# Development of applied materials science in the Republic of Belarus



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The main aim of works in the field of materials science in the Republic of Belarus is increasing of a technical level and competitiveness of national production, providing import substitution due to creation of promising metallic, ceramic, polymeric, composite and other materials using high-efficiency technologies and equipment to produce articles and coatings with required set of functional properties.

Development physical and chemical science allowed to work out methods for purposeful regulation of structure formation in heterogenic systems, which include most state-of-the-art composite materials. Intensity of bonds at the boundaries of structure elements in such materials is determined by a technological mode for processing initial components using physical influencing factors and chemical reagents.

Non-reagent treatment consists in transformation of mechanical, heat, electrical and other kinds of energy in potential physical and chemical one of future structure elements. Usually, such energy is concentrated on a surface preconditioning a level of interaction in a contact zone. As resistance of composite materials to external actions is determined, mainly, by a degree of structure elements interconnection, it is possible to control properties of materials and articles on their base changing treatment modes.

Surface properties of structure elements can be changed also by chemical treatment using special reagents and surfactants. New compounds capable of actively interacting with formation of strong bonds are formed in the contact zone. As above-mentioned processes proceed, mainly, at a molecular level, nanotechnology becomes of high priority providing strengthening of the contact zone using different compounds, for example, fullerenes, synthesis of novel structures at a submicron level, surface treatment of ultradispersed powders by activating radiation.

The tasks of material science in Belarus are solved executing state scientific and technical programmes: «Crystal and molecular structures», «Nanomaterials and nanotechnologies», «Mechanics», «Materials in techniques», «Polymer materials and technologies», «Novel materials and technologies», «Microelectronics», «Optotech», «Mechanical Engineering», «Chemical reagents and materials», «Metallurgy».

Different scientific and technical projects financially supported by the Belarusian Republican Foundation for Fundamental Research are carried out. There are traditions in technical science in the field of development and production of novel materials and technologies. It is to single out academic establishments among main executors, for example SSI Powder Metallurgy Institute having formed the Institute of Welding and Protective Coatings, as well the Institute of Impulse Processes within its

walls, Physical-Engineering Institute, Metal Polymer Research Institute, Joint Institute of Mechanical Engineering, as well Scientific and Practical Materials Research Center recently created on the base of the Institute of Solid State Physics, which includes Institute of Applied Physics, Institute of Chemistry of New Materials, Institute of Technical Acoustics, Institute of Metal Technology, EP RUE «Ferrit», RUE «SKTB Metallopolimer», SI RUE «Elkerm», RSE UE «Diatech», RE UP «Technomag».

The Center's main aims are carrying out of research works and R&D in the field of physical and physicochemical material science. The tasks are solved on creation of novel magnetic, ferroelectric, semiconductor, metallic, superconducting, superhard and optical materials in the form of crystals, ceramics, disordered systems, nanomaterials and nanostructures. Developed are methods and technologies to obtain composite organic and inorganic materials and articles on their base, methods and devices for non-destructive testing and technical diagnostics of materials and articles.

High-productivity and low-energy separators for ore and nonmetallic material purification and concentration at ore-dressing and processing enterprises, glass and ceramic factories, in plants for secondary raw materials treatment, food industry were created on the base of a technology for obtaining strong permanent magnets developed in the Center. A unique machining tool based on high-quality superhard materials (synthetic diamonds and cubic boron nitride) was developed. Novel ceramic and ferroelectric materials and elements were created. Proprietary technologies for obtaining synthetic precious stones (emerald crystals) were developed, that allowed to organize small-batch production of jewelries.

Ultradispersed diamonds forming at rapid cooling of explosives detonation products are developed in the field of nanotechnology. Detonation synthesis in explosion chambers is the most cheapest and manufacturable method of industrial production of diamonds. Such diamonds are used to modify structure and enhance properties of galvanic, ion-plasma and microarc oxide coatings, for superfinishing processing and lubrication. Uniqueness of nanodiamonds having a round shape, diameter of 4-7 nm and specific surface of 300±30 $m^2/g$ consists in combination of a diamond structure, hardness and chemical resistance with aggregative and sedimentation stability.

Using impulse cathode arc spraying method, a technology and equipment were developed to obtain high-quality wear-resistant diamond-like nitrogen-containing coatings for friction pairs and production tooling. The usage of electromagnetic carbon plasma separator provides removing microparticles with the size of ≥6μm from a film surface and reducing 1-5 μm particle quantity by 20-25 times. It allows to apply quality coatings with thickness of 165 nm for 1000 impulses with speed 3 times higher than speed of deposition in vacuum. Friction coefficient ($\varphi \approx 0.09$) of nitrogen-containing coatings is significantly lower in comparison with hydrogen-free and hydrogenised ones. It is connected with a surface layer enriched by a nanosized graphite-like phase. Coatings allow to increase friction units' service life three-fold. Their usage in a technological tooling provides high antistick properties at plastic production and ten-fold increase its service life in comparison with a chromic electroplating.

Methods for nanocladding of cubic boron nitride and diamond powders by boron, titanium, silicon and amorphous carbon, obtaining diamond polycrystals from nanodiamonds, forming superhard materials from them for processing nonferrous metals, hard steel and ceramics were developed at the Joint Institute of Mechanical Engineering of the NAS of Belarus.

The use of nanostructured materials, first of all, based on detonation synthesis of nanodiamonds, whose industrial production was mastered at SE JSC «Sinta» in the form of eight ultradispersed diamond modifications differing in phase composition, purification degree, value and sign of surface charge. Successful mastering of nanodiamond production allowed to transform laboratory technologies in industrial ones for the usage of this material in key for the Republic branches.

Among works conducted in the Scientific and Practical Materials Research Center, it is to single out a fundamentally new technology to obtain highly dispersed conditioning agents for microstructure modification of workpieces made of steel, iron, brass, bronze and silumin. Such cast conditioning agents are cheaper, as they are produced from secondary raw materials and contain fewer active elements.

A set of import-substituting and export-oriented polymer composite materials for mechanical engineering, electrotechnical industry, general technical purposes was created. Heat-resistant low-

nickel steel was introduced at RUE «Minsk Tractor Plant». Pallets made of this steel for heat-treatment furnaces passed successfully production tests.

Methods for diagnostics of critical technological equipment based on the use of acoustic-emission, magnetic, ultrasound and capillary non-destructive control techniques were introduced at JSC «Mozyr Oil Refinery». Shape memory alloys, hip prosthesis were developed for Ministry of Health of the Republic of Belarus.

Achievements in the field of highly effective solar elements and modules, electronic sensors, new technological solutions on creation of multilayer electromagnetic screens for protection of space vehicles` on-board equipment enabled the Center to begin cooperation with the Space Research Institute of the RAS (Moscow) within the framework of the Common State's programme «Kosmos-NT».

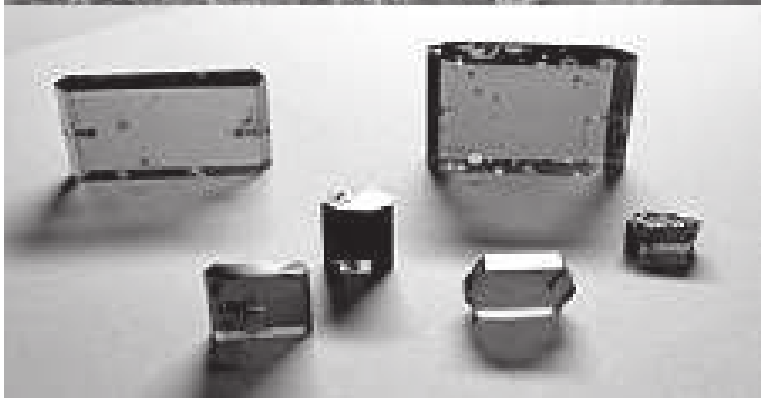
Works of a number of research organizations in the field of material science are connected with development of new materials for powder metallurgy, ceramics, composite, nanosized and superhard composite coatings, welding, including the use of dynamic and impulse loading methods. Technologies for applying of protective, strengthening, wear-resistant and biocompatible coatings are being developed; multifunctional special and multicomponent materials based on thermodynamically stable compounds are being created. Scientific and technological fundamentals for creation and processing new structure materials, including the use of high-energy sources, are being developed.

It is to note the following directions:

- scientific approaches with the use of computer simulation to control properties of composite powder materials with a metallic base with inclusions of a hard (soft) phase, peculiarities of their microstructure and behavior at external force and temperature actions;
- principles for creation and control of microstructure and properties of nanocrystalline composite materials for different purposes;
- creation of permeable materials with an organized structure obtained by powder metallurgy methods for combustion, filtration and catalysis processes;
- investigation of heat and mass transfer in porous powder materials with a irregular porous structure;
- obtainment of composite powders with a preset composition by mechanical alloying, granulation, self-propagating high-temperature synthesis (SHS), applying of functional protective coatings from powder materials;
- theoretical and technological fundamentals for material modification by microplasma-spark methods in conditions of a control electric discharge;
- valid approaches for creation of novel composite electrode materials on current-conduction substrates by microplasma-spark methods;
- investigation of strengthening mechanism of gas-thermal composite coatings at treatment by high-concentrated energy flows;
- physical and chemical interphase interaction at high-speed shock and impulse action, theoretical fundamentals of high-speed shock dynamics and deformable solid mechanics on the following lines: explosion welding, explosion compaction, shock wave focusing, structural failure;
- novel materials, including laminated composite, ceramics, construction, powder ones, technological processes and equipment for their synthesis by explosion at high pressures, temperatures and loading speeds.

Research in the field of laser and electron-beam surface treatments, effective methods for strengthening, which allows to obtain micro- and nanostructured materials in a surface layer make a great contribution in development of material science and technologies. A spectrum of technologies for laser and electron-beam surface modifying is broad and enables to improve practically all working characteristics of machine parts surfaces. Target parameters (hardness, wear-resistance, etc.) can be increased by 2 and more times.

It is to note developments of the Institute of Powder Metallurgy generally recognized in the Republic and world. The Institute is a head organization on realization of the scientific and technological programmes «New materials» and «Resource-saving». Material compositions and different technologies of their obtainment and application are developed within the framework of these programmes. In



particular, it is possible to provide the following examples: copper coating formation by the magnetron sputtering method on friction discs workpieces; composite antifriction and protection layers on surfaces of cultivators` spherical body supports, antifriction layers on hinged joints; high-density bimetallic coatings on friction units parts of machine hydrosystems using hypersonic metallization; friction units parts of «rotor» and «pivot» rotor groups for axial-piston pumps; applying of multilayer protection layers in vacuum on linings of gas consumption sensing devices for ultrasound counters; formation of coatings with a complex strengthening effect by the microplasma-spark alloying method with ultrasonic modification of a surface of parts for machine engineering; production of an antifriction consistent lubricant for tribological surfaces protection based on vacuum oil distillates and paraffin oil production drips.

Compositions being developed are used for deposition of wear-resistant, anticorrosive and heat-shielding coatings by high-velocity oxygen-fuel (HVOF) spraying. In particular, chrome and titanium carbide-based powders allow to form coatings working in conditions of abrasive and erosive wearing, corrosion up to 7000C. They are recommended for protection of energy equipment parts, forging tooling, crushing roles, dies for hot pressing, bearing inserts.

Nickel aluminide-based powders allow to use a technology for deposition of protection coatings resistant to erosion wearing at increased temperatures in conditions of low- and high-temperature corrosion in presence of chlorides for protection of energy equipment, parts used in production and re-use of chemical fibers, recovery and protection of salt-mining equipment against corrosion and wear. Iron aluminide-based powders are intended for applying coatings resistant to erosion wearing at elevated temperatures in sulfur-containing atmosphere. They are recommended for protection of energy equipment, parts for coal gasification units, mechanisms working with salt melts. High-technology products of the Institute are the following:

- construction, tribotechnical and special materials and articles on their base (starter inserts, friction bearings, guide bushes, antifriction materials of different application, friction discs, parts of mechanical and steam-mechanical nozzles, synchronizing rings for gear boxes);
- materials and articles for electrical engineering and radio electronics, technical ceramics;
- tool based on superhard materials, nature and synthetic diamonds (drills, mills, wheels, discs, segments, roles);
- porous filtering and capillary - porous materials, articles on their base (metal foam, filters for melts, separators, heat tubes);

- materials and technologies for production of implants (maxillofacial prosthetics, electrodes for heart electrostimulation, cervical and thoracic vertebrae, dental and ophthalmologic composite implants);
- materials and technologies for applying coatings;
- welding materials, technologies and equipment.

In the field of construction material science, composite materials resistant to sign-changing temperatures typical for conditions of the Republic are developed. Modified concretes with high frost and corrosion resistance for monolithic and assembled concrete and reinforced concrete articles and structures of bridgeworks and coverings subjected to action of chemical deicing agents and other aggressive external environment factors are developed in the Belarusian Road Traffic Research Institute. Concrete compression strength is B30-B70, frost-resistance is F150-F300, water resistance is W20, water absorption by weight is less than 3%. High working properties of concretes are achieved by means of surfactants, in particular, GP-1 hyperplastifying agent developed by Belarusian Research Institute for Civil Engineering. Production of GP-1 hyperplastifying agents is organized at the «BarChim» chemical plant.

Emulsion technologies for obtaining organic bindings and construction materials on their base are broadly used at road construction in the Republic. Using colloidal chemistry, emulsion-mineral oils with accelerated formation time providing rapid strength gain of roadway covering structure layers due to intensive water drainage and formation of a stable structure have been developed. To increase load-carrying capability of highways, dispersed reinforcement in the form of synthetic fibers, fullerene glass fibers is introduced in composition of road-building materials. The latter is proposed to apply on a surface of fine-dispersed binding cements and fillers, mineral powders, that allows to reinforce a contact zone in a structure of composite materials. Developments are carried out at the Belarusian National Technical University.

Over the 2006-2010 years 103 tasks were fulfilled; 239 new technique objects were created, including equipment-19, materials, substances, tools-74, technological processes - 88. 46 sites and production facilities were created and modernized.