

## ***Materials Research and Nanotechnology***

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### **1. RIS3 SK area of specialisation from the point of view of available scientific and research capacities**

Materials research and nanotechnology

Research and development in the area of specialisation “Materials Research and Nanotechnology” focus on the research and development of selected prospective materials for industry, products from such materials, production technologies, including nanotechnology, processing of (domestic) raw materials, as well as research of specific material structures, layers, surfaces and interfaces. The aim is to enhance research and development so as to increase the innovativeness of Slovak enterprises and, hence, their ability to better meet customers’ requirements, including those of multinational companies. The related aim is to enhance the capacity of enterprises to supply innovative products and solutions outside the existing supply chains, thus increasing to the stabilisation of the Slovak economy through major diversification of the customer structure.

### **2. Specific sub-topics of the areas of research specialisation:**

- I. New construction materials for use in industry, the energy sector and electrical engineering
- II. Advanced materials, structures and nanotechnology
- III. Organic and polymer materials
- IV. Extraction and processing of raw materials

#### **I. New construction materials for use in industry, the energy sector and electrical engineering**

**Short description:** Research and development of light construction materials, materials for application under extreme conditions and composites with an application potential in mechanical engineering, automotive and railway industry, the energy sector, electrical engineering and building, including production technologies and products from these materials, construction items, groups and systems.

**Key words:** special steel, light metals, light alloys, aluminium, magnesium, ceramic materials, polymers, composites, mixtures, binders, high-value building materials, joining of materials, joining of different materials, material working, forming, machining, powder technologies, non-conventional technologies, coating, foam structures, handling of materials, automation of manufacturing processes

**Subtitle 1:** Research and development of advanced materials and technologies for the purposes of the automotive and railway industry, electrical engineering and mechanical engineering:

- Research of new metal, non-metal and polymer materials and composites for the manufacturing of car components, machines, devices and equipment (steel, light metals, aluminium, non-metallic materials, metal-ceramic materials, new alloys, foam structures, various kinds of composite materials, gradient materials, coated materials, nanostructured materials, etc.);
- Research and development of production technology for new materials and products from such materials, including the use of non-conventional technologies, powder technologies,

vacuum metallurgy technologies, precision casting, 3D printing of composites, advanced technologies for the creation of surface layers using plasma, electrochemistry, technology based ion, laser or electron rays and other technologies, technologies for the refinement and bonding of different materials;

- Research and development of equipment and systems for the handling of materials and parts in manufacturing;
- Checking, measurement, testing and verification of a complex of utility features of these materials with respect to their use in vehicles, robots, aircrafts, rolling stock and related structural units, including testing of structural parts of vehicles and rolling stock: the integrity of surfaces, mechanical properties, the proportion of internal stress, abrasive and corrosion resistance, etc.

**Subtitle 2:** Research of advanced steels for automotive production, railway industry, energy industry, electrical industry, petrochemicals and packaging – production and processing of higher-performance iron and steel with lower energy and environmental demands

**Subtitle 3:** Research of advanced, high-value ceramic, metal and composite materials for extreme conditions, such as high pressures, high temperatures, chemical and corrosive actions, etc., in particular:

- Research and development of high-strength construction materials and/or materials with enhanced durability, research of materials with high corrosive resistance and resistance to aggressive environments;
- Research and development of special materials and technologies for the energy sector and electrical engineering, including development of new types of power facilities, prolongation of the life-cycle of existing equipment, and decommissioning of nuclear power facilities;
- Research of advanced types of concrete and cements, binders and composite materials for extreme temperatures, humidity and/or pressure, and alternative binders with low CO<sub>2</sub> production, composite reinforcement based on glass, basalt and other fibres;
- Research and development of materials and technology for the protection of persons and technology against the effects of fire, explosives, improvised explosive devices, the effects of firearms used in fire and rescue operations, in the activities of the security and armed forces, in the protection of the population and of the country's critical infrastructure elements (EU).

## II. Advanced materials, structures and nanotechnology

**Short description:** Research of new materials, modification of organic- and inorganic-based surfaces, structures and elements for applications in information and communication technology (ICT), electrical engineering (electronics, photonics, optics, sensorics), energy and small-volume production of chemical substances; research in the field of innovative diagnostic and analytical methods and new technologies for the preparation of these materials.

**Key words:** nanomaterials, nanocomposites, nanostructures, composites, ceramics, semiconductors, superconductors, insulants, magnetics, sensors, thin layers and coating, surfaces, interfaces, surface modifications, low-size materials, graphene, nanopipes, quantum computers, standardisation for nanometrology.

**Subtitle 1:** Research of new advanced materials and structures for ICT, electrical engineering, electronics, photonics, sensorics and energy industry:

- new semiconductor, superconductor, magnetic and nanomagnetic materials for

electronics, electrical engineering, electronic structures, sensorics, bioapplications, energy industry, automotive industry and new generation computers;

- Research of materials, structures and elements for micro-electronics, sensors, high-density memories, quantum computers, storage of energy and fuel elements, greenhouse gas separation;
- Materials for light, lighting technology, X-ray optics, organic-inorganic photovoltaics, energy recuperation and storage, and magnetic cooling;
- Natural and environmental nanomaterials and nanostructures.

**Subtitle 2:** Research of innovative small-size structures, nanomaterials and nanoobjects:

- Research of surfaces, thin layers, interfaces and modifications of the surfaces of materials and their technologies;
- Graphene, graphene oxide and 2D materials similar to graphene
- Innovative sensors (actuators) for the detection of chemical substances and gases, and for diagnostics;
- Polymer-based nanocomposites, ceramic nanocomposites with new improved features (application in fuel elements, greenhouse gas separation, sensorics, electrocatalysis, biomedicine and microfluidics).

**Subtitle 3:** Research of innovative technologies for the preparation of materials, methods of analysis and diagnostics of their properties, including nanometrology at the atomic and subatomic level:

- New physical, chemical and other methods of preparation of small-sized materials, nanomaterials, nanoobjects and nanostructures, including surface modification;
- Diagnostics of surfaces, interfaces and structures of nanomaterials, nanoobjects, nanostructures and small-sized materials;
- Chemism in the processing, forming, compaction and granulation of inorganic materials and other auxiliary substances enabling the reaching of excellent quality under changed raw material inputs.

### III. Organic and polymer materials

#### *Short description:*

Organic- and polymer-based materials for use in packaging technology, construction materials and composites, fibre and textile applications, biomedical applications, elastomeric materials and composites for special applications, small-volume production of chemical substances.

**Key words:** organic materials, polymers, plastics, biodegradable polymers, packaging materials, active packaging materials, composite materials, materials from renewable sources, elastomeric materials, fibres, artificial fibres, textiles, micro-fillers, nano-fillers, graphene, printing, printing papers, printing electronics

**Subtitle 1:** Research and development of biodegradable plastics, composite materials and materials from renewable sources

- Research and development of new types of biodegradable plastics from renewable sources for industry, packaging technology, including active packaging materials for food industry;
- Research and development of new types of composite materials based on biodegradable polymers from renewable sources and natural fibres;
- Research and development of new types of materials and composites based on biodegradable polymers and polymers from renewable sources for special use in medical

applications using 3D printing;

- Research and development of new types of elastomer-based blending and composite materials using nano-fillers, graphene and raw materials from renewable sources for special applications.

**Subtitle 2:** Development of new types of polymer, textile and fibre materials with technological design of their processing, such as:

- Development of special fabric and fibre technology, such as polyvinylidene fluoride PVDF with a design enabling the preparation of shaped (textured) fibres for application in, for example, automotive industry, sporting goods and clothes, flat fibres for mining or for military applications;
- Development of technical fabrics using, for example, combinations of fabric structures and nanoparticles for fire-proof design for use in households, in means of transport, in the civilian and military sectors, in building and other industrial sectors;
- Development of fabrics for medical applications – antibacterial fabrics and fabrics with supporting healing;
- Research of printing papers with special surface treatment, natural and synthetic materials and new, modified printing inks for different use, including incorporation of nanoparticles, semiconductor and di-electric organic substances for printed electronics.

#### IV. The extraction and processing of raw materials

**Short description:** Identification of the raw materials and energy base; research and development of more effective technologies and equipment for increasing its value; use of renewable sources mainly with the focus on the production of light metals, materials for the production and processing of steel and special chemical substances for polymers, energy industry, electronics and higher energy efficiency, and the use of sites after the shut-down of industrial activities and recycling of industrial and building waste.

**Key words:** identification of the domestic raw materials base, raw materials base, energy base, recovery of raw materials, renewable sources, industrial waste, building waste, critical metals, strategic minerals, magnesite, refractory materials

**Subtitle 1: Research of advanced technologies for the survey and extraction of domestic raw materials and their processing into new products with a higher added value:**

- Research and identification of the potential of the domestic raw materials and energy base, including structures for underground reservoirs;
- Research of smart technologies and equipment for increasing the value of the domestic raw materials and energy base and for increasing their effectiveness, use of renewable energy sources and modern materials for safe hydrogen storage and transport;
- Research of new refractory and composite materials with a higher performance complex and of modern refining slag systems based on domestic raw materials and waste for the production and processing of iron and steel;
- Research of technologies for a more effective and complete recovery of Slovak magnesite through the diversification of products to support wider involvement in supply chains and internationalisation;
- Research of the conditions of accumulation and progressive technologies for recovery of the sources of critical metals.

**Subtitle 2: Research supporting the development of production processes focused on**

**better use of available sources:**

- Research and assessment of new possibilities of use of sites after the shut-down of industrial activities;
- Research of advanced technologies for the processing and recycling of industrial and building waste.

**Key words:**

Materials research, nanotechnologies, light construction alloys, special steel, materials for extreme conditions, small-sized systems, surfaces, interfaces, thin layers, surface modification, fabrics, biodegradable materials, renewable materials, high-value concrete, non-metallic reinforcements, composite materials, semiconductors, ceramics, sensorics, photonics, insulants, recycling, new binders.

### **3. Links/relationships between the long-term strategic research programme and the addressing of some/several development trends on the basis of available R&I capacities:**

The mutual relationships and links between the long-term strategic research programme from the point of view of available R&I capacities and the development trends of economic specialisation and prospective areas of specialisation are shown in the table below.

<b>Development trends for the areas of economic specialisation</b>	<b>I New construction materials for use in industry and the energy sector</b>	<b>II Advanced materials, structures and nanotechnology</b>	<b>III Organic and polymeric materials</b>	<b>IV Extraction and processing of raw materials</b>
Increasing domestic value-added products, particularly through the effective transfer of technology and R&D results into the production process	a	a	a	a
Development of production processes in industry focusing on better use of available resources, greater use of recycling materials and environment-friendly materials through scientific and technological development and innovation	a		a	a
The use, placement and replacement of previously used materials for advanced materials with a new and more complex performance, including technological processing (machining, forming, binding)	a			
Development of technological investment units, particularly in the field of metallurgy, engineering, energy and integrated industrial equipment, with respect to the application and use of light metals and advanced materials in the manufacture of transport and construction facility to reduce overall weight and contribute to the green economy, development and application usage of composite materials	a			a
Development of technological investment units, particularly in the energy and industrial facilities, with respect to internationalisation activities and the development of "emerging countries"	a			
Increasing the effectiveness of production and logistics processes	p			
Use of ICT and robotics in production processes		p		
Involvement in supply chains and internationalisation - "the purchase of cooperation is a purchase, too"	a		a	a
Know-how transfer from large to small subjects and vice versa in the framework of cooperation	a			

Energy efficiency and renewable energy	a			
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	I New construction materials for use in industry and the energy sector	II Advanced materials, structures and nanotechnology	III Organic and polymeric materials	IV Extraction and processing of raw materials
<b>Areas of economic specialisation</b>				
Automotive and mechanical engineering industries	a		a	a
Consumer electronics and electrical equipment	a	a	a	
ICT products and services		a	a	
Production and processing of iron and steel	a			a
<b>Prospective areas of specialisation</b>				
Automation, robotics and digital technology	p	a		
Processing and increasing the value of light metals and their alloys	a			a
Production and processing of polymers and advanced chemical substances			a	
Creative industry	p			
Increasing the value of domestic raw material base			a	a
Supporting smart technologies in the processing of raw materials and waste in the region of their occurrence			a	a

y – yes, p – partially

#### 4. **Expected outputs and the potential of their application and use in economic and social practice:**

In general, the expected research and development results include new products or the innovation of existing products bringing higher economic effectiveness, higher quality, added value, life-cycle, more acceptable energetic and ecological impacts or safer production, use or liquidation of products.

Specifically, long-term strategic research and development in the above-mentioned fields has the potential to bring the following outputs for practice in the RIS3 SK areas of economic/prospective economic specialisation:

- New or innovated products in the subcontractors' chain of the automotive, mechanical engineering, railway, electrical engineering industry, such as various construction components, functional systems or fluid systems;
- New types of materials and thin layers for new technologies aimed to increase the life-cycle of components produced from such materials and reduce the energy demands of their production;
- Increasing the effectiveness of use of the domestic raw materials base – manufacturing of products with a higher added value;
- New largely innovated materials and related technologies with a major added value for launch of production;
- New types of sensors to be deployed in different areas of use;
- New substances substituting prohibited materials in accordance with the REACH standard;
- New materials for daily use – new types of packages (e.g. biodegradable packages, hydrophobic coats of packaging materials, etc.);
- New materials with a smaller environmental burden for increasing the safety of nuclear power plants.

#### 5. **Quality objectives to which the support of long-term strategic programme is expected to contribute under the RIS3 SK objectives:**

- Development of the research base targeting the areas of actual needs of industry in Slovakia (in particular automotive, mechanical engineering, railway, chemical, electricity and electronic industries, industry of building materials, as well as processing of minerals and secondary raw materials) to ensure more innovation and added value in production through more novelty based on own research, and hence, major economic effect;
- Systematic development of human resources focusing on the technological needs of industry in the near future;
- Systematic development of the methods, skills, and technical background needed for research, experimental development and production of advanced and innovative materials, related structures, technologies, as well as diagnostic and analytical methods;
- Own development base to meet the specific objectives of the REACH standard;
- Creation of new and maintenance of existing jobs and relationships with industry;
- Supporting regional economic growth;
- Direct domestic and foreign investments in research and development;
- Increased co-operation between the academic sphere and businesses, setting up of new common enterprises;
- Increased number of patents and their commercialisation;
- Better integration in international projects on industrial research and development;
- Preventing the drain of talented and highly qualified people abroad;
- Modernisation and streamlining of Slovak science for its better incorporation in the European Research Area and enhancing Slovakia's competitiveness;
- Supporting projects in the framework of transfer of scientific results into practice by, for example, the setting-up of spin-offs or start-ups;
- Creation of new technologies and designs with a high added value.

#### **6. Links to research trends within the EU:**

This priority relates to all principal thematic priorities of Horizon 2020: Supporting excellent science, Enhancing the leading position of industry in the following fields: New Materials, Nanotechnologies, Advanced Manufacturing and Processing, and Biotechnologies; social needs: Safe, Clean and Efficient Energy; Smart, Green and Integrated Transport; Climate Action, Environment, Effectiveness of Sources and Raw Materials. This priority is also linked to the programme of reduction of CO emissions, energy security or EuropeCar 2020. The priority in the field of low-sized materials (graphene and related materials) with new unique features is directly linked to the Future Emerging Technologies programme which anticipates future key technologies for the EU.