Description of the specialization

I. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR MEDICAL PURPOSES AND HEALTH CARE AND HYBRID MATERIALS INVOLVING LIVING TISSUES AND CELLS

1. New materials, including composite and nanostructural materials and innovative technologies of their production in the scope of 3D printing technologies and hybrid biodegradable polymer materials with controllable bioactivity, hybrid fibre structures for regenerative medicine applications,
   polymer nanocomposites and nanocomposite fibres, for medical and hygienic purposes, for innovative medical and dental equipment, instruments and products,
   for providing and supporting medical diagnostics, as well as treatment and methods in the area of regenerative medicine.
2. New materials, including composite and nanostructural materials used for manufacturing medical and dental products and implants, as well as stents with varied chemical and phase composition of the core and outer layers, characterised by anisotropic and biomechanical properties, biocompatibility, biodegradability, adjustable degradation time, as well as nanocomposite materials used for porous scaffolds for cell cultures and innovative technologies for their production based on 3D printing, hybrid and surface engineering methods and involving tissue engineering methods.
3. New materials, including composite, nanostructural and hybrid bio-engineered materials
   involving living tissues and cells, used for medical implants, including dental implants, stents, artificial organs and hybrid bio-engineered implants, and innovative technologies for their production based on 3D printing and hybrid methods.
4. New composite and nanostructural materials acceptable by the human body, used for medical nano-
   and microimplants, biocompatible fluorescent nanomarkers, for nanoencapsulation of pharmaceuticals, for applications in bioimaging and drug transport, for diagnostic and treatment purposes, enabling creation of smart medical and telemedical nanolaboratories, as well as development of innovative technologies for their production.
5. New smart composite and nanostructural materials for dressings, for surgical and hygienic
   products, enabling dosing of drugs and nanopharmaceuticals, with adjustable time of biodegradation and separation from bed, as well as innovative

technologies for their production.

6. Technologies and nanotechnologies of special-purpose surface and nanostructural layers for products used for medical instrument system and medical and dental
   implants, as well as in food sector equipment.

II. ECOMATERIALS, COMPOSITE AND NANOSTRUCTURAL BIOMIMETIC, BIONIC AND BIODEGRADABLE MATERIALS

1. New functional materials, nanomaterials and nanocomposites for natural environment protection, including protection against pollution and greenhouse gas emission, used in low emission systems and for strategic substitution of environmentally hazardous materials, with materials free from harmful substances, ensuring good environmental protection, more suitable for recycling, and innovative technologies for their production.
2. New materials, technologies and constructions for material, technological and construction conversions in view of ensuring sustainable development, reduction of manufacturing costs
   and energy consumption, elimination of harmful substances or their emission, reduction of consumption of scarce elements, as well as development of related engineering design methods and computer-assisted engineering design methods.
3. New cost-effective materials and nanomaterials, including alloys and structures relevant for environmental development, for water filtration, for moisture or fog absorbers, solar collectors, solar cookers, thermoelectric roof tiles using diffused solar radiation, as well as innovative technologies of their production.
4. New composite and nanostructural ecomaterials with adjustable time of degradation or resorption
   from natural raw materials, biopolymers reinforced with fibres of plant origin and subject to controllable biodegradation.
5. New and bio-inspired technologies, metal materials and constructions and their superhydrophobic surfaces, for vessel-shaped cooling channels, hierarchical alloys/foams/composites, and new multifunctional biomimetic and bionic materials, nanomaterials and nanocomposites
   and new multifunctional structural composites and nanocomposites, bionic layers and structures, as well as innovative technologies for their production.

III. ADVANCED MATERIALS AND NANOTECHNOLOGIES IN RENEWABLE ENERGY AND FOR TRANSFORMATION, STORAGE AND RATIONALISATION OF ENERGY MANAGEMENT

1. New multifunctional materials, nanomaterials and nanocomposites for

production, transformation, storage and rationalisation of energy management.

2. New advanced materials, nanomaterials and nanocomposites for highly efficient photovoltaic energy production based on mono- and polycrystalline silicon, inorganic and organic materials, used for production of perovskite and dye-sensitised cells,
   involving conducive polymers and antireflection coatings containing particles, thin coatings, carbon nanotubes and graphene, heat transfer fluids, multiphase materials, receptors
   and their combinations, as well as innovative technologies for their production.
3. New advanced materials, nanomaterials and nanocomposites ensuring integration of grid energy storage technologies, as involving advanced functional particles, fibres, layers, coatings, in order to integrate mass storage equipment within an electric netowrk, and based on using high-capacity cables and superconductors, high-voltage
   cables and accessories, materials for medium-voltage and electrical accessories, smart new materials for extreme conditions and surface treatment of existing materials to protect and improve performance in the context of grid energy storage and new copper-, silver or aluminium-based composites, containing various allotropic forms of carbon, including graphene, intended for applications in the electricity industry, for heat dispersing materials, low- and high-voltage joints, power transfer wires.
4. New advanced materials, nanomaterials and nanocomposites ensuring the choice of energy storage methods through transformation of electricity to chemical energy carriers, materials for durable high-capacity proton transfer membranes, hydrogen generators using high-pressure electrolysis, for permanent low-pressure hydrogen storage and direct hydrocarbon synthesis, for photochemical water splitting reactors using new catalysts based on advanced materials.

IV. MULTIFUNCTIONAL COMPOSITE AND NANOSTRUCTURAL, ULTRALIGHT AND ULTRADURABLE MATERIALS WITH RADICALLY IMPROVED HEAT RESISTANCE AND HEAT CREEP RESISTANCE

1. New advanced light construction materials, nanocomposites and nanocomposites, characterised by improved mechanical properties, composites with metal warp reinforced with micro- and nanostructures , containing various light components, such as Mg, Al, Ti in construction and heating applications, and as Cu, Al, with a low friction coefficient, wear-resistant, shock-resistant, for electric applications, as biocompatible materials, new low-density and high-

resistance materials, very plastic steels and alloys, polymer and composite layered materials and high-resistance foams with a reduced unit mass, as well as as their innovative technologies.

2. New advanced light high-resistance intermetallic materials in the scope of aluminides, silicides and ductile lanthanides and cerments, new nanocrystalline Mg, Al or Li hydrides
   characterised by high absorption and desorption kinetics for hydrogen storage, materials, nanomaterials and nanocomposites, as well as precipitation-hardened core-coating Al-Li-Sc, Al-Mg-Sc alloys for high-resistance specialised elements and their innovative technologies.
3. Technologies of advanced light and new solid metallic glasses based on Mg, Al, Ti, Fe and amorphous, nanocrystalline and crystalline composites and nanocomposites for applications for specialised construction, functional or biomedical wear- and corrosion-resistant elements and microelements, as well as as their innovative technologies.
4. Technologies of advanced ultralight new wear-resistant cell structures with metal, polymer, ceramic and composite warping and hybrid cell structures, metal foams, micro- and nanoscaffold, grid and hybrid constructions.
5. New advanced materials, including compound metal alloys characterised by high entropy, which ensures unique structural properties and greater phase stability for high
   temperature applications, heat-resistant alloys of W, Ta, Re, Hf, Nb, Mo, V and platinum-group metals for operation in the most extreme high-temperature and oxidising environments and for thermonuclear applications, as well as new metallic-ceramic composite materials with unique properties and their innovative technologies.
6. Technologies of new advanced fine-grained superplaistically deformed Ti or Al alloys and of high-resistant super-bainite steels grade TRIP, TWIP and TRIPLEX, new ODS steels and bearing steels.
7. Technologies of new advanced light composites with fibre-reinforced polymer warping and hybrid composites, which improve mechanical properties and reduce the mass of the final product.

V. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR APPLICATIONS RELATED TO SAFETY

1. Technologies of new advanced polymer and hybrid materials, nanomaterials and nanocomposites with fibre reinforcement characterised by improved mechanical properties
   and reduced mass, using spatially formed fibre structures, with a 3D-printing formed structure, reinforced additionally with inorganic or organic fibres and

integrated with sensors, for personal protective equipment and smart specialised clothing.

2. Technologies of new advanced multilayer composite and hybrid materials based on surface engineering technologies, using laser technologies, and of ceramic-metal composite materials.

VI. ADVANCED MATERIALS AND NANOTECHNOLOGIES FOR PRODUCTS WITH HIGH ADDED VALUE AND HIGH SIGNIFICANCE FOR VALUE CHAINS IN INDUSTRY

1. New methods of production of sintered and ceramic materials, including superfine-grained materials, and innovative products manufactured with those technologies, methods for powder metallurgy and productions, in the scope of atomisation, cold spraying, extrusion forming and coating, other innovative forming techniques, incremental sheet forming, blast forming or creep forming, isostatic densification, new processing technologies and increase in metal production and their forming process, near-net-shape precision processing, thermal processing, thermal-plastic and surface processing, as well as joining and recycling techniques.
2. New incremental technologies, technologies of laser selective sintering and melting as well as 3D printing, along
   with proper devices, new innovative solid and porous materials, including hybrid and gradient
   materials with properties gradient or properties transforming in a designed manner in rleation to their volume, or anisotropic layer composites with continuously transforming compositions, from metal to ceramics, or with various compositions and core and surface properties, composites composed of materials differing in physical and chemical properties, melting point, heat conductivity, absorptivity, regarding heat creep resistance requirements, wear resistance, passivation abilities, corrosion resistance, innovative materials with geometrically designed internal structure, filled with grid and rod structures, or layer materials with special mechanical properties, controllable rigidity or elasticity, vibration damping or dispersing capacities,
   to a degree other than may be allowed by the qualities of the base material alone, hybrid materials volume- or surface-doped with powders differing in their size or composition from the base material.
3. Innovative technologies for manufacture of unit or small batch products, with new functionalities, characterised by a complex shaped, with adjustable porousness, “smart” products through integration with sensors and effectors, with short time of implementation into the production process, multi-material products and products from materials impossible to be produced with other technologies, from components with varied melting and boiling points, for

application in various sectors of industry and economy, as well as in medicine and health care.

4. New innovative technologies for production and processing of nanocrystalline multifunctional alloys with methods of plastic deformation by twisting, cyclical squeezing, multiple angular channel pressing, with hybrid rolling methods, hydrostatic squeezing and alternate forging, in relation to various construction elements, through pressure casting with infiltration, microcasting and imprinting of alloys, composites and solid metallic glasses, used for specialist elements of microdevices, integrated electromechanical MEMS microsystems, as well as nanostructural matrices and surface hierarchic coatings, in Cu, through electrolytic settlement to be applied
in boilers, heat exchangers and pipelines.
5. New advanced hybrid technologies for materials and final products related to nanostructure and nanofunction forming during the standard process for finished or semi-finished products, in crystallisation additives in nanoparticles during injection moulding of a metal layer or during forging or independent creation of hierarchical structures while coating, in order to produce non-standard finished products or semi-finished products from advanced materials, nanofoams and nanocomposites, following the provision of an increased level of reliability and repeatability of industrial processes.
6. New and developed microfluidisation devices based on polymer materials through 3D printing or injection of polymer or ceramic materials, during the production of microflow integrated electromechanical MEMS microsystems, for nozzles and filters, applied for sensors, lab-on-chip systems, printed biochemical materials, soft beds for biological micro- and nanoapplications, biomedical and biophysical sensors, biocompatible or non-toxic scaffolds for active cell grwoth, and also in order to reduce costs of quick production and prototyping of a new series of single-use products, where production costs have to be reduced to minimum, and in order to use them for practical applications after shifting from the laboratory or small-batch scale to industrial applications simultaneously to the growth in the level of reliability and repeatability of industrial processes.

VII. MATERIALS, NANOMATERIALS AND FUNCTIONAL COMPOSITES WITH ADVANCED PHYSICAL-CHEMICAL AND UTILITY QUALITIES

1. Technologies for production and processing of new advanced smart materials, nanomaterials and nanocomposites, integrated in 2D and 3D forms, advanced light composites in polymer, metal, organic fibre and textronic warping, as well as metal materials, involving carbon nanoparticles, in order to provide new functionalities, communicating and cooperating with the environment, archiving data on its state and reacting to external stimuli, changing their physical

properties, viscosity, shape, colour due to changes in temperature, tension, electric field, solar energy, having the capacity to collect, store and transfer data, to be used for sensors in self-diagnosing elements, elements that identify damages on their own or can repair themselves during exploitations, for functional composite gradient materials with variable magnetic purposes, for vibration and sound damping, conducive polymers generating heat energy.

2. New advanced functional materials with non-standard electric and heat conductivity, intended for industries producing final products, for condensers, thermal coatings, insulation panels of energy-efficient buildings, and with application of new production devices and processes of incremental technologies and 3D printing, in order to advance integration with multifunctional nanomaterials and their utilisation in practical applications on a big scale, much bigger than the previously limited niche applications, after moving from laboratory scale to industrial applications, together with an increase of reliability and repeatability level of such industrial processes.
3. New innovative technologies for production and processing of nanostructural advanced materials with new functionalities, superhydrophobic, self-cleaning, self-repairing systems, smart biomimetic textiles and papers, with controllable shape change and memory, self-organising systems acquiring energy, intended for industrial and economic sectors relevant for industrial design, in order to obtain added value for products through application of new material and non-material functionalities, as well as designing and producing radically new products with a strong market competitive advantage.
4. New technologies that enable application of paper and textiles for functional electronic elements or devices, with promising technical, economic and environmental advantages, for smart displays for labels, packaging, biological marks, in medicine in relation to development of lab-on-chip and interconnected development of new production technologies for paper and textiles, with use of reinforcement fibres and fillers, with provision of a required level of porosity and development of new paper and textiles, with proper organic, inorganic or hybrid layers, processing and functionalisation of paper and textiles surface with use of nanocellulose, plasma or gas, and introduction of new materials, including conductive materials, insulator semiconductors, electrochromic materials, electrodes for batteries as well as print that is highly precise and profitable, or other large-scale production technologies, with application for ink printers and in roll-to-roll processes.
5. Advanced multifunctional smart nanostructural materials to be applied in electronics, optoelectronics, sensorics, IT, photonics and communication, and their technologies.

VIII. MULTIFUNCTIONAL COMPOSITE NANOMATERIALS WITH WARP OR

STRENGTHENING FROM NANOSTRUCTURAL CARBON MATERIALS AND OTHER NANOFIBRES, NANOWIRES AND NANOTUBES AND THEIR TECHNOLOGIES

1. Technologies of advanced multifunctional nanostructural and nanocomposite materials, including those in metal, polymer and ceramic warp, with strengthening from various kinds of carbon nanostructural materials, nanotubes, fullerenes, nanofibres, graphene, together with development of production scale from laboratory to industrial, with improvement of reliability and repeatability of relevant industrial processes, and other organic and inorganic natural materials, halloysite and synthesized substances, titanium dioxide, nanowires, nanofibres, nanotubes and other nanostructural objects, in order to obtain an added value of products and unexpected results in a form of improvement of mechanical and physical-chemical properties through application of new material and non-material functions, as well as design and production of radically new and significantly developmental products with a strong competitive market advantage.
2. Technologies for advanced multifunctional nanostructural and nanocomposite materials with a warp of various types of carbon nanostructural materials, nanotubes, fullerenes, nanofibres, graphene, decorated with precious metals nanocrystals, applied for nanosensors, with nanolayers of polymer complexes applied on fibres in order to embed metals into the surface and change its qualities – heat, bactericidal and catalytic, use as reactors for matrix polymerisations, together with development of a production scale, for use in nanosensorics, nanoelectronics, nanoencapsulation of medicines, in order to obtain added value of products, through use of new functionalities and production of radically new and highly developmental products.

IX. MULTIFUNCTIONAL LAYERS AND PROTECTIVE AND ANTIWEAR NANOLAYERS AND SPATIAL, LAYERED AND SELF-REPAIRING COMPOSITES AND NANOCOMPOSITES

1. New technologies for surface processing through surface shaping and applying layers, *inter alia* nanostructural layers, including applying self-assembled monolayers, immobilisation, templating, and applying diamond layers and diamond-like carbon coatings and electrophorethic and sedimentation settlement, providing good biocompatibility and corrosion resistance of coatings, and a possibility of applying them to elements of highly-complex geometries, in relation to production of innovative devices, instruments and medical and dentist products.
2. New nanotechnologies for processing of anti-bacteria surfaces through use of surface coatings or modification of surface morphology, for use in hospitals on surface layers of furniture, equipment and medical devices, surgical implants, as

well as in water treatment systems, textiles, packagings, to storing food and on household appliances, and their utilisation for practical purposes after moving from laboratory scale to industrial applications, along with increasing the level of reliability and repeatability of relevant industrial processes.

3. New technologies of surface processing through shaping the surface and applying layers – *inter alia* nanostructural ones – through physical and chemical embedment of coatings from a gas phase (PVD/CVD), implantation of ions and coating with ceramics and cermets in relation to metal construction materials, and physical and chemical application of coatings from a gas phase, embedment with impulsive laser or through EUV laser and plasma sources radiation, and with a sol-gel method and through electrophoretic embedment in relation to non-metal construction elements, applied in various industrial sectors, mainly in machinery and electro-machinery, and application of powder polymer coatings, painting and lacquering with liquid polymer materials, hot dip galvanizing with additional annealing, application of layers from polymer foils and metal spraying, through laser ablation (PLD), hybrid technologies, with participation of laser processing, the method of gradient coatings application, physical and chemical application of coatings from a gas phase (PVD/CVD), in relation to materials for instruments.
4. New nanotechnologies for surface processing through application of nanostructural coatings or nanotexturisation of surface, in order to provide increased resistance to scratch
and abrasion, high hardness, resistance to wear and corrosion, colour or gloss, for self-cleaning surface of buildings, for technical textiles coatings with increased resistance and mechanical properties, for construction elements of machinery, structures and means of transport, in various sectors, including packagings, sea, water treatment, electronics, construction industry, motor industry, energetics, in textiles and leather products, and their practical application together with an increase in the level of reliability and repeatability of relevant industrial processes.
5. New technologies for glass surface processing, micro- and optoelectronic and photovoltaic elements, and functional products manufactured from those materials, through shaping a surface and applying layers, *inter alia* nanostructural, though chemical and physical embedment from a gas phase (PVD/CVD), a sol-gel method, laser texturing, production of hybrid coatings – organic and inorganic, and new technologies for processing of surfaces of polymer and fibre materials, through creation of gradient and self-development coatings, polymerisation in situ, physical and chemical embedment of coatings from a gas phase (PVD/CVD), a sol-gel method, EPD and ALD, and surface laser processing, along with broader use of those technologies on an industrial scale.

6. New and developed nanotechnologies for processing flame retardant and anti-electrostatic surfaces through the use of surface coatings or modification of surface morphology, in order to eliminate or significantly reduce the accumulated charge in connection with flame retardant qualities, applied in places exposed to volatile substances explosion, in warehouses, mines and on landfills, and packagings, when storing volatile substances and their practical application after moving from the laboratory scale to industrial applications, along with an increase in the level of reliability and repeatability of relevant industrial processes.
7. The InnovativeNew multifunctional advanced structural, spatial, shell, layered composites and nanocomposites, with a gradient of qualities, with qualities transforming in a designed manner in their volumes or anisotropic materials and foams, with warp and/or strengthening of metal, polymers or ceramics, shaped with laser selective sintering and melting, and 3D printing technique, or through infiltration and impregnation, with innovative internal 3D geometrical structure, with both micro-
and nanostructural strengthening, or strengthened with organic or inorganic fibres, carbon nanomaterials
and natural nanotubes, with use of spatially formed fibre structures, thin textiles, or such filled with grid and rod structures, with structures of layers and bionic structures, honeycombed structure, with special mechanical and physical-chemical qualities, with elevated resistance, thermal and acoustic insulation, resistance to environmental impact, strikes and cracks, with low density, and innovative technologies for their production.

X. STRUCTURE MODELLING AND QUALITIES OF MULTIFUNCTIONAL MATERIALS AND COMPOSITES, INCLUDING NANOSTRUCTURAL ONES WITH ADVANCED QUALITIES

1. Computer aided design of materials, especially the newly introduced advanced materials, nanomaterials and nanocomposites, along with modelling in an atom scale and in a large scale, with simulation of microstructure and micro-mechanical properties, with use of virtual reality tools and artificial intelligence as well as data exploration methods, with a purpose of virtual designing, virtual processing and virtual testing of advanced materials for technical applications.
2. Modelling and simulating phenomena of degradation and damage to materials in exploitation conditions, in order to predict in conditions of virtual testing the behaviour of advanced materials in technical application.