potentially resulting in failures that immobilize equipment during operations.

Technology overview

The technology involves developing rubber compounds that retain their flexibility and mechanical properties at temperatures as low as −80°C. The use of specially selected elastomers and fillers produces materials resistant to low-temperature embrittlement and suitable for manufacturing components intended to operate under extreme climatic conditions.

Key advantages of the technology

- Retention of flexibility and vibration-damping properties at temperatures as low as −80°C
- Reduced risk of rubber components cracking or becoming damaged during operation
- Suitability for demanding Arctic and high-altitude environments
- Compatibility with the production of a wide range of technical components

Current technology readiness level

TRL 5 – Rubber compounds have been developed, and prototype components with properties confirmed through testing have been produced. Laboratory tests and internal industrial trials have also been completed. Further work is going to include optimizing the compound formulations and testing them under operational conditions.

Implementation potential

The technology could be used to manufacture tyres, seals, hydraulic hoses, suspension components, vibration dampers, and other components intended to operate at extremely low temperatures. Potential applications include military and specialized vehicles, machinery operating in polar regions, and critical infrastructure.

Developed by

Institute of Polymer and Dye Technology,
Lodz University of Technology.



35. Wear-resistant surface layers for armament components and drive systems

I11 – Institute of Materials Science and Engineering

Challenge

Components used in defence systems operate under conditions of intensive wear, high mechanical loads, mechanical and thermal fatigue, and changing environmental conditions. A key requirement is to extend their service life, while minimizing component deformation and production costs.

Technology overview

The technology uses ferritic nitrocarburizing (FNC), as described in patent application PL 450898. The process is conducted at reduced pressure in retort furnaces or universal vacuum furnaces, which produces surface layers with high hardness, wear resistance, and favourable tribological properties, while maintaining the high dimensional accuracy of the treated components. The process does not require salt baths and offers an environmentally responsible alternative.

Key advantages of the technology

- High resistance to abrasive wear and seizure
- High surface hardness
- Generation of compressive stresses that reduce mechanical and thermal fatigue
- Limited component deformation due to treatment within the ferritic temperature range
- Compatibility with existing vacuum furnaces
- High repeatability of surface-layer parameters
- Reduced emissions of harmful substances and improved process safety
- Lower operating costs than conventional FNC technologies

Current technology readiness level

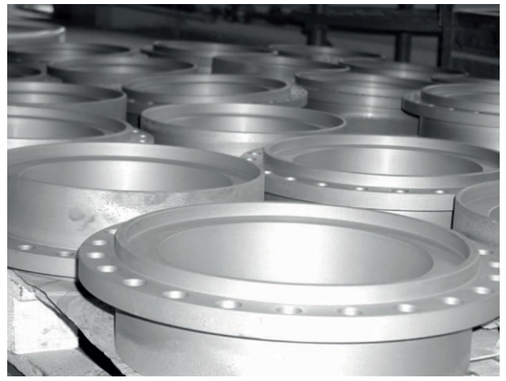
TRL 8 – The final process has been developed and validated using industrial batches. A catalogue of processing parameters for various applications has also been prepared, and a licence for industrial use of the technology has been purchased.

Implementation potential

The technology could be implemented by manufacturers of components for the defence, machinery, energy, and aerospace industries. It is suitable for a broad range of applications, including power transmission systems, and barrels. The technology affords a particular advantage as it is adaptable to existing vacuum furnaces without the need to construct new production lines.

Developed by

Institute of Materials Science and Engineering, Lodz University of Technology.



Example of structural components after low-pressure FNC treatment.

36. Hardened surface layers for high-load gears and drive systems

I11 – Institute of Materials Science and Engineering

Challenge

Machine and equipment components used in defence systems and security infrastructure require both exceptional resistance to surface wear as well as adequate core strength. Conventional gas carburizing processes involve long processing times, a risk of surface oxidation, limited control over carbon distribution, and process atmospheres with high gas consumption.
Modern components manufactured from high-alloy steels as well as parts with complex geometries require more precise thermochemical treatment technologies.

Technology overview

The technology uses the FineCarb low-pressure carburizing (LPC) process, conducted in a hydrocarbon atmosphere under reduced pressure, with the option of direct gas or oil quenching[1,2]. The process enables precise control of the carbon concentration profile within the surface layer and produces uniform carburized layers of high metallurgical quality. The developed solutions include modelling and optimization of LPC processes for various structural, tool, and special-purpose steels, as well as the selection of process parameters to achieve the required hardness, fatigue resistance, and service life of component.

Key advantages of the technology

- Carburizing of modern high-alloy steels at elevated temperatures
- Significantly shorter processing times than conventional atmospheric carburizing
- High uniformity of the carburized layer
- Elimination of intergranular surface oxidation
- Effective carburizing of complex components and densely packed loads
- Reduced process-gas consumption and lower environmental impact than atmospheric carburizing
- Increased durability, reliability, and wear resistance of critical mechanical components operating under high loads

Current technology readiness level

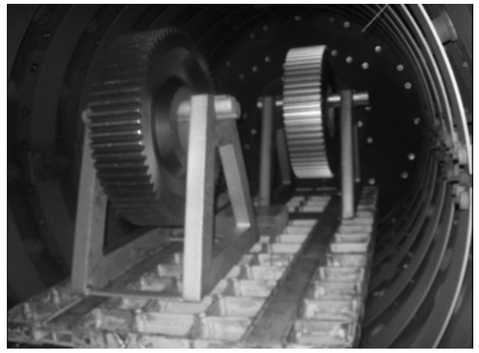
TRL 9 – The technology is used in automotive and aerospace manufacturing, including the treatment of AISI 9310, Ferrium® C64™, Pyrowear Alloy 53, and M50NIL steels. It has been confirmed that the process can produce carburized layers meeting industrial requirements for hardness, effective case depth, and operational performance.

Implementation potential

LPC technology supports the development of modern defence systems by improving the durability, reliability, and operational readiness of critical mechanical components. It is particularly relevant to the production of propulsion components, gears, and mechanisms operating under high loads in land vehicles, aircraft, maritime systems, and unmanned platforms. The technology is especially suitable for manufacturing gear assemblies, gear wheels, shafts, power transmission components, and parts for helicopters and other aircraft operating under high loads and intensive wear.

Developed by

Institute of Materials Science and Engineering, Lodz University of Technology.



Toothed components after LPC carburizing and quenching. Source: SECO/WARWICK S.A.

[1] P. Kula, J.Olejnik, P.Heilman.Method for under-pressure carburizing of steel workpieces. Patent EU 1,558,781, 2006.
[2] P. Kula, J.Olejnik, P.Heilman. Hydrocarbon gas mixture for the under pressure carburizing of steel. Patent EU 1,558,780 2007.

Biomedical engineering and biotechnology

37. Wound dressing materials for battlefield trauma care

I32 – Institute of Organic Chemistry and I42 – Textile Institute

Challenge

On the battlefield as well as during emergency response operations, the first few minutes following an injury can determine a casualty's chances of survival. Rapid bleeding control, wound protection, and access to simple and effective dressing materials suitable for different types of trauma are critical. What is required are solutions that can be applied quickly while supporting wound healing and reducing the risk of infection.

Technology overview

The technology comprises a bioactive wound-care kit designed to control bleeding and support wound treatment. The kit includes an absorbent dressing with a bandage, wound-packing material for gunshot and stab wounds, a nonwoven dressing, and a tactical tourniquet. The developed materials are based on biopolymers and natural active compounds, combining haemostatic, antimicrobial and bioresorbable properties. Their high absorbency supports wound healing and the regeneration of damaged tissue.

Key advantages of the technology

- Comprehensive kit for treating different types of wounds
- Rapid and effective bleeding control
- Combination of haemostatic, antimicrobial, and regenerative properties
- Bioresorbable and biocompatible materials
- Straightforward application in battlefield and emergency response conditions

Current technology readiness level

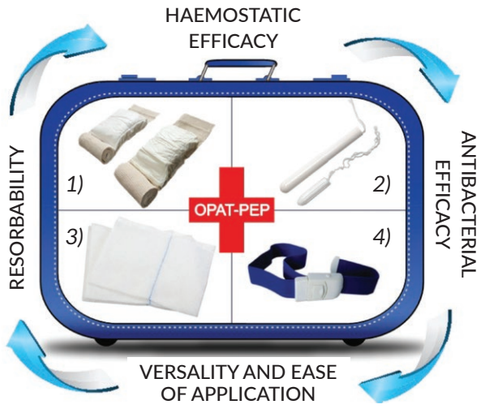
TRL 6 – Bioactive wound dressing materials have been developed, and their functional properties have been validated. The technology is ready for further implementation work and adaptation to medical-device requirements.

Implementation potential

The technology is ready for implementation in production of specialized wound-care kits for the military, emergency services, healthcare sector. It may also be implemented by manufacturers of medical equipment. Potential applications include battlefield medicine, emergency response, first-aid kits, and equipment for special operations units.

Developed by

Institute of Organic Chemistry and Textile Institute, Lodz University of Technology.



UNIVERSAL TRAUMA DRESSING KIT

The innovative, versatile and comprehensive dressing kit will consist of:
1. Absorbent dressing integrated with a bandage
2. Wound packing gauze for gunshot and stab wounds
3. Nonwoven fabric
4. Tactical tourniquet

38. Bioactive coatings for textile materials

I33 – Institute of Polymer and Dye Technology

Challenge

During extended military, emergency response, and crisis-management operations, textiles are used intensively under austere field conditions. This is conducive to microbial growth on material surfaces, reduces user safety and comfort, and places greater demands on durability and resistance. What is needed are solutions that inhibit the growth of microorganisms while maintaining high performance and safe use.

Technology overview

The technology involves bioactive coatings for application to knitted, woven, and nonwoven fabrics and gives textile materials biostatic properties. The solution uses natural, biodegradable biopolymers, and naturally derived compounds, preserves the materials' sustainable character, while inhibiting microbial growth.

The technology can be used to produce clothing, underwear, bed linens, air-conditioning inserts, and other textile products intended for specialized applications. Its biostatic activity has been verified against *Escherichia coli* and *Staphylococcus aureus* bacteria, *Candida albicans* yeast, *Aspergillus niger* mould, influenza A/H1N1 and A/H3N2 viruses.

Key advantages of the technology

- Bioactive coating based on natural, biodegradable biopolymers
- Applicability on knitted, woven, and nonwoven fabrics
- Inhibition of bacterial, fungal, and viral growth on material surfaces
- Improved mechanical resistance of coated materials
- Reduced material flammability

Current technology readiness level

TRL 7 – A bioactive polymer composition and a process for applying the coating to textile materials have been developed. The solution's biostatic properties have been validated, and the conditions required for implementation at a technical scale have been established.

Implementation potential

The technology is ready for implementation in the production of clothing, underwear, bed linens, medical textiles, and other products made from knitted, woven, and nonwoven fabrics for the military, emergency services, healthcare sector, and crisis-management organizations, as well as by manufacturers of specialized textile materials.

Developed by

Institute of Polymer and Dye Technology, Lodz University of Technology.



Textiles with a bioactive coating (antiviral, antifungal, and antibacterial)

39. VR system supporting post-traumatic stress disorder (PTSD) therapy

I25 – Institute of Mechatronics and Information Systems

Challenge

Military personnel, uniformed services and emergency responders are particularly vulnerable to post-traumatic stress disorder (PTSD) and acute stress reactions. Effective therapy requires stressful situations to be recreated safely while the patient's responses are monitored. However, available methods can be costly, difficult to standardize and unable to provide a sufficiently precise assessment of treatment progress.

Technology overview

The technology comprises a virtual reality (VR) system designed to support therapy for people with post-traumatic stress disorder. It enables controlled therapeutic sessions using immersive scenarios and monitors the patient's responses with biometric sensors, including galvanic skin response (GSR) and electroencephalography (EEG).

The system supports the assessment of therapeutic progress and enables sessions to be tailored to each patient's individual needs.

Key advantages of the technology

- Therapy conducted in a controlled and safe environment
- Objective assessment of patient responses using biometric signals
- Monitoring of therapeutic progress over time
- Personalization of therapeutic scenarios
- Support for specialists delivering PTSD therapy

Current technology readiness level

TRL 5 – A system prototype has been developed, and pilot studies involving users have been conducted. Ongoing work includes expanding the range of therapeutic scenarios, conducting clinical validation and evaluating the solution's effectiveness in PTSD therapy.

Implementation potential

The technology could be implemented in psychological therapy and rehabilitation centres, medical facilities and organizations responsible for providing mental health support to military personnel, uniformed services and emergency responders.

Developed by

Institute of Mechatronics and Information Systems,
Lodz University of Technology.



Fig. 1. Virtual reality environment



Fig. 2. Selected biomedical sensors (GRS and EEG)

40. Effervescent orodispersible tablets containing green coffee, providing prolonged stimulation and supporting concentration

I54 – Institute of Food Technology and Analysis

Challenge

During prolonged physical and mental exertion, operational tasks and field activities convenient solutions are needed for the rapid delivery of caffeine to support concentration and physical performance. Conventional caffeinated beverages and supplements are not always practical and their preparation may be difficult under field conditions. There is therefore a need for shelf-stable, easy-to-use formats that enable precise caffeine dosing.

Technology overview

The technology comprises effervescent orodispersible tablets (designed to rapidly disintegrate and dissolve directly in the mouth without the need to take them with water), developed using a freeze-dried, standardized green coffee extract with a high caffeine content. The solution employs a freeze-drying process that ensures high extract stability, together with a carefully selected formulation enabling controlled caffeine release and prolonged stimulating effects, while improving the sensory properties by reducing the characteristic bitterness of green coffee. The tablet formulation has been supplemented with plant extracts with adaptogenic properties to support sustained concentration and help prevent excessive stimulation. The developed prototype provides a basis for further optimization of the tablets' textural properties, stability, and sensory profile, as well as for preparing the technology for implementation.



Key advantages of the technology

- Rapid and convenient caffeine delivery without beverage preparation
- Precise caffeine dose in each tablet and extended absorption over time
- Prolonged stimulation and enhanced concentration during periods of increased physical and mental exertion
- Reduced bitterness and improved acceptability
- Convenient use while travelling or performing tasks in the field
- Alternative to energy drinks and other conventional caffeine sources
- High caffeine content combined with naturally occurring bioactive compounds from green coffee
- Antioxidant properties resulting from phenolic compounds, including chlorogenic acid, at levels higher than in products based on roasted coffee

Current technology readiness level

TRL 4 – A prototype effervescent tablet based on green coffee extract has been developed and its fundamental technological assumptions and functional properties have been verified. A prior-art analysis identified no apparent obstacles that could limit the possibility of obtaining patent protection for the solution.
Further work is going to include formulation optimization, improvement of tablet shelf-life and mechanical properties, production of prototype batches, technological and user validation.

Implementation potential

The technology can be implemented in the production of functional foods, dietary supplements and nutraceuticals intended for:

- Uniformed services and emergency responders
- People working under increased physical and mental strain
- Athletes
- Outdoor activity enthusiasts, including tourists, climbers, and participants in survival expeditions

Developed by

Institute of Food Technology and Analysis,
Lodz University of Technology.

Biomedical engineering and biotechnology

41. Tea resin concentrate for functional beverages

I54 – Institute of Food Technology and Analysis

Challenge

Prolonged field operations, military missions, rescue operations, and emergency situations subject the body to extreme physical and psychological stress, increasing the risk of dehydration, energy depletion, and reduced concentration, which directly jeopardizes mission success and personnel safety.

There is therefore a need for a product that not only provides basic hydration but also supports psychophysical resilience by promoting alertness and readiness to act at critical moments, or facilitating recovery and stress reduction during periods of rest.

Technology overview

The technology comprises a tea resin concentrate designed for the rapid preparation of a functional beverage by dissolving it in cold or hot water. The product has been developed in two versions: stimulating and calming.
The stimulating version contains caffeine, adaptogens, B vitamins, and vitamin C, which rapidly reduce fatigue, sharpen the senses, and enhance concentration during intense physical exertion. The calming version contains adaptogens and natural calming agents that soothe the nervous system, reduce psychological stress, and facilitate effective recovery during short breaks between activities.

The technology under development ensures high solubility of the formulation, stability of the active ingredients during storage, and a convenient single-serving format suitable for transport and use in field conditions.

Key advantages of the technology

- possibility of preparing a functional beverage using cold or hot water,
- supplementation with vitamin C and B vitamins,
- lightweight and compact format facilitating transport and storage,
- no added sugars,
- long-term product storage.

Current technology readiness level

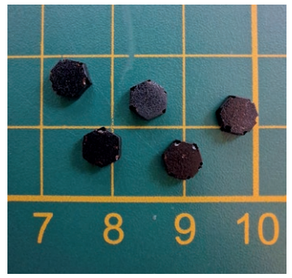
TRL 4 – Fully functional prototypes have been developed, along with the technology for their production at laboratory scale. A prior-art analysis revealed no indications that could limit the possibility of obtaining patent protection for the developed solution. Further work is going to involve technological and user validation.

Implementation potential

The technology may be applied in the production functional foods and dietary supplements for uniformed services, emergency responders, and humanitarian organizations, as well as for the outdoor market, including tourists, expedition participants, and physically active individuals.

Developed by

Institute of Food Technology and Analysis,
Lodz University of Technology.





42. Platform for probiotic and postbiotic formulations

K51 – Department of Environmental Biotechnology

Challenge

Prolonged stress, exposure to adverse environmental factors, and intense physical strain can disrupt the gut microbiota, weaken the skin barrier and immune function. This is particularly relevant to people operating under demanding environmental conditions, including soldiers, emergency responders, and medical personnel. There is therefore a need for formulations that support microbial balance and the body's natural protective mechanisms.

Technology overview

The technology involves a platform of formulations based on selected probiotic strains and their metabolites known as postbiotics. The formulations are intended to support the intestinal barrier, skin regeneration, and immune function.

The solution builds on the experience gained through the development, patenting, and implementation of Latopic® probiotic products, expanding their range to include new formulations intended for use under conditions of increased environmental and physiological strain. The platform enables the development of oral and topical formulations tailored to different user groups and applications.

Key advantages of the technology

- Validated technology platform based on experience gained from commercially implemented Latopic® products
- Development of both oral and topical formulations using a single technology platform
- Combined support for the intestinal barrier, skin and natural immune function
- Formulations adaptable to various civilian and specialized applications
- Potential for the development of products for use under conditions of increased environmental strain

Current technology readiness level

TRL 5 – The solution builds on previously developed, patented, and implemented probiotic products and on the research into new formulation variants.
Further work is going to include the development of new formulations and getting them ready for implementation, with a target readiness level of TRL 8.

Implementation potential

The technology could be used to produce probiotic and postbiotic formulations, dermo cosmetics, medical devices, and foods for special purposes intended for people exposed to increased environmental strain, uniformed services, emergency responders, and medical personnel.

Developed by

Department of Environmental Biotechnology,
Lodz University of Technology.

Biomedical engineering and biotechnology

Biomedical engineering and biotechnology

Notes

Notes

Lodz University
of Technology

CONTACT:
Research Center for Defense and Security Technologies
of Lodz University of Technology
Lodz 90-530, Wolczanska Street 181,
building A15, 3rd floor, room 305
Phone: 42 631 24 06, e-mail: cbob@adm.p.lodz.pl
www.p.lodz.pl/nauka/cbob

Lodz University
of Technology



CONTACT:
Research Center for Defense and Security Technologies
of Lodz University of Technology
Lodz 90-530, Wolczanska Street 181,
building A15, 3rd floor, room 305
Phone: 42 631 24 06, e-mail: cbob@adm.p.lodz.pl
www.p.lodz.pl/nauka/cbob

September 2026