

THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE

in 2019



SUMMING UP THE YEAR

Last year, in spite of all difficulties, scientists of our Academy continued their dedicated work and obtained numerous results of truly high scientific relevance in many important areas of science and technology.

Our experts in cybernetics were the first in the world to develop a method, which, relying on artificial intelligence, enabled them to automatize the process of choosing the most rapid algorithm for solving intricate problems with the help of supercomputers. A new information technology for the classification of environment objects in terms of heavy metals concentration in them was also developed, as well as methods of information coding that are several times better than those currently available in the world. Materials scientists produced unique inorganic luminescent nanoparticles for biomedicine. Owing to the results obtained, these nanomaterials could be regarded as novel multifunctional therapeutic agents with highly effective wound healing properties, antitumor and radioprotective action, the ability to correct endocrine pathologies and retard aging. Experts in nuclear physics and energy proposed a technology to control the power of fast neutron reactor operating in the mode of self-sustaining nuclear burn-up wave by changing the efficiency of radial neutron reflector. They also produced an entirely new class of materials — high-entropy alloys reinforced with nano-sized particles of thermally stable oxides. Such alloys are more reliable than steel and can be used in all types of next-generation nuclear reactors.

Academy chemists proposed an innovative effective single-stage mechanochemical method of producing graphene doped with nitrogen and fluorine atoms, which is intended for chemical current sources, electrocatalysis, selective electrochemical sensors for biologically active compounds etc. Researchers in life sciences obtained important fundamental data for the treatment of a wide range of neurodegenerative di-



sorders, Parkinson's disease in particular. The use of the proposed technique of intermittent hypoxic therapy, via the mechanisms of transitory rise in leptin levels and the support of higher expression of specific proteins, ensures a positive effect in the treatment of the early stages of type II diabetes and Alzheimer's disease. Scientists in genetics obtained a number of unique genotypes for producing novel wheat varieties for bread baking and confectionary products. Biologists developed a system for accumulating a special protein — colicin — in edible plants; it is capable of destroying pathogenic strains of *Escherichia coli* that cause acute intestinal infections in humans and animals.

The results of applied research and R&D carried out by Academy institutions are also worthy of notice. A significant number of those are either used in practice now or being prepared for deployment in the near future. For example, researchers in mathematics and mechanics developed a methodology for assessing the functional status and determining the actual fracture loads of rocket shell structures, in particular, oxidizer tanks of the propellant compartment under internal pressure. This development work has already been adopted to be used at the state enterprise 'M.K. Yangel "Pivdenne" Design Office'. Experts in cybernetics proposed algorithms of nonsmooth optimization as well as software that enabled engineers to achieve

a 2–3 fold reduction in the term of designing the surfaces of compressor blade stylus and aviation motor turbine and to improve their output performance. The results have already been deployed at 'Ivchenko–Progress' State Enterprise (Zaporizhia). Researchers in electric welding discovered the regularities of forming the structure of dissimilar weld joints of heat resistant nickel alloys in butt-seam resistance welding. This enabled them to develop technological procedures for preventing cracking during welding of heat-resistant nickel alloys that are used in gas-turbine aviation engines produced in Ukraine ('Motor Sich' Joint Stock Company, 'Ivchenko—Progress' State Enterprise). Ukrainian coalmines ('Pivdenodonbaska' mine, 'Almazna' mine of 'Dobropilske' mine directorate, 'Vidrodzhennya' of 'Lvivuhillya' State Enterprise) and paramilitary mine-rescue teams adopted special equipment that allowed them to improve the accuracy of measurements in the ventilation systems of coal and ore mines and the effectiveness of mine decontamination systems, reduce methane concentration in the exhaust airstream. In the framework of collaboration between the Institute for Scintillation Materials, the European Organization for Nuclear Research (CERN) and *AddiPoleAdvanced ManufacturingCenter* (Switzerland), technological foundations of the 3D printing of polystyrene plastic scintillators were developed. Prototypes of scintillation calorimetry modules for experiments in particle physics were produced on their basis. Geochemists elaborated a novel method of removing radioactive contamination, heavy metals, organic compounds from technological water, which relies on the use of nanomaterials and nanocomposites produced with plasma chemical synthesis.

A special focus should be given to applied developments of our scientists for the Armed Forces of Ukraine. Among them is the technology of producing laminated structures based on titanium alloys and metal matrix composites that are intended for armor protection elements. Researchers carried out computer simulation of the process of dynamic penetration of steel rods (cores) of armor-piercing bullets into solid and discrete ceramic elements of a shockproof target obstacle based on self-bonded silicon carbide with Kevlar support. Its results will be used for designing ceramic composite armor blocks with discrete ceramic armor elements in compliance with NATO standards. Optimum physico-chemical conditions were determined for growing crystals of magnesium-aluminum spinel according to the "iridium-free" technology. The spinel is the material for passive modulators, which are effective as components of military rangefinders produced ac-

ording to NATO requirements. A pilot version of the highly effective control system of the driving gear with electric motors that uses permanent magnets and is intended for hybrid military transport vehicles was developed and tested for the first time in Ukraine. This system has already been offered for application in the electric driving gear of the БТР-4Е armored troop carrier, which is being developed by the State Enterprise "O.O. Morozov Kharkiv Machine-Building Design Office".

A novel medical thermoelectric device for contact cooling of human eyes through eyelids was developed and tested. This device has no counterparts in the world and is intended for treating acute and chronic ophthalmological diseases, reducing intraocular pressure, treating pain syndrome and inflammation processes in the eye. The man-made autotransplant analog is also a unique development. This is a composite implant for large-volume regeneration of bone tissue; it is based on a modified bioactive ceramics, which is an analog of the mineral component of bone tissue and patient's own bone cells. Obtaining a fully functional implant that can entirely replace a bone defect is vital for the treatment of locomotor system injuries of soldiers. Another development that has no counterparts in the world is three-dimensional algorithms of the visualization and analysis of electrophysiological processes in the ventricular system of human heart. The algorithms were employed in the new magnetic cardiograph device developed by cybernetics scientists. It has already been used in the National Military Clinical Center 'Head Military Clinical Hospital' of the Ministry of Defense of Ukraine for the diagnostics of military personnel having combined myocardial lesions, heart ischemia and ventricular arrhythmias. Chemists produced a binary cold-cured polyurethane adhesive for sealing the junctions and damages in concrete and reinforced concrete structures and carried out its field trials, in particular at the facilities of the Armed Forces of Ukraine. 'АТНВ' fuel was also developed and tested for military needs. This product can have diverse functional application in field conditions.

The studies of our scholars in socio-humanities do not avoid vital socio-political problems of today's Ukraine. For example, politologists examined the influence of the processes of globalization and social transformations on the social and national consolidation in present-day Ukraine, detected the "critical zones" of artificially constructed or triggered social antagonisms, revealed the dynamics of the differences in personal and group interests and related identities.

On that basis, they elaborated proposals towards improving the ethno-national policy of the state. Economics scientists elaborated modern applied instruments for on-line assessment and forecasting of the living standards of Ukrainian citizens and its dynamics, with the account being taken of the economic conditions in the country and managerial decisions in the social and economic spheres. This makes possible the on-line assessment of the living standards of Ukrainians. Our scholars also place high emphasis on scientific expertise. At the request and in the interests of state administration bodies they have prepared a large volume of various information and analytical data, expert conclusions, proposals and recommendations, program and prognostic documents.

Regrettably, in 2019, as in all recent years, the Academy was faced with numerous acute problems – the chronic underfunding of research, low demand for scientific developments from the economy, and the outflow of research personnel. After adopting the Law of Ukraine ‘On Scientific and Scientific and Technology Activities’ in 2015, there appeared some possible signs of changes for the better. However, many provisions of this law have not been implemented and remain mere declarations. The introduction of the grant system of research funding, which is envisaged by the law, has not been executed despite the relevant provisions in the State Budget.

It should be pointed out that persistent work towards reforming the Academy activities is going on, in accordance with the demands of modern times and science advancement. In recent years, the changes have been implemented in accordance with the measures envisaged by the Concept of the Development of the National Academy of Sciences of Ukraine in 2014–2023, and certain positive results in this direction have been achieved.

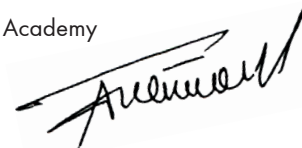
The efficiency of the activities of our research institutions is evaluated with reliance on a new methodology, which was elaborated taking into account foreign experience. Organizational units of the institutions that were included into category “A” received extra earmarked funding, while optimization measures are taken in respect of the institutions whose activities were ineffective. In 2019, the decision on the liquidation of

the Center of Monument Studies operating under the NAS of Ukraine and the Ukrainian Society for the Protection of Monuments of History and Culture was adopted. Last year, the new form of support to young scientists – youth laboratories and groups for research in priority areas of S&T development – received significantly higher funding. Essential changes took place in the activities of the former hospital for scientists, which several years ago was reorganized into the State Institution ‘Center for Innovative Medical Technologies of the NAS of Ukraine’ and its facilities were radically innovated. Now it can provide laparoscopic surgical procedures and implement up-to-date rehabilitation protocols.

Last November, several working groups of our Academy were set up. They are engaged in preparing proposals for the advancement of the science sphere of Ukraine, the amendments to current laws, which are necessary, in particular, for further reforming the NAS activities, determining priorities in the development of science and technology, measures taken by the government in support of young scientists. Now we have concrete results of the activities of these groups.

The work towards reforming the Academy should not merely be continued but should be intensified. Our high-priority in this direction are to finish the assessment of Academy’s institutions and to reduce their number by 10% by taking into account evaluation results, to improve the system of allocating their institutional funding from the state budget, to optimize the network of R&D organizations and pilot plants. We initiate the start of state targeted programs of the development of economy branches, social spheres and enhancing country’s defense capability. It is also important to strengthen ties with the production sphere, to engage more extensively in the commercialization of the R&D results produced by Ukrainian scientists and in the development of innovative infrastructure. Hence, there is a great deal of rather difficult but much-needed work ahead of us. I am sure we will certainly cope with it.

President of the National Academy
of Sciences of Ukraine
Academician



RESEARCH ACHIEVEMENTS. NATURAL AND ENGINEERING SCIENCES

Dynamic interaction of single and double supermassive black holes in the centers of large star systems and galaxies

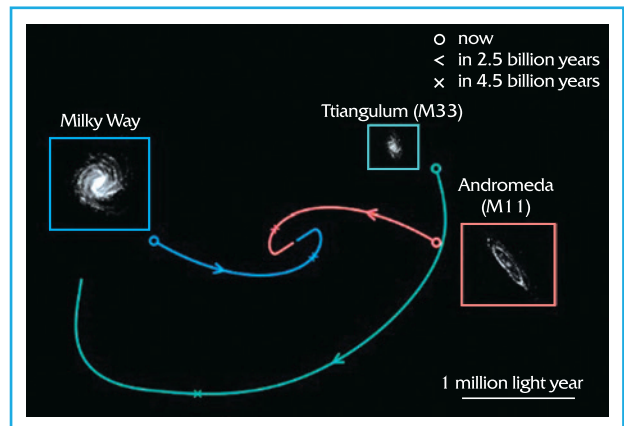
Researchers of the Main Astronomical Observatory of the NAS of Ukraine, in collaboration with German and Italian astrophysicists, investigated the merging of supermassive black holes and galactic structures. The numerical simulation of the merger of our Milky Way galaxy with the neighboring Andromeda galaxy, performed with the highest resolution, enabled scientists to observe the sequence and timing of the merging of the galaxy center, as well as the merging of the supermassive black holes of both galaxies. The global evolution of the system of two galaxies (*Milky-Way + Andromeda = Milkomeda*) and the central supermassive black holes of these galaxies were computed before the final merging of the black holes due to gravitational radiation. As a result of this merger, the Solar System will be in a much broader orbit in about 4 billion years.

Separately, the interaction of the central supermassive black hole (SMBH) with the system of globular clusters of galaxies was investigated. In particular, it was shown that due to the interaction of the double SMBH with the globular cluster system, the time of merging of the dual system should be significantly reduced. Different relationships of black hole masses with the masses of globular systems were studied in detail. The results show that, starting from the ratio of the mass of a globular cluster to the mass of the SMBH of about 10 %, their mutual effect becomes very significant.

It was also shown that the observed number of high-velocity stars (~ 2000 km/sec) in our Galaxy is several dozen, which is easily accounted for by the tidal decomposition of compact globular clusters in the gravity field of the central SMBH. However, compact objects (neutron stars and black holes of the stellar masses), which are the remnants of globular clusters, concentrate mainly in the galaxy center, providing an excess of massive stellar objects as compared with ordinary stars.



Illustration of the merging of our Galaxy with the Andromeda galaxy. Aerial view of the Stellar Sky from the Earth towards the center of the newly formed galaxy. The sequence between frames is approximately 0.5 billion years. (Source: NASA Internet archive: <https://archive.org/details/nasa>)



Orbital evolution of the merging of our Galaxy with the Andromeda galaxy. (Source: <https://iopscience.iop.org/article/10.3847/1538-4357/ab001b>)

The research results were published in *Monthly Notices of the Royal Astronomical Society* (2019, Volume 484, Issue 1, P. 520-542).

<https://ui.adsabs.harvard.edu/abs/2019MNRAS.484..520A/abstract>.

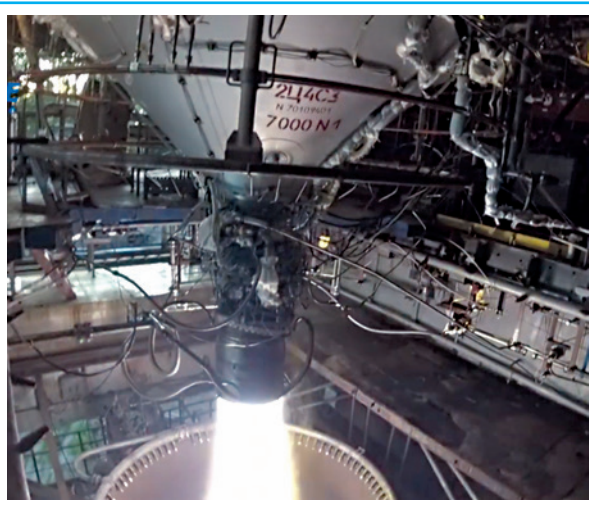
P.P. Berczik, M.O. Sobolenko

Computation and methodology of the development and testing of the upper-stage control engines of 'Cyclone-4M' launch vehicle

The distinctive feature of 'Cyclone-4M' launch vehicle, produced by the state enterprise 'M.K. Yangel "Pivdenne" Design Office', is the use of multiple start-ups of liquid-propellant rocket engine in the upper stage. That allows several spacecraft being put to different orbits in a single launch. For the first time in the world aerospace industry, to control the system of the upper stage motion, the propellants feed to combustion chambers of low-thrust control jet engines is provided not from their own tanks with the gas squeeze of fuel components but from the main engine feed pipeline. Such design of the feed system of low-thrust control engines permits an increase in the mass of the payload launched into orbit.

The joining of the upper stage low-thrust engines and the main engine feed lines could lead to gas and liquid mixtures of propellants, which could cause gas inclusions. This is due to the fact that the propellant pressures at the input of combustion chambers of low-thrust engines are several-fold lower as compared with the traditional design of propulsion system. Besides, start-ups and shutdowns of the main engine result in pressure and flowrate disturbances in the feed lines and lead to losses arising from hydraulic impact processes related to the operation of engine propellant valves.

The Institute of Technical Mechanics, operating under the NAS of Ukraine and the State Space Agency of Ukraine, developed a mathematical model and soft-



Fire tests of the main engine of the upper stage of 'Cyclone-4M' launch vehicle in conjunction with low-thrust control engines

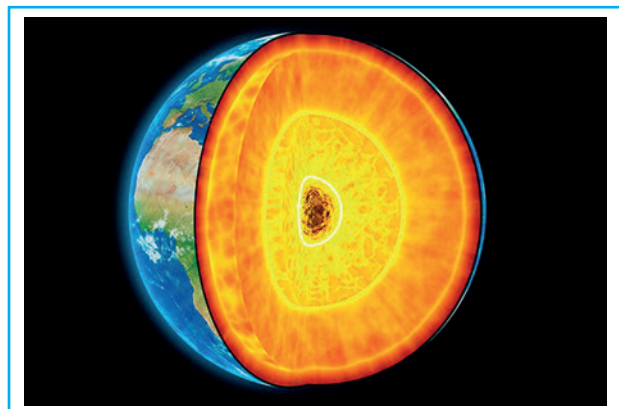
ware for determining hydraulic and gas-dynamic processes in feed lines and combustion chambers of low-thrust propulsion engines. They take into account the gas saturation of propellants and the electrodynamic characteristics of propellant valves for any number of engines in non-stop and pulsed function modes. At the same time, the hydraulic connection between feed lines of the main engine and the system of low-thrust control engines are also taken into consideration.

O.V. Pylypenko, V.I. Tymoshenko, Yu.V. Knyschenko, O.D. Nikolayev, S.I. Dolgoplov

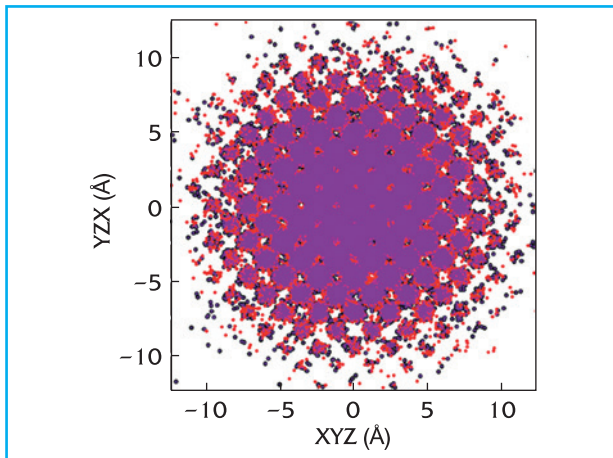
Origin of low viscosity in the Earth's inner core

At the Institute of Condensed Matter Physics of the NAS of Ukraine, in collaboration with scientists of Sweden, China and Spain, an important result was obtained concerning the processes that take place in the Earth's inner core. In general, geophysical problems as regards the structure and dynamic phenomena in the Earth's core and its outer molten shell are important for understanding the physics of planet formation as well as for studies of material stability under extreme conditions of high temperatures and pressures.

Experimental studies of the Earth's core structure are limited to the observations of seismic waves, while computer simulations open up new avenues for analyzing microscopic processes under various conditions. Relying on the combination of *ab initio* molecular dynamics and the EAM (Embedded Atom Model) approach, scientists investigated dynamic processes taking place in crystalline iron at the temperatures and pressure typical of the Earth's inner core ($T \sim 6000\text{--}7000\text{ K}$, $P \sim 320\text{--}360\text{ GPa}$). It was found that at temperatures above 6500 K a part of iron atoms makes cooperative jumps between neighboring equilibrium positions in the (110) plane of the bcc structure, which



Earth's structure with a solid core



Projection of atomic displacements in the (110) plane of bcc iron at the temperatures and under pressures characteristic of the Earth's inner core

are known in solid state physics as ring-like exchange of atoms. This generates a new mechanism of the damping of acoustic excitations, which was observed in the behavior of the 'density–density' time correlation functions.

The obtained dependences of atomic mean-square displacements and calculations of the respective diffusion coefficients enabled researchers to explain the damping of seismic waves and evaluate iron viscosity in the Earth's core. In particular, it was shown that the viscosity of iron at the temperatures and under pressures typical of the Earth's core is low exactly because of the cooperative atomic jumps giving rise to diffusion processes. The research results were published in the high-impact scientific journal *Nature Communications* (2019, 10, 2483:1-7).

A.B. Belonoshko, J. Fu, T. Bryk, S.I. Simak, M. Mattesini

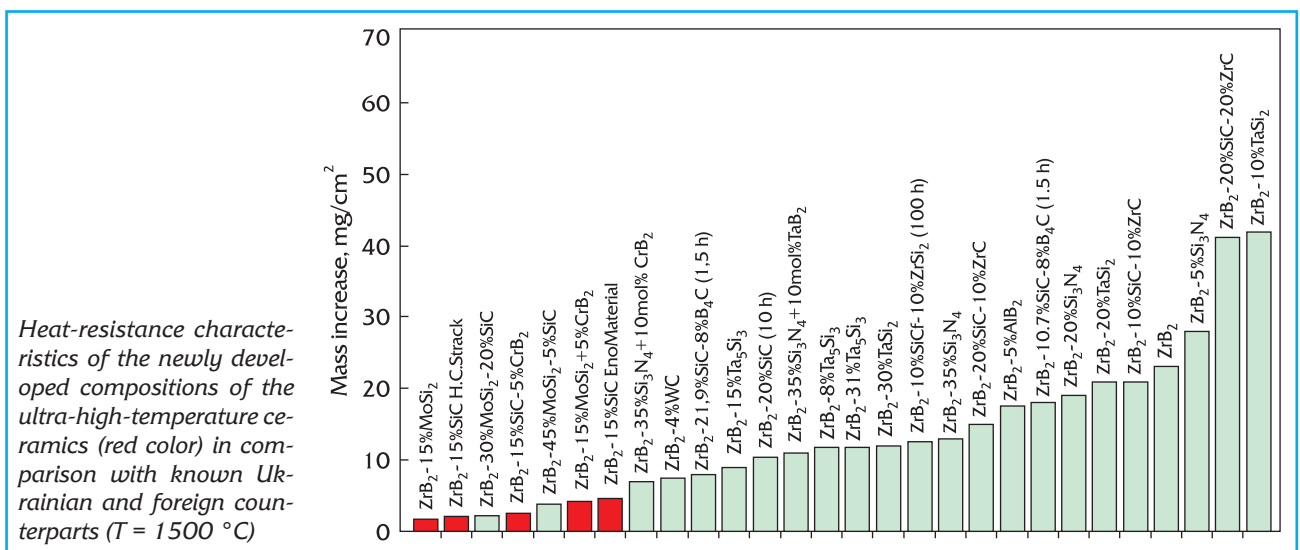
Ultra-high-temperature zirconium boride ceramics with high heat, erosion and oxidation resistance

Scientists of I.M. Frantsevich Institute for Materials Science Problems of the NAS of Ukraine developed new components and a technology for producing ultra-high-temperature ceramics (UHTC) based on ZrB_2-SiC system. It has increased heat, erosion and oxidation resistance at the temperatures of up to 2000 °C in oxidizing gaseous environments containing combustion products.

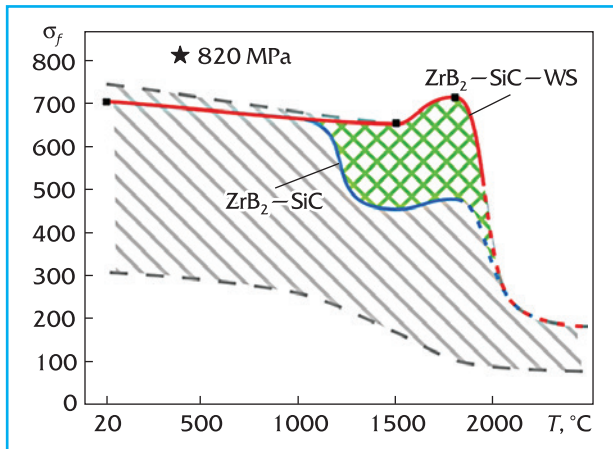
The technology is based on the method of hot pressing without a protective atmosphere, which allowed a significant improvement of the process efficiency and a reduction of its cost as compared with the method of vacuum hot pressing that is traditionally used in producing this class of materials. Due to the optimization of its component composition and production modes, record-setting ceramics strength was achieved. In particular, in the temperature range 20–1700 °C its strength is 700 MPa, while at the temperature of 1800 °C it amounts to 820 MPa.

The highest oxidation resistance was demonstrated by ceramic composites with silicide additives, which ensure the work of the material at 1500 °C for more than ten hours. High-temperature trials proved that the proposed ceramics components have significantly higher oxidation resistance as compared with available Ukrainian and foreign counterparts.

Under the thermal erosive impact of the supersonic flow of the combustion products of stoichiometric air-fuel mixtures at the temperature 2100 °C, the tested UHTC coatings extend the lifecycle of C/C composite



Heat-resistance characteristics of the newly developed compositions of the ultra-high-temperature ceramics (red color) in comparison with known Ukrainian and foreign counterparts (T = 1500 °C)



Comparative characteristics of the strength of the batch composition of ZrB_2-SiC ceramics and that of the newly developed $ZrB_2-Si-WC$ ceramics in the temperature range 20–1800 °C

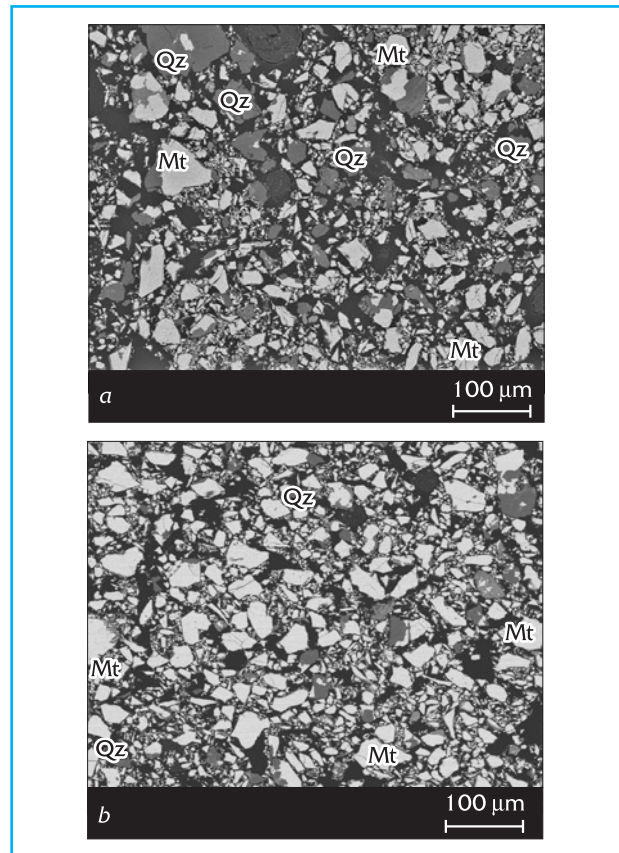
substrates before the onset of surface disintegration by 20 min. at the least for $ZrB_2-15\% MoSi_2$ ceramic coating and by 12 min. for $ZrB_2-3 SiC-5 WC$ ceramic ones.

Possible areas of application of the UHTC and the coatings made of it are outer surfaces of space vehicles, inserts and cones of the supersonic parts of the nozzles of solid-propellant rocket engines, sharp edges and nose domes of supersonic aircraft, high-temperature units of gas turbine engines and other machines and apparatuses.

O.M. Grigoriev, O.V. Koroteev, L.M. Melakh, A.V. Stepanenko

Separation of ore and non-metallic constituents of iron-ore raw materials with heteropolar pulses of magnetic field

Ukraine has large resources of iron ore, yet by now the deposits of high-grade and easily enriched iron ores are nearly exhausted. Therefore, there is an increasingly pressing need for producing iron ore concentrates from poor oxidized iron ores and widely available waste of ore processing plants. Across the Kryvyi Rih iron ore basin, there are tens of billions of tons of lean hematite quartzite deposits and over 2 billion tons of the waste of ore treatment plants (waste heaps and tailings ponds). The waste heaps contain up to 20–30 mass % of iron in the form of hematite and/or goethite, occupying large areas and polluting the environment with highly dispersed iron oxides and hydroxides. Those can be considered as man-made deposits of iron ore, which do not require mining, grind-



Electronic photographs of the initial magnetite quartzite sample (saturation magnetization $M_s = 60 A \times m^2/kg$) (a) and the concentrate (saturation magnetization $M_s = 86 A \times m^2/kg$) produced by the magnetic separator that relies on heteropolar magnetic field pulses (b); Mt is magnetite, Qz is quartz

ing, and many other technological processes. Therefore, the development of energy-efficient technologies for producing iron ore concentrates from lean oxidized iron ores and ore-processing waste is of high current importance for maintaining and developing iron-ore mining and metallurgical industry of Ukraine.

A facility for magnetic separation of highly dispersed iron ore materials by pre-magnetization of the raw material with unipolar magnetic field pulses and further impact of an alternating magnetic field in the form of heteropolar pulses was developed and produced at M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the NAS of Ukraine. In the equipment proposed, short and powerful magnetization pulses are formed in time intervals between the heteropolar pulses. The latter ensure the movement of pre-magnetized particles that are under the action of inhomogeneous field towards an area of stronger magnetic field. The crucial role during that

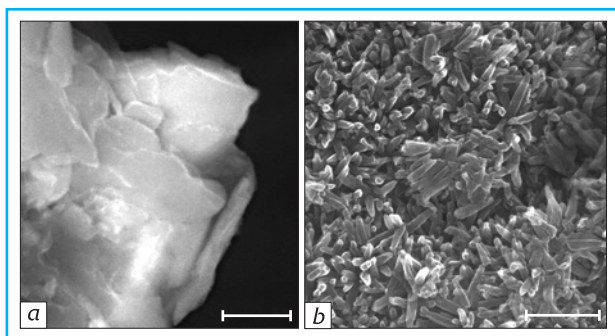
movement is played by the rotation and/or re-orientation of the magnetized particles in accordance with the polarity of magnetic field pulses acting on them. It is centrifugal forces due to the rotation/re-orientation that destroy magnetic floccules, overpower the adhesion forces and detach magnetic particles (iron) from non-magnetic ones (quartz), providing in that way high-quality magnetic separation.

By using the equipment developed, magnetic separation of the ore and non-metallic components of ferrous quartzite samples was carried out. The initial sample consisted of magnetite (~60 mass %) and an impurity phase. After the separation the magnetite content increased to 93 mass %, and iron concentration amounted to nearly 68%. The equipment developed could be used to obtain high-quality competitive iron ore concentrates.

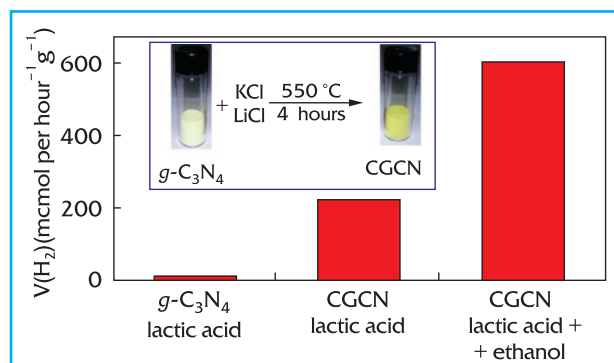
O.M. Ponomarenko, A.B. Brik, N.A. Dudchenko, Yu.I. Cherevko, V.V. Ovsienko

Highly efficient graphite carbon nitride redox photocatalysts

L.V. Pizarzevsky Institute of Physical Chemistry of the NAS of Ukraine obtained highly efficient, sensitive to visible light photocatalysts of various redox processes, which are based on a new promising material — layered graphite carbon nitride $g\text{-C}_3\text{N}_4$. In the process of synthesizing such catalysts, researchers implemented an approach to producing samples of potassium-doped crystalline graphite carbon nitride (CGCN) that has a more sophisticated crystal structure, more intensive visible light absorption, and fewer defects — centers of undesired recombination of photogenerated charges. The effect of the conditions of the initial $g\text{-C}_3\text{N}_4$ synthesis was determined, as well as the modes of its thermal treatment in the LiCl and KCl melt in the inert gas (ar-



8 Microphotographs of the original $g\text{-C}_3\text{N}_4$ (a) and the synthesized nanostructured CGCN (b) (scale 500 nm)



The rates of hydrogen evolution under visible light in $g\text{-C}_3\text{N}_4$ and CGCN systems containing different electron donor substrates. The inset shows the mode of $g\text{-C}_3\text{N}_4$ thermal treatment in the melt of salts and sample photos

gon) atmosphere and in the air on the morphology, physico-chemical characteristics of the materials obtained, as well as their photocatalytic activity.

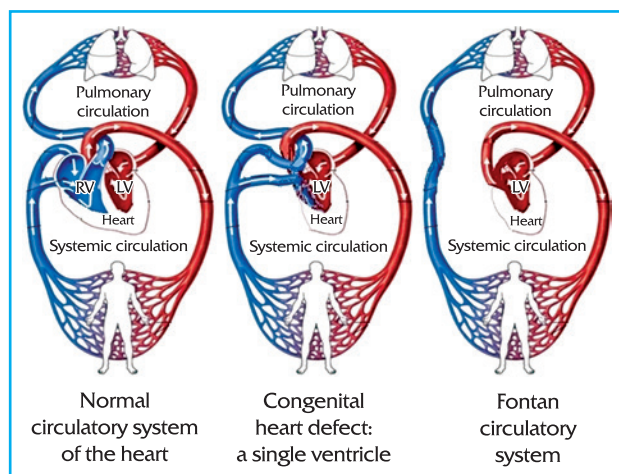
It was found that under the action of visible light these synthesized materials exhibit significantly higher photocatalytic activity than the original carbon nitride in the processes of selective oxidation of aliphatic and aromatic alcohols, oxidative aromatization of 1,4-dihydropyridines and the evolution of molecular hydrogen from aqueous solutions of electron-donating substrates of natural origin — organic acids and ethanol. In particular, under optimal conditions, the conversion of benzyl alcohol is 81%, the selectivity for benzaldehyde amounts to 96%, while the maximum quantum yield of hydrogen evolution from aqueous-alcohol solution irradiated with light quanta of $\lambda = 405 \text{ nm}$ is 54%, which is higher than that of most of its known analogs.

The obtained photocatalysts based on crystalline graphite carbon nitride are stable, free of toxic and costly elements and can be used for the development of practically important systems for hydrogen energy, in fine organic synthesis, for environment protection against hazardous pollutants.

S.Y. Kuchmiy, V.V. Shvalagin, G.V. Korzhak

Mathematical modeling to study pressure regimes in normal and Fontan–Kreutzer blood flow circulation

Researchers of the Institute of Applied Mathematics and Mechanics, in collaboration with their overseas colleagues James P. Keener (University of Utah, USA), Marina Chugunova (Claremont Graduate University, USA) and Matthew G. Doyle (University of Toronto, Canada), to save the lives of children with congenital



Circulatory system diagram

heart diseases after employing Fontan—Kreutzer procedure, developed a mathematical approach for the quantitative assessment of postoperative anatomical and hydrodynamic changes, comparison of different anatomy variants for predicting patient's condition and determining the criteria for the success of this procedure.

Fontan procedure, or Fontan—Kreutzer procedure, is a palliative surgical procedure that involves a multi-stage complex surgical approach and is used in children with univentricular hearts. In such heart, the single ventricle is doing nearly twice the expected amount of work, since it has to pump the blood for the body and lungs. The operation diverts venous blood from the inferior *vena cava* and the superior *vena cava* to the pulmonary arteries, without passing through the morphologic right ventricle; i.e., the systemic and pulmonary circulations are placed in series with the functional single ventricle.

Two mathematical lumped parameter models of blood pressure distribution in the Fontan blood flow circulation were developed: a spatially homogeneous model in the form of ordinary differential equations (ODE) and a spatially heterogeneous model in the form of parabolic equations with partial derivatives (PDE).

Numerical calculations of the ODE model with physiologically consistent input parameters and cardiac cycle pressure — volume outputs, reveal the existence of a critical value for pulmonary resistance above which the cardiac output decreases dramatically.

For the PDE model, the existence of solutions was proved for the case of two initial boundary-value problems with dynamic boundary conditions switched in time, which model the blood pressure distribution in the cardiovascular system with and without Fontan sur-

gery. Besides, necessary conditions were determined for parameter values of the PDE model for generating synthetic data to overcome the lack of training data.

The results of the mathematical models developed were in good agreement with the clinical data obtained at Toronto General Hospital — the main university hospital of Canada. Further implementation of these models will permit reliable evaluation of postoperative anatomical and hydrodynamic changes in pediatric patients and prediction of their condition after performing the Fontan—Kreutzer procedure to reduce the risk to their lives.

R.M. Taranets

Highly selective methods of synthesizing heterocyclic compounds for the development of new drugs

Scientists of V.P. Kukhar Institute of Bioorganic Chemistry and Petrochemistry of the NAS of Ukraine and the Institute of Organic Chemistry of the NAS of Ukraine, on the basis of systemic combination of pharmacological screening methods using computer structure—effect correlation programs (*in silico*) and biological *in vitro* and *in vivo* tests, discovered various types of the effects of synthesized heterocycles, — in particular, antibacterial, anti-inflammatory, antitumor, antituberculous, antiviral, antioxidant, antidiabetic, anti-hypertensive and analgesic ones — with low background toxicometric parameters. The “hit compounds” were identified for further optimization, in-depth research and directed synthesis of new biologically active molecules as potential drugs. E.g., a number of sulfonamide derivatives of oxazole and thiazole demonstrated ten times higher activity with respect to human papillomavirus in comparison with the *Cidofovir* reference drug.

“Hit compounds” were also found in the search for antiviral drugs against poliovirus, which causes a dangerous polio disease. These are pyrolopyrimidine derivatives, which are isosteres of purine bases. Compound A was identified and investigated; its chemotherapeutic index is 310 as compared with index 31 found for the *Pirodavir* reference drug. This compound has passed the first stages of preclinical testing at the Department of Pediatrics at the University of Alabama, Birmingham (USA).

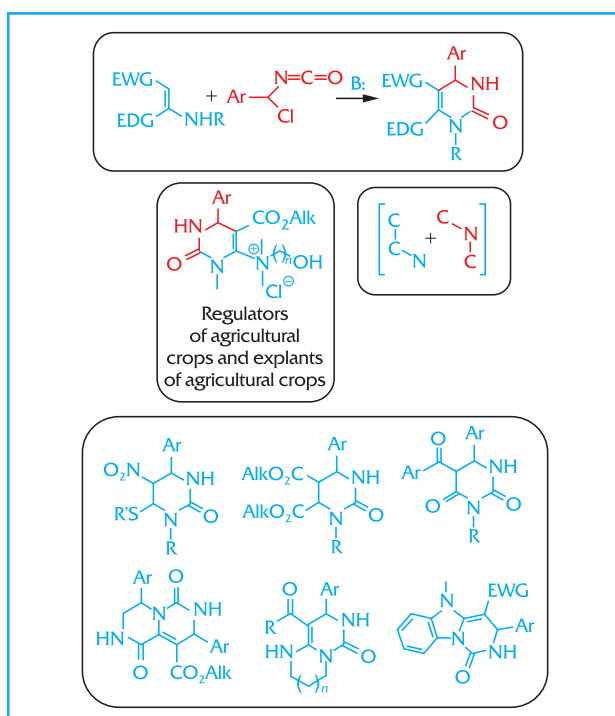
It was shown that 1,3-oxazol-4-ylphosphonic acids are unique reactants for synthesizing new derivatives of α -aminophosphonic acids, phosphorylated peptides and phosphonopeptidomimetics, which are intensively studied by chemists, biologists and pharma-

| Human papilloma virus HVP-11 (cell line: HEK 293) | | | | | | | |
|---|----------------------------------|----------------------------------|------------------|----------|----------------------------------|----------------------------------|------------------|
| Compound | EC ₅₀ (mkg/ ml) | CC ₅₀ (mkg/ ml) | SI ₅₀ | Compound | EC ₅₀ (mkg/ ml) | CC ₅₀ (mkg/ ml) | SI ₅₀ |
| | 8.44 | >100 | >12 | | 9.62 | >100 | >10 |
| | 6.13 | >100 | >16 | | 8.5 | >100 | >12 |
| | 4.91 | >100 | >20 | | 1.73 | >100 | >58 |

| Poliovirus (cell line: Vero 76) | |
|---------------------------------|---|
| | EC ₅₀ = 0.32 CC ₅₀ = 100 SI ₅₀ > 310 |

← Preclinical testing

Antiviral activity of oxazole, thiazole and pyrrolopyrimidine derivatives



A new strategy for the synthesis of 3,4-dihydropyrimidin-2-ones

cologists due to their ability to open the cycle in the acidic environment.

Innovative bielectrophilic α -chloroalkylisocyanates and α -chloroalkylidene carbamates were proposed, which allowed the introduction of new equivalents of azaallyl synthons into the synthetic practice as well as the development of a new scheme for the design

of partially hydrogenated azine compounds, which involves the formation of C—C bonds.

Preparative methods for the synthesis of nitrogen-containing heterocyclic compounds using original acyclic reagents, in particular, unsaturated azlactones and acrylonitriles were developed. They enabled researchers to selectively introduce nitrogen-, sulfur- and phosphorus-containing pharmacophores in five-, six-, seven-, eight-, nine-membered nitrogen heterocycles and their fused derivatives.

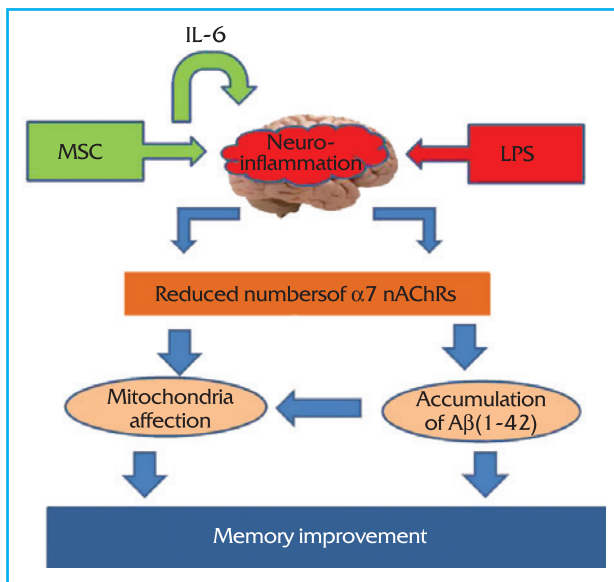
Highly selective methods for constructing structurally diverse functional heterocyclic systems with powerful synthetic and pharmacological potential were developed, which is a precondition for creating novel antiviral, antitumor, and antibacterial drugs.

V.S. Brovarets, M.V. Vovk, V.I. Kalchenko

New opportunities for the use of mesenchymal stem cells

A new experimental model of neuroinflammation, as a factor of Alzheimer's disease pathogenesis, was developed at Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine. Neuroinflammation was induced by administration of bacterial lipopolysaccharide (LPS) into mice, resulting in reduced numbers of nicotinic acetylcholine receptors (nAChRs) and accumulation of pathogenic β -amyloid in the brain, increased sensitivity of brain mitochondria to the apoptogenic effect of calcium ions, and significant decline in episodic memory, which are indicators of the early stages of Alzheimer's disease.

For prophylaxis and correction of these pathogenic changes, it was proposed to use mesenchymal stem cells (MSCs), which can differentiate into different cell types, including neurons, and produce various trophic and growth factors. It was shown that intravenously injected MSCs penetrated the brain by crossing the blood-brain barrier damaged by neuroinflammation and subsequently prevented LPS-induced memory decline, reduction of nAChRs, decline in mitochondrial resistance to apoptosis, and accumulation of β -amyloid in the brain. This effect was in part due to the soluble substances released by MSCs into the culture medium. At the same time, it was observed that repeated administration of MSC-conditioned medium stimulated an immune reaction and, thus, had only a temporary positive effect. In contrast, a single administration of MSCs two weeks after LPS led to memory improvement lasting for several months. It was shown that MSCs administration elevated interleukin-6 levels in the brain and improved the memory of animals



Schematic representation of the effect of lipopolysaccharides (LPS) on the brain

lacking $\alpha 7$ nAChRs by increasing the expression of other cognitively important nAChR subtypes. Administration of recombinant interleukin-6 to $\alpha 7^{-/-}$ mice also temporarily improved their episodic memory and stimulated upregulation of all nAChR subunits in their brain.

The results obtained provide new opportunities for the optimization of the therapeutic use of mesenchymal stem cells for the treatment of cognitive dysfunctions caused by neuroinflammation.

M.V. Skok, O.Yu. Lykhmus, O.M. Kalashnyk, K.R. Uspenska

Biotechnology product for the targeted delivery of drugs

The targeted delivery of drugs is a highly relevant issue in the treatment of different pathologies, especially oncological diseases, since current therapeutic regimens not infrequently do not provide the expected positive effect. Poly- γ -glutamic acid (γ -PGA), which is able to create complexes with many chemical substances, is very promising for the development of targeted drug delivery systems.

At present, *Bacillus* genus bacteria are the only industrially important producers of poly- γ -glutamic acid; for this reason, they are extensively studied and used. In order to find highly effective producers of this substance, scientists of D.K. Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine carried out the screening of more than 500 *Bacillus* strains and se-

lected 11 promising ones, whose productivity in deep cultivation is 2–18 g/l of γ -PGA. It was shown that the polymer of poly- γ -glutamic acid with molecular weight of >2 MDa, which is synthesized by *B. licheniformis* M20g strain, consists of glutamic acid monomers and does not contain any polysaccharides. The studies of antitumor activity of the obtained γ -PGA in the culture of finite cell line of human laryngeal carcinoma Hep-2 and B-lymphoma B95-8 helped establish the effective concentrations of γ -PGA low polymer (EC50) that inhibited the proliferation of cell population by 50%. Thus, the studied substance demonstrated a more pronounced inhibiting action to B-lymphoma (EC50 = 11 mkg/ml) than to carcinoma (EC50 = 116 mkg/ml).

It was shown that γ -PGA polymer could be combined with a wide range of antitumor substances due to the presence of free carboxyl groups in its side branches, which serve as points of conjugation with drugs. The combination of γ -PGA polymer with drugs makes the latter more soluble and facilitates their delivery to target tissues. The resulting complexes are quickly transported to tumor locations and release active substances. The polymer cleavage product is glutamic acid, which then enters normal metabolic processes in cells and produces no toxic effects on macroorganisms. The results obtained open up wide opportunities for the development of the systems of targeted delivery of medicinal substances.

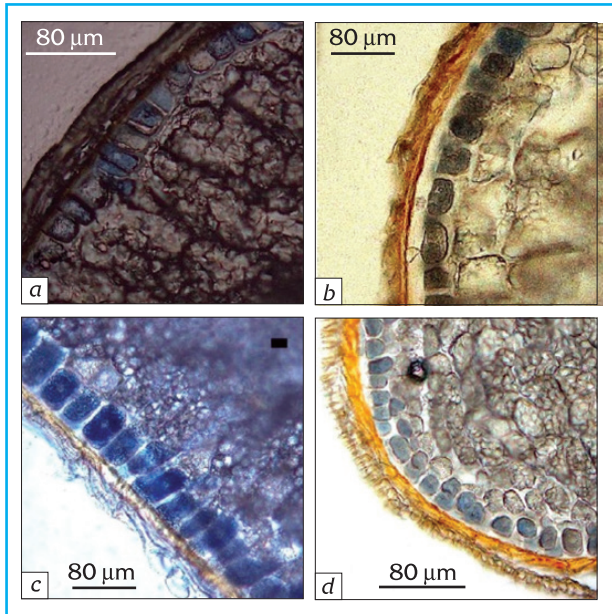
M.A. Kharkhota, L.B. Zelena, S.D. Zagorodnya

Colored grain is a new strategy for creating cereals of high biological value

Colored cereals (wheat, barley with black, purple and blue grains) are novel foods that contain *anthocyanins* and *phenolic acids* – bioactive phytochemical compounds that are important for human health. Such plants and bioactive substances are able to prevent cardiovascular diseases, cancer, diabetes, hypertension, obesity, as well as contribute to the slowing of aging, protect the human body from the ruinous effects of UV radiation. The combination of these properties makes colored cereals increasingly popular in the diet of people in the developed countries.

In view of this, scientists of the Institute of Plant Physiology and Genetics of the NAS of Ukraine developed a strategy of creating domestic grain cereals with high biological and nutritional value of the grain.

The research produced original breeding material and varieties of wheat, barley and spelt with various colors of the grain and its high biological value. The



Sections of cereals with black pericarp (a, b) and blue aleuron (c, d)

first, new for Ukraine, varieties of black wheat developed by the Institute have already been included in the State Register and recommended for wide introduction. Those priority studies are the basis for the appearance of new functional foods in our country's food market.

Active plant-breeding work is going on towards creating hull-less barley varieties with blue and black grains. They have an increased antioxidant activity and a high content of dietary fiber, beta-glucans, amylose in starch, and mineral phosphorus due to a lower content of organic phosphorus in phytate form.



Hull-less barley with regular (left) and black (right) grain

Following the developed countries, the Institute initiated the development of a national strategy of healthy (functional) nutrition, which is aimed at maximizing (by 50% at the least) the percentage of groats and whole-grain foodstuffs in the diet of Ukrainians.

To that end, biofortification of grain is successfully implemented through the selective introduction of unique mutant genes of wild relatives or biotechnological genetic constructs into plant genotype. That can radically change the ratio of starch components, increase the protein and mineral content, improve grain technological characteristics, enhance its antioxidant activity, etc.

Cereal biofortification — improving the biological value of the grain in terms of the quantitative and qualitative content of basic food components in combination with its bioactive phytochemical compounds and minerals — is to transform foodstuffs into the products that will be not mere sources of vital energy but also a vanguard of preventing various diseases.

V.V. Morgun, O.I. Rybalka, B.V. Morgun

RESEARCH ACHIEVEMENTS. SOCIAL SCIENCES AND HUMANITIES

Scholars of the Section of Social Sciences and Humanities of the NAS of Ukraine performed a large amount of research into the issues of economy, socio-political and cultural development of the Ukrainian society.

The traditional practice of preparing the National Reports on the issues of utmost importance for the state and the society was continued: this year the National Report "The Euro-Atlantic Vector of Ukraine" has been presented. Its preparation was hosted by Koretsky Institute of State and Law of the NAS of Ukraine and involved a team of Section's experts headed by Serhii I. Pyrozshkov. The research into the issues of the Euro-Atlantic integration is of utmost relevance at the present stage of Ukrainian state transformation, since it is concerned with identifying the ways of its civilizational development based on European values, elaboration of effective mechanisms for ensuring the national security in the conditions of global hybrid war. The importance of these subjects also stems from the recent amendments to the Constitution of Ukraine that guarantee nation's strategic course towards achieving the full-fledged membership of Ukraine in the European Union and the North Atlantic Treaty Organization.

Political, economic and security turbulence of today's world, which demonstrates quite pronounced variance of different integrative unions, strengthening of the global economic competition and heightening confrontation, the manifestations of great-power aggression, aggravation of migration and climate problems determine Ukraine's choice of the Euro-Atlantic vector, with the emphasis on internal changes when reforms are implemented not for the external praise but for survival and prosperity of the nation as a subject of history, creating proper prerequisites for the successful implementation of its own civilizational project.

The National Report provides the interested reader with a deep insight into the general state, trends and prospects of Ukraine's relations with the Euro-Atlantic political and civilizational complex. It examines geopolitical, legal and socio-cultural aspects of the Euro-Atlantic integration of Ukraine, formulates proposals

and recommendations of Academy experts towards elaborating the strategy of our state's accession to the Euro-Atlantic civilizational area, searching for effective ways of adopting European democratic standards, enhancing the security and defense potential of the country. Much attention is given to the socio-cultural orientations of the Ukrainian population, the dynamics of citizens' attitudes towards Ukraine entering the EU and NATO. The focus of special analysis is the search for the ways of overcoming separatist tendencies as a threat for the Euro-Atlantic vector of Ukraine, examining the particular features of developing the relations with NATO of the countries that have current problems of restoring their territorial integrity and achieving interethnic concord.

According to report's authors, the implementation of the Euro-Atlantic vector of our country envisages not mere getting "under the umbrella" of unions or alliances. It is, first and foremost, introducing qualitative innovative changes in the Ukrainian society that are inherent to our mentality and whose purpose is the enhancement of our country's active role in the world and actual improvement of the lives of its people. It is for this very reason that the Euro-Atlantic orientation of Ukraine is not reduced to the membership in the European Union or NATO; it is a much more complex process of mental and civilizational transformations. It is this process that is the precondition of achieving the sovereignty of the country in the multipolar turbulent world.

The report stresses that in the process of elaborating state's new strategy of relations with NATO, it is to be taken into account that the accession to NATO is not a purpose in its own right but an instrument of ensuring the defense capability, peaceful existence, territorial integrity and independence of Ukraine, primarily, in the context of opposing the Russian aggression. In view of that, the accent in relations with NATO should be placed on receiving much greater, more specific assistance in building up the national defense potential. At the same time, Ukraine should be more pro-active in implementing its internal transformations: promoting its democratic institutions, ensuring the rule of law, overcoming corruption, reforming the sector of security and defense as a basis of successful integration of the country into the Euro-Atlantic structures.

Scientists of the NAS Institute of Industrial Economics revealed the processes of establishing smart industry in Ukraine in the context of the fourth industrial revolution. They proved that the essence of the new industrial revolution is neither in the progress of new material (physical) technologies nor in the progress of digital technologies *per se*, but in their fusion with

the physical world, which forms a new cyberphysical reality that is neither purely physical (material) nor purely digital (informational).

The establishing of smart industry in Ukraine should be considered as a part of a broader issue of national and supranational innovation systems. Conceptual theses concerning the life cycle of technologies, technological and financial gaps in the context of cyberphysical systems were proposed for the first time. According to those, for the parameters of the S-shaped curve of the dependence between the costs and results, of vital importance is the dynamics of capital structure — the specific weight of digital capital in its overall value. The structure of basic aggregate criteria of the analytical evaluation of industry “smartization” trends was elaborated. It involved the particularization of indicator variables with the account of object-subject and branch specificity, as well as the possibility of the information and methodological follow-through of the analytical process.

Experts of the Institute proposed a scientific and methodological approach to the inter-national comparisons as to assessing the readiness of national economies to the transition to Industry 4.0, with environmental requirements being taken into account. They were the first in Ukraine to develop a scientific methodology for modeling the factor of production system informatization, which provides higher payoff of traditional production factors in smart industry implementation. This approach relies on the model of production function that enables researchers to evaluate the informatization factor effect on the value added and could be used for grounding the trends of smart-technology implementation to maximize the effect for Ukrainian economy (NAS Academician V.P. Vishnevsky, S.I. Knyazev, O.M. Garkushenko, V.D. Chekina, O.V. Viitska, A.F. Dasiv, L.O. Zbarazska et al.).

The second book of the special volume “Ukraine—Ukrainians” of the “Encyclopedia of the History of Ukraine” was published (the Head of its Editorial Board is NAS Academician Valerii A. Smolii, Deputy Heads are NAS Corresponding Member Hennadii V. Boriak, Doctor of History Stanislav V. Kulchytsky).

NAS Presidium started the project of the “Encyclopedia of the History of Ukraine” as a scholarly universal encyclopedia in Ukrainian history in June 1997; it was inspired by highly relevant and fundamental needs for systematizing, codifying and representing the socio-humanitarian knowledge on the history of Ukraine in modern times. The initial stage of the project was developed around and focused on ordering, systematizing and generalizing the vast amount of reliable information that appeared in the scholarly con-

text in the 1990-ies—early 2000-ies. In a decade (2003—2013), ten volumes of the “Encyclopedia of the History of Ukraine” were published. In the early 2010-ies, during the work on its last volumes, the editorial board started planning further stages of the project in the light of the leading trends and innovations of today’s Ukrainian and international encyclopedia research, viz., the preparation of additional volumes and the specialized volume “Ukraine—Ukrainians” in two books.

This specialized volume of the “Encyclopedia of the History of Ukraine” is aimed towards unified and integral presentation of the socio-humanitarian, historical in particular, knowledge about Ukraine on an enlarged encyclopedic scale. The edition is to meet cognitive and informational needs of various groups of readers — scholars, education workers, graduate and post-graduate students, history lovers.

The specialized volume presents the concentrated comprehensive image of Ukraine in its basic categories — the state, the territory, the people, the history of their formation and development since the earliest times until today. The two books of this volume present a series of ingenious encyclopedic narratives about Ukraine. The first book contains summarizing texts about its state system, natural environments and resources, the history of forming its territory and borders, of administrative and territorial division, the size, composition and migrations of the population that inhabited the Ukraine’s territory since the earliest times, its traditional material and spiritual culture. The integral part of this ethnological unit is a series of essays on the ethnic history, material and spiritual culture of the major ethnic communities living in Ukraine.

The second book of the volume contains a broad essay about Ukraine’s past, a review of respective sources (written, oral, visual, maps and archeological finds), historiography (both domestic and foreign), chapters on major stages in the history of Ukraine (presented in the chronological order): ‘Prehistoric period’, ‘Early history’, ‘Old Rus state and peoples of the Steppe. IX – mid-XIII century’, ‘South Rus lands and the Golden Horde. Mid-XIII – late XIV century’, ‘Ukrainian lands in XV – the first half of XVI century’, ‘Ukrainian lands in mid-XVI – mid-XVII centuries’, ‘Ukrainian national revolution of mid-XVII century’, ‘Ukrainian Cossack state in the second half of XVII – XVIII centuries. Ukrainian lands as a part of Rzecz Pospolita’, ‘The Crimean Khanate in mid-XVII – late XVIII centuries’, ‘Ukrainian lands as parts of the Russian and the Habsburg empires: 1772—1917’, ‘Ukrainian revolution of 1917—1921’, ‘Radianska Ukraine: 1917—1939’, ‘Western Ukraine: 1919—1939’,

'Ukraine in World War II: 1939–1945', 'Ukraine in 1945–1989', 'Independent Ukraine: 1990–2019'). This chapter is supplemented with articles 'Ukraine and the world. Modern epoch' and 'The Ukrainian diaspora', as well as a brief essay on the memory institutions in modern Ukraine — archives, libraries, museums, cultural and historical reserves.

The final part of the second book texts in the alphabetic segment is the dictionary unit consisting nearly 400 entries of the classical encyclopedic format, which in different contexts supplement, make more profound, add expressiveness and nuances to the encyclopedic narratives of the first unit.

"Encyclopedia of the History of Ukraine" is well known in today's scientific information sphere as a powerful resource, since its electronic version is also presented on the web portal of the NAS Institute of the History of Ukraine. The encyclopedia successfully fulfils its socio-cultural, cognitive and educational functions, which are of the utmost importance for the Ukrainian society, by transforming high academic knowledge and novel scholarly achievements of the circle of historical and adjoining disciplines into a generally available body of dictionary entries for both the professional community and the broad reading public.

Scholars of Rylsky Institute of Art Studies, Folklore and Ethnology of the NAS of Ukraine prepared and published their work "**Ethnographic Image of Ukrainians Living in Foreign Countries. Part I. Culture of Life Support and Traditional Normative Social Practices**". This unique edition for the first time in the national ethnological studies elucidates the ethno-cultural heritage of the Ukrainians living in foreign countries. The book contains folklore and ethnographic records concerning the singularity of Ukrainians' traditional culture in the post-soviet and post-socialist countries (the Republic of Belarus, the Republic of Lithuania, the Republic of Kazakhstan, the Republic of Moldova, the Republic of Poland, the Russian Federation, the Slovak Republic); those were made by Institute's scholars and

by their foreign colleagues in the second half of the 20th– early 21st century. The presented information on economic practices, home- and handicrafts, folk construction and architecture, culinary traditions, family and calendar rituals, stories about the settlement of the territory inhabited, oral history stories are a valuable source base for today's ethnological, linguistic, folkloristic and culturological studies. The corpus of the documents published would allow the authenticity as well as territorial and local differences of the Ukrainian culture to be examined, it shows the community of its basic features and that its manifestations are similar for the whole ethnos.

The records from Ukrainian ethnic territories contained in the publication prove a high degree of Ukrainian traditions preservation in the foreign milieu. The Ukrainian communities of the countries examined still keep Christmas and New-Year traditions, Whitsun and Easter ceremonies, wedding ritual culture, as well as Ukrainian cuisine. Folk stories preserve plots that have disappeared in the mainland Ukraine. The original illustrations of the book show the historical continuity of Ukrainian cultural tradition, its regional diversity, they vividly emphasize the thesis about its ethno-genetic unity in the widely separated territories.

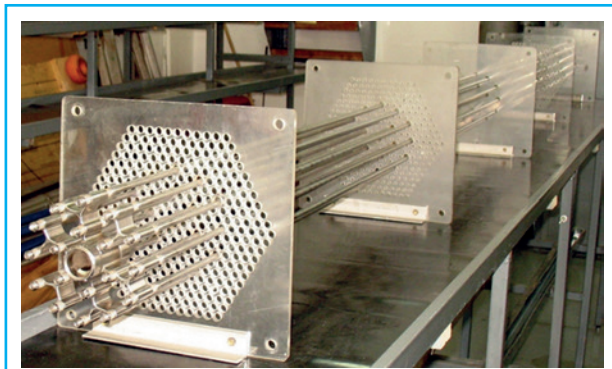
The book embraces a long chronological period — since the events of the early 20th century that are kept in the folklore memory of narrators up to now, so alongside the varied information about the life-support culture and the spiritual existence of the Ukrainian communities abroad, it contains information about specific features and problems of the ethno-cultural Ukrainian movement outside Ukraine. The data presented provide a bright proof of high civilizational, ethic and esthetic manifestations of the creative spirit of the Ukrainian ethnos, the incredible diversity of the Ukrainian culture and its prominent phenomena.

NAS Academician H.A. Skrypnyk, H.B. Bondarenko, Yu.I. Bidnoshyya, I. Varkhol, N. Varkhol, O.M. Holovko, V.H. Kozhukhar, K.S. Kozhukhar, N.P. Oliynyk, M. Sopolyha, D.A. Cherniyenko, I.I. Shulha, A.V. Yarova.

Development of new absorber rods for WWER-1000 reactor control and protection systems

Nuclear power plants are the major source of electricity that ensure Ukraine's energy independence. At the same time, safe and efficient operation of nuclear power plants is largely determined by the structural neutron-absorbing and fuel materials used in their operation. As of today, diversification of nuclear fuel for water-cooled power reactors (WWER-1000) is a highly urgent and complex task for the safety of reactors at Ukrainian NPPs.

This requires not merely solving all physical and engineering problems for the introduction of new types of nuclear fuel for WWER-1000 reactors but also setting up Ukraine's own industrial production of nuclear fuel, which will promote the energy independence of Ukraine. Neutron-absorbing materials as well as reactor



New absorber rods for WWER-1000 reactor control and protection systems

control and protection components based on them are integral parts of nuclear fuel and are used to control reactor operation.

The National Science Center 'Kharkiv Institute of Physics and Technology' is carrying out step-by-step works to develop neutron-absorbing materials and absorber rods based on them. In particular, on commission from the 'Energoatom' NNEGC, a number of R&D activities were implemented to design absorber rods for Rod Cluster Control Assembly (RCCA) of Ukrainian WWER-1000 reactors. The RCCA absorber rods are the basis of the reactor core control and protection system; they are also used in storage containers at Zaporizhska NPP dry spent fuel storage facility.

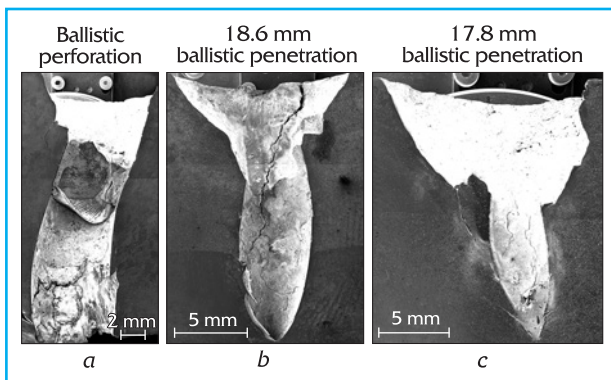
To launch the production of the RCCA design developed, a laboratory facility was established and the processes for manufacturing dysprosium titanate as an absorber material, absorber rods for RCCA were elaborated. A test batch of RCCA absorber rods was manufactured for preliminary and acceptance tests to validate the design and technological solutions used in the project and to obtain permission from the State Nuclear Regulatory Inspectorate of Ukraine to manufacture a pilot batch of the products and conduct their trial operation in the reactor.

V.S. Krasnorutskyy

Manufacturing technology for titanium armor elements

Besides their conventional application in aerospace, automotive, chemical and medical industries, titanium alloys are very promising materials for manufacturing armor protection elements. Having approximately the same level of protective characteristics as steel, they are about half as light in terms of weight, have high corrosion resistance, are non-magnetic etc. The manufacturing of multilayered structures made of materials based on titanium alloys that would combine a ductile body with surface layers of increased hardness and strength is a new trend in armor protection.

Scientists of G.V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine, in collaboration with their colleagues from the University of California (Los Angeles, USA), in the framework of NATO program 'Science for Peace and Security' (project G5030-'Titanium armor: advanced technology'), developed a general concept of and a technological approach to producing multilayer structures of titanium-alloy and metal-matrix composites relying on powder technologies, which are to be used as armor protection elements. The high levels of deformation energy of such layered structures, which are required for sufficient



Comparison of the ballistic tests of titanium-based materials. Tests were performed with armor-piercing incendiary bullets B-32 of 7.62×54 mm caliber, having kinetic energy 3500-3800 J. Ti-6Al-4V rolled plate 22 mm thick (a); Two-layer 22 mm thick plate based on Ti-6-4 with the surface layer strengthened by TiB (b); Three-layer 22 mm thick plate based on Ti-6-4 with the surface layers strengthened by TiC (c).

protective characteristics, are ensured by the combination of top layers of metal matrix composites having the optimized content of high-modulus particles of TiC or TiB phases and base layers of ductile titanium alloys with controlled porosity and strong adhesion between the layers. This was confirmed by a comprehensive study of quasi-static and dynamic mechanical properties as well as real ballistic testing in a certified laboratory.

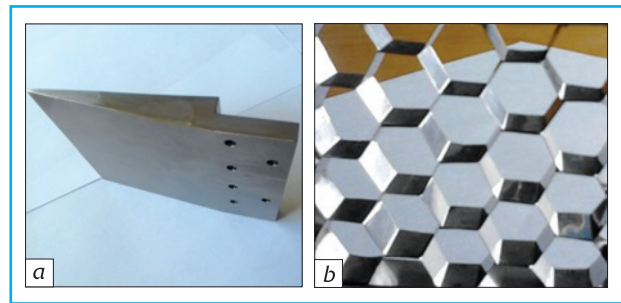
The multilayer materials developed have an undeniable advantage over the standard titanium alloys used today for ballistic protection. The US co-director of the project is in talks with a US company about the possibility of acquiring the relevant patent by it.

O.M. Ivasishin, P.Ye. Markovskiy, D.G. Savvakin, O.O. Stasyuk, M.M. Gumenyak, B.Ya. Melamed

Nano-hardened nickel-based heat resistant materials: technologies for their production and soldering

Scientists of I.M. Frantsevich Institute for Problems of Materials Science of the NAS of Ukraine, under the assignment from 'Pivdenne' Design Office developed a group of heat resistant nanohardened nickel-based alloys for extreme temperature and power service conditions.

A new method of reaction sintering applied to this group of materials for the first time ever ensured significantly better technological and functional properties of the alloys as compared with well-known technologies of mechanochemical synthesis. The mate-



Air intake edge model of hypersonic aircraft (a) and honeycomb panel for reusable spacecraft (b) made of nano-hardened nickel-based alloy

rials produced are able to work for a long time in an oxidizing environment containing hydrocarbon combustion products at the temperatures up to 1200 °C. Furthermore, these materials are characterized with high values of cyclic heat resistance. In particular, they can withstand over 500 cycles of sharp heating up to 1200 °C in the air environment, exposure to those conditions for about 20 minutes with subsequent rapid cooling. Available commercial materials of the similar class burned out almost completely under such test conditions.

Using the new alloys developed, edges of the wings and air intake systems for hypersonic aircraft and honeycomb panels for reusable space vehicles were produced and successfully tested. These materials, the technologies of their production and reaction soldering were adopted by 'Pivdenne' Design Office for manufacturing respective components of serial production aircraft.

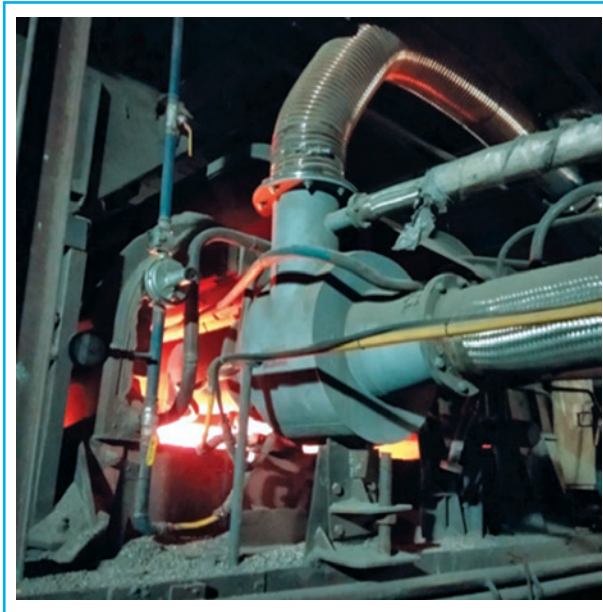
The materials developed can also be used for manufacturing the elements of high-temperature bellows, blades and guide parts of jet engine turbines, turbine disks, honeycomb heat shielding panels, as well as for thermal protection of reusable spacecraft systems, structural parts of co-generation plants, nuclear reactors etc.

V.P. Solntsev, T.O. Solntseva, K.M. Petrash, V.A. Nazarenko

Upgrading of metallurgical equipment at the plant of 'ZAPORIZHSTAL' PJSC

Researchers of the Gas Institute of the NAS of Ukraine solved the problem of improving the efficiency of metallurgical units and reducing natural gas consumption at the metallurgical plant of 'Zaporizhstal' PJSC.

The specific feature of the development was the need to elaborate a technology and equipment for using the fuel consisting of the mixture of coke-oven



MGP-2.0 gas burner of KM-14 agglomeration machine



GNB-1500 high-speed burner in operating condition before immersion into a 250-ton ladle

and blast-furnace gases, whose calorific value is lower by a factor of 3–3.5 than that of natural gas. It was also necessary to take into account the presence of a significant amount of hydrogen in the coke-oven gas, which necessitated the reliable stabilization of flame.

To solve this problem, a technology and a device for the combustion of different gases in one structural unit were developed, and a novel burner was produced, which allows combustion of both a mixture of two gases and natural gas in the sintering machine. The burner

is equipped with two rows of nozzles of a special design, which ensures that high-speed jets of combustion products are directed to the raw material layer. Under these conditions, intense heating of the entire volume of the layer, not just its surface, is provided.

As a result of deploying the novel burner and using automation, the machine automatically switches, if necessary, from working on mixed gas to natural gas and vice versa. At the same time, natural gas consumption is reduced to 110–130 m³/h, and the total natural gas saving amounts to 1 280 000 m³/year.

Institute's researchers and engineers also worked at eliminating the disadvantages of the heating systems of stands for drying and heating the 250-ton steel ladles of open-hearth shop, which involved significant costs of natural gas, long process duration, uneven heating of the lining and insufficient heating of the ladle bottom.

In particular, they proposed to use the kinetic energy of the jet of combustion products of the previously prepared mixture of natural gas with air. The high, up to 100 m/s, speed of the jet provides high-quality warming of the bottom lining of the ladle, whose height exceeds 5.0 m. The rarefied zone near the jet stream 'root' causes the intense circulation of combustion products inside the ladle. Due to the circulation, there is intensification of heating and equalizing of the ladle lining temperature.

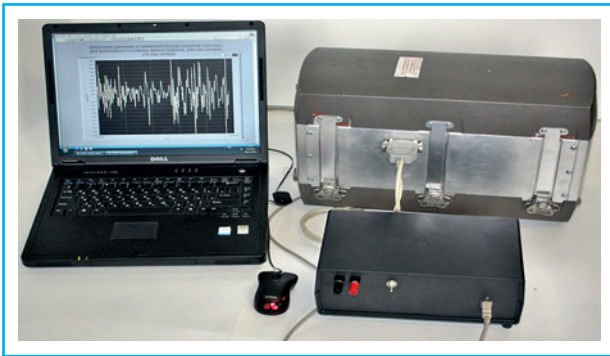
The GNB-1500 high-speed burner was developed to create the appropriate jet, which supplemented the existing 80–1000 kW series of high-speed GNB burners.

Due to the upgrading of this stand, fuel consumption dropped by 19%. The duration of the process was reduced to 12 hours and heating uniformity was $\pm 10^\circ\text{C}$.

R.A. Pylypenko, V.S. Pikashov, R.V. Melnikov, B.S. Smyan, E.S. Tsvetkov

Location and identification of heavy moving objects and man-made emergencies

The Institute for Information Recording of the NAS of Ukraine developed a digital seismograph — a combined geophysical device relying on digital laser interferometry, which allows the identification and determination of the location of heavy moving objects: military equipment, trains, heavy transport. The device also enables scientists to study geophysical phenomena in order to prevent the destructive effects of hazardous geological processes in the earth's surface on the condition of buildings, bridges and other structures.



Combined geophysical device relying on digital laser interferometry

The basic element of the device is a miniature digital interferometer relying on a semiconductor laser that measures the amplitude of displacements of soil layers, structure elements etc. When measuring the displacement, the noise level is much lower than that in speed or acceleration measurements, which permits a high precision of the instrument (less than 1 nm) to be achieved. It is possible to register vibrations of the lowest frequencies possible. The digital seismograph is promising for use in military operations.

A number of experimental studies were carried out with this device, including hazardous exogenous processes in soils (subsidence and failure) in the historical part of Kyiv, on the territory of the 'Sofia Kyivska' National Reserve and at the Lavra Bell Tower of the National Kyiv-Pechersk Historical and Cultural Reserve. Measurements of short-term variations of microseismicity in the territory of the 'Sofia Kyivska' National Reserve showed the presence of five anomalous zones, four of them correlating with already known soil subsidence zones.

V.V. Petrov, O.I. Britsky, I.V. Kosyak, Y.O. Borodin, O.A. Tsubin

Seismic vibration resistance of buildings and structures under dynamic loads of natural or man-made origin

Ukraine is located in the zone of seismic risk: hazardous territory covers 20% of the country, with the population of 10.9 million. In these regions, earthquakes of the intensity of 6–9 points by the MSK-64 scale are quite possible. In addition to natural earthquakes, earthquakes of man-made origin also happen in Ukraine. In particular, in the Kryvyi Rih basin, in the areas of extensive mining operations, the blasting technique is often used, causing local earthquakes and

activating such dangerous natural and technogenic processes as landslides, rock falls, rock strikes, etc.

In this regard, an important objective is to improve the seismic stability of buildings and structures (seismic protection) by using special structural elements that enhance the ability of buildings to withstand seismic impacts without complete destruction and the loss of human lives. Seismic protection should also protect people against harmful dynamic loads (mainly, noise and vibration) and provide comfortable living conditions in the metropolitan areas.

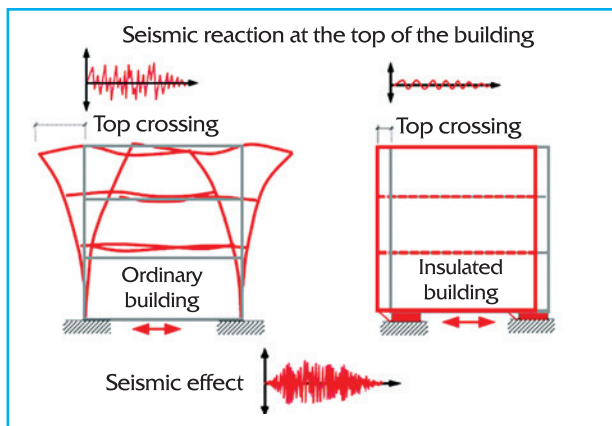
To protect buildings and structures against seismic impacts and vibration, N. Polyakov Institute of Geotechnical Mechanics of the NAS of Ukraine, in collaboration with the State Enterprise 'State Research Institute of Building Constructions', elaborated State Building Standards B.1-12:2014 "Construction in Seismic Regions of Ukraine", which are in harmony with the European standards and which stipulate designing of anti-seismic structures with the predetermined rate of seismic safety. The key difference between the behavior of ordinary and anti-seismic buildings under a seismic load is relative horizontal displacements of their upper floors due to the earthquake: in anti-seismic buildings, those are much smaller.

In addition, novel systems of seismic and vibration protection of buildings and structures were developed. In particular, seismic vibro-insulators — rubber-layered seismic blocks made of special elastomers and installed between the base plate and the walls of the basement floor — were designed for 10- and 27-storey buildings, and a method for calculating parameters of vibro-seismic units under uniaxial linear and non-linear deformations was worked out. The elastomeric elements were tested by compression on special test stands, and the tests demonstrated an important role of a lead core in the elastomers, which increases the rigidity of the seismic block and intensifies energy dissipation. The design of the elastomeric elements is protected by a patent.

In collaboration with the experts of the State Research Institute of Building Constructions, the IGTM developed recommendations towards design solutions of the vibro-seismic protection system for the case of pile foundation grillage, and a procedure for installing such system was proposed. In the case of pile foundation grillage, vibration insulators are mounted on pile heads. In this case, the reinforced concrete monolithic grillage rests on vibration insulators and not merely performs the functions of vibration and seismic protection, but also improves the stability of the building against tipping under the action of wind or seismic loads due to lower center of mass.



Seismically insulated 27-storey buildings. Kyiv, Obolonsky Avenue



The differences in the behavior of ordinary and seismically insulated buildings under the seismic effect

In Ukraine, 16 buildings with seismic vibration protection have been built and partially put into operation: ten 10-storey buildings with protection against vibration caused by shallow metro railway and three 27-storey buildings with protection against vibration caused by motor vehicles in Kyiv; and three buildings with protection against vibration impact of railway transport in Lviv. Experimental tests have shown that the amplitude of vibration acceleration on all floors of the buildings decreases as compared with the amplitudes of foundation vibration by a factor of 5–7, and this rate is within the limits regulated by sanitary norms.

V.I.Dyrda

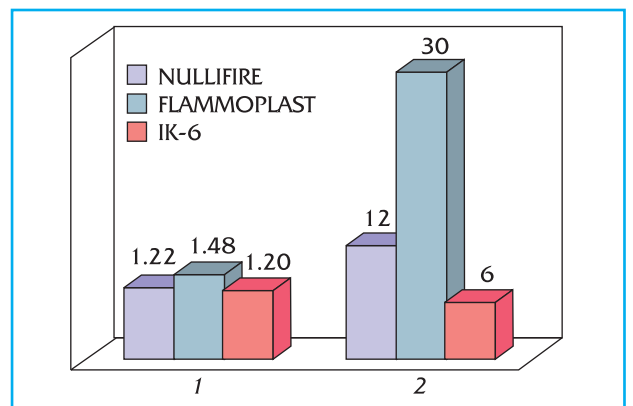
Development and industrial deployment of fireproof cover for steel structures at strategic objects

Fire protection of critical objects (buildings of defense and military infrastructure, nuclear power plants, chemical and oil refinery plants etc.) by their treatment with special fireproof materials is an important and pressing issue of the national security of Ukraine. The most widely used in the international practice fire protection means are intumescent (reactive) coatings of the ammonium polyphosphate/melamine/pentaerythritol composition. In fire, the coating bloats and forms a strong heat-insulating coke layer that protects the steel structure from losing its bearing capacity.

Scientists of L.M. Litvinenko Institute of Physical-Organic & Coal Chemistry of the NAS of Ukraine developed the formulation and flowchart of the production of the IK-6 intumescent coating, which can compete successfully with imported counterparts. The IK-6 coating was tested for fireproof treatment of various metal columns and beams, and according to the con-



Steel structure treated with IK-6 intumescent coating



Comparative diagrams for intumescent agents: 1 – coating thickness that will provide fireproofing of steel structures for 60 min.; 2 – price of 1 kg, €

clusions of independent experts, it demonstrated excellent rheological and technological parameters. The comparison of the effectiveness of the novel IK-6 coating with the leading European counterparts (*Nullifire S 707-60* and *Flammoplast SP-A2*) showed that it has not inferior and by some criteria even superior fireproof characteristics. In addition, the cost of IK-6 is much lower than the cost of foreign intumescent substances.

Technical specifications and regulations of fireproofing treatment with the IK-6 agent were developed, which permits it to be used in the fireproofing treatment of nuclear and heat power plants, ammunition depots etc. 'Kovlar Group' Ltd. (Kyiv) has already produced a 1000 kg pilot batch of this product.

L.M. Vakhitova, N.A. Taran, K.V. Kalafat

A new exclusive technology of remediating the soils polluted with pesticides

One of the acute present-day environmental problems is the pollution of the environment with various toxic compounds. A special role in it is played by the chemical means of plant protection — pesticides. Their main function is to control various plant pests, weeds, pathogenic fungi, microorganisms, etc. However, the use of pesticides produces grave impacts on the environment and human health. They persist in the upper layers of the soil, slowly migrate downwards, accumulate in foodstuffs of plant and animal origin and, getting into human organism, produce a toxic effect and cause various diseases. Pesticides are able to remain and accumulate in the environment for decades, continuing and increasing their harmful effects on ecosystems.

To minimize the injurious impacts of pesticides, the Institute of Sorption and Endoecology Problems of the NAS of Ukraine developed an exclusive technology of soil remediation from the accumulated toxic chemicals that relies on the use of granulated bio-sorption composite — 'Grandetox' pesticide detoxicant. It consists of porous sorption materials of plant origin and natural microorganisms that are consolidated on the sorbent surface and are able to decompose pesticides into environmentally safe compounds. Such combination enhances the destructive action of the microorganisms.

Field tests of 'Grandetox' on the crops of maize and sugar beet, according to the novel procedure developed, proved the high efficiency of the composite: the concentration of the soil agrochemical pollution is reduced by 70% over three months. Of no less importance is the fact that the productivity of the abovementioned crops on the experimental plot is higher

than that on the reference plot by a factor of nearly 1.5, and the sugar content in beets increases by 30%.

Thus, the new technology allows farmers not only to increase the yield of crops but also to grow high-quality and environmentally safe produce. The effectiveness and low cost of the biosorption composite and the availability of the raw materials is a considerable argument for wide-scale introduction of this technology into agricultural industry.

L.Y. Khokhlova, A.V. Khokhlov

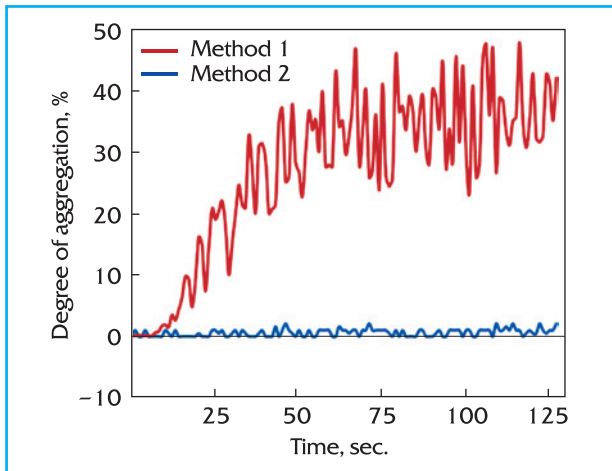
A method for concentrating platelets from autologous blood plasma for cell therapy and its clinical testing

Cell therapy is an advanced medical approach that relies on the use of live cells to accelerate tissue regeneration and healing as well as to reduce inflammatory processes. The most common method among cell therapies is the use of platelet (thrombocyte)-rich plasma which is prepared from patient's own (autologous) blood and, thus, does not trigger allergic reactions and does not cause infections. This method is widely used in dental implantation, orthopedics, dermatology, etc.

The method of obtaining human blood plasma rich in platelets was improved at the Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine to yield concentrations exceeding 10^6 cells/ μL . At the same time, the fraction of cells with morphological changes did not exceed 30%, whereas more than 60% of cells are activated during the suspension preparation using the standard commercially available method. The platelets obtained



Plasma lifting procedure using the platelet suspension



ADP-induced aggregation of platelets obtained with the new (1) and commercially available (2) methods

with the new method were native, able to be activated and to aggregate, whereas platelets obtained from the commercially available method lack these properties.

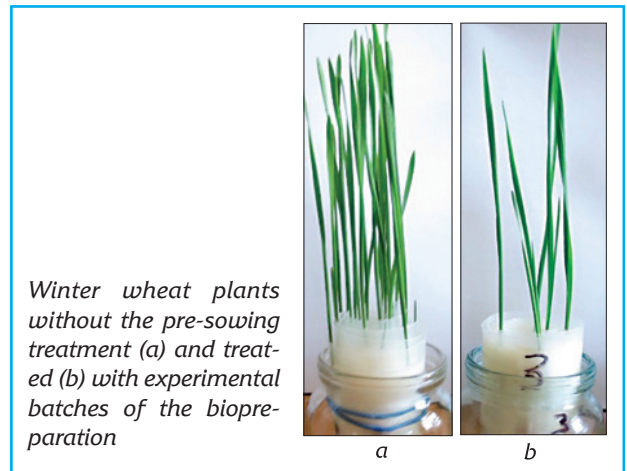
This original method was successfully adapted for skin regeneration at the VIKYUR clinic. The use of the suspension rich in functionally active platelets accelerated the achievement of the desired effect.

S.V. Komisarenko, V.O. Chernyshenko, D.S. Korolova, V.I. Gryshchuk, K.M. Shtainberg

A new effective biological preparation for plant farming

It is well known that pathogens (especially those of agricultural plants) are able to adapt to commonly used biopreparations; thus, the search for new bacterial strains with a broad spectrum of biological activity as well as the development of new preparations with antagonistic and growth-promoting properties on the base of these strains are always important. The use of biopreparations in agriculture improves the quality of the crops produced and the state of the environment, revitalizes soils, stabilizes plant productivity, and neutralizes the phytotoxic effects of pesticides and agrochemicals.

In D.K. Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine, a new *Bacillus* strain that showed pronounced antifungal and phyto-stimulating activity was isolated. It was identified as *Bacillus amyloliquefaciens* subsp. *plantarum* and obtained number IMB B-7524 in the Ukrainian Collection of Microorganisms. Researchers found that high antagonistic activity of *B. amyloliquefaciens* subsp. *plantarum* IMB B-7524 results from its ability to synthesize li-



Winter wheat plants without the pre-sowing treatment (a) and treated (b) with experimental batches of the biopreparation



Fermenter for obtaining small batches of the biopreparation based on the *B. amyloliquefaciens* subsp. *plantarum* IMB B-7524 strain

peptide antibiotics that belong to fengycin and iturin families. It was shown that these substances are able not only to inhibit the development of plant diseases due to their fungicidal properties but can induce protective responses in plants. Among *B. amyloliquefaciens* subsp. *plantarum* IMB B-7524 exometabolites, three classes of stimulating phytohormones and one

anti-stress hormone were identified. Besides their phyto-stimulating and anti-stress activities, the hormonal compounds examined are able to promote the initial stages of plant ontogenesis, which are the most sensitive to pathogens. As a result, the negative impacts of biotic factors on young plants are significantly reduced or almost neutralized.

The regulations for obtaining the biological preparation for plant farming that rely on the strain studied were elaborated. Cultivation conditions for the fast obtaining of the preparation within one day were chosen. It was shown that molasses, malt and corn extracts, which are available for biotechnological enterprises in Ukraine, are the main and optimal components of nutritious media for growing *B. amyloliquefaciens* subsp. *plantarum* IMB B-7524.

The preparation was developed commercially at pilot production Center LLC 'Cherkasybiozakhyst' (Cherkaska Oblast), where the experimental industrial batches of preparation were produced. Field studies confirmed that this biopreparation significantly inhibits the growth of causative agents of root and leaf rots of cereals, and the pre-sowing treatment of winter wheat seeds with it considerably increases the germination of plants and the accumulation of biomass by them.

H.Yu. Hrabova, M.A. Kharkhota, I.V. Drahovoz, L.V. Avdeeva

Advanced adaptive technologies of producing original winter wheat seeds and the transfer of innovative varieties

Agriculture is one of the most important sectors of Ukraine's economy. Its part in GDP is 12%, and in export, the part of agricultural products amounts to nearly 40%. Therefore, the development and large-scale introduction into agricultural production of a new generation of plant varieties and hybrids, cereals in particular, as well as a radical improvement of the seed farming system are of utmost importance. This is particularly relevant in the context of climate change, experienced by Ukraine and other countries in the world.



Harvesting winter wheat seed crops at the Institute of Plant Physiology and Genetics of the NAS of Ukraine

Scientists of the Institute of Plant Physiology and Genetics of the NAS of Ukraine are working persistently and successfully towards the creation of new advanced high-yielding and stress-resistant winter wheat varieties. With a view to active and widespread implementation of their research results, accelerated creation of new varieties, and production of the necessary seed amounts, they have developed modern adaptive technologies for the cultivation of original winter wheat seeds, which are based on innovative developments.

In particular, in 2019, a number of new technology elements were developed and mastered, which allowed a 4–5 time increase in the seed production rate and a 2–3-fold reduction in the time of new varieties introduction into farming.

The efficiency of the developed seed production scheme and innovative technologies was confirmed by a number of leading seed farms in Ukraine, such as LLC 'TERRA MAKAS' (Kyivska Oblast), LLC 'Seeds of Slobozhanshchina' (Kharkivska Oblast) and LLC AF 'Slavutysh' (Dnipropetrovska Oblast) located in different natural zones of Ukraine. These enterprises were able to grow and sell high quality winter wheat seeds worth of over € 12.5 million, and their profitability exceeded 175%.

V.V. Morgun, M.M. Havryliuk

IMPORTANT EVENTS

The working group of the NAS of Ukraine, which involved leading Ukrainian scientists, prepared and approved at the session of NAS Presidium of 27 March 2019 proposals to the Draft State Strategy of the Advancement of Science, Technologies and Innovative Activities (hereinafter — the Draft Strategy).

The main aim of this document is to enhance the competitiveness of the science sphere and ensure high rates of economic, social and cultural development of society, which is based on the scientific and technological progress. It contains the analysis of the status of science and R&D sphere and identifies the main principles of its development and ways of optimization. The advancement of innovative activities was thoroughly elaborated, all elements of the innovative system — from research institutions and pilot production facilities to banks, finance and credit institutions and venture funds — were covered. Important emphasis was placed on the fiscal policy for stimulating S&T and innovative activities — particular directions and fiscal mechanisms to promote all entities of the innovation chain. The proposals for the Draft Strategy also outlined priority measures towards enhancing the efficiency and effectiveness of scientific research in the National Academy of Sciences of Ukraine and the sectoral national academies of sciences. The draft focuses on such important components of S&T progress as the integration of science and education, and support to young scientists. The Draft Strategy was forwarded to the Prime Minister of Ukraine, to the Parliamentary Committee for Education, Science and Innovations and the Ministry of Education and Science of Ukraine.

On 5 November 2019, a session of the National Council of Ukraine for Science and Technology Development headed by the Prime Minister, the Chairman of the National Council of Ukraine for Science and Technology Development discussed the principles of the state policy in science and R&D. Taking into account that an important component of this policy should be effective legislation provisions, the National Academy of Sciences of Ukraine prepared and submitted proposals for the amendments to the Law of Ukraine

‘On Scientific and S&T Activities’ to the Prime Minister of Ukraine and the Committee of Verkhovna Rada of Ukraine for Education, Science and Innovations. In particular, the proposals concerned a broader NAS authority in coordinating, planning and evaluating the efficiency of conducting basic research; preferential tax rates for scientific institutions; strengthening human resources for novel and most relevant research areas; compulsory approval of the results of state expert examination, including the environmental one, in the NAS of Ukraine, etc. The Academy also put forward legislative initiatives regarding currently important amendments to Tax, Budget and Economic Codes of Ukraine, in particular, proposals on tax immunity for the scientific institutions providing operational (administrative) management of Ukrainian natural reserves of the national scope etc., as well as draft laws of Ukraine ‘On the special regimen of innovative activities in innovation parks’, ‘On amendments to certain legislative acts involving the simplified procedure of state registration of the termination of inactive legal entity through its liquidation’.

The aforementioned session of the National Council of Ukraine for Science and Technology Development also discussed the proposals towards reforming science that were prepared by the Scientific Committee of the National Council and recommended the Cabinet of Ministers of Ukraine to take them into account when preparing the government action plan in respect of the implementation of the Program of the Activities of the Cabinet of Ministers of Ukraine.

It is worthwhile to note that these key proposals were thoroughly discussed by the National Academy of Sciences of Ukraine in October 2019. They were examined by the meetings of NAS department bureaus, by research teams of NAS institutions, sessions of the councils of regional science centers, and research communities of respective regions. Relying on the results of the discussions, a decision was adopted



Session of the National Council of Ukraine for Science and Technology Development

that assessed each clause of the key proposals, concrete remarks, clarifications and supplements.

Besides, the National Council set up working teams on individual issues of reforming and promoting the science sphere, including a working group for preparing proposals towards amendments to the legislation for reforming the National Academy of Sciences and sectoral national academies of sciences. NAS representatives were actively involved in the activities of these and other working teams.

On 20 November 2019, the session of the NAS Presidium discussed the issue 'On further reforming of the National Academy of Sciences of Ukraine aimed at improving the efficiency of its activities' and approved the relevant resolution.

This NAS Presidium resolution, taking into account the decision of the National Council of Ukraine for Science and Technology Development of 5 November 2019 and the Decree of the President of Ukraine 'On exigent measures for implementing reforms and strengthening the statehood' of 8 November 2019 #837, envisages measures towards further concentration of financial, material and technical, human resources in priority areas of science and R&D, optimization of the network of NAS scientific institutions, organizations and pilot production plants, promoting the collaboration with major R&D and production facilities, launching targeted state-funded programs of developing economy sectors and social sphere, enhancing Academy's science expertise function, involvement and retention of young researchers in the NAS of Ukraine, deepening the integration with educational institutions, promoting international collaboration in science, developing scientific infrastructure etc.

In particular, the resolution set the task of optimizing in 2020 and the first quarter of 2021 the network of NAS scientific institutions by taking into account the results of their evaluation and laying them off by 10 % in the Academy as a whole. This is to be done through dissolving the institutions that have low rating as compared with the same-field institutions, do not have up-to-date scientific infrastructure, have small numbers of employees and are inefficient.

NAS Presidium set up the Working Group of the NAS of Ukraine for preparing proposals on the advancement of science sphere in Ukraine, which is headed by NAS Academician Volodymyr P. Gorbulin, First Vice-President of the NAS of Ukraine. Its task is to elaborate proposals on reforming the system of scientific research organization, raising the efficiency of scientific institutions and enhancing the influence of science on the innovative progress of the country, liaison on these issues with high government agencies and the National Council of Ukraine for Science and Technology Development. The Working Group for monitoring the Ukrainian legislation in the scientific, R&D and innovation spheres was also established.

On 15 January 2020, a session of the Presidium of the National Academy of Sciences of Ukraine, through the initiative of the NAS Working Group for preparing proposals on the advancement of science sphere in Ukraine considered the issue 'On further development of normative legal framework for science sphere and improving the administration structure in the NAS of Ukraine' and adopted the relative resolution.

This resolution of the NAS Presidium approved NAS proposals on the issues that need legislative adjustment in 2020 along with draft normative legal acts in the sphere of scientific, R&D and innovation activities that are to be submitted to the Cabinet of Ministers of Ukraine in accordance with the established procedure.

It also approved the decision on setting up new advisory expert bodies — the S&T Board of the NAS of Ukraine and research-coordination boards of NAS sections. Their major task would be to promote accelerated deployment of R&D products; advance interdisciplinary research; form respective all-Academy programs; elaborate proposals concerning priority research trends in respective science areas; enhance research coordination with scientific institutions of other agencies and universities, etc. A more extensive practice of establishing supervisory boards in major institutions that have the status of scientific research institute was recommended as well.

PILOT PROJECT OF FUNDING SCIENTIFIC RESEARCH

In 2019, State budget-supported program 6541230 'Support to priority trends of scientific research' was continued in the NAS of Ukraine. It involves a new funding model that consists in the broad use of the results of evaluating the efficiency of research institution activities along with contest principles to identify priority research areas that are important for science and society. The program is aimed at providing targeted support to scientific teams that conduct research according to the international standards, in particular, to the teams of young scientists, to collaborative international projects, as well as supplying this research with innovative equipment.

Five lines (areas) of spending State Budget money were determined. In the first area — 'Support to priority scientific research and S&T (experimental) developments that are of top priority for the state' — financial support went to research units that got the highest ratings by the results of evaluating the efficiency of their activities (rating A). On the whole, 325 research units received finance for implementing 161 projects (141 projects in the sphere of basic research and 20 — in applied research), the total funding amounting to € 274.6 million.

In the second area, 'Implementation on the competitive basis of the most important R&D, including products with a high degree of readiness', NAS supported research efforts important for Ukraine's economy and defense potential that are carried out in the framework of Academy targeted programs and single targeted projects. Those studies were selected on the competitive basis with broad involvement of external experts. According to the expert evaluation of the applications submitted, 277 research units (182 of which had A rating) received the total funding of € 155.35 million for implementing 267 projects, 76 of those being in basic research and 191 — in applied one. As a result, 1041 pieces of R&D produce were created: novel products, technologies, materials, crop varieties, me-

thods and theories. 375 of them were commercialized in various industries, in particular, in machine building, energy engineering, housing construction, in agribusiness, medicine etc.

In the third area — 'Research and development performed by young scientists through competitive launch of research laboratories (groups) of young scientists' — 10 research laboratories and 20 research groups were organized with reliance on competitive selection. The funding for each laboratory was € 1.0 million and 0.6 million for a group. The total annual budget of youth laboratories (groups) amounted to € 22 million. During grant implementation, young scientists were involved in 64 business trips and internships, 43 of those were concerned with foreign scientific centers, where they were able to familiarize with advanced research and use state-of-the-art equipment for investigations under their projects. The results of the research performed by young scientists were published in 154 scientific papers, 71 of those were issued in foreign professional editions. 8 monographs were published, 12 patents and 11 implementation certificates were received. The results were presented to broad scientific circles at 233 scientific conferences and scientific workshops.

In the fourth area 'Collaborative international research on competitive principles', financial support was provided to the works selected through joint contests of the NAS of Ukraine and Ukrainian S&T Center (4 projects), the NAS of Ukraine and the NAS of Belarus (10 projects), the NAS of Ukraine and the National Center for Scientific Research of France (CNRS) (2 projects). The total funding of the projects amounted to € 5.39 million. The distinctive feature of the projects is that respective applications are subjected to parallel independent expert evaluations of the event organizers and the winners are financed on the principles of parity. The outcomes of the investigations carried out were presented in 48 works published in specialized scientific editions, 32 of those — in international ones; 3 patents were received. Last year, 4 scientists visited their foreign partners under CNRS projects for conducting joint research and discussing the results obtained.

In the fifth area — 'Procurement of innovative scientific equipment and upgrade of the available one' — 40 NAS research institutions were allocated € 60.994 million of targeted funds for purchasing equipment and components necessary for implementing scientific projects supported under other lines of budget-supported program 6541230.

ON THE MAP OF WORLD SCIENTIFIC CENTERS

In the year under review, the NAS of Ukraine continued its active support to the participation of its institutions in international programs and projects along with the activities aimed at promoting the bilateral scientific and R&D co-operation. The scope and geography of the international collaboration was extended.

In September 2019, a regular session of the Council of the International Association of the Academies of Sciences (IAAS) was held in Dushanbe (the Republic of Tajikistan). NAS Academician V.G. Koshechko, Vice-President of the Academy, headed its delegation. Taking into account the outstanding contribution that NAS Academician B.E. Paton, the President of the NAS of Ukraine, made to the development of the Association (he was its founder and the first President for nearly 25 years), B.E. Paton was elected the Honorary President of the IAAS. The session approved the Declaration on the IAAS Development out to 2030 and a number of other decisions.

Information events aimed at enhancing the role of NAS scientists in scientific programs of NATO and the European Union were of significant importance for strengthening their positions in European and North Atlantic Treaty projects. The experience of NAS institutions participation in implementing projects under the NATO program 'Science for Peace and Security' was presented during the information day of this program in Ukraine. Scientific collaboration with NATO extends the opportunities of improving research infrastructure, establishing new international contacts, attracting additional finance sources for scientists. The quality of research implementation by NAS scientific teams in the framework of the projects was highly appreciated at the meeting of a representative of 'Science for Peace and Security' program with the leaders of the Academy. A meeting of NAS leadership with a delegation of the U.S. Army Corps of Engineers was also held; it was a logical continuation of the contacts established by NAS scientists during the seminar 'NATO Advanced Workshop' that took place in Rovaniemi (Finland). The American delegation visited several NAS institutes.

The active involvement of NAS institutions in the EU framework program for research and innovation 'Horizon 2020' continued. The European Commission gave a high estimate to the completed NAS project AERO-UA concerned with promoting research collaboration between Ukraine and the EU in aviation industry. The implementation of the new *Neurotwin* project with the total budget of € 780 000, whose coordinator and Ukrainian partner is Bogomoletz Institute of Physiology of the NAS of Ukraine, will provide additional opportunities for conducting research according to the international standards, along with training Institute's post-graduate students with the involvement of the European universities. *Neurotwin* enables Ukrainian scientists to work in conjunction with their colleagues from Germany, Great Britain, Austria, Sweden and Portugal.

The new National EURATOM Contact Point in Ukraine, supported by the *UAinEURATOM* project, started its activities. Hosted by the National Science Center 'Kharkiv Institute of Physics and Technology', Telecommunication Center (TC) of this contact point, possessing specialized equipment, can hold video-conferences, distance meetings in the framework of international and national projects etc. The aim of TC *UAinEuratom* is to provide communication means for enhancing collaboration and integration of the Ukrainian scientific community into European scientific research. E.g., the Information Day in Ukraine was organized by the Euratom program, which is complementary to the EU framework program for research and innovation 'Horizon 2020'. Representatives of the scientific and academic spheres were informed about the *Euratom 2019–2020* program and its calls as well as the new EU framework program for research and innovation *Horizon Europe*, which starts in 2021, including the new *Euratom 2021–2025* program.

Active co-operation with the International Institute for Applied Systems Analysis (IIASA) continued. 18 scientific reports within the joint project of the National Academy of Sciences of Ukraine and IIASA were presented and discussed at the joint workshop of the NAS and IIASA 'Integrated robust management of food—energy—water—land use nexus for sustainable development'. It was attended by researchers of Glushkov Institute of Cybernetics, the Institute for Economics and Forecasting, the Institute of General Energy and the Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences. Academy scientists made 9 presentations (4 of those — in collaboration with IIASA researchers) on systems analysis methodology, the analysis of agrarian production, the social development of regions,



Inauguration of the Telecommunication Center of the Euratom Contact point in Ukraine



Participants of the joint workshop at IIASA 'Integrated robust management of food–energy–water–land use nexus for sustainable development'



Ukrainian delegation at the International GEO Week 2019 and GEO Ministerial Summit

energy sector modeling, evaluation of water resources pollution.

In the framework of the *European Endangered Landscapes Programme*, the implementation of the project 'Reclamation of Water, Wetlands and Steppe Territories of the Danube Delta Region (2019–2023)', with the participation of the Danube Biosphere Reserve of the NAS of Ukraine, was launched. This program is under the guidance of *Cambridge Conservation Initiative (CCI)* – a unique project of collaboration between the University of Cambridge and leading international nature conservation organizations. The *Danube Delta Biosphere Reserve (Romania)* and *Verde e Moldova NGO (Moldova)* are partners of this project.

In 2019, Ukraine joined the **Europe's Part of the Group on Earth Observations GEO (EuroGEO)** and set up the Ukrainian GEO-UA Committee. Space Research Institute operating under the NAS of Ukraine and the State Space Agency of Ukraine became an official member of the *Copernicus Academy* network of educational centers, whose task is to link research and academic institutions with authorities and service providers, to facilitate collaborative research and to develop educational materials. In the same year, under the **Earth Observation Cloud Credits Programme GEO-AMAZON**, the realization and implementation of the methodologies developed for computing the indicators of sustainable development goals with reliance on the *Amazon* cloud platform was launched. In the future, it is planned to be developed for Argentina and India in the framework of international collaboration.

Collaboration under bilateral agreements with the academies of sciences and research institutions of other countries, which is traditional for the NAS of Ukraine, went on.

A spectacular example of deepening the Ukrainian–German scientific collaboration was the visit of the **delegation of the Federal Ministry of Education and Research (BMBF)** headed by Thomas Rachel, State Secretary, to G.V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine and Kyiv Academy University of the NAS of Ukraine and the MES of Ukraine (KAU). The State Secretary of *BMBF* emphasized the success of *UKRATOP* and *AcademCity*, implemented by KAU jointly with its German partners. In the framework of the international project GUTT.UP – 'German–Ukrainian University Partnership for the Julius-Maximilians Universität Würzburg (FRG), jointly with KAU and with the support of the German Academic Exchange Service (DAAD), a German–Ukrainian conference on technologies transfer was held.

The versatility of bilateral German–Ukrainian cooperation can be seen in collaborative research car-

ried out jointly by Ukrainian and German scholars and experts involved in the **return of the Charter of Peter the Great on the Kyiv Metropolitan Appointment of Ioasaph Krovovskyi in 1708 from Germany to Ukraine**. The ceremonial transfer of this historical document to V.I. Vernadsky National Library of Ukraine took place on 30 May. This outstanding event was marked with a special Ukrainian–German colloquium ‘Kyiv Metropolitan Appointment of Ioasaph Krovovskyi in 1708: the Ukrainian–German history of the original Charter of Peter the Great’, held at V.I. Vernadsky National Library of Ukraine under the auspices of the Ministry of Foreign Affairs of the Federal Republic of Germany and the National Academy of Sciences of Ukraine.

Contests for research visit grants for young scientists from our partners — the Polish Academy of Sciences and the Royal Society of Canada were continued. According to their results, 20 representatives of the NAS of Ukraine were provided with opportunities to have internship experience in scholarly institutions of Poland and two — in scientific research institutions of Canada. Members of a research team of B. Verkin Institute for Low Temperature Physics and Engineering of the NAS of Ukraine and B. Trzebiatowsky Institute of Low Temperature and Structure Research of the Polish Academy of Sciences were awarded the **2019 Prize of the National Academy of Sciences of Ukraine and the Polish Academy of Sciences** for a cycle of collaborative research works “New mechanisms of heat conduction in non-conducting solids”.

The memorandum of understanding as regards the research collaboration between the University of Padua and the National Academy of Sciences of Ukraine was signed, as well as the **Framework Agreement on the S&T collaboration between the NAS of Ukraine and the People’s Government of the Shandong Province (PRC)** during the visit of the Shandong Province delegation headed by its Vice-Governor Yu Jie to the Academy. In May 2019, the NAS Institute for Safety Problems of Nuclear Power Plants, the Chornobyl Nuclear Power Plant, the State Agency of Ukraine



Unique historical document of the 18th century returned to V.I. Vernadsky National Library of Ukraine



Visit of the governmental delegation of the Shandong Province (PRC)

for Exclusion Zone Management and *Xianchu Group* Company approved a **joint decision on setting up a Ukrainian–Chinese integrated laboratory for research and testing under exposure to high radiation**. The laboratory will be situated within ‘Shelter’ facility, which will make it the only laboratory in the world permitting scientists to examine and test equipment prototypes under actual conditions of high radiation levels.

SCIENCE AND SOCIETY

Science popularization in society and maintaining close contacts with the public are important areas of the activities of the National Academy of Sciences of Ukraine. Every year, with extended communication opportunities and increased information streams, science popularization also undergoes significant changes, becomes more varied and moves to a new level of development. Academy institutions and leading scholars of the NAS of Ukraine give considerable effort to informing the society about the achievements of the world science, the results of their own research and their practical application, to forming scientific outlook and propagation of reliable scientific knowledge. Large-scale nation-wide popular science events have become traditional, and every year they involve an increasing number of scientific and educational institutions of various Ukrainian cities and towns. Such activities attract broad circles of visitors — from the very young to people well advanced in age. Media interest to science issues is increasing: national and regional TV and radio channels, Internet resources produce broadcasts and features covering science — their frequent guests or authors are our scientists and scholars. Lectures and excursions addressing highly relevant science problems were organized, scientific achievements were presented at exhibitions and forums.

Last year, the XIIIth All-Ukrainian Science Festival (16–18 May) was the event of the largest scale for popularizing science in the society. Over a thousand of popular science activities of varied formats — from Open Doors Days to quests — took place within the Festival across the country. On 16 May, E.O. Paton Electric Welding Institute of the NAS of Ukraine held Festival-opening ceremony, and Professor David Pas-tré from the University of Evry, Director of the laboratory of structures and activities of normal-pathological molecules (SABNP, France) delivered a lecture 'Control of gene expression by cell division and human diseases'. NAS Academician O.S. Onyshchenko, NAS V.I. Vernadsky Gold Medal Laureate of 2019, also presented a lecture 'The national scientific heritage are intellectual treasures of the state'. Besides, before and during the festivities an exhibition of the

scientific achievements of NAS institutions was demonstrated along with presentations of scientific research works and poster reports of schoolchildren who are members of the Junior Academy of Sciences of Ukraine and pupils of Kyiv schools.

For the seventh year running, Academy institutions and scientists were actively involved in another grandiose popular science project — 'Science Days', which was started by young scientists of the NAS of Ukraine. On 25–26 May and 10–11 November 2019, lectures, experiment demonstrations, master classes and excursions were organized in Kyiv, Ivano-Frankivsk, Zhytomyr and — for the first time — in Zaporizhzhya, Poltava and Mykolaiv. During them, our scientists introduced visitors to the achievements of the world and Ukrainian science, promoted scientific outlook. All those willing were able not merely to watch and listen, but also communicate with researchers and receive from them profound answers to the questions asked.

Traditionally in May and September, different Ukrainian cities organized 'science picnics' — interactive popular-science outdoor activities for the general public. Scientific lectures in the talk-show format, as well as numerous experiments, games, trainings, tests etc. were waiting for their visitors. As in the previous years, Academy employees joined the 'science picnics'.

The third week of 2019 March in Kyiv, as everywhere around the world, was marked by the global popular-science campaign whose aim was to draw attention of the society to research in neurosciences and studying the structure and functioning of the human brain. Leaders of the Brain Week in Ukraine, among whom also were NAS scientists, presented popular-science demonstrations, showed films for schoolchildren, students, delivered lectures for specialists and all comers. The schedule at Bogomoletz Institute of Physiology of the NAS of Ukraine was very rich in events. During "neural" 'Science Days', which took place there, scientists explained and visually demonstrated various aspects of nervous system functioning and delivered a series of lectures on biology and medicine.

On 14 March, the International Day of Pi Number was marked in Kyiv. It was organized by the NAS Institute of Mathematics, Kyiv Academic University operating under the NAS of Ukraine and the MES of Ukraine, the National Center 'Junior Academy of Sciences of Ukraine' of the NAS of Ukraine and the MES of Ukraine, Kyiv extra-school educational institution 'Kyiv Junior Academy of Sciences' (Kyiv JAS) and Borys Hrinchenko University. Its visitors were provided with brain ring 'Interesting mathematics', lectures about Euler's identity and about dark matter and dark energy in the Universe.

On 20 April, the NAS Institute of Mathematics conducted the first large-scale all-Ukrainian event devoted to women in mathematics. Its aim was to popularize mathematics among girls, reduce gender imbalance in this sphere, allow schoolgirls and female students to establish personal contacts with successful female mathematicians.

On 4 May, in the same place — the Institute of Mathematics of the NAS of Ukraine — an exciting team competition ‘Mathematical Merry-Go-Round’ was carried out; it involved solving mathematical problems by schoolchildren of the 5–6 forms.

Our institutions held numerous activities to mark the professional holiday of Ukrainian scientists — Science Day, which is celebrated every year on the third Saturday of May. E.g., on 11 May, ‘Science Holiday’ took place at G.V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine. Its guests had an opportunity to learn about the achievements of this institution’s scientists and to watch the unique interactive performance ‘Ultra-violet’, staged by Science Theatre, about interesting phenomena related to the radiation that is invisible to us.

On 18 May, to mark the International Museum Day, the National Museum of Natural History presented fascinating educative programs prepared by scientists and friends of the museum.

On 20 May, traditional popular-science event was held at B. Verkin Institute for Low Temperature Physics and Engineering of the NAS of Ukraine (Kharkiv) to celebrate the International Day of Light (in 2019, it fell on 16 May). It was organized by Institute’s Council of Young Scientists and *IRE SPIE Student Chapter*, which is hosted by this Academy institution. At the invitation of event’s organizers, about 300 Kharkiv schoolchildren visited it and, in particular, had an opportunity to watch physical experiments conducted in the popular format 15×4, i.e. for 15 minutes at each of 4 locations: ‘Optical demonstrations’, ‘Life under the microscope and its equipment’, ‘Infrared imagers’, ‘Low-temperature experiments’.

Our astronomers, who told the visitors about their major research achievements, presented new books and carried out discussions, also organized several popular-science activities. On July 15, the Main Astronomical Observatory of the NAS of Ukraine held an Open Doors Day, on 20–21 September — events on the Autumnal Equinox Day, on 5 October it celebrated the Autumn Astronomy Day and the International ‘Observe the Moon’ Night. On 25 October, popular-science activities were held to mark the 75th anniversary of the Observatory.

An interesting event intended to draw the attention of the society and authorities to the achievements and



At the posters of the National Center ‘Junior Academy of Sciences’ of the NAS of Ukraine and the MES of Ukraine at the all-Ukraine Science Festival in E.O. Paton Electric Welding Institute of the NAS of Ukraine



Spring ‘Science Days’-2019 at the NAS Institute of Molecular Biology and Genetics



Participants of the event ‘Women in mathematics: history and future prospects’ at the NAS Institute of Mathematics



Participants of the third Ukrainian March for Science

problems of the national science sphere was held on 4 May: it was the third time that Ukrainian scientists, including those of the NAS of Ukraine, walked along Kyiv streets in the framework of the global initiative – March for Science.

The archeological lectorium ‘What archeology tells us about’, which functions within the Archeology, Museum of the NAS Institute of Archeology, in the format of popular-science lectures, travel lectures and workshops, continued its work in 2019.

Scientists of Bogomoletz Institute of Physiology of the NAS of Ukraine delivered a cycle of open lectures on molecular physiology for university students in biology, medicine and other professions that study the living matter, as well as for all those who want to understand how the human body functions. In this institution, open lectures in neuroscience have been going on since October.

The Lectorium of the Pavlivskiy Public Garden in Kyiv opened its doors for the second time. This is a free educational popular-science project set up by active members of the local community. The highlight of the previous year in the lecture center was the division of its activities into lectures proper and excursions. The lectures, as in the autumn of 2018, were provided, in particular, by NAS scientists.

In 2019, Academy scholars were extensively involved in the activities under the program of IX International Festival ‘Book Arsenal’, which took place in Kyiv on 22–26 May. They became the speakers of the discussions “What will we tell extraterrestrial civilizations about us?”, “How does genius brain work?”,

“Science popularization: clear explanation of difficult things”, “Popular science literature: what it is for and who reads it?”, “PopSci: made in Ukraine”, while ‘Science Days’ project organized its own “Scientific micro-lectorium”.

Every year, Academy scientists also present their research results under the umbrella of several large-scale specialized exhibitions. Last year, R&D products of the NAS of Ukraine were demonstrated at the Farming Technologies Forum and VIII specialized exhibition of technologies and equipment ‘Greenhouse Farming 2019’ (12–14 March), exhibitions of X International Medical Forum ‘Innovations in Medicine – Health of the Nation’ (17–19 April), XXIV International Exhibition of Security Industry ‘Security 2019’ (22–25 October), IV International Innovation Forum ‘Innovation Market’ (5–7 November).

In 2019, scientists of the NAS of Ukraine continued their close co-operation with Ukrainian media, in particular, TV channels ‘UA: Pershyi’, ‘Rada’, ‘Priamyi’, ‘Inter’, ‘5 Channel’, ‘TRC Kyiv’ and Internet channels ‘Hromadske Telebachennia’ and ‘Ya-UA’; radio stations ‘UA: Ukrainske Radio’ (Channel 1, ‘Promin’, ‘Kultura’), ‘Radio NV’, ‘Hromadske Radio’, ‘Radio Svoboda’; printed periodicals ‘Den’, ‘Dzerkalo Tyzhnia’, ‘Holos Ukrainy’, ‘Uriadovyi Kurier’, ‘Ukraina Moloda’, ‘Svit’, ‘Demokratychna Ukraina’, ‘Ukrainske Slovo’, ‘Ukrainskyi Tyzhden’, ‘Kraina’, ‘Siohodni’, ‘Fakty’, ‘Hazeta 2000’, ‘Expres’; popular-science magazine ‘Kunshyt’ and popular-science Internet edition ‘Science Ukraine’; electronic resources ‘Ukrainska Pravda’, ‘Tsensor.NET’, ‘ZAXID.NET’, ‘theBabel’, ‘Hlavred’, ‘WOMO’; ‘UKRINFORM’ information agency et al.

A comprehensive interview of Academician Borys Paton, President of the NAS of Ukraine, and a documentary project ‘Borys Paton. Man of the Future’ were featured by ‘Inter’ – a major all-Ukraine TV channel. On the occasion of the jubilee of Academician V.P. Gorbunin, NAS First Vice-President, ‘Demokratychna Ukraina’, ‘Uriadovyi Kurier’, ‘Fakty’ newspapers and the Internet site of ‘Ukrinform’ Information Agency published articles on the life and professional achievements of the scientist, as well as an interview with him. An extensive interview of Academician Serhii Pyrozhkov, NAS Vice-President, covering the current situation in Ukrainian science was issued by ‘Den’ newspaper.

AWARDS

The V.I. Vernadsky Gold Medal of the NAS of Ukraine was awarded to NAS Academician O.S. Onyshchenko and to Michael Moser, an Austrian scholar, — for their outstanding achievements in studying and popularizing the Ukrainian national scholarly heritage.

Significant accomplishments in promoting international scientific collaboration were marked by conferring the title 'Doctor Honoris Causa of the Academy of Sciences of Ukraine' to Takaaki Kajita, a famous Japanese scientist, 2015 Nobel Laureate in physics; Professor Lam Kin Yong, Vice-President of Nanyang Technological University for Research and Innovation, Singapore; Cai Zhiming, a renowned Chinese scientist, Director of Urological Department at Shenzhen University, the President of Shenzhen Medical Association.

31 researchers of the NAS of Ukraine were honored with high state awards of Ukraine. For a significant personal contribution to building up the statehood, socio-economic, scientific, technological, cultural and educational advancement of the Ukrainian state, for their notable achievements in research, conscientious work of many years, awarded were:

with Order of Prince Yaroslav the Wise I Class, — NAS Academician V.P. Gorbulin, First Vice-President of the NAS of Ukraine, and NAS Academician V.A. Smolii, Academician-Secretary of the NAS Department of History, Philosophy and Law, Director of the Institute of the History of Ukraine;

with Order of Prince Yaroslav the Wise V Class, — NAS Academician A.G. Bilous, Head of the Department of V.I. Vernadsky Institute of General and Inorganic Chemistry; NAS Academician S.O. Dovhyi, Head of a Department of the Institute of Telecommunications and Global Information Space of the NAS of Ukraine; NAS Corresponding Member A.I. Danylenko, Labor Veteran; V.F. Sirenko, Principal Research Scientist of Koretsky Institute of State and Law of the NAS of Ukraine;

with Order 'For Services' I Class, — NAS Academician B.V. Burkinskyi, Director of the Institute of Market Problems and Economic-and-ecological Research of the NAS of Ukraine; NAS Academician L.A. Bulavin; O.P. Reent, NAS Corresponding Member, De-

puty Director of the Institute of the History of Ukraine; NAS Corresponding Member M.D. Tronko; NAS Corresponding Member A.I. Shevchenko, Director of the Institute of Artificial Intelligence Problems of the MES of Ukraine and the NAS of Ukraine;

with Order 'For Services' II Class — NAS Academician M.O. Perestyuk and NAS Corresponding Member A.V. Rudenko;

with Order 'For Services' III Class — NAS Corresponding Member M.S. Slobodianyky; N.R. Malysheva, Dr. of Law, Head of a Department of Koretsky Institute of State and Law of the NAS of Ukraine; V.O. Perevezii, Cand. Sci. (History), Academic Secretary of Kuras Institute of Political and Ethno-National Studies of the NAS of Ukraine;

with Order of Princess Olga III Class — NAS Corresponding Member S.M. Orlyk, Head of a Department of L.V. Pisarzhevsky Institute of Physical Chemistry, and O.V. Zernetska, Dr. Sci. (Politics), Head of a Department of the State Institution 'The Institute of the World History of the NAS of Ukraine'.

Academician B.E. Paton, President of the NAS of Ukraine, received from the International Association *Institute of Electrical and Electronics Engineers (IEEE) the 2020 IEEE Honorary Membership Award* — 'For life achievements in the development of electrometallurgy, materials science, electric welding of metals and biological tissues within engineering IEEE branches'. Academician Borys Paton was also a recipient of the award of the PRC Embassy in Ukraine on the occasion of the establishment of the People's Republic of China and for his significant personal contribution to strengthening friendship between China and Ukraine, promoting bilateral S&T collaboration.

The Prize of Kostyuk Foundation was bestowed on Halyna Volynets, Cand. Sci. (Biol.), research associate of the Biomedical Chemistry Department of the NAS Institute of Molecular Biology and Genetics. This prize was established in 2010 by the followers of Platon Kostyuk (1924–2010) — the world-renowned Ukrainian biophysicist and neurobiologist; it is traditionally awarded to young scientists doing research in biomedical sciences in Ukraine.

The title 'Honored Worker in Science and Technology of Ukraine' was conferred on ten scientists and the title 'Honored Doctor of Ukraine' — on three scientists of the NAS of Ukraine.

6 NAS researchers received the State Prize of Ukraine in Science and Technology for the work "The structure and interaction of atomic nuclei in elastic, non-elastic and radioactive processes"; 5 scientists — for the work "Innovative methods of mathematical modeling of complex processes and systems based on



Meeting of Academician Borys Paton with the delegation of the Ukrainian Section of the International Association Institute of Electrical and Electronics Engineers (IEEE) and the presentation of the IEEE President's letter about conferring to him the 2020 IEEE Honorary Membership Award

high-productivity computations"; 3 researchers — for the work "Providing functional security of critical information control systems"; 7 scientists — for the work "Deep lithosphere structure and seismic hazards of the territory of Ukraine"; 3 — for the work "Development of rotors of high-capacity turbines"; 3 researchers — for the work "Scientific fundamentals of innovative technologies for anthracite substitution in thermal power engineering and their implementation"; 3 scientists — for the work "Obtaining polymer materials and structures made of them under the effect of physical fields"; 5 researchers — for the work "High-selectivity methods of synthesizing heterocyclic compounds for developing components of functional materials and producing novel medicines".

11 Academy researchers became the winners of the Cabinet of Ministers Prize 'For the development and implementation of innovative technologies', and 28 researchers became the recipients of the President of Ukraine Prize for young scientists. 8 NAS employees were awarded the Honorary Diploma of the Verkhovna Rada of Ukraine for their essential contribution to the development of national science, fruitful science-management activities, dedicated work of many years, and high professionalism; 3 were the recipients of the Diploma of the Verkhovna Rada of Ukraine; 2 — the recipients of the Honorary Diploma of the Cabinet of Ministers of Ukraine; 3 received the Commendation of the Prime-Minister of Ukraine.

49 researchers of the Academy won numerous NAS prizes named after prominent Ukrainian scholars; 19 young Academy scientists were awarded the

prizes of Kyiv Mayor in the 'research achievements' nomination.

According to Web of Science platform, the winners in 9 of 16 nominations of the award '2019 Science Leader of Ukraine, *Web of Science Award*' were the following research institutions of the National Academy of Sciences of Ukraine: M.M. Bogolyubov Institute of Theoretical Physics, the Institute of Molecular Biology and Genetics, O.Ya. Usikov Institute of Radio Physics and Electronics, the National Science Center 'Kharkov Institute for Science and Technology', Ya.S. Pidstrihach Institute of Applied Problems of Mechanics and Mathematics, M.H. Kholodny Institute of Botany, Institute for Nuclear Research, the Main Astronomical Observatory, I.I. Schmalhausen Institute of Zoology.

The *Scopus Awards Ukraine* in the nomination 'Outstanding contribution to natural sciences' went to the National Science Center 'Kharkov Institute of Physics and Technology'; Kyiv University of Law won the gold award in the nomination 'Integration of the national science and education into the international space' in the framework of its participation in the annual international specialized exhibition 'Education and Career'.

Kateryna Terletska, Dr. Sci. (Physics and Mathematics), Senior Research Associate of the NAS Institute of the Problems of Mathematical Machines and Systems, became the Laureate of II Ukrainian L'ORÉAL-UNESCO Prize, and Professor Nana Voitenko, neurophysiologist, Dr. Sci. (Biology), Head of the Sensory Signalization Department of Bogomoletz Institute of Physiology won the annual all-Ukraine Prize of the widely known Ukrainian *Yedinstvennaya* magazine 'The Woman of Ukraine — 2019' in 'Science' nomination.

According to the results of the all-Ukraine contest 'The Best Book of Ukraine', which was founded and is annually held by Derzhcomtelradio, the winner in the 'Bestseller of the year' nomination was the book of memories "My Way through the Looking Glass. Not Only Travel Notes" by Academician V.P. Gorbulin, First Vice-President of the National Academy of Sciences of Ukraine.

173 Academy employees received NAS awards: 53 of them — 'For Scientific Achievements', 37 — 'For Training Young Generation', 66 — 'For Professional Accomplishments', 8 — 'For Promoting Science Advancement', 9 — the award for young scientists 'Talent, Inspiration, Work'.

107 persons and 4 research teams received NAS commendation.

118 persons and 2 research teams were the recipients of the Diploma of NAS Presidium and NAS Trade Union Central Committee.

BACKGROUND INFORMATION. STATISTICS

Structure of the NAS of Ukraine

The structure of the NAS of Ukraine includes 3 sections and 14 departments, which incorporate 154 research institutions and research-and-production organizations (R&D offices, pilot production facilities etc.). Functioning within some research institutions are science objects that have the status of National Asset (nuclear, physical and astronomical research facilities, testing equipment complexes, archive scientific collections and museum displays, plant genetic funds, collections of microorganism strains and plant lines, landmarks of history and culture etc.), as well as centers for shared use of scientific equipment.

Research organizations that have the National Institution status:

- V.I. Vernadsky National Library of Ukraine
- National Science Center "Kharkov Institute of Physics and Technology"
- "Olbia" National Historical and Archeological Reserve
- M.M. Gryshko National Botanical Garden
- "Sofiivka" National Dendrological Park
- National Museum of Natural History
- V. Stefanyk Lviv National Scientific Library
- National Center "Junior Academy of Sciences" of the MES of Ukraine and the NAS of Ukraine.

Functioning in the Academy are five regional science centers of dual subordination with the Ministry of Education and Science of Ukraine:

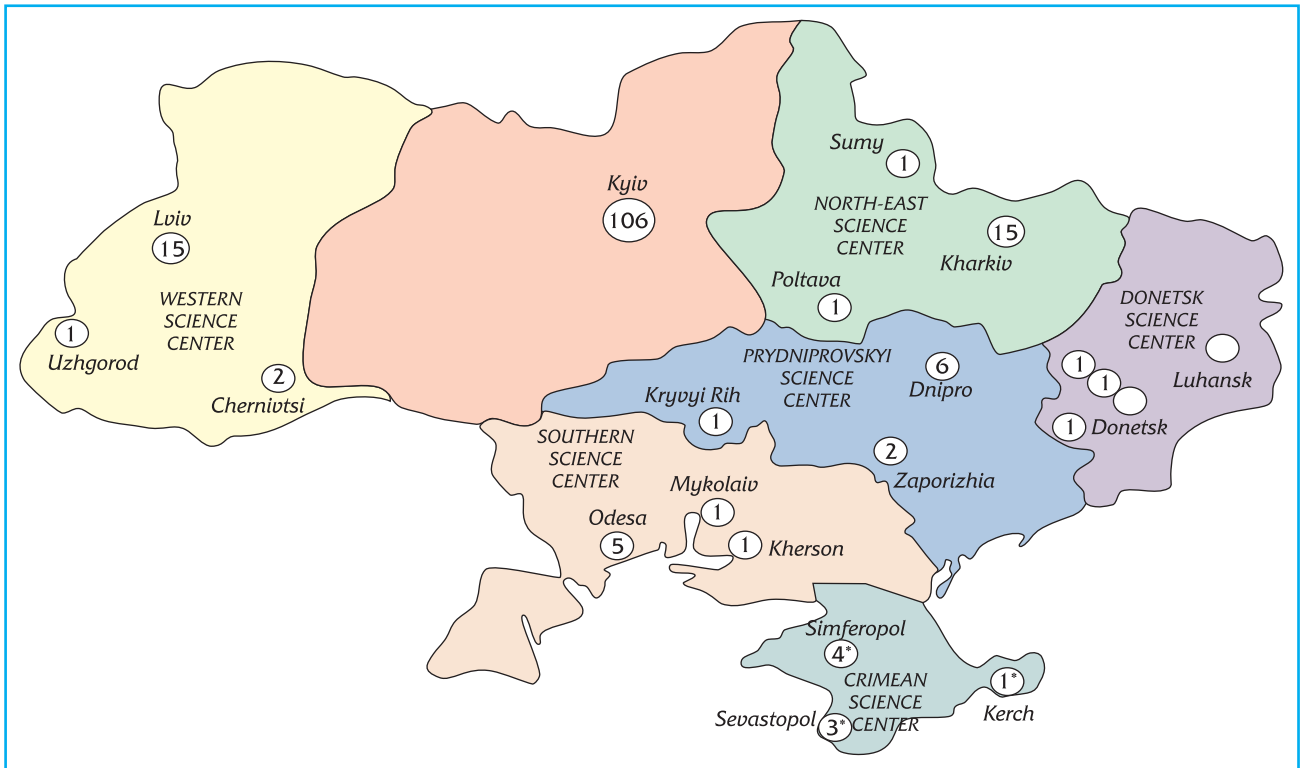
- Donetsk Science Center (Kramatorsk, Donetsk oblast)
 - Western Science Center (Lviv)
 - Southern Science Center (Odesa)
 - North-East Science Center (Kharkiv)
 - Prydniprovskiy Science Center (Dnipro),
- as well as the Center for Evaluating Research Institutions and Scientific Support to Regional Development (Kyiv).

The statutory activities of Crimean Science Center and its funding from the NAS budget were suspended in 2014.

DISTRIBUTION ACROSS SECTIONS AND DEPARTMENTS

| Department | The number of research institutions | The number of pilot production organizations | The number of objects that have the National Asset status | The number of centers for shared use of equipment |
|---|-------------------------------------|--|---|---|
| The Section of Physical, Engineering and Mathematical Sciences | | | | |
| Dpt. of Mathematics | 4 | — | — | — |
| Dpt. of Information Science | 7 | — | — | — |
| Dpt. of Mechanics | 6 | 4 | 3 | 7 |
| Dpt. of Physics and Astronomy | 16 | 3 | 9 | 16 |
| Dpt. of Earth Sciences | 15 | 1 | — | 5 |
| Dpt. of Physical and Technological Problems of Materials Science | 11 | 18 | 1 | 12 |
| Dpt. of Physical and Technological Problems of Power Engineering | 11 | 7 | 2 | 4 |
| Dpt. of Nuclear Physics and Power Engineering | 6 | 2 | 2 | 6 |
| The Section of Chemical and Biological Sciences | | | | |
| Dpt. of Chemistry | 13 | 8 | — | 11 |
| Dpt. of Biochemistry, Physiology and Molecular Biology | 8 | 1 | 5 | 9 |
| Dpt. of General Biology | 22 | 1 | 19 | 12 |
| The Section of Social Sciences and Humanities | | | | |
| Dpt. of Economics | 9 | — | — | — |
| Dpt. of History, Philosophy and Law | 17 | 3 | 5 | — |
| Dpt. of Literature, Language and Art Studies | 9 | — | 4 | — |

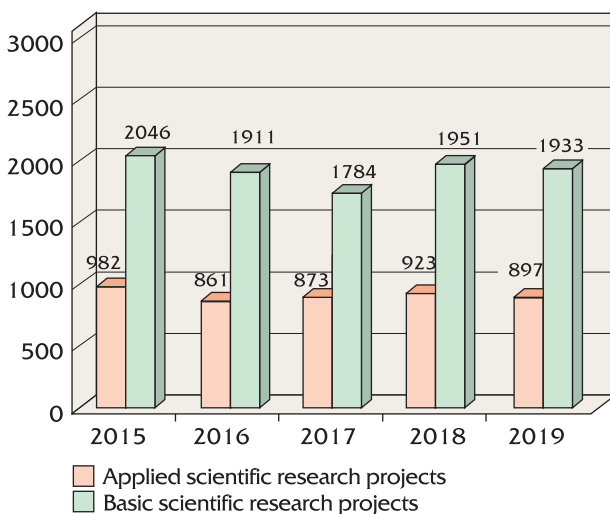
Regional structure of the NAS of Ukraine



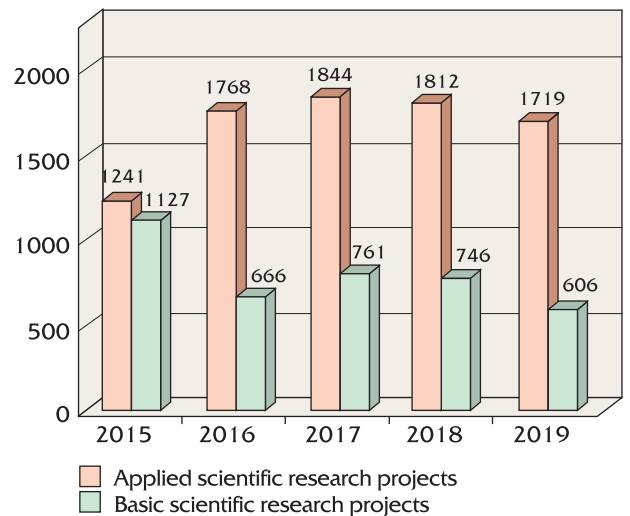
The figures in the map show the number of research institutions

* The status of NAS institutions located in the Autonomous Republic of Crimea is defined by the Law of Ukraine 'On guaranteeing the rights and freedoms of citizens and legal regime on the temporarily occupied territories of Ukraine'

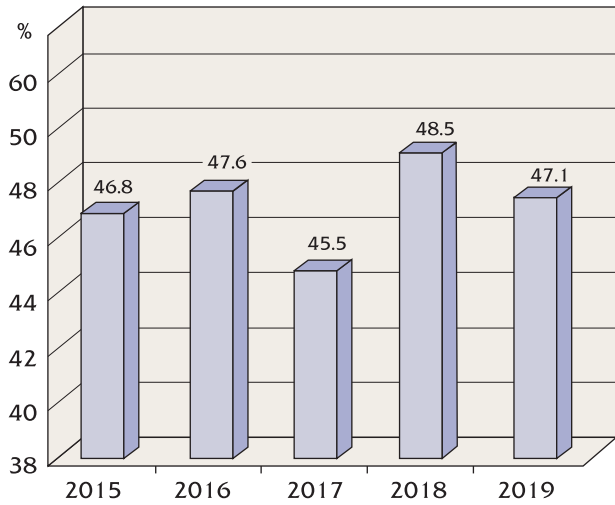
Conducting scientific research



The number of research projects financed by the general fund of the state budget



The number of implemented research projects financed from the special fund of the state budget

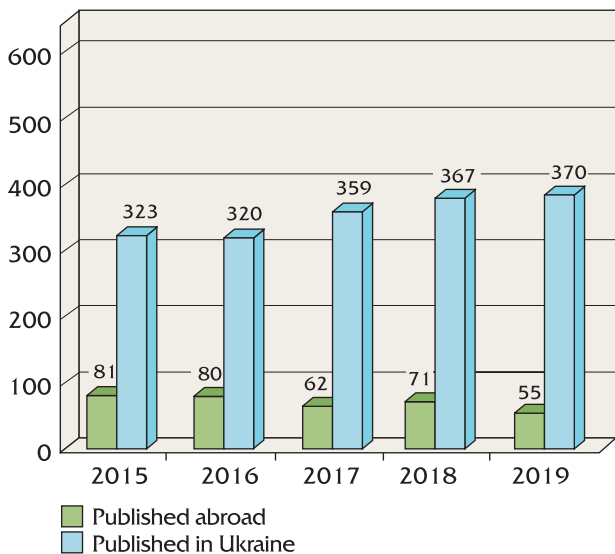


Part of targeted-program and contest-based research projects of NAS institutions in the total number of research works

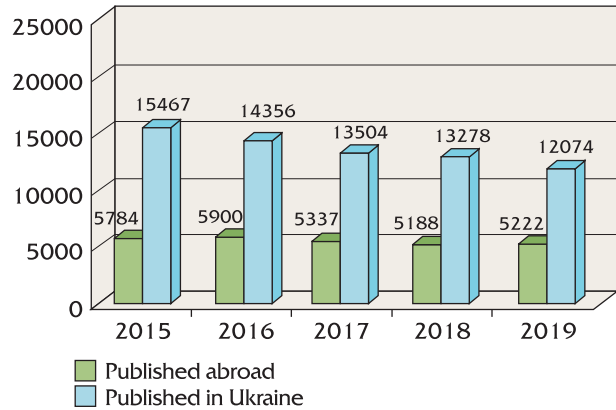
Targeted-program and contest-based research projects of the NAS of Ukraine in 2019 involved research conducted under:

- 8 NAS targeted programs of basic research;
- 15 NAS targeted programs of applied research;
- 7 separate targeted projects;
- and were based on the results of:
 - joint contests with foreign and international organizations;
 - a contest of S&T (innovation) projects
 - a contest of research projects in socio-humanities
 - contests of research projects of young scientists of the NAS of Ukraine.

Publication activity



Number of scientific monographs



Number of papers by NAS scientists in periodicals

Published in Ukraine

- the total number of Academy journals:

84 scientific journals, 1 popular science journal (*Svitohliad*) and abstract journal *Dzhereło* in four series;

- 10 editions are published in English in Ukraine:

1. Science and Innovation
2. Semiconductor Physics, Quantum Electronics & Optoelectronics
3. Journal of Mathematical Physics, Analysis, Geometry

4. The Paton Welding Journal
5. Journal of Thermoelectricity
6. Ukrainian Journal of Physics
7. Functional Materials
8. Biopolymers and Cell
9. Experimental Oncology
10. Problems of Cryobiology and Cryomedicine

- 21 journals are published in English abroad:

by Springer Publisher

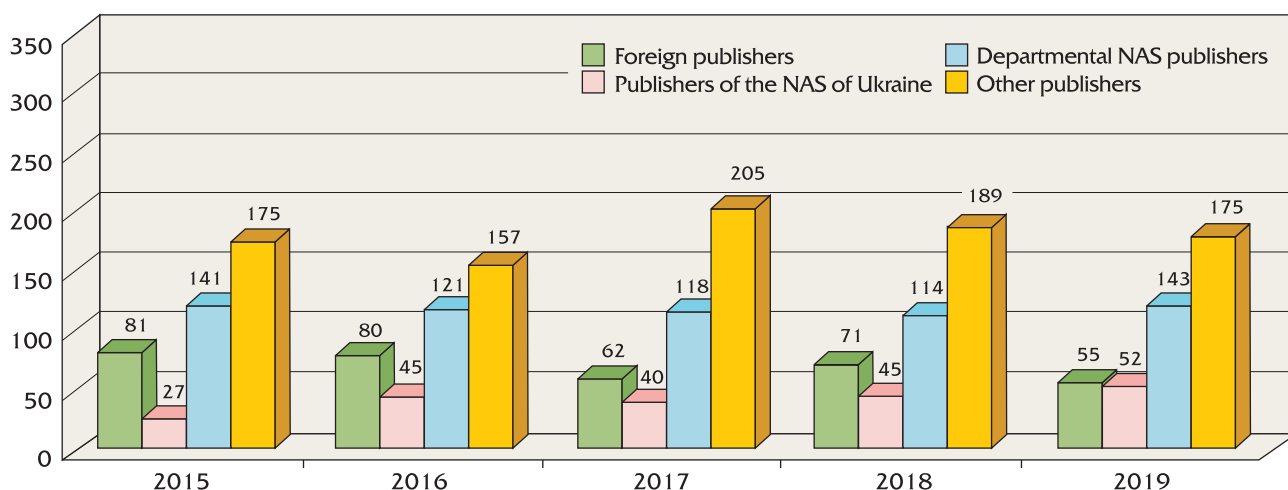
1. Ukrainian Mathematical Journal
2. Cybernetics and Systems Analysis
3. International Applied Mechanics
4. Strength of Materials
5. Materials Science
6. Theoretical and Experimental Chemistry
7. Neurophysiology

by Pleiades Publishing, Inc.

1. Kinematics and Physics of Celestial Bodies
2. Journal of Superhard Materials
3. Journal of Water Chemistry and Technology
4. Cytology and Genetics

by Begell House Inc. Publishers

1. Journal of Automation and Information Sciences
2. Radio Physics and Radio Astronomy
3. Telecommunication and Radio Engineering
4. International Journal on Algae
5. Hydrobiological Journal
6. International Journal of Physiology and Pathophysiology



Distribution of scientific monographs across groups of publishers

by other publishers

1. Journal of Low Temperature Physics (American Institute of Physics)
2. Technical Diagnostics and Non-Destructive Testing (Cambridge International Science Publishing)
3. Advances in Electrometallurgy (Cambridge International Science Publishing)

electronic editions in English produced abroad

1. De Gruyter

Scientific expertise

In 2019, NAS experts were involved in preparing:

- Strategy of the national security of Ukraine;
- Annual Address of the President of Ukraine to the Verkhovna Rada of Ukraine 'On the Domestic and International Situation of Ukraine';
- State strategy of regional development till 2027;
- Annual report on youth situation in Ukraine;
- National action plan on natural environment protection for 2020–2025;
- National strategy for invasive foreign fauna and flora species management in Ukraine for the period until 2030.

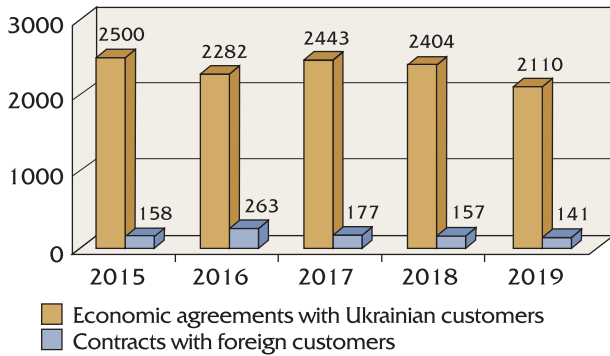
Expert conclusions, notes, proposals were prepared, in particular, to legislation drafts:

- 'On introducing amendments to certain legislative acts of Ukraine concerning the turnover of agricultural land';
- 'On railway transport in Ukraine';
- 'On inland water transport';
- 'On introducing amendments to certain laws of Ukraine concerning the implementation of competition in centralized heat supply systems';
- 'On providing competitive conditions of generating electrical power from alternative sources';
- 'On tax sovereignty of Ukraine and offshore companies';
- 'On administrative procedure';
- 'On the legal regime of the territories radioactively contaminated in consequence of Chernobyl accident';
- 'On general comprehensive secondary education';
- 'On intellectual property and allied rights';
- 'On introducing changes to some legislative acts concerning the implementation of certain provisions of the European Union legislation in the sphere of intellectual property';

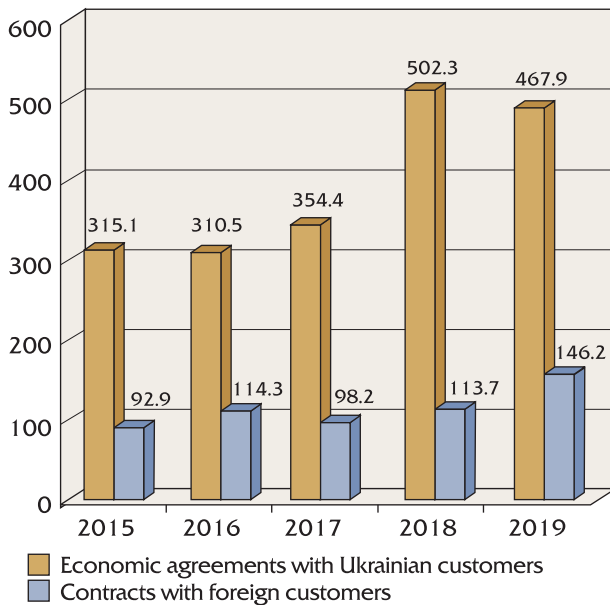
| Expert conclusions | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|------|------|------|------|------|
| Concerning normative legal acts and program documents, information and analytical materials on various issues of socio-economic development provided for state power bodies | 2017 | 2160 | 2200 | 2320 | 2330 |
| Concerning the feasibility of financing scientific research projects from the State Budget | 1752 | 606 | 393 | 378 | 428 |

- 'On the status of the Crimean Tatar people in Ukraine';
- 'On the procedure of using languages in Ukraine'.

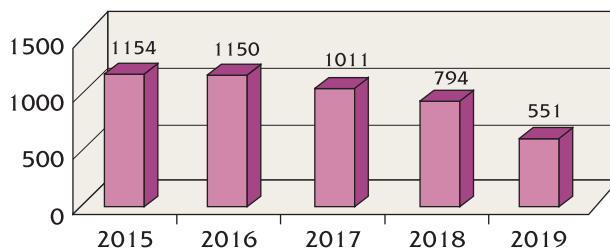
Innovation



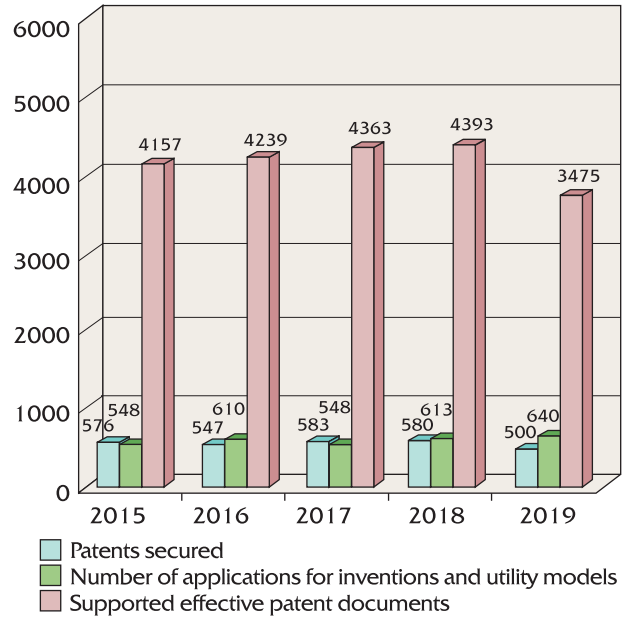
Number of economic agreements and contracts



Money earned by NAS institutions for implemented economic agreements and contracts, ₴ million



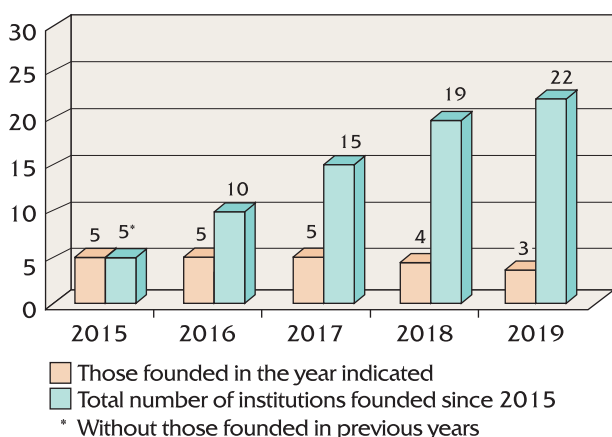
Number of commercialized development products



Protection and use of intellectual property objects, number

Collaboration between institutions of higher learning and institutions of the MES of Ukraine

| | |
|---|------|
| Collaboration agreements concluded by research institutions and institutions of higher education | 244 |
| Research topics and projects implemented collaboratively with academics | 203 |
| Published monographs co-authored with academics | 115 |
| Research scientists who worked in education: | 1234 |
| including: | |
| NAS active members | 35 |
| NAS corresponding members | 86 |
| Published textbooks and manuals for institutions of higher education | 84 |
| Scientists at the head of chairs in institutions of higher education | 60 |
| Students of higher education institutions who pursued/are pursuing Master's degree programs at joint research-and-training agencies hosted by scientific organizations: | |
| in academic year 2018/2019 | 407 |
| in academic year 2019/2020 | 412 |
| Students who wrote their graduate papers at research institutions | 1088 |
| Academics incorporated to specialized academic councils of research institutions | 555 |

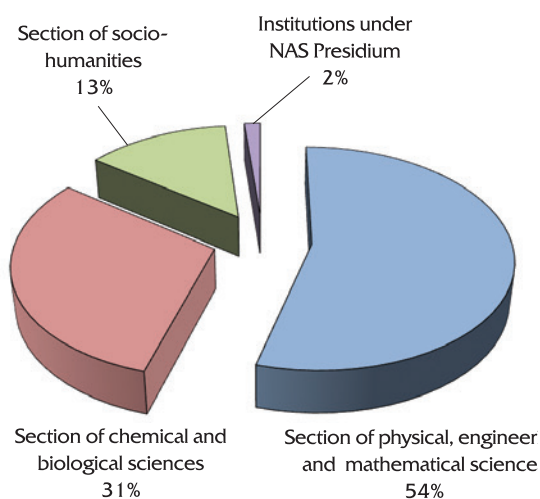


Joint research-and-training agencies

| | |
|--|-----|
| Scientists of research institutions incorporated to specialized academic councils of higher education institutions | 466 |
| Newly arrived graduate specialists who attended study groups of the Junior Academy of Sciences in their school days | 9 |
| Research scientists and lecturers of higher education institutions and MES organizations who upgraded their professional skills at research institutions | 413 |
| Theses of academics defended at specialized academic councils of scientific research institutions | 232 |

International ties

Legal contractual framework for the international collaboration of the NAS of Ukraine (effective agreements, contracts, memorandums etc.) — a total of 138 documents.



Distribution of direct contracts and agreements across the institutions of NAS Sections

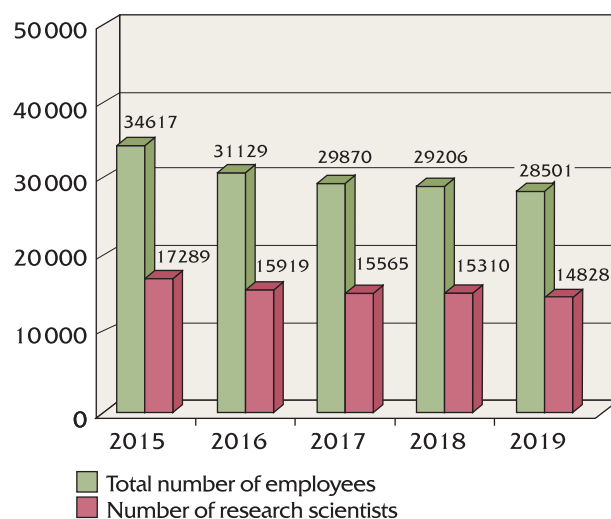
In 2019, the Academy signed two new collaboration agreements:

- Memorandum of mutual understanding concerning the start of academic collaboration between the University of Padua and the National Academy of Sciences ;
- Framework Agreement on the scientific and technological collaboration between the NAS of Ukraine and the People’s Government of Shandong Province (PRC);

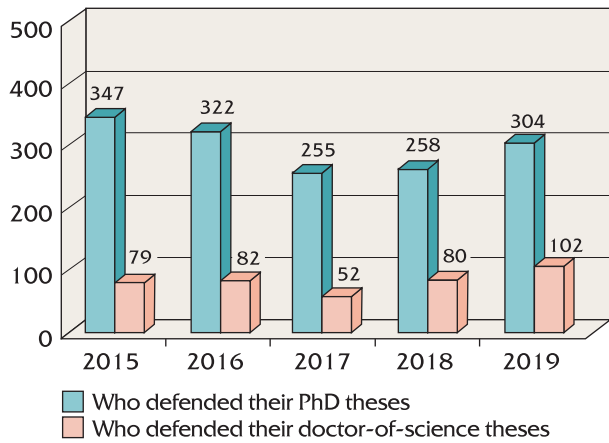
Nearly 600 direct agreements and contracts, concluded by NAS institutions with international partners are in force.

Employment figures (as of 01.01.2020)

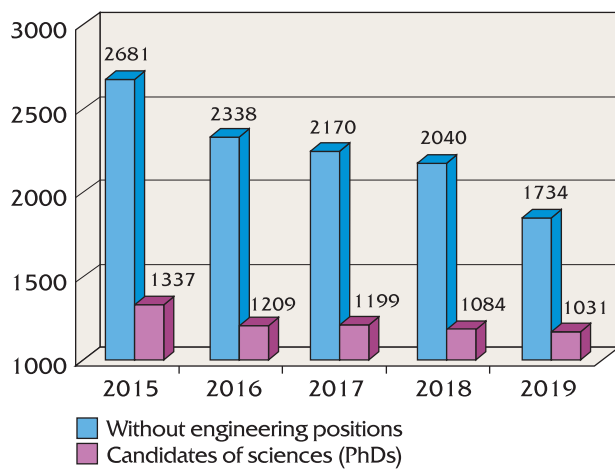
| | |
|---|-------|
| Total number of employees | 28501 |
| of them: | |
| in research institutions | 26922 |
| in research-and-production facilities | 1241 |
| in services organizations | 338 |
| Number of research scientists | 14828 |
| of them: | |
| doctors of science | 2382 |
| candidates of science (PhD) | 6686 |
| researchers without an advanced degree | 5760 |
| The number of young specialists recruited in 2019 | 285 |
| The number of those who pursued post-graduate studies | 1149 |
| including full-time studies | 970 |
| Defended PhD theses | 304 |
| Doctoral fellowships | 97 |
| Defended doctor-of-science thesis | 102 |



The number of employees

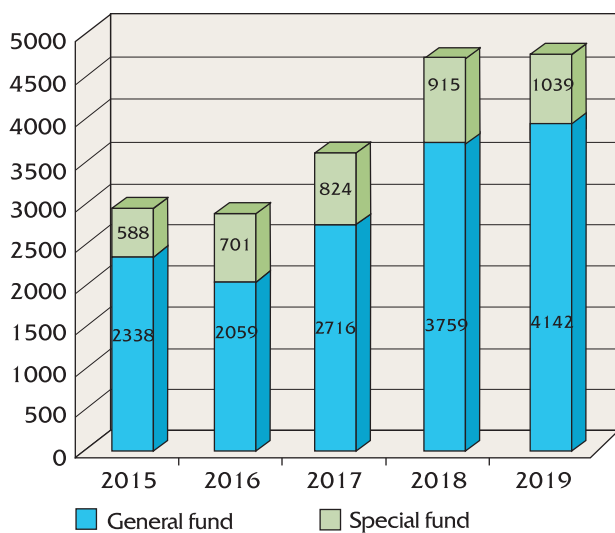


Training of scientific personnel, the number of people

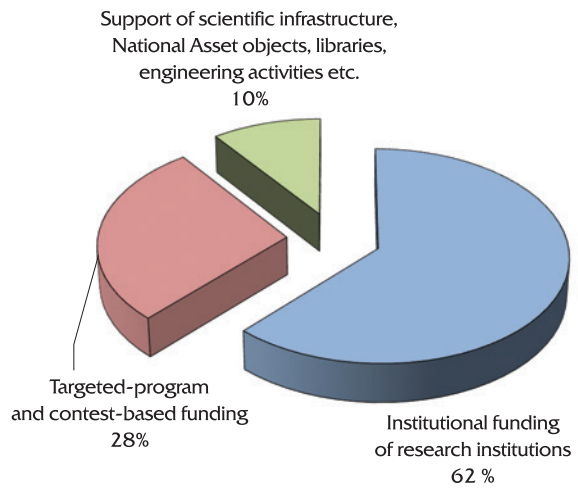


The number of young scientists

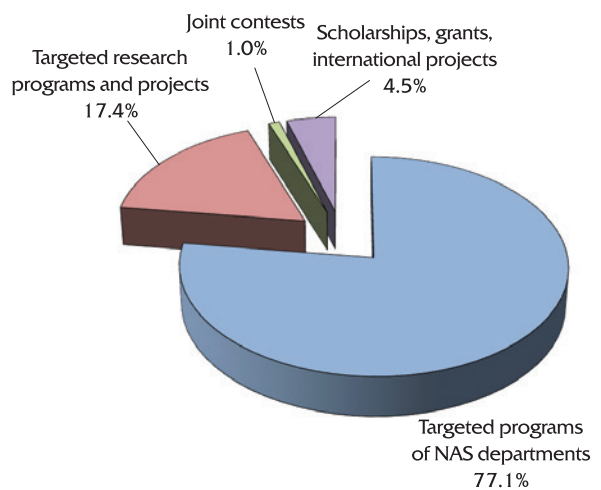
Financial provision



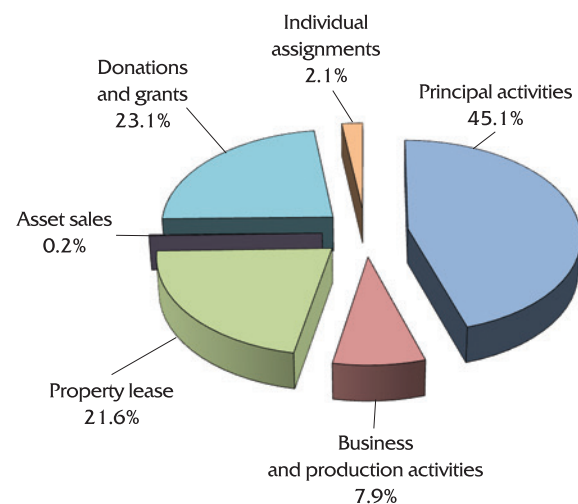
The total amount of NAS funding, r million



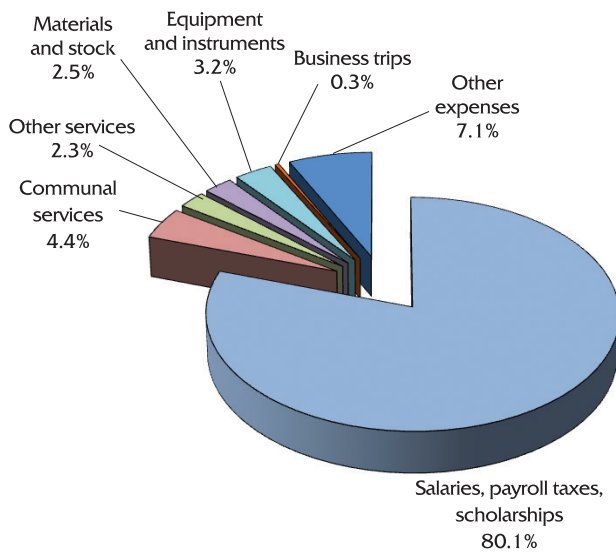
Distribution of finance from the general fund for conducting scientific research



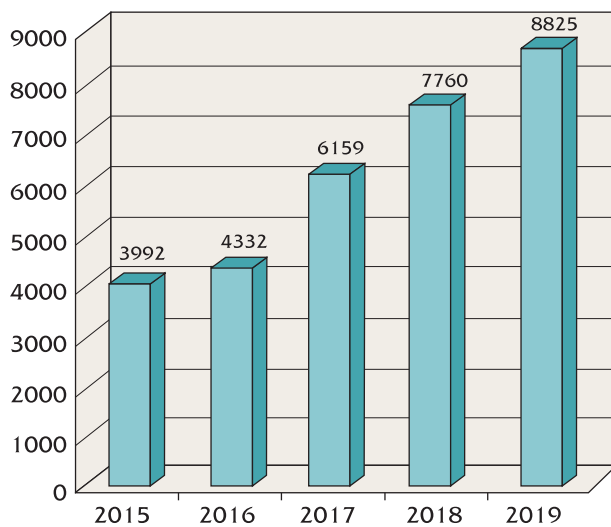
Targeted-program and contest-based funding



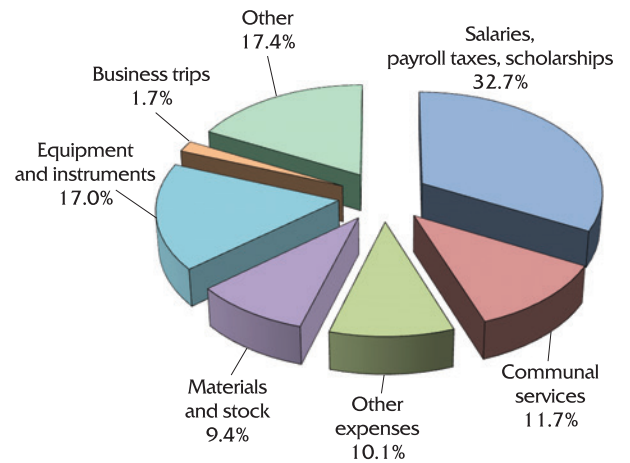
Structure of revenues to the special fund



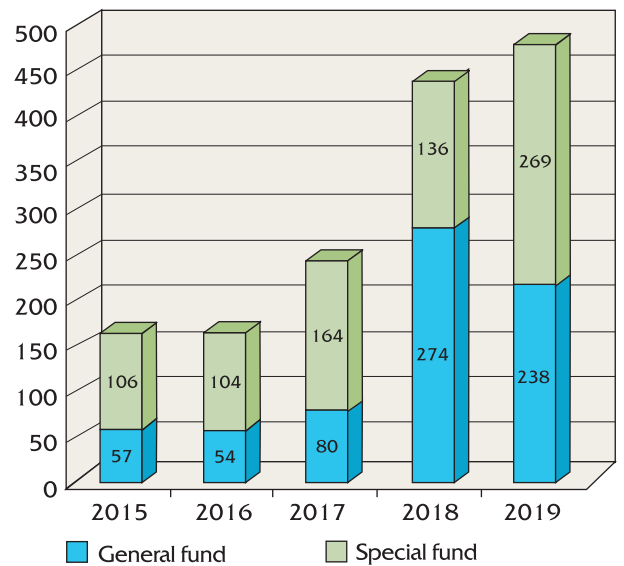
Structure of general fund expenses



Average monthly salaries of employees, ₺



Structure of special fund expenses



Expenses for infrastructure support (procurement of equipment and materials), ₺ million



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I.I. Рахманової

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