FOREWORD OF ACADEMICIAN ANATOLII ZAGORODNY, PRESIDENT OF THE NAS OF UKRAINE

Undoubtedly, 2020 deeply shocked the entire world. That was a year of hard trials which no one had expected. And the Academy, as always, did not avoid new challenges, the fight against *COVID*-19 in particular.

At the very beginning of the pandemic in Ukraine, scientists of the NAS Institute of Molecular Biology and Genetics, at the request of the National Security and Defense Council of Ukraine, produced reliable test systems for diagnosing the coronvirus disease. Academy experts also contributed to the development of an immunoferment express assay for detecting the disease and it is now produced by one of Ukrainian enterprises.

Besides, two scientific teams for prognosticating the pandemic spread in Ukraine were set up and started working in the Academy: one is based at the Institute of Mathematical Machines and Systems Problems (Kyiv) and the other — at the Institute of Market Problems and Economic-Ecological Research (Odesa). Their forecasts are used by both state authorities and mass media.

Last year, E. Paton Electric Welding Institute of the NAS of Ukraine launched the project for developing effective antiviral and antimicrobial nanocomposite polymer biomaterials, along with the technologies of 3*D* printing of items made of them.

Scientists of other NAS institutions also carry out important R&D work to counteract *COVID*-19. NSC "Kharkov Institute of Physics and Technology" handed the air ozonizers developed and produced by its researchers to Kharkiv Oblast Infectious Hospital and the Kharkiv Administration of the State Emergency Service of Ukraine. One of NSC KIPT accelerators sterilizes 60% of all medical materials in Ukraine — bandages, cotton wool, syringes, blood transfusion systems, medicine droppers. At present, the NSC KIPT has increased the amount of such work by 30%. "*Radma*" small business operating under L.V. Pisarzhevsky Institute of Physical Chemistry has also built up the volume of radiation sterilization work.

The research towards creating Ukrainian coronavirus vaccines was started. Such research, in particular, is carried out at the Institute of Cell Biology and Palladin Institute of Biochemistry of the NAS of Ukraine.

In spite of all difficulties and the coronacrisis, which has changed the usual lifestyle of not only Ukrainians but of the entire mankind, scientists of our Academy continued their hard work and research of the truly international level.

Our experts in cybernetics developed a computational scheme for solving problems on quantum-computer search for the largest independent set in a graph, which enabled them to obtain exact solutions of complex problems in combinatorial optimization within several microseconds, while solving them with classical computers would take hundreds of years of computer time. Scientists in informatics created a new method of textual information encoding, which provides the maximum information compression with the simultaneous self-synchronization of messages and fast decompression. Theoretical physicists constructed the quantum gravity theory that significantly simplifies calculations and is a counterpart of the well-known and powerful Young–Mills formalism in the theory of fields. I cannot omit mentioning the achievements of our materials scientists. They were the first in Ukraine to weld plastic under anomalous conditions. Another project of the utmost interest was the design of the specialized high-frequency generator prototype, which is intended for implementing the technology of irreversible electroportation of pathologically changed cells. It causes the destruction of pathological tissues in the malignant process with no reversal of such cell growth. Engineering solutions concerning electrosurgical instruments for removing hypercalcination in major blood vessels were also found; that will considerably facilitate the work of vascular surgeons. Jointly with their colleagues in Australia and Germany, Academy scientists proposed an innovative approach to creating internal architectures in metallic materials, which was referred to as lithomimetics (by analogy with lithospheric structures). Relying on this approach, novel materials with high viscous fracture, low density, high strength, high plasticity and biocompatibility etc. can be produced. Last year, our chemists developed new biopolymer compounds based on synthetic cyclic carbonates of soybean oil. They are environmentally friendly and a very good alternative to synthetic light-weight materials used in construction, automobile, furniture and other industries. Very promising for the treatment of wounds and burns are novel highly active stable materials of the combined proteolytic activity with serratiopeptidase fixed on dressing materials by means of polymers.

Academy scientists in socio-humanities studied important issues of the Ukrainian society current status. Published were a next volume of the new academic 12-volume "History of Ukrainian Literature", "Taras Shevchenko's Epistolary" in two books, the 12th issue of the "Panslavic Linguistic Atlas", the 11th volume of the explanatory "Dictionary of the Ukrainian Language". Scholars prepared for publication several volumes of "Ivan Franko" and "Lesya Ukrainka" electronic encyclopedias. An important event was the publication of the first unabridged edition of the "Chronicle" by Samiilo Velychko — the Ukrainian Cossack chronicler of the late 17th — early 18th century, the author of the first systemic presentation of the history of the Ukrainian Cossack State. The original "Chronicle" is now kept in the St. Petersburg National Library. Never before it was comprehensively studied and published in full. It is only due to immense efforts of scholars, publishers and smartphone patrons that this large-scale work will be in the open access for researchers in Ukraine.

A considerable number of our scientists' research results are already used or are being prepared to practical use in the near future. E.g., informatics scientists developed a new state-of-the-art intellectual information technology for assessing the adaptation potential of a human organism. It was implemented on the smartphone, relying on the analysis and interpretation of the pulse wave (photoplethysmogram) registered by smartphone web camera without additional external devices. An innovative approach to producing super strong adhesive bonds by using spatially ordered graphene nanocomposites was proposed; it increases the bond strength by several times and can be used, e.g., in the aerospace industry. New Ukrainian PT-32 centimeter radio telescope was commissioned. This, undoubtfully, will enhance the potential of domestic radio astronomy and space navigation, will give a new impetus to the advancement of basic research. A very good example of the collaboration of our experts with industrial production: in close co-operation with "*Turboatom*" state-owned company, an innovative 220 MWt low-pressure cylinder of steam turbine for nuclear power plants was developed. Its unique characteristics will ensure the best efficiency and reliability among the commercially available counterparts. Our materials scientists obtained interesting internationally recognized results. They synthesized and characterized over 40 multicomponent phases (carbides, nitrides, borides, and oxides) that had not been known before. These innovartive materials were obtained by forming their crystallochemical structure at the atomic level (this is the pico- rather than nano-level of materials structure). In terms of the aggregate properties, they are considerably superior to the conventional binary and ternary compounds and have already found practical application as coatings with higher performance characteristics. Novel ultra-high-temperature ceramics was developed as well; it is superior to the best world analogs for products used in engine building, aerospace industry and heat power engineering.

Interesting products were developed for medicine, military medicine included. Scientists produced a new nanophase composite material that induces the formation of mature bone tissue with gradual implant substitution. This is a very important step in the development of domestic reconstructive surgery and the introduction of the state-of-the-art bone tissue engineering. No doubt, this product is very promising for practical use in the cases of considerable losses of bone material in patients with severe injuries or cancer.

A number of novel developments were deployed in the spheres of defense and state security. Particularly, informatics scientists elaborated an innovative information technology for the offline navigation of unmanned aerial vehicles. Such systems have already passed state tests and are used in the Armed Forces of Ukraine. Research of our scientists is also concerned with the improvements in performance characteristics of weapon, ammunition, missile systems, the development of technologies for enhancing ballistic protection, increasing the durability of equipment parts.

Besides, our scientists are involved in varied expert evaluation activities. Under orders and in the interests of state authorities, they prepared a large number of various information and analytical documents, expert conclusions, proposals and recommendations, programs and forecasts.

Last year, the Academy witnessed many changes and, regrettably, sorrowful events. Borys Paton, its President of many years, an outstanding and legendary personality, passed away. That is an irreparable loss for science, for Ukraine and for the entire world. And our major task is to continue worthily his life's work: advance and build up Academy's scientific achievements and serve for the good of our country and its citizens.

Lately, Ukraine's science sphere was faced with generally known problems, and its successful future will depend on their fast and efficient solution.

It should be noted that the NAS of Ukraine has always paid attention to the issues of its reformation, optimizing the structure and principles of organizing its activities, which is reflected in the Concept of NAS Activities in 2014-2023 and respective decisions of Academy Presidium. Significant steps towards positive changes were made last year as well.

One of our top priorities was to take a complete inventory of the infrastructure and land plots that are under Academy's jurisdiction. A commission for analyzing the operation of pilot production facilities and other business entities of the NAS of Ukraine was organized. With reliance on commission's conclusions, real estate objects and land plots that have not been in use for a long time

will be identified, proposals were made towards repurposing or transferring some of them to other scientific institutions of the Academy, as well as setting up NAS innovation facilities on their basis.

Of no less importance is the optimization of Academy's structure. It will be conducted with the utmost balance and care, with taking into account the results of the evaluation and the state certification of NAS institutions carried out last year. Some R&D facilities will be reorganized or liquidated, and proposals on the transfer of some enterprises under the jurisdiction of the State Property Fund of Ukraine will be prepared. Over two last years, eight scientific institutions were liquidated, 220 structural units were downsized or restructured. Optimization of NAS Presidium staff was also carried out. 12 self-supporting organizations were dissolved. 12 more organizations are in the process of liquidation. A list of over 50 enterprises that could be offered for future privatization was sent to the Ministry of Economic Development and Trade of Ukraine. 17 institutions of that list were transferred under the jurisdiction of the State Property Fund of Ukraine.

Of great importance is the further advancement of innovative activities, intersectoral cooperation, integration of science and education. Great hopes in this area are anchored on the implementation of the *Academ. City* project jointly with the "*Adlershof*" Science and Technology Park (Berlin, Germany). This initiative of the Kyiv Academic University has interested the Ministry of Education and Science of Germany. The core of the project is to set up a science park as an open innovative ecosystem based on the cluster of NAS institutions situated in the "Akademmistechko" microdistrict. The first steps towards the implementation of this project have already been made.

In the near future, the formation of the membership of the NAS Scientific and Technological Council will be completed. It will be the platform to facilitate the attraction of investments and deployment of Academy developments. Research coordinating boards have already been formed at the NAS sections. Proposals concerning amendments to the NAS Statute are being accumulated as well.

Another important area is to introduce new principles of budget funding distribution across Academy institutions. This has always caused and still causes certain discontent. Therefore, we need to ensure a transparent, unbiased and efficient finance distribution. The first steps in this direction have already been taken — the funding of institutions in 2021 has been determined taking into account the results of the academic evaluation and the state certification. Now each department has the rating of its institutions according to which extra funds received by the Academy will be distributed in the future. The next step will be the distribution of funding across sections and departments. And here research coordination councils are to play their expert role. They are to elaborate criteria for distributing finance between departments.

As of today, the major task is to provide support to young scientists. Quite a number of initiatives have been started here, but we have to do even more. Back in 2018, with the support of the Cabinet of Ministers of Ukraine, we launched NAS grants for research laboratories/groups of young scientists of the Academy for doing research in top-priority areas of science and technology. In 2021, the funding of research projects within these grants was doubled. That permitted us to call a third contest for winning NAS grants by research laboratories/groups of young scientists of the Academy in 2021-2022. The total funding for this aspect of support to young scientists in the current year will amount to ₴ 44.5 million. Besides, early in this year, another contest among young NAS scientists for providing funding to 100 best research projects is to be held.

The practice of launching additional sectoral topics for young researchers who made scientific presentations at NAS Presidium meetings was continued. At the end of the previous year, a program of post-doctoral research was launched. Its aim is to open temporary positions to be taken by young scientists having PhD degree. In the current year, 30 positions of senior research associates at Academy institutions will be provided for post-docs who will be chosen through competitions.

It is also important that in the current year, with the support of the Cabinet of Ministers of Ukraine, the Ministry of Finance of Ukraine and Verkhovna Rada Budget Committee, the budget-supported program of providing service housing for youth was started. Such program is planned not only for Kyivites but for young scientists in other Ukrainian cities as well.

Besides, in the several months that have passed since the election of the new Academy Presidium, the NAS Commission for Communication with the Society and Popularizing Scientific Activities was set up. Its main task is to increase Academy's presence in in the information space significantly. The membership of the Commission for Scientific Ethics, Struggle against Pseudoscience and Academic Dishonesty was modified.

IMPORTANT EVENTS

The National Research Foundation of Ukraine unfolded its work in 2020. In May, the Foundation called two contests "Science for Safety and Security" and "Support to Research of Leading and Young Scientists". The contests were open to all scientific organizations of Ukraine, irrespective of their departmental affiliation, and did not limit the number of applications from a single organization. It was permitted to provide decent salaries for researchers, which are not set by the adopted tariff scale. Unlike the contest "Science for Safety and Security", where the condition for application was the conformity of the project with the topic declared, the contest "Support to Research of Leading and Young Scientists" was announced as a bottom-up one, for the best researchers to win, irrespective of the subjects of their research. All in all, 931 applications were submitted to both contests.

Last September, the Foundation approved the results of the contests held. Under the contest "Science for Safety and Security", the Foundation determined 77 winning projects with the total funding of ₴ 398.6 million. Their implementation was aimed at solving various problems of biosafety, biomedicine, environment, cyber and information security that were concerned with responding to economic, social, humanitarian challenges that resulted from natural and technological emergencies, as well as with overcoming medico-biological, economic, social, psychological, humanitarian and cultural impacts of the *COVID*-19 pandemic.

The contest "Support to Research of Leading and Young Scientists" was represented by 141 winner projects, with the total funding amounting to ₴ 975.2 million. These projects are implemented by leading scientists of Ukraine in collaboration with gifted young researchers. Their purpose is to obtain new basic and applied knowledge, assist in solving the highly relevant problems of the state, man and society, as well as facilitate the integration of Ukrainian science into the global scientific space.

Scientists of the NAS of Ukraine were active participants in the contests mentioned and many of their projects were among the winners.

In the contest "Science for Safety and Security", the NAS of Ukraine was represented by 35 projects (45% of the total number), submitted by researchers of 22 Academy institutions. The total funding of these projects in 2020-2021 amounted to ₴ 216 million. Special credit goes to scientists of the NAS Institute of Molecular Biology and Genetics, who submitted 6 winner projects with the total funding of over ₴ 46 million.

Among the winners of the contest "Support to Research of Leading and Young Scientists", 74 projects (52% of the total number) were submitted by scientists of 40 NAS institutions. The total funding for these projects in 2020-2022 is ₴ 570 million. Six projects for the total amount of ₴ 33.5 million are implemented by scientists of Bogolyubov Institute for Theoretical Physics of the NAS of Ukraine.

On 7 September 2020, a meeting of the Presidium of the National Academy of Science was held. It started with the minute of silence to pay tribute to the memory of Borys E. Paton.

On behalf of NAS Presidium Bureau, Academician Anton Naumovets, First Vice-President of the NAS of Ukraine, presided over the meeting. According to the first issue on the agenda, Academician Volodymyr Gorbulin, First NAS Vice-President, was appointed the Acting President on the National Academy of Sciences of Ukraine till the election of its new President. The participants of the meeting considered the election procedure, as well as the date and program of the election session of the NAS General Meeting.

Then, those present at the meeting considered the issue of perpetuating the memory of Academician Borys Paton. Academician Anton Naumovets, First Vice-President of the Academy, headed the NAS commission for commemorating Academician Borys Paton.

Taking into account the proposal of Ukraine President Volodymyr Zelenskiy concerning the establishment of Borys Paton Prize in Science, the Presidium of the National Academy of Science of Ukraine approved the decision to initiate the renaming of the State Prize of Ukraine in Science and Technology to Borys Paton National Prize of Ukraine, which is to be awarded for prominent achievements in science and technology and, respectively, renaming the Committee for the State Prizes of Ukraine in Science and Technology to the Committee for Borys Paton National Prize of Ukraine in Science and Technology.

The meeting of the NAS Presidium also approved the decision to submit the proposal to Kyiv City State Administration to rename the Boulevard Druzhby Narodiv in Kyiv to Borys Paton Avenue.

Besides, to commemorate Academician Borys Paton and award scientists for outstanding achievements in innovative R&D that have found wide practical application, NAS Presidium approved the decision to establish B.E. Paton Gold Medal of the National Academy of Sciences of Ukraine.

On 7 October 2020, the Election Session of the NAS of Ukraine was held to elect the President of the National Academy of Sciences of Ukraine. In accordance with the NAS Statute, it was attended by NAS academicians and

corresponding members, as well as delegated representatives of the scientific teams of NAS institutions, numbering half of the academicians and corresponding members taking part in the General Meeting.

Five candidates for the President of the National Academy of Sciences of Ukraine were nominated. They were NAS Academicians Vladislav Goncharuk, Bogdan Danylyshyn, Anatolii Zagorodny, Serhiy Komisarenko, Volodymyr Semynozhenko. Bogdan Danylyshyn withdrew his candidacy on the eve of voting.

During the session, every candidate for the office of the NAS President had an opportunity to present his electoral program. Their presentations were broadcast in the videoconference mode at all polling stations. Session participants asked questions and received comprehensive answers from the candidates. After that, all candidates and their electoral programs were discussed by representatives of all polling stations.

According to the results of the secret ballot, Academician Anatolii Glibovych Zagorodny was elected the President of the National Academy of Sciences of Ukraine. 426 electors (67.2%) voted for him.

This session of the NAS General Meeting also elected new members of the Presidium of the NAS of Ukraine. According to the election results, the NAS Presidium got new members both in terms of positions — 15 positions (45.5%), and in terms of personalities — 11 persons (33.3%) who were elected to the Presidium for the first time.

On 23 October, a meeting of NAS Presidium headed by Academician Anatolii Zagorodny, President of the Academy, was held in the Major Conference Hall of the NAS of Ukraine. One of the main issues on its agenda was the participation of Academy representatives in elaborating draft strategic documents in the field of national security and defense.

In accordance with the decision of the National Security and Defense Council of Ukraine "On the Strategy of the National Security of Ukraine", state executive bodies are to elaborate and submit to the NSDC draft strategies: of human development, the development of Defense Industry Complex of Ukraine, economic security, biosecurity and biological defense, information security, cybersecurity of Ukraine, foreign policy, energy security, environmental security and adaptation to climate change, food security.

The National Academy of Sciences was proposed to involve its experts to drawing up respective draft documents and submit candidacies for the membership of interdepartmental working groups for elaborating those strategies.

The following NAS experts were approved as respective responsible executives: Academician Volodymyr Gorbulin, NAS First Vice-President, (Strategy of the Development of Ukraine's Defense Industry Complex of Ukraine); Academician Vyacheslav Bogdanov, NAS Vice-President, (Strategy of Energy Security, Strategy of Cyber Security of Ukraine); Academician Vyacheslav Koshechko, NAS Vice-President, (Strategy of Environmental Security and Adaptation to Climate Change, Strategy of Food Security); Academician Serhii Pyrozhkov, NAS Vice-President (Strategy of Human Development, Strategy of Foreign Policy); NAS Corresponding Member Oleg Rafalskyi, NAS Vice-President (Strategy of Information Security); Academician Ella Libanova, Academician-Secretary of the NAS Economics Department, (Strategy of Economic Security); Academician Serhiy Komisarenko, Acting Academician-Secretary of the NAS Department of Biochemistry, Physiology and Molecular Biology, (Strategy of Biosecurity and Biological Defense).

Among the approved candidacies proposed as members of the interdepartmental working groups for elaborating the abovementioned strategies are leading experts of numerous NAS institutions.

Besides, this meeting of the NAS Presidium considered some issues of reforming the National Academy of Sciences of Ukraine and adopted the relevant resolution. It defined major strategic directions of reforming the Academy along with measures for their implementation. Among them is the preparation of proposals towards introducing amendments to the Statute of the NAS of Ukraine. With this purpose, the membership of the commission for drawing up the new version of the Statute was modified and it was given the task to prepare respective proposals for further discussion by the General Meeting of the Academy. It was also decided to set up the Coordination Council for NAS Reforming, which is to ensure coordination and control of the measures for reforming, as well as the preparation and generalization of additional proposals towards reforming.

In accordance with the abovementioned decision of the NAS Presidium, the elaboration of the draft Concept of the National Program of Developing the Humanitarian Sphere of Ukraine was organized. To enhance NAS publicity, establish effective mechanisms of scientific community communication with the society, the NAS Commission for Communication with the Society and Popularizing Scientific Activities was set up. Also, the implementation of the first stage of improving the principles of budget finance distribution in the Academy was started. It envisages the rejection of the equalizing distribution of financial and material resources among institutions by taking into account the efficiency of their work when determining the amounts of funds, and thus providing priority support to competitive research teams. Such a mechanism of distributing institutional funding allocated by the state budget is a component of the new model of financing the scientific activities of the Academy.

RESEARCH ACHIEVEMENTS. NATURAL AND ENGINEERING SCIENCES

Observations of *CP*-Symmetry Violation in Decays of $B^0(s)$ Mesons in the LHCb Experiment on the Large Hadron Collider (CERN)

The Institute for Nuclear Research (INR) of the NAS of Ukraine is one of the founders of the LHCb International Collaboration, which has functioned for nearly 25 years. The principal research subject of the LHCb experiment has been the violation of *CP*-invariance as one of the possible factors of the asymmetric Universe building (http://lhcb-public.web.cern.ch/lhcb-public). *CP*-invariance or *CP*-symmetry (*CP* is *Charge Parity*) is the unchangeability of physical laws in respect of the combined reversal of the electric charges of all particles in the system and the operation of changing the directions of coordinate axes. According to the generally accepted current views (the Standard Model), the Universe, which was initially formed as a result of the Big Bang, should have been materially symmetric. However, all previous searches for the world made up of antimatter were not successful. The Standard Model cannot explain this imbalance of matter and antimatter; therefore, respective experimental investigations are of primary importance.

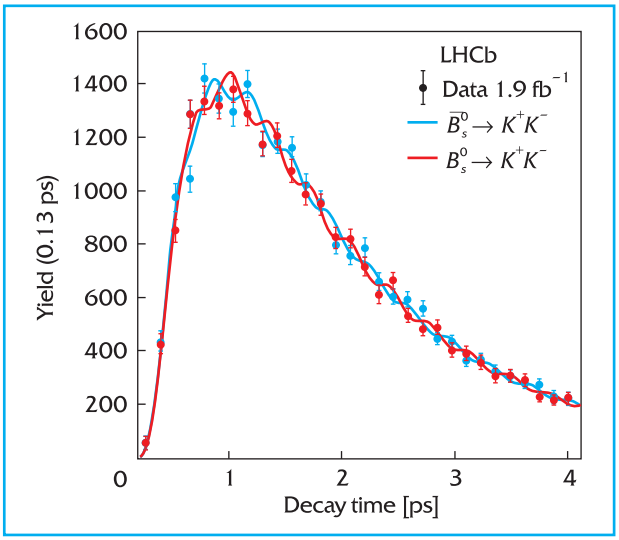


Illustration of $B^0(s)$ mesons oscillation. Y axis is the yield (number) of observed mesons in each 0.13 picoseconds: $B^0(s)$ – red line, anti $B^0(s)$ – blue line. X axis is the decay time in picoseconds

In the LHCb experiment, in the collisions of protons accelerated to the energy of 13 TeV, the conditions of the emergence of matter and antimatter in equal quantities are created in the laboratory. Selecting from the data accumulated the samples of matter (*B*-mesons) and antimatter (anti *B*-mesons), scientists investigate their evolution to get an insight into the nature of difference in their properties, by measuring, in particular, the degree of *CP* symmetry violation during their decay. The violation of *CP* symmetry mathematically describes the difference in the properties of matter and antimatter in the Standard Model of particle physics.

In 2020, when investigating the evolution of the decays of $B^0(s)$ mesons, which are composed of "beauty" and "strange" quarks (*b*, *s*), their *CP* characteristics (*violations* of *CP* symmetry) were measured with the world's best temporal resolution (about 45 fs). In particular, for the first time ever, oscillations of $B^0(s)$ mesons were observed during their decay into charged kaons (K^+, K^-). The extremely high measured frequency (3×10^{12} c^{-1}) of these oscillations indicates evidence that during their lifetime $B^0(s)$ mesons cross the matter–antimatter borderline about nine times. This is the so-called phenomenon of time-dependent *CP* symmetry violation.

The experimental results obtained are, within the margin of error, in line with the Standard Model predictions, which would be a stimulus for further research with essentially increased precision and the search for phenomena beyond the Standard Model.

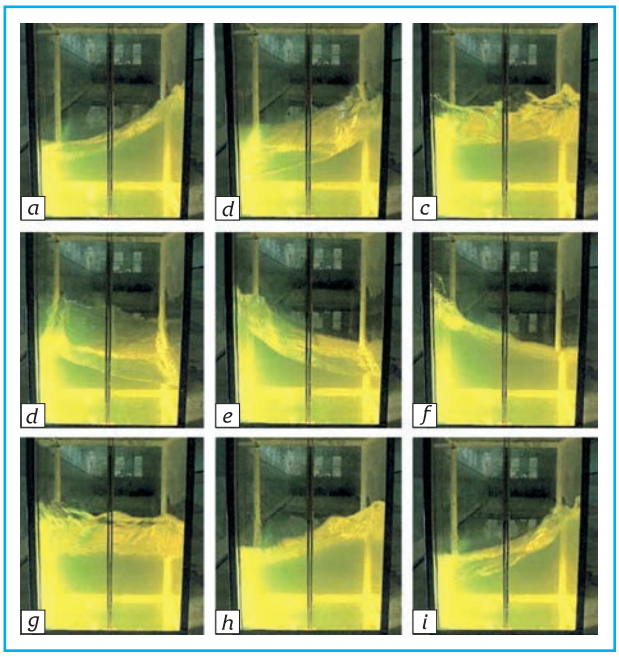
The upgrading work at LHCb detector is aimed at these tasks, with a view to starting a new 3-year series of experiments *RUN* 3. In particular, experts of the INR of the NAS of Ukraine, relying on their own design, as well as physical and technological principles, created a novel radiation monitoring system *RMS-R*3, which is intended for checking the experiment progress under ultra-high radiation loads in the collision point of LHC ion beams. According to the decision of the CERN Science and Technology Facility Council, the *RMS-R*3 system is to be installed at CERN in 2021.

The financial support of the grant provided by the Associated International Laboratory LIA IDEATE (France–Ukraine, STCU project P9903) contributed to the successful R&D of INR of the NAS of Ukraine in high energy physics.

V.M. Pugatch, V.M. Dobishuk, S.M. Koliiev, I.O. Kostiuk, O.A. Kot, V.Ie. Lukashenko, O.S. Okhrimenko

Mathematical "Rediscovery" of the Circular Wave

The technologies of sea fish farming in tanks, growing protein in bioreactors, manufacturing liquid metal electric batteries, and even sloshing in laboratory test tubes are



Sequence of photographs (a), (b), ...(i) demonstrates a steady-state running (circular) wave (anticlockwise) in a square base basin for the case of resonance harmonic horizontal sloshing (Faltinsen, Rognebakke, Timokha. Journal of Fluid Mechanics, 2003, 487, 1-42)

based on averaged fluid flows (azimuthal mass transport) that emerge due to resonance circular wave, which, as illustrated by the sequence of photos in the figure, is, in fact, a running wave along container walls.

Since there exists an infinite number of circular wave initiation scenarios, especially under arbitrary 3*d* tank sloshing, the criteria of its existence cannot be determined from the limited number of natural and numerical experiments. That can only be done by constructing a relevant analytical theory. Such theory was developed by scientists of NAS Institute of Mathematics in collaboration with researchers of the Norwegian University of Science and Technology.

The boundary-value problem with free surface was reduced to a special type of complex dynamic systems (non-linear ordinary differential equations). The analysis of these systems proved that for an arbitrary 3*d* resonance motion of a container there exists its equivalent elliptical orbital motion for which the classes of steady-state waves coincide with the initial ones. With the involvement of the parametric changes in the values of "ellipse axes" and sloshing frequencies, the bifurcations of steady-state waves, their instability and/or multistability, as well as chaos emergence, were studied, and the conditions of steady-state circular waves generation were investigated in detail.

A circular wave causes the steady-state transport of fluid particles in the direction of the running wave (the Prandtl phenomenon, Ludwig Prandtl, 1875-1953, *ZAMM*, 1949, **29**, No. 1/2, 8-9). This phenomenon provides the technologies of fluid mixing in the abovementioned technological processes. The paradox of the Prandtl phenomenon is that it cannot be quantitatively accounted for within both Lagrangian and Eulerian concepts of hydromechanics. Due to analytical approximations of the circular wave presented via the solutions of the complex dynamic systems mentioned, an analytical formula was derived, which adequately describes the Prandtl azimuthal mass transport through meridional section, in particular, for the case of Hutton's classical experiments (Hutton, 1964). This analytical result is a counterexample for the basic hypothesis of averaged flows (Lagrangian averaging) = (Eulerian averaging) + (Stokes's displacement), i.e., <L> = <E> + S.

Further research in this scientific area was supported by the National Research Foundation of Ukraine (project 2020.02/089).

The results were published in two papers of the most prestigious journal in theoretical and applied hydromechanics and were also partially summarized in the monograph:

1. Faltinsen, O.M., Timokha, A.N. (2019). *Journal of Fluid Mechanics*, 865, 884-903.

2. Faltinsen, O.M., Lagodzinskyi, O., Timokha, A.N. (2020). *Journal of Fluid Mechanics*, 894, A10, 1-2.

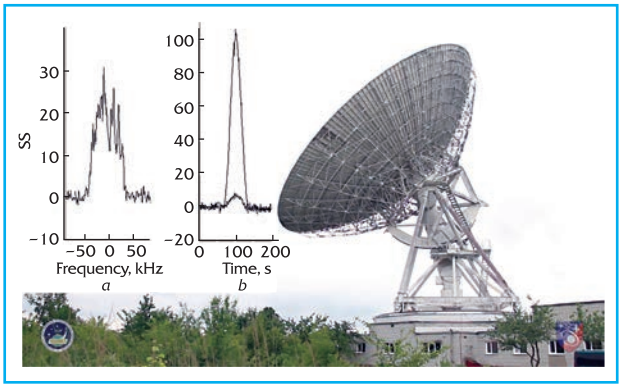
3. Raynovskyy, I., Timokha, A. *Sloshing in Upright Circular Containers: Theory, Analytical Solutions, and Applications* (CRC Press/Taylor & Fransis Group, 2021).

A.N. Timokha

New Ukrainian PT-32 Radio Telescope — a Renewal of Domestic Surveys in the Centimeter Range

In November 2020, the main work on commissioning centimeter wave range radio telescope PPT-32 was completed (Zolochiv, Lvivska Oblast). It is equipped with high-sensitivity receiving facilities, which permit simultaneous observations in 6 and 1.35 cm wave ranges.

After the loss of PT-70 radio telescope (Yevpatoria, AR Crimea) due to Crimea annexation, radio astronomy and space exploration in the centimeter wave range became impossible in Ukraine. To resume those, NAS scientists and specialists of the National Space Facilities Control and Test Center (NSFCTC) proposed to re-equip the ground space communication stations which at that time stopped to be used by the Broadcasting, Radio Communication and Television Concern (BRCTC). With the Government support, in close cooperation with the State Space Agency of Ukraine, NSFCTC, BRCTC, and with NAS contribution, the abovementioned ground stations were transferred to NSFCTC and formed the basis of the Space Exploration and Communication Center.



Results of surveying maser emission of the W3 molecular cloud: a – methanol line: high signal-to-noise ratio was achieved for frequency resolution 0.977 kHz and time accumulation 1s; b – simultaneous detection of methanol (6.668 GHz) and hydroxyl (6.035 GHz) lines in the space source scanning mode; temporal resolution is 1s, frequency accumulation is 80 kHz

PT-32 is a unique S&T achievement of Ukraine and has a significant development potential, in particular, the elaboration of equipment in the 3 and 18 cm wave ranges. All frequency ranges will work simultaneously and that will be a unique characteristic of the PT-32. Besides, in each wave range, receiving channels are duplicated, so the total band in any channel amounts to 2GHz. High resolution — from tens of kilohertz to parts of a hertz — ensures effective research of both radio astronomic sources and space vehicles, recording their "radio portrait" and very small Doppler shifts of radiation or reflection frequencies. Exceptional temperature stability of the equipment permits high sensitivity of long-term observations.

Due to such characteristics, the scope of PT-32 scientific tasks is very broad: the research of masers, active galactic nuclei, sites of star formation, the Sun, pulsars, solar wind and ionosphere studies by examining the twinkling of space radio emission sources. In particular, multi-range and multi-channel operation of PT-32 are aimed at studying quick radio bursts in a wide range, afterglow of gamma bursts and multi-channel radio astronomy phenomena of the GW170817 type, when gravitation and electromagnetic waves of very broad ranges were generated simultaneously. It is important that time—frequency scale is provided with the so-called primary frequency standards: now the cesium one and the hydrogen standard in the future. Thus, the equipment ensures all opportunities for PT-32 to be included in several scientific networks and consortiums (e.g., to radio interferometric networks of the USA and Europe — *VLBI* and *EVN*, respectively) and will provide participation of our country in international projects of outer space exploration and use. That will give a new impetus to the development of basic science in Ukraine.

V.V. Zakharenko, O.M. Ulyanov

High-Entropy Intermetallics with Shape Memory Effect

G.V. Kurdyumov Institute for Metal Physics of the NAS of Ukraine produced and investigated a radically new class of functional materials — multi-component (high-entropy) intermetallics with the shape memory effect (SME). The need for developing such materials is caused by the instability of functional characteristics of available alloys with the shape memory, whose use is only limited to certain temperature ranges. E.g., until now, the utilization of the best commercial materials of the nitinol (TiNi) type was possible at the temperatures ≤ 400 K.

Institute's scientists determined the consistent patterns of controlling the mechanisms of martensite-type phase transformations $B2 \leftrightarrow B19'$ for the TiZrHfCoNiCu system and produced an intermetallic that has twice as high strength as nitinol and an extended temperature interval of use within 77—900 K.

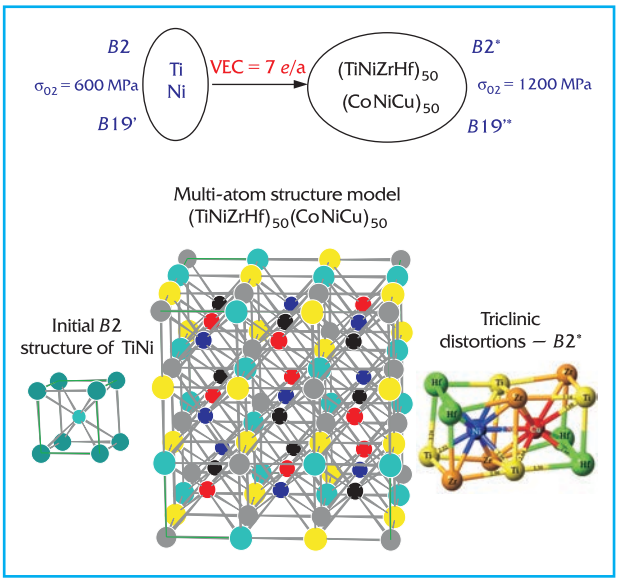
Symmetry reduction was determined for the structure of $(TiZrHf)_{50}(CoNiCu)_{50}$ intermetallics as compared with TiNi intermetallic due to the triclinic lattice deformation of the high-temperature ordered phase of the superstructural type *B*2 and the presence of pico-level crystal lattice distortions. These distortions provide an abnormally high strengthening of the material proposed, which significantly limits the manifestation of dislocation inelasticity, does not prevent martensite transformation and, respectively, does not suppress the shape memory effect.

Structural features of the developed intermetallics at the atomic level provide their deformation in accordance with the martensite mechanism, which is not complicated by dislocation plasticity even at high temperatures. The near absence of dislocation plasticity manifestation permits the functional fatigue to be avoided in the case of multiple use. Such materials demonstrate an outstanding combination of parameters — the stable shape memory under reversible deformation of 3% and the damping capacity nearly twice as high as that of nitinol.

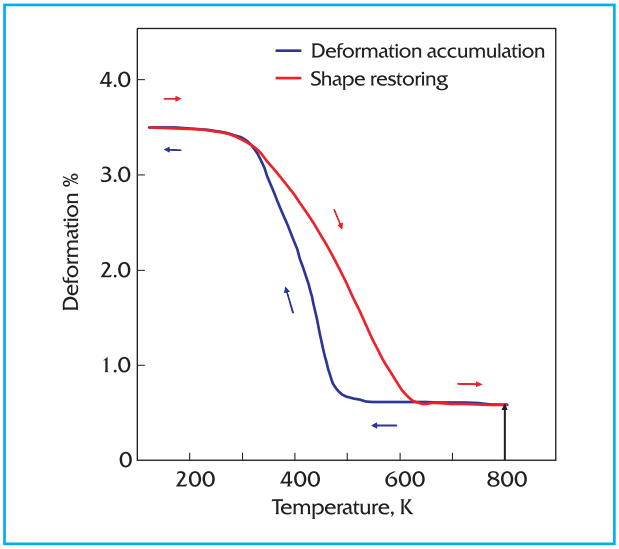
Innovative high-entropy intermetallics with shape memory can be used in modern sensors, systems of vibra-

Comparison of nitinol properties and those of the developed intermetallics with shape memory effect

Property	TiNi	Innovative high-entropy intermetallics
Temperature interval, K	77—390	77—900
Young's modulus, GPa	45	70—80
Yield point, MPa	70—600	1200—1500
Reversible deformation, %	8→1	stable 3
Work performed, J/cm^3	10—20	30



Scheme of multi-element approach to producing high-entropy intermetallics with a multi-atom structure of low symmetry and pico-level distortions, which provides a rise in yield point from 600 MPa in TiNi to 1200 MPa in TiZrHfCoNiCu



Shape memory in $Ti_{16.67}Zr_{16.67}Hf_{16.67}Co_{10}Ni_{25}Cu_{15}$ intermetallic under heating – cooling regime under 600 MPa static stress

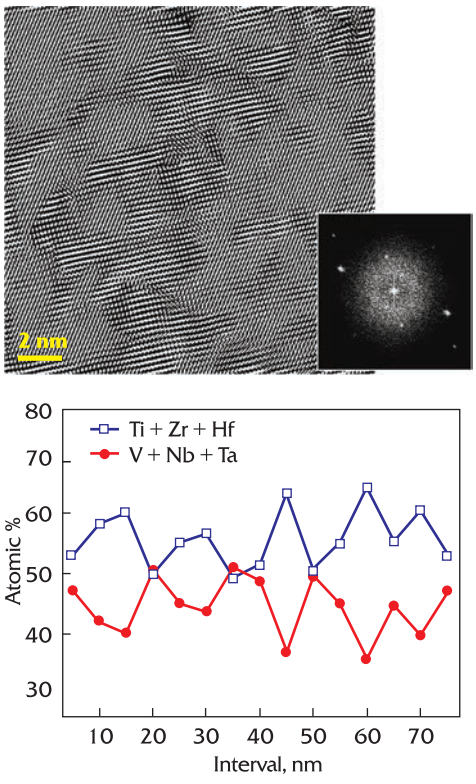
tion dampening and actuator devices in aerospace and automobile industries, power engineering (in the systems for nuclear reactor overheat protection), mining industry, instrument-making and medicine. E.g., the materials developed can be used in the temperature interval 77-900 K, they are promising for nearly ten items in the design of gas turbine engines.

G.S. Firstov, Yu.M. Koval, T.O. Kosorukova

Multi-Component (High-Entropy) Refractory Compounds — a New Promising Scientific Trend

Scientists of I.M. Frantsevich Institute for Problems of Materials Science of the NAS of Ukraine were the first to synthesize, systemically study and characterize over 40 multi-component (high-entropy) carbides, nitrides, borides and oxides. The types and parameters of their crystal lattices, hardness, elasticity moduli and some performance characteristics (wear resistance, friction coefficients etc.) were determined. Special features of the crystal structure of those materials result from the formation of new compounds on the metal sublattice, e.g., in the case of high-entropy carbides of the (ZrHfTiVNbTaMoW)C type — specific multi-component solid solutions. The "simple" lattice of the NaCl type with parameter a = = 0.4489 nm is preserved in such multi-component compound.

Due to the special nano-cluster structure formed, multi-component refractory compounds in certain characteristics are superior to respective double and triple ones. E.g., the hardness of multi-component (TiZrHfVNbTa) carbide is 43 ± 4 GPa, which is not characteristic of any carbide. In general, monocarbides making up the high-entropy carbide have characteristic hardness values of



Typical nano-cluster structure of super-hard high-entropy nitride coating, which is due to atom size disparity and nano-level non-uniformity in elements distribution

24—40 GPa. Multicomponent nitrides demonstrate uniquely high hardness (over 60 GPa). Multi-component oxides have an increased heat resistance and a reduced friction coefficient, while multi-component borides are promising for the development of a new class of high-temperature diborides with enhanced mechanical and emission characteristics.

The results obtained, in fact, lead to a new-level scientific trend "materials science of refractory compounds", whose world-renowned founder was G.V. Samsonov — an outstanding Ukrainian scientist. They start a new promising research area — materials science of multi-component (high-entropy) refractory compounds. Actually, started was the development of a new class of materials that had not been known before. A nearly unlimited diversity of varied compositions, electron structures, size disparity of atoms, entropy and enthalpy open up extremely wide prospects for scientific research.

Owing to their unusual properties, these compounds can find (and already do find) a most extensive use, in particular, for developing a new generation of composite materials, innovative multi-component 2*D* materials and as coatings with unique high-performance characteristics.

S.O. Firstov, V.F. Gorban, M.O. Krapivka, N.I. Danilenko, A.O. Andreyev

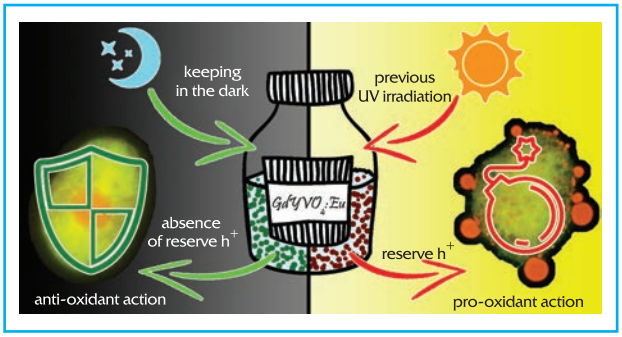
Inorganic Nanomaterials with Controlled Redox Activity

Reactive oxygen species (ROS) play the key role in the functioning of live organisms, controlling numerous processes at the cell level. However, an uncontrolled increase of their concentrations results in the development of oxidizing stress, which is the cause of numerous pathologies, in particular, cardiovascular and cancerous diseases. One of the modern strategies that help control the level of reactive oxygen in live cells and prevent the development of respective pathologies is to use redox-active nanomaterials, i.e., nanomaterials able to destruct or generate ROS.

The NTC "Institute of Single Crystals" (Institute for Scintillation Materials of the NAS of Ukraine) developed luminescent nanomaterials based on the nanoparticles of gadolinium-yttrium orthovanadate $GdYVO_4$: Eu^{3+}, whose redox properties can be changed depending on the previous treatment of nanoparticles.

It was revealed that nanoparticles that had been kept in the dark are antioxidants, viz. they are capable of destroying ROS due to the presence of changeable valency ion nanoparticles in their structure, which can donate electrons during their interactions with ROS.

At the same time, nanoparticles pre-treated with ultraviolet (UV) radiation demonstrate pro-oxidant properties, i.e., they effectively generate ROS both without further irradiation and with further UV or X-ray irradiation. This effect results from nanoparticle defect structure. Charge carriers (electrons and holes) formed under previous UV irradiation are caught on traps (ions with changeable valency, defect centers resulting from oxygen vacancies) and gradually diffuse on the nanoparticle surface, which produces the effect of ROS "dark" generation even in the absence of further direct nanoparticle irradiation.



Scheme of pro- or anti-oxidant action of nanoparticles depending on their preliminary treatment

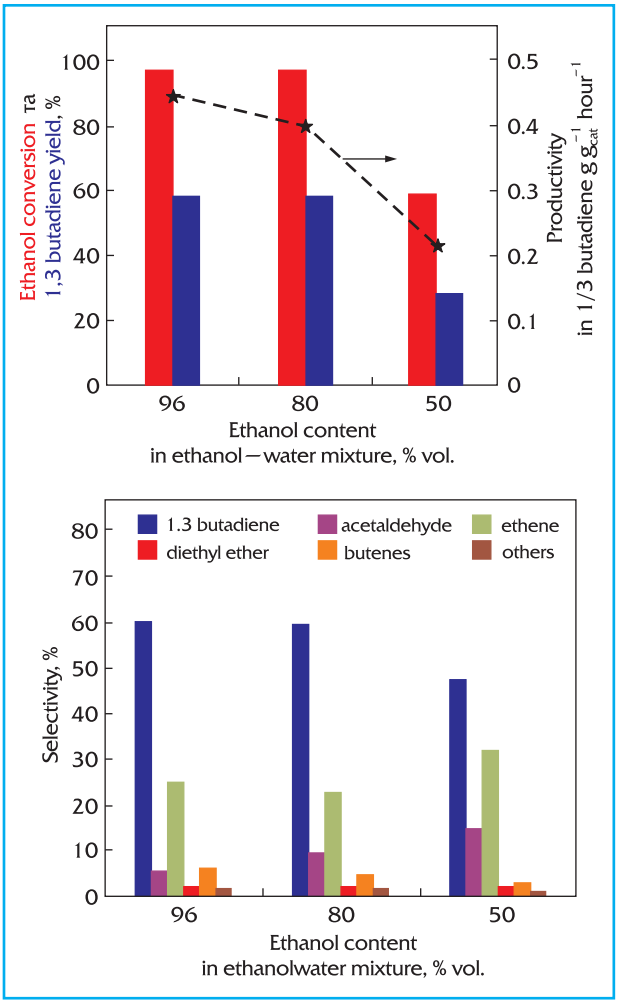
Nanomaterials with controlled pro- or anti-oxidant action are promising for use in the biomedical sphere as a new class of medicinal agents that, due to the effect of "dark" ROS generation, can radically change the strategy of cancer radiotherapy.

Y.V. Mallyukin, S.L. Yefimova, P.O. Maksimchuk, V.K. Klochkov

High-Efficiency Catalysts of Obtaining 1,3 Butadiene from Ethanol—Water Mixtures

L.V. Pisarzhevsky Institute of Physical Chemistry of the NAS of Ukraine developed high-efficiency Zn—Zr—Si catalysts for the process of obtaining 1.3 butadiene — an industrially important monomer for producing rubber and several plastics from bioethanol. In developing the method of preparing such catalysts, approaches of structural and functional design were implemented. They consisted in using for the synthesis of complex $ZnO/ZrO_2—SiO_2$ compositions the zinc oxide particles of determined morphology and size, as well as the method of $ZrO_2—SiO_2$ wet mixing (as opposed to the traditional approach — impregnation with zinc salt solution). Due to that, catalyst activity and selectivity were enhanced. The effect of zinc oxide synthesis conditions on the morphology, acid-base characteristics and catalytic properties of the catalysts obtained were determined in the process of transforming ethanol–water mixtures into 1.3 butadiene.

It was shown that the higher values of activity and selectivity of $ZnO(nano)/ZrO_2—SiO_2$ catalysts are due to acid-base characteristics of zinc oxide surface in the abovementioned compositions, in particular, to the pre-



Indicators of the process of transforming ethanol-water mixture into 1.3 butadiene in the presence of ZnO(nano)/ZrO_2 – SiO_2 at the temperature of 400 °C, the load is 1.3 g gcat^{-1} hour^{-1}

valence of acid centers content over the base ones. In the presence of catalytic systems with the domination of acid centers on the ZnO surface, higher ethanol conversion and 1.3 butadiene selectivity were achieved. It was revealed that the ZnO(nano)/ZrO_2—SiO_2 catalyst prepared by wet mixing of ZrO_2—SiO_2 with zinc oxide nanoparticles provided a higher resistance to the suppression of the target process by water molecules in the transition from rectified ethanol to ethanol–water mixtures, which can be obtained by fast membrane filtration of enzymatic solutions.

The catalysts developed on the basis of oxide Zn—Zr—Si systems are characterized with the simplicity of preparation, the absence of precious metals in their composition and the possibility of using ethanol—water mixtures as the feedstock for synthesizing 1.3 butadiene with high yield.

S.M. Orlyk, S.O. Soloviev, P.I. Kirilenko, O.V. Larina

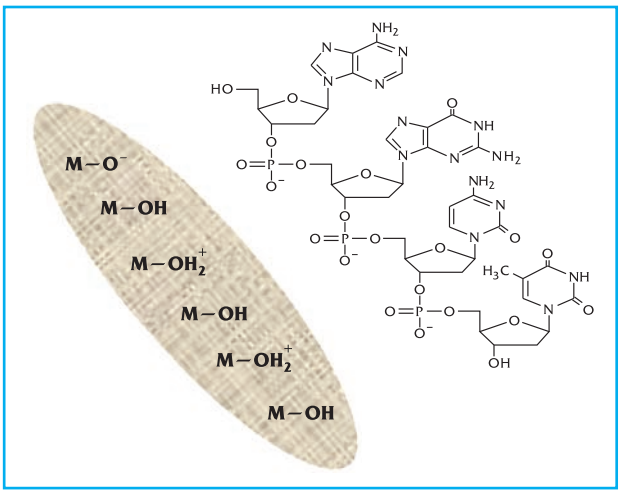
Features of DNA Interaction with the Surfaces of Metal Oxides

O.O. Chuyko Institute of Surface Chemistry of the NAS of Ukraine investigated the peculiarities of biomolecules interactions with surfaces of nano-sized metal oxides as a promising trend of developing novel hybrid bio-organic—mineral materials.

Lately, desoxyribonucleic acid (DNA) has drawn researchers' attention as the central molecule for developing radically new materials in nanobiotechnology. DNA anchoring and integration on the surfaces of solids is one of the promising ways of producing biosensors, means for the analytical separation and delivery of genes. Due to their low toxicity and high biocompatibility, nanosized titanium and cerium oxides are among the most promising materials, which are increasingly used in biomedicine. Electrostatic interaction between phosphate ions of nucleic acid and positively charged protonated groups of oxide surface was found to be the driving force of DNA adsorption on the surface of titanium and cerium dioxides from aqueous solutions. The principal role in the adsorption process is played by phosphate ions, which are free for interaction, since nucleic bases in the DNA form hydrogen bonds.

The shapes of curves of orthophosphate adsorption *vs* pH on the surfaces of both oxides coincide with the shapes of DNA adsorption curves. On the curves of adsorption dependence on pH, there are no maximums for DNA, which are observed with nucleotide adsorption and show the pH dependence of the basicity of nitrogen atoms in their nucleic bases. DNA approach to oxides surfaces due to electrostatic attraction also makes possible other types of interactions, such as the formation of covalent and hydrogen bonds.

DNA molecule immobilization on the surfaces of nanomaterials due to the electrostatic interaction with metal



Adsorption interaction of the polynucleotide fragment of DNA chain with metal oxide surface

oxide surfaces plays the decisive role in developing bioelectronic devices. There are real prospects of using titanium and cerium dioxides in biomedicine for the treatment and diagnostics of several socially significant diseases. Investigations of the interactions of nano-sized titanium and cerium dioxides with biopolymers at the molecular level helps get an insight into their effect on human body cells. Such understanding is necessary for the successful use of hybrid bioinorganic nanomaterials based on metal oxides in various areas of biomedicine and biotechnology.

N.M. Vlasova, O.V. Markitan

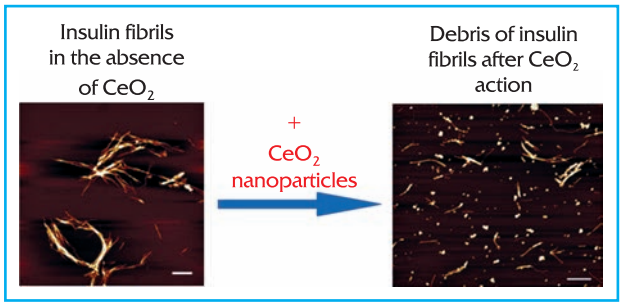
Cerium Dioxide Particles for the Therapy of Neurodegenerative Diseases

V.I. Vernadsky Institute of General and Inorganic Chemistry of the NAS of Ukraine developed innovative methods of synthesizing nanocrystalline cerium dioxide that enabled Institute's scientists to obtain small-sized non-agglomerated CeO_2 particles of controlled sizes. The research showed the feasibility of regulating the Ce^{3+}/Ce^{4+} ions ratio on the surfaces of CeO_2 particles, depending on their sizes. It was determined that synthesized CeO_2 particles form highly stable aqueous suspensions (the value of ζ-potential is above +40 mV) without additional stabilization agents, which is of utmost importance for their medico-biological use.

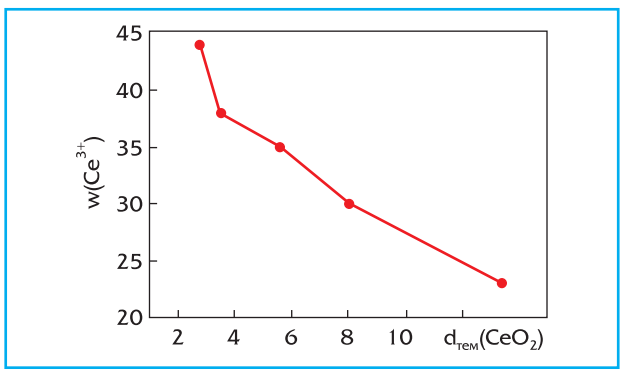
The research carried out in collaboration with the Institute of Experimental Physics of the Slovak Academy of Sciences (Košice, Slovakia) revealed that synthesized CeO_2 particles demonstrate high antioxidant activity. Biological studies on model amyloid insulin fibrils provided evidence that "clean" non-functionalized CeO_2 nanoparticles actively destroy the formed amyloid fibrils of insulin and, besides, act as inhibitors in the case of forming new amyloid fibrils.

It was also determined that CeO_2 nanoparticles possess high anti-amyloid activity, which could be promising for medical practice, in particular, for the treatment of diseases caused by oxidative stress and amyloid fibrils formation (neurogenerative diseases, inflammation processes etc.).

A.G. Bilous, Yu.Yu. Slapa, S.O. Solopan, I.P. Timashkov



Effect of CeO_2 nanoparticles on amyloid insulin fibrillation



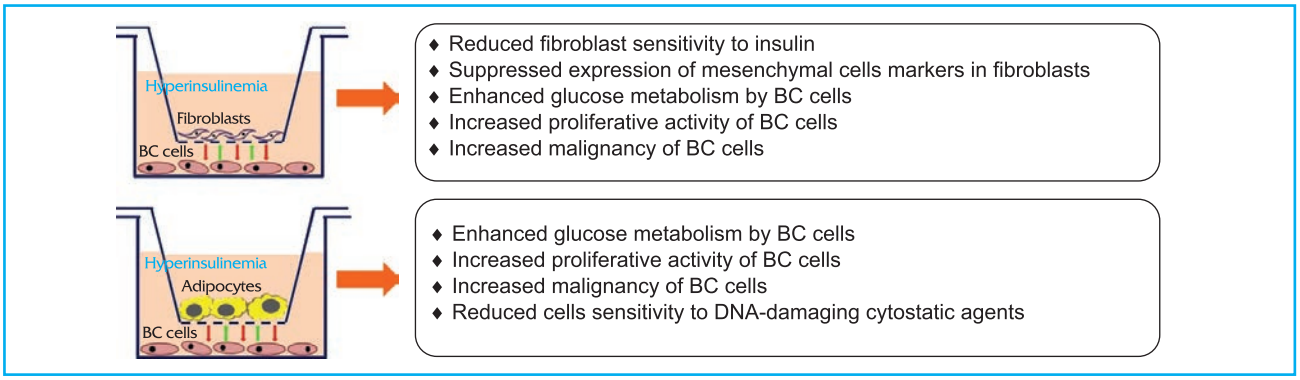
Dependence of Ce^{3+} ions located on the surfaces of CeO_2 nanoparticles on their sizes

Using the Indicators of Tumor Cells Metabolic Profiles to Evaluate Their Malignancy and Sensitivity to Cytostatic Agents

Scientists of R.E. Kavetsky Institute of Experimental Pathology, Oncology and Radiobiology of the NAS of Ukraine determined that an impaired level of insulin receptor expression and glucose metabolism in cells are accompanied with enhanced expression of the proteins involved in their malignant transformation and the formation of tumor cells sensitivity to the effect of DNA-damaging cytostatic agents. It was proved that hyperinsulinemia and insulin resistance factors produce considerable effect on the metabolic phenotype of both tumor cells and cell elements of their microenvironment.

With reliance on the cutting-edge molecular biology methods, it was shown in an *in vitro* system that contactless co-cultivation of human breast cancer (BC) cells with stromal microenvironment components under hyperinsulinemic conditions result in reduced fibroblasts sensitivity to insulin along with enhanced glucose metabolism by tumor cells and their increased proliferation.

It was also found that co-cultivation of BC cells and fibroblasts under high insulin concentration suppresses the expression of the markers of mesenchymal cells in fibroblasts and enhances the expression of these molecules in BC cells. Such changes provide the evidence of malignantly transformed cells' ability to modify the phenotype of connective tissue cells and increase their malignancy. Co-cultivation of BC cells and adipocytes under hyperinsulinemia was accompanied with reduced sensitivity of tumor cells to the action of DNA-damaging anti-tumor drugs.



Scheme of contactless co-cultivation of human BC cells with cell elements of their microenvironment under conditions of hyperinsulinemia

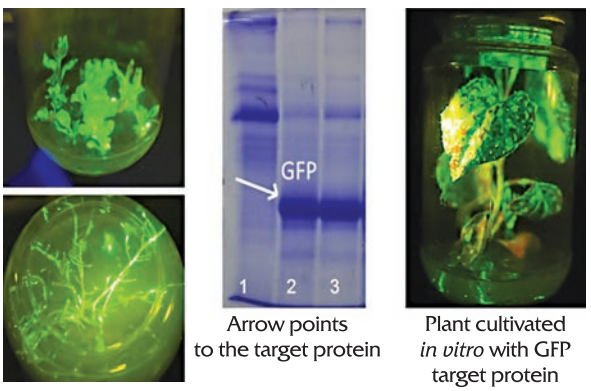
These results have a significant potential of further practical application in clinical practice for choosing the most efficacious therapeutic schemes and prognosticating the cancer disease course.

V.F. Chekhun, O.O. Lykhova

Production of Recombinant Proteins Using *in vitro* Plant Culture

Recombinant proteins produced with the technologies of recombinant DNA (genetic engineering) have been used in the treatment of numerous diseases for quite a long time. In particular, several vaccines against *COVID*-19 have also been developed with reliance on this technology. Now all such commercialized substances are produced in the cells of microorganisms or mammals.

Scientists of the NAS Institute of Cell Biology and Genetic Engineering proposed plants as an alternative system for obtaining recombinant therapeutic proteins. Plant systems, unlike traditional ones, have a number of advantages concerning the production of recombinant therapeutic proteins: the absence of bacterial endotoxins and animal oncogenic sequences, the ease of cultivating vegetable raw materials etc. Innovative approaches to obtaining recombinant therapeutic proteins by the transient expression of the target gene in plant tissue culture *in vitro* were developed. In a greenhouse, it is difficult to standardize fluctuations of nutrient content in the soil, while the physiological condition of producer plant depends on many factors, including pests and pathogenic organisms.



Obtaining recombinant proteins in plants cultivated in vitro

The proposed method is much easier in the adaptation to pharmaceutical production standards in conformity with the international requirements of Good Manufacturing Practice (GMP).

Among other advantages, it is worth mentioning that: "infecting" new plants does not require special equipment and occurs naturally, due to systemic propagation of the genetic structure created on the basis of plant virus genome; the production of recombinant proteins is more easily standardized *in vitro*; plants *in vitro* are easily cloned, which provides a large number of producer plants; a high level of recombinant protein (up to 47% of the total soluble cell proteins or 2 mg/g of the leaves raw weight) can be obtained; the effective period of gene expression and recombinant protein production is longer (up to several months).

These advantages show a high potential of the transient *in vitro* system for a large-scale production of recombinant, therapeutic in particular, proteins in plants. After optimizing the production conditions, the new system could be used for obtaining various recombinant pharmaceutical proteins.

M.V. Kuchuk, Ya. R. Sindarovska

Evaluation of the Effect of Climate Change on Vegetation

Bioclimatology examines multiple ties and mutual dependence of climate and biota. One of the promising research directions here is the development of synphytoindication, which aims at evaluating climatic factors by reliance on the characteristics of vegetation. This opens up possibilities of using a wide range of today's mathematical methods of data processing, helps build forecasts

Examples of calculating the possible loss of syntaxa due to a rise of mean annual temperatures by +1. +2 and +3 °C as compared with thermal regime change

Syntaxon	Tm	max	min	Tm+1	Tm+2	Tm+3
Caricion curvulae	5.09	5.42	4.76	5.28	5.49	5,69
Juncion trifidi	5.84	6.46	5.22	6.06	6.3	6,54
Pinion mugo	7.01	7.51	6.5	7.28	7.55	7,84
Salicion albae	9.08	9.34	8.82	9.43	9.79	10,16
Alnetea glutinosae	8.61	9.24	7.99	8.94	9.28	9,64
Fagion sylvatica	8.89	9.35	8.43	9.23	9.58	9,95
Tulipo quercetori-Quercetum roboris	9.08	9.34	8.82	9.43	9.79	10,16
Dicrano-Pinetum	7.19	8.04	6.35	7.47	7.75	8,05
Elytrigio nodosae-Quercion pubescentis	10.24	10.7	9.78	10.63	11.04	11,46
Bracypodio-Pinion pallasianae	8.43	9.57	7.29	8.75	9.09	9,43
Stipion lelessingianae	9.38	9.59	9.16	9.73	10.11	10.49

Threats: green — does not exist; yellow — possible changes; red — possible loss.

and scenarios of future ecosystem changes, evaluates the risks of their existence and possible losses.

The studies of scientists of M.G. Kholodny Institute of Botany of the NAS of Ukraine, who used the abovementioned approaches, raised synphytoindication research to a qualitatively new level. Due to that, the degree and nature of correlations between hydrothermal indicators of the bioclimate, edaphic factors and vegetation were determined. It was shown that an indirect climate effect on biota *via* changed edaphic soil properties is much stronger than the direct one. The revealed interrelation patterns formed the basis for further assessment of ecosystems differentiation and distinguishing four ecoclimatic regions of Ukraine (the mountainous Carpathian, humid nemoral, arid steppe and sub-Mediterranean south Crimean ones). These regions are different in quantitative indicators of limiting factors and the nature of interdependences between them, therefore, they need the development of separate assessments of risks, scenarios and measures to counteract negative changes in ecosystems.

Tests of the procedure based on sampling rare species and plant communities permitted the risks and limits of their loss to be determined. It was demonstrated that in the case of mean annual temperature rise by 2.5 °C as compared with its current value, the majority of natural ecosystems in Ukraine will lose their stability and the future changes will be irreversible and disastrous.

Ya.P. Didukh

RESEARCH ACHIEVEMENTS. SOCIAL SCIENCES AND HUMANITIES

Scholars of the Section of Social Sciences and Humanities of the NAS of Ukraine carried out a large amount of research in economics, socio-political and cultural development of the Ukrainian society.

The Section continued its practice of preparing National Reports on the most important issues for the state and the society. This work resulted in the **National Report "Ukraine as the Civilizational Subject of History and the Present"**, prepared by a team of Section's experts under the leadership of NAS Academician Serhii Pyrozhkov. The report is an attempt to answer the question how Ukraine can establish itself as a full-fledged subject of the global civilizational system in the conditions of hybrid world order and geopolitical turbulence. Scholars of the Section comprehensively studied historical prerequisites, specific features, problems and factors of achieving civilizational subjectivity by Ukraine in the present-day world; they thoroughly analyzed the ideas of Ukrainian citizens about the degree of nation's self-reliance in various spheres of its domestic and foreign policy; the attitude of its international partners to the subjectivity of Ukraine was shown; the prospects of Ukraine's civilizational subjectivity in the 21st century were studied along with the ways of its strengthening in the spheres of politics, economy, international law, its spirituality and culture.

The civilizational subjectivity of the country is considered as the state under which it is not an object of the influence of "powers that be", but through the efforts of political, economic, scientific and artistic elite, it is able to design its own civilizational future, formulate and realize its national interests. It has to be stated that since gaining its independence Ukraine, due to internal and external factors, was not able to achieve the proper subjectivity in the global world. Its subjectivity was minimized as a result of destructive internal processes and the incessant, up to the armed aggression, pressure of the Russian Federation. As a result of the ineffective public administration, increased corruption and the role of oligarchs in political and economic processes, Ukraine fell under the influence of stronger players.

As shown by the representative monitoring survey conducted by the NAS Institute of Sociology, the majority of Ukrainians do not consider their state to be sufficiently independent in its actions and decisions, while regional ideological and ethno-cultural characteristic features can divide people in their attitude to the state. In particular, residents of the West and the Center of Ukraine, as well as Ukrainian-speaking citizens rate nation's subjectivity higher than residents of the East, the South, and Russian-speaking citizens of Ukraine. Instead, economic factors can reduce differences; especially significant among those factors is the material standard of living. Defeating poverty, improving the material standards of Ukrainian families will contribute to the gradual rise in the ratings of state subjectivity.

It was emphasized that increasing Ukraine's subjectivity is strongly related to the necessity of efficiently using the available resources — its industrial and scientific potentials, its unique geographical position, which creates favorable conditions for the deployment of production facilities oriented towards the markets of both the EU and the Asian countries; raw material resources; the potential of becoming an agrarian leader of today's world; the powerful human potential, its reserve of educated workforce, the system of training professional personnel.

In the context of reforming the economy and of the transit from the raw-material to high-tech economic structure, the emphasis should be placed on the predominance of breakthrough industries, which are to become the "engine" of the Ukrainian economy, and on the competitiveness of Ukrainian products on the international markets. Such clusters of the Ukrainian economy growth could be IT technologies, IT business, infrastructure development, construction industry, tourism, promotion of green energy, growing organic products, and other high-tech spheres.

Of utmost importance is to implement the democratic model of an up-to-date competitive political system based on the rule of law, developed legal culture, well-balanced representative democracy, strong self-government, effective state management. To establish itself as a self-reliant civilizational subject, Ukraine is to achieve high national consolidation, to create an atmosphere of mutual trust and solidarity, enhance activist dynamics, establish the system of norms that would reflect the values, interests and ideals of all social groups and become the result of their true interaction.

One of the major challenges of Ukrainian reforms is to overcome corruption, create instruments for reducing the decisive influence of oligarchs and financial-and-industrial groups on the state policy. Reforming law enforcement bodies and the judicial system remains highly relevant for our society.

The Strategy of the National Security of Ukraine needs implementation, primarily, such provisions as the de-occupation of Crimea and some regions of the Donetsk and Luhansk oblasts, the strengthening of the Armed

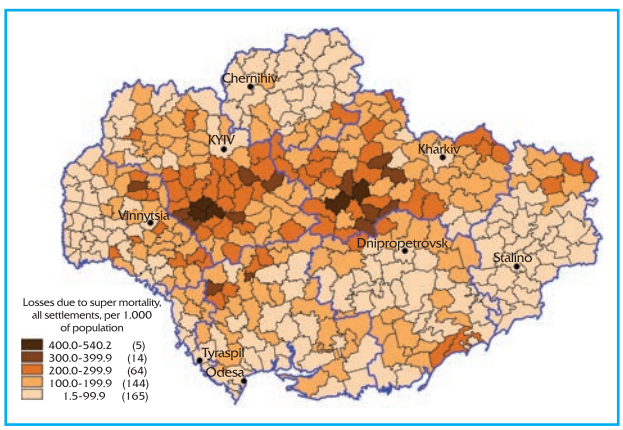
Forces of Ukraine, and other segments of security and defense sphere.

An extremely important task of the foreign policy of Ukraine, which is predetermined by its belonging to the European culture and civilizational community, remains its further European and Euro-Atlantic integration, and in the future — achieving the full membership in the EU and the NATO. It is the fulfillment of this strategic goal that will radically change the international legal subjectivity of Ukraine.

It should not be expected that civilizational subjectivity is able to evolve in its own right. It must be the focus of incessant attention of the state authorities and the academic community. In the development of its subjectivity, Ukraine should rely, first and foremost, on itself and consistently implement its civilizational project.

Scientists of M.V. Ptoukha Institute of Demography and Social Studies of the NAS of Ukraine **examined the long-term demographic dynamics of Ukraine**. The information base of that research was the reconstructed continuous series of demographic dynamics. The full-scale reconstruction was done for the period 1795-2013, but the largest array of detailed indices was reconstructed since the All-Russia Census of 1897. These are more exact data in terms of sex and the locality of residence: age profiles of the population and the dead, migration balance, birth rate *vs* maternal age. Demographic series were brought into correspondence with the current territorial borders of the state. The availability of such demographic series placed Ukraine among the leading countries in this field.

The study of the long-term demographic dynamics of Ukraine covered a significant historical period and included all components of the demographic process: birth and death rates, migration, as well as certain social characteristics of the population (marital status and family composition, ethnic, linguistic composition, and education level), which are examined along with demographic characteristics. Considerable attention was paid to revealing the specific features of demographic processes during three demographic disasters of the 20th century (1914-1923, 1932-1934, 1937-1946). The losses of Ukraine due to super mortality and birth deficit resulting from those disasters were evaluated. The impacts of famine (1921-1923), the Holodomor genocide (1932-1933), the Second World War (1939-1945) on demographic dynamics were examined in detail. The demographic aspects of the deportation of Crimean Tatars from Crimea in the May of 1944 were investigated for the first time ever.



Losses due to super mortality as a result of Holodomor in 1933 in Ukraine (within administrative districts as of 1 April 1933)

A special place in studying the long-term demographic dynamics of Ukraine belongs to the evaluation of population loss due to the Holodomor in 1932-1933. For the first time, such evaluation was made in the comparative context for several characteristics, and the features of the loss structure at the national, oblast and district levels were determined. The evaluation of losses due to super mortality enabled researchers to determine that Ukraine takes the first place in terms of the absolute loss indicator among the USSR republics of that time. The total demographic losses of Ukraine resulting from the famine of 1932-1934 amounted to 4.5 million people, including 3.9 million due to super mortality and 0.6 million due to the births that did not happen.

The losses due the super mortality resulting from the famine in Ukraine were evaluated across regions, the analysis was made of the possible factors that could influence the regional distribution of population loss: historical, political, geographic, economic and some indicators of the anti-Soviet resistance and repressions against peasants in 1932. For the first time, the losses due to super mortality were evaluated for the administrative-territorial districts of that time.

The results of the scientific research provided a much deeper and broader insight into the demography of the Holodomor in Ukraine. The main results of that work have also been used in the demographic module of the electronic interactive *Atlas Mapa. Digital Atlas of Ukraine*, which is being compiled by the Ukrainian Scientific Institute of Harvard University: https://gis.huri.harvard.edu/historical-atlas.html.

O.M. Gladun, N.M. Levchuk, O.P. Rudnytskyi

2020 will be remembered by the publication of **the first unabridged edition of the "Chronicle" by Samiylo Velychko**, the author of the first systematized narration of the history of the Ukrainian Cossack State. His 350th birth anniversary was marked according to Verkhovna Rada Resolution of 3 December 2019 #325-IX "On the celebration of memorable dates and jubilees in 2020". Experts of the NAS Institute of the History of Ukraine and V.I. Vernadsky National Library of Ukraine contributed to the preparation of that edition. The chronicle is a unique

record of the Cossack historical ideas and baroque belles-lettres of the first half of the 18th century. The original of the "Chronicle" is now kept in St. Petersburg National Library and it was never before comprehensively studied and published in full.

In 2012-2019, a research team of the NAS Institute of the History of Ukraine, led by NAS Corresponding Member Hennadii Boriak, NAS Corresponding Member Lyubov Dubrovina and Prof. Tatiana Tayrova-Yakovleva, Sci.Dr., Director of the Center for Studying the History of Ukraine at the St. Petersburg State University, implemented this unique project. The edition contains the unabridged text of Samiylo Velychko's writing, his biography, an analysis of the manuscript original and its copy made in Kyiv in the late 18th century, the history of writing and safekeeping the "Chronicle" etc.

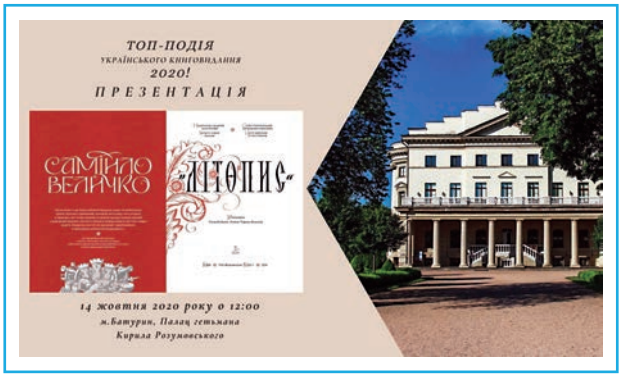
The "Chronicle" was issued by Kyiv Clio Publishers, whose director Vira Soloviova, together with their partners, were able to overcome numerous obstacles and unite scholars, publishers and Ukrainian patrons for implementing this project. On 14 October, the Day of Ukrainian Cossacks, the presentation of the edition took place in the 'Hetman Capital' National Reserve (the town of Baturyn). It is symbolic that the event was held in Baturyn, where the author of the "Chronicle" served for eighteen years of his life as a clerk in the government of Hetman Ivan Mazepa.

Owing to those efforts, the large-scale work by Samiylo Velychko became available for proper studies in Ukraine, which will enable scholars to get a deeper insight into the Cossack period of Ukrainian history.

"Taras Shevchenko's Epistolary" was publicized: a thoroughly elaborated edition of Taras Shevchenko's letters and letters to him produced by textual critics of T.H. Shevchenko Institute of Literature of the NAS of Ukraine (in 2 books). It was issued by Kharkiv Folio Publishers in the "Library of Ukrainian Literature" series.

The edition was edited by Serhii Halchenko and Halyna Karpinchuk, the author of the foreword is Mykhailyna Kotsiubynska, scholarly editor is Oleksandr Boron. The two-volume edition contains profound comments by Vasyl Borodin, Volodymyr Movchaniuk, Mykola Pavliuk, Tetiana Riznychenko, Valeriia Smilianska, Nina Chamata, Vasyl Shubravskyi.

For the first time, Shevchenko's letters and those of his addressees are presented chronologically within a single corpus. The epistolary covers 22 years of life and creative work of the poet: from 15 November 1839 till March 1861 (the latest messages came after his death). There are 238 private letters of the addresser, 15 official letters and business papers, 4 collective letters with poet's signatures, as well as 242 messages to him and 8 official letters. For the first time after 90 years, 32 letters to Shevchenko were presented. Luckily, their originals, which had been considered as lost, were found in an archive in



2015. A number of corrections and clarifications in the texts were made. The scholarly commentary takes into account the achievements of recent Shevchenko studies.

The extensive historical and ethnological popular-science edition **"Ethnographic Groups of Carpathian Ukrainians"**, prepared by scholars of the NAS Institute of Ethnology, was published (in 3 books, Kharkiv: Folio, 'Major Scientific Project' series). The structuring and scholarly editing of the books was made by NAS Academician Stepan Pavlyuk; the members of the editorial board are: Yaroslav Taras, Myroslav Sopolyha, Ulyana Movna, Roman Siletskyy, Hanna Vrochynska, Tamara Patsay, Lyudmyla Herus.

This monographic study gives a comprehensive coverage to the unique heritage of culture and traditions of the ethnographic groups of the Ukrainian Carpathians — boikos, hutsuls, and lemkos. All aspects of their lives were studied: anthropological features, civil life, traditional lore, habitation, transport, agriculture, folk crafts, legal and ethical norms, beliefs, prejudices, demonology, customs, rituals etc. All that makes up complex and extremely valuable material for research. The monograph is structured in such a way as to cover the entire sphere of highlanders' culture, and distinguish important aspects of the acquired traditions of each ethnographic group of the Ukrainians living in the Eastern Carpathians since time immemorial. Shown is the dynamics of mutually penetrating phenomena inherent to other ethnoses in ethno-traditional directions: their intensity in the spheres of production and economy as well as in traditions and outlook.

Electron Beam Equipment for Manufacturing Metal Parts by Additive Electron Beam Technology of 3*D* Printing

Unlike the majority of traditional processing technologies, additive technologies (AT) combined with software for automatic design permit the manufacturing of product of a predetermined shape with unique properties, which cannot be obtained by other methods. They also reduce material consumption, as well as production and marketing time.

E.O. Paton Electric Welding Institute of the NAS of Ukraine developed, for the first time in Ukraine, equipment for layer-by-layer manufacturing of the items of the given shape and structure by 3*D* electron beam method by using domestic spherically- and arbitrarily-shaped powdered metal material. The effectiveness of the 3*D* printing machine of metal products amounts to 80 cm^3 per hour.

The machine consists of a small-sized vacuum chamber, mechanisms for platform vertical movement, mechanisms for feeding and distributing the metal powder, and an electron beam gun with the maximum electron beam capability of 60 kW along with high-voltage power supply. The control of the machine operation and the technological process of 3*D* printing is fully automated and is performed by an industrial computer.

Pilot electron beam facility for 3D printing

The equipment is optimized for using powders of titanium-based alloys BT1-0, BT-6, BT-20 etc., cobalt-chromium alloys ASTM F75, nickel-based high-temperature inconel 718 alloys, as well as copper and aluminum alloys. These powders are produced by Ukrainian plants, which significantly reduces the cost of items manufactured by 3*D* printing and ensures the competitiveness of the above-mentioned electron-beam equipment and domestic additive technologies in the global market.

The equipment produced is intended for deployment at turbine-manufacturing and aerospace industry plants of Ukraine: *Zoria Mashproyect* State Enterprise "Research and Production Complex of Gas Turbine Manufacturing" (Mykolaiv), *Motor* Lutsk Repair Plant (Lutsk), *Motor Sich* JSC (Zaporizhzhya), and State Enterprise M.K. Yangel DB *Pivdenne* (Dnipro).

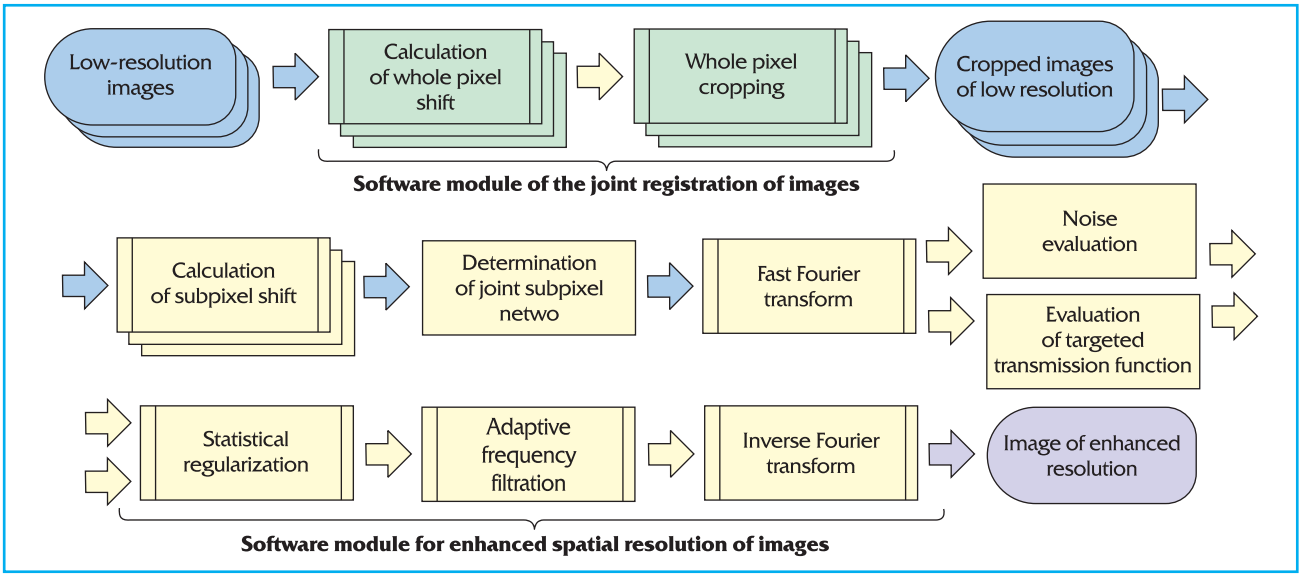
V.M. Nesterenkov, V.A. Matviichuk

Method of Subpixel Enhancement of Satellite Imagery Spatial Resolution

Due to their very high information content and prompt processing, satellite images are important tools for remote investigation of natural and man-induced processes. One of the limitations of further implementation of satellite remote sensing is the space resolution of satellite imagery. Unfortunately, there are quite a number of physical factors that limit this spatial resolution. Those are, first and foremost, technological difficulties of manufacturing multi-component microelectronic sensors of optical radiation and the maximum permissible size of the optical system's input "eye".

The State Institution "Scientific Center for Aerospace Studies of the Earth", operating within the NAS Institute of Geological Sciences (hereinafter Center), developed a method for subpixel enhancement of satellite imagery space resolution, which relies on the model of accumulating useful information from the sequential images of the same scene. To improve spatial resolution, subpixel shifts between all incoming images are necessary. Such shifts are nearly always present between satellite images due to innumerable stochastic factors, it only remains to evaluate them precisely.

To achieve maximum superresolution of satellite imagery through common subpixel processing of several (from two to ten) incoming images of low resolution, Center's scientists proposed and implemented an innovative solution (know-how) that consists in evaluating mutual subpixel shifts, statistical regularization of a set of subpixelly aligned images, evaluating their transfer functions and noises, restoration and adaptive filtration of the outcoming images of subpixel resolution. All calculations are carried out exclusively in the frequency domain, which allows an essential reduction of computing costs and processing huge amounts of satellite data.



Flow chart of the processing of subpixel-shifted satellite images

The method is implemented in the form of specialized standalone software module developed with reliance on cutting-edge computer technologies and effective 64-bit software libraries with open-source codes. Alongside the principal software module, two auxiliary software tools were developed: a module for joint registration of satellite images intended for the automatic alignment and cropping of sets of incoming satellite images, using correlation in the frequency domain, and a special instrument for evaluating the actual spatial resolution of a digital image.

As of now, the software module is used in the Beijing Institute of Space Mechanics and Electricity (PRC) to process the images obtained by Chinese satellite systems of Earth remote sensing of the *Gaofen* series.

S.A. Stankevich, M.O. Popov, S.V. Shklyar, K.Yu. Sukhanov, A.A. Andreiev, A.R. Lysenko

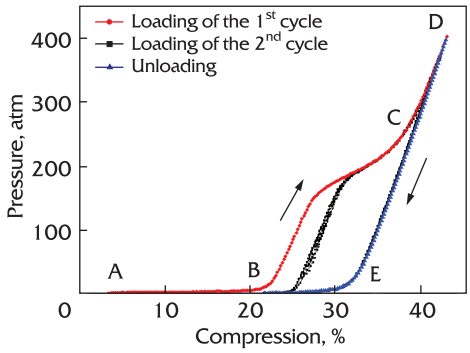
Porous Materials for Manufacturing Next-Generation Shock Absorbers

L.V. Pisarzhevsky Institute of Physical Chemistry of the NAS of Ukraine developed a number of novel hydrophobic porous substances based on nano-porous silica gels that are able to absorb water reversibly or irreversibly under high pressure and could be used as the working bodies of next-generation dampers — "molecular springs". The effect of water absorption under high pressure appears since the surface of porous material is not wetted by water and the filling of nano-sized pores becomes an energetically disadvantageous process. The value of the external pressure under which pores are filled is determined by the optimum combination of several factors: pore diameter, the nature of alkyl groups on the surface etc. Porous materials demonstrating multiple reversible water absorption under loading can be used as working bodies of various shock absorbers, while the systems where the effect described is irreversible open up prospects for developing novel means of protection against powerful impacts.

The research conducted showed that several modified silica gels and porous coordination polymers of 3*D* metals are suitable for use as working bodies of shock absorbers. The hydrophobicity of the silica materials obtained results from the presence of alkyl groups on their surface, and the hydrophobicity of porous coordination polymers is due to the location of groups with C—N bonds in pores. The effect of the silica gel pore size, the modifier nature, the size of hydrophobic material pores on the pressure value under which water is absorbed, and the characteristics of this process reversibility were determined.

The efficiency of the materials examined in the attenuation of shock loads was evaluated by analyzing the interrelation between the system volume V and pressure P up to 1000 atmospheres. In the case of system compression merely by 13%, external pressure rises to 260 atm (area B—C on the plot), water fills hydrophobic pores, and loading energy is dissipated or transformed into the inner energy of the system.

In collaboration with the State Enterprise *Catalysis and Ecology* of L.V. Pisarzhevsky Institute of Physical Chemistry of the NAS of Ukraine, the respective regimen was elaborated and a pilot batch of silica gel hydrophobized with a complex of various alkyl groups was produced. This silica gel can be used in manufacturing a new generation of shock absorbers for attenuating high



Operation of shock absorber based on a sample of hydrophobized silica gel. The arrows show changes in the system during successive pressure increases and reductions

shock loads, whose operation relies on a significant (up to 25%) reduction of the system volume due to liquid absorption by the porous material in the case of pressure increase.

S.V. Kolotilov, O.V. Shvets

Design of Armored Units for Protective Glazing of Aircraft Cockpits

Scientists of G.S. Pisarenko Institute for Problems of Strength of the NAS of Ukraine were successful in developing innovative technologies and designs of the armored elements of optical structures for protecting windows of aircraft cockpits from sudden ballistic impacts of firearms. The problem is of utmost importance for enhancing crew safety under extreme exploitation conditions in the zone of special operations carried out by internal law enforcement bodies and in the circumstances characteristic of local military conflicts.

In collaboration with the aviation glass plant *Spetstekhsklo A* Ltd., *Antonov* State Enterprise, Arsenal Special Device Production State Enterprise and other plants, Institute's specialists elaborated promising designs of armored protective glazing units for aircraft cockpits and the technologies of producing their strengthening and functional structural elements from durable glass modified in accordance with requirements to its strength characteristics that were recommended by the Institute.

To provide the specified strength, impact resistance and operation life of aviation "transparent armor" units under static loads and shock impacts provided for by the state standard and additional requirements to the ballistic resistance of aircraft cockpit glazing in the case of sudden firearms shots, Institute's researchers developed and used in industrial production a complex of production control methods to determine the resistance to shattering and damaging of glass elements in the form of transparent multilayered composite and hybrid plates.

Armored unit for ballistic protection after positive ballistic tests of СК 3 ДСТУ4546:2006 class

With the engineering support of *Antonov* State Enterprise and aviation glass plant *Spetstekhsklo A* Ltd, special witness samples of modified durable glass were tested, and the enterprise was provided with recommendations towards improving the designs and production technologies of translucent elements used to manufacture the frontal unit of aircraft cockpit glazing for flight and special bench tests.

The development results are also promising for ballistic protection of pilot cockpits; for manufacturing new and upgrading available helicopters at *MOTORSICH* JSC and *AVIACON* Aircraft Repair Plant.

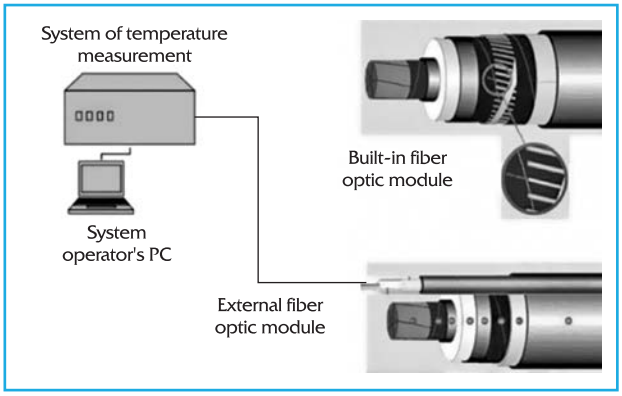
In 2020, the work concerned with producing innovative optical materials and technologies of high-precision shaping and application of highly functional coatings on optical surfaces, which was performed by the research team involving experts of *Arsenal* Special Device Production State Plant and Yu.M. Rodichev, department head at G.S. Pisarenko Institute for Problems of Strength of the NAS of Ukraine, was awarded the Prize of the Cabinet of Ministers of Ukraine for the development and implementation of innovative technologies.

Yu. Rodichev, O.Soroka

Intelligent Technologies for Enhancing Power Supply Reliability in Energy Complexes

Today, the world is faced with the problem of determining the reliability of available high-voltage and ultra-high voltage cables, which depends on the intensity of electrophysical processes of their insulation degradation. The principal methods of diagnosing such processes are to analyze local strengths of the electric field in the insulation and monitor the partial discharges that occur in it.

Scientists of the NAS Institute of Electrodynamics discovered the invariance of the maximum electric field strength in the polymer insulation of power cables at in-



Structure of the system for power cables diagnostics

creased sizes of inserted micro-inclusions of similar shapes and spatial configurations. It was substantiated that under such conditions new electrophysical threshold processes of insulation degradation do not appear, instead, stressed insulation micro-volumes increase, in which, over time, local temperature stochastically rises while their electrical and mechanical strength decreases. In the case of changes in shapes, configurations and an increase in the density of micro-inclusions whose sizes are smaller than permissible, new threshold electrophysical processes of insulation degradation of the partial discharge type may begin.

The discovered conditions of invariance and the difference of electrothermal and threshold processes of polymer insulation degradation are used for developing new tools for diagnosing the condition of power cables and electric power complexes. They rely on the state-of-the-art intelligent fiber optic systems containing a laser emitter and an optical unit connecting them to diagnostics zones. On fiber surfaces in such systems situated are distributed temperature sensors whose signals are transmitted to measurement and transformation modules and then to computer processor devices.

During power cables diagnostics, the effect of temperature on the intensity of signal attenuation is measured, which permits the creation of automated systems of protecting cables of the *SCG* (*Smart Cable Guard*) type that provide control of temporal changes in the level of partial discharges along the cable and ensure the detection of damage on its surface. That is, the intelligent system of cable protection of the *SCG* type is able to not merely control the change in the level of partial discharges but also to determine the exact place of damage and prevent emergency operation modes.

As compared with electronic systems, fiber optic ones have a higher capacity, reliability, durability and the rate of transferring large amounts of information, small signal attenuation at the distances of tens of kilometers, immunity against radio interference, radioactivity and strong magnetic fields. Their high resistance to overheating and to the impact of aggressive environments, as well as small size and weight, significantly facilitate their use.

In 2020, the manufacturing of the aforementioned flexible fiber optic systems, which provide information transfer with the speed of over 10 Gbit/s, was launched at *Pivdenkabel* Plant (Kharkiv). The first supply of this science-intensive product with high added value was exported to France in December 2020.

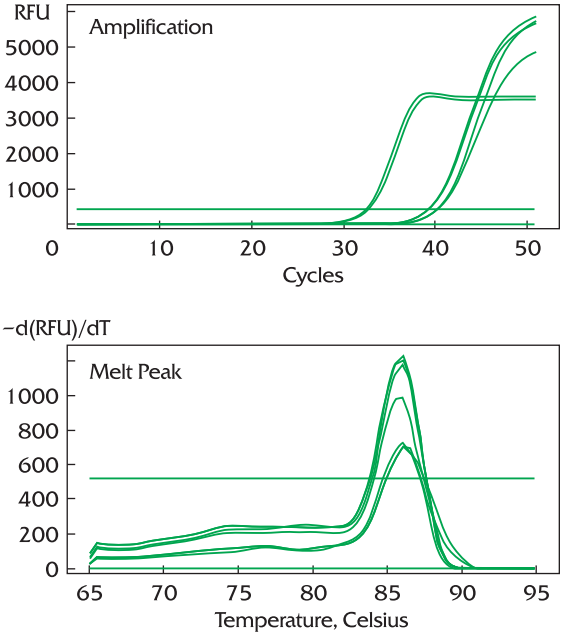
A.A. Shcherba, O.D. Podoltsev, I.M. Kucheriava

Development of the First Ukrainian Assay System for Laboratory Diagnostics of *SARS-CoV-2*

The NAS Institute of Molecular Biology and Genetics, at the request of the National Security and Defense Council of Ukraine of 21 January 2020 #173/14-04/2-20, was engaged in developing the laboratory version of domestic PCR assay system for diagnostics of *SARS-CoV-2* coronavirus, which causes *COVID-19*.

A month later, scientists presented a kit for detecting the new virus, which was developed with reliance on viral cDNA amplification in the sample by using intercalation fluorescent dye *CYBR Green* (*EvaGreen*). In particular, highly specific primers to *N*-protein of *SARS-CoV-2* were selected. A version of the kit with extra primers on the RNA site encoding viral S protein was also developed.

Employing the intercalation fluorescent dye of the *SYBR Green* type enables users to check the presence of



Example of specific sample amplification (above) and curves of amplification products melting (below). Detection: V – SARS-CoV-2; R – beta actin (internal control); control: +K – positive; -K – negative

the specific amplification product by the melting curves and is an additional source of information that confirms test results. In case of any doubts concerning the results obtained, the latter can be proved by sequencing the PCR product.

The assay system for coronavirus *SARS-CoV-2* diagnostics was registered in Ukraine in March 2020, and is a ready-to-use set for quantitative polymerase reaction (qPCR). It contains PCR mixtures with intercalation fluorescent dye *SYBR Green*, highly specific primers to *N*-protein of *SARS-CoV-2* and the reference gene of beta actin, reagents for positive, negative and internal control. The assay system developed is able to detect 30—100 virus copies in a sample.

V.I. Kashuba, N.S. Melnichuk, G.V. Gerashchenko, T.V. Marchyshak, Z.Yu. Tkachuk, M.A. Tukalo

Immunoferment Test System for Monitoring the Level of Anti-Diphtheria Antibodies

Monitoring of the anti-diphtheria immunity status in the population is an important element of comprehensive measures aimed at preventing a new diphtheria epidemic in Ukraine. Hence, the procedure of Immunoferment Analysis (IFA) developed by Palladin Institute of Biochemistry of the NAS of Ukraine, using recombinant *CRM197* to determine antitoxic anti-diphtheria antibodies in human blood serum, is to play a major role in monitoring the status of humoral immunity against diphtheria and evaluating the efficacy of anti-diphtheria prophylactic.

This procedure for determining the level of human anti-diphtheria antitoxic antibodies was elaborated using human blood sera, in particular, those of healthy volunteers with various statuses concerning anti-diphtheria vaccination and pregnant women inoculated with anti-diphtheria vaccine. The developed immunoferment analysis system, which relies on recombinant *CRM197* to determine the level of anti-diphtheria antitoxic antibodies, has no counterparts in Ukraine and is no less effective and economically affordable than the commercial standardized assay system based on diphtheria anatoxin *Diphtheria IgG ELISA produced by Demeditec Diagnostics GmbH* (Germany). The analysis system developed relies not on the reactions of passive hemagglutination but on a more up-to-date quantitative method — the immunoferment analysis. Besides, it uses as antigen not the diphtheria anatoxin but *CRM197* recombinant toxoid, which, retaining the antigen characteristics of the diphtheria toxin, permits a safer production process, since there is no need for cultivating the diphtheria pathogen.

In collaboration with *KHEMA* Ltd (Kyiv), a prototype of immunoferment analysis system that uses recombinant *CRM197* for determining the level of anti-diphtheria antitoxic antibodies in human blood serum was produced.

Prototype assay system using recombinant CRM197 toxoid to determine the level of anti-diphtheria antibodies in humans, developed at Palladin Institute of Biochemistry of the NAS of Ukraine

A draft specification of its production and instruction for using it in compliance with the state standards were developed. There are all reasons to hope that the new analysis system will be successfully used in mass screenings of the anti-diphtheria immunity and in clinical tests of new vaccines against diphtheria.

S.V. Komisarenko, D.V. Kolybo, O.Yu. Galkin, S.I. Romaniuk, A.A. Siromolot, O.I. Krynina, Ya.S. Kulyk

Technologies and Equipment for Diagnostics of Heart Diseases

Scientists of V.M. Glushkov Institute of Cybernetics of the NAS of Ukraine developed and implemented the intelligent information-and-diagnostic magnetometric *SQUID*-sensor technology and equipment (magnetocardiographer) for early diagnostics of the most common heart diseases. Contactless measurements of heart's magnetic field rely on using superconducting quantum interference device (*SQUID* — **S**uperconducting **QU**antum **I**nterference **D**evice) — a super-sensitive magnetometer designed for measuring very weak magnetic fields. The magnetocardiographic (MCG) technology includes new *3D* algorithms and software for visualizing electrophysiological processes in human heart, as well as methods of evaluating the distribution of current density vectors for diagnostics and determining the degree of ischemic heart disease. Magnetocardiographer characteristics (sensitivity and diagnostic criteria specificity, measuring system reliability, its ability to operate in unscreened premises) exceed those of its counterparts in the global market.

The results of testing the produced equipment at the National Military Medical Clinical Center "Main Military Clinical Hospital" and in the academic hospital of Oxford University (*John Radcliffe Hospital*) convincingly showed the high efficacy of the new method of MCG scanning in diagnostics and determining the degree of ischemic heart disease. High sensitivity (93.75%) and

Magnetocardiographic system for diagnostics of ischemic heart disease

Portable software – hardware electrocardiographic complex

specificity (87.10%) of diagnosing, which was achieved even when the patient was at rest, allowed doctors to avoid any complications related to patient's body stress during testing.

Besides, Institute's scientists developed and deployed an innovative portable electro-cardiographic software and hardware system with the software that implements a novel method of scaling the cardiogram and heart rhythm variability, which is able to detect the smallest pathological changes in the electro-cardiographic signal. Owing to the analysis of large amounts of electro-cardiographic data (*ECG Big data*) obtained in Ukraine and received from the researchers of Oxford University epidemiology department, scientists elaborated mathematical models that enabled them to create the technology for determining individual risks of cardiovascular events.

The results of the aforementioned R&D are protected by US and Ukrainian patents. According to the *Innolytics Group* rating (2020), two patents concerning the development of magnetometric technology were included in the list of 10 most valuable inventions of Ukrainian authors.

In 2020, M. Primin and I. Chaykovskyy, scientists of V.M. Glushkov Institute of Cybernetics of the NAS of Ukraine, as members of author's team of the work "Development and deployment of software and hardware for diagnosing cardiovascular diseases and controlling rehabilitation process in the clinic and in the field" received the Prize of the Cabinet of Ministers of Ukraine for the development and deployment of innovative technologies.

М.А. Прімін, І.А. Чайковський, І.В. Недайвода, Ю.Д. Мінов, П.Г. Сутковий

System of Multi-Functional Magnetic Laser Therapy

In connection with combat operations in the east of Ukraine, of special importance are diagnostics and treatment of the injured with gunshot wounds of soft tissues. Lately, procedures involving low-energy laser radiation sources are used for those purposes, which facilitates a better visualization of the wound and the tissues surrounding it, the determination of wound type and damage boundaries. Employing low-intensity pulsed infrared laser radiation and constant magnetic field in combination with photosensitizers and antibiotics in the cases of mine wounds significantly reduces the time of wound cleansing and the appearance of granulations, reduces blood coagulation, accelerates wound epithelization, enhances microflora sensitivity to antibiotics, all of which is of utmost relevance during medical evacuation in the zones of today's local military conflicts.

Researchers of the State Institution "The Institute of Environmental Geochemistry of the NAS of Ukraine" developed and produced photodynamic multi-frequency polywave laser equipment with software-controlled computerized management of the treatment process, which is intended for the treatment of battle wounds and trophic disorders, for the rehabilitation of patients who suffer from battle traumas. The facility is equipped with 10 generators of laser radiation along with a guided scanner with three sources of laser radiation, which permits the simultaneous treatment of seven patients with different pathologies.

The practical value of the laser equipment and efficacious treatment methods is in the increased survival of the wounded and the patients with vascular damage, various defects of soft tissues, as well as a reduced number of amputations and of the people with disability, in faster healing of wounds and ulcers. The employment of

System of multifunctional magnetic laser therapy for the treatment of combat wounds and trophic disorders of the ATO and UFO fighters, and for their rehabilitation

laser technologies enables doctors to provide their patients with a wide range of minimally invasive, virtually painless medical procedures in sterile, safe conditions.

The practical implementation of these research results is carried out in the University clinic of Taras Shevchenko National University of Kyiv. Potential users of the innovative products are military hospitals, treatment and rehabilitation centers for combatants, as well as other medical and health centers.

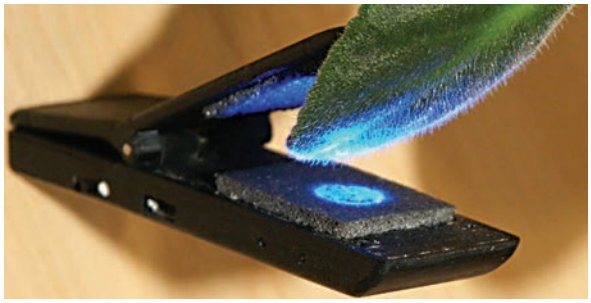
The introduction of the devices for the laser treatment of soft tissue wounds, immunity stimulation by intravenous laser irradiation of blood and thymus into clinical practice would enable doctors to treat the wounded and the sick with soft tissue defects in frontline hospitals and at all stages of medical evacuation.

Yu. Zabulonov, V. Burtnyak, L. Odukalets, O. Arkhipenko, V. Nikolenko

Information Technology for Express Assessment of Plant Condition

One of the major tasks of protecting the megalopolis vegetation, forest parks, gardens and farmlands is the express assessment of the condition of plants on large territories under the action of stress factors. That would permit taking necessary and timely measures to preserve green plants.

Scientists of V.M. Glushkov Institute of Cybernetics of the NAS of Ukraine developed an information technology that provides real-time data on the impacts of stress factors on the condition of plants in the green covers of megalopolises, farmlands, nature reserves and forest parks. "Smart" wireless sensors, united into "smart" sensor networks, determine the intensity of fluorescence and its changes for each plant, which allows the simultaneous assessment of the condition of plants under the action of natural and man-induced stresses on large territories. The technology developed, relying on real-time data on plants condition, enables relevant specialists to take respective managerial decisions for mitigating effects of the factor involved.



"Smart" wireless sensor for determining the condition of plants

The serially produced network elements are deployed in Taiwan in greenhouses with vertical cultivation of fruit and vegetables, and, also, in the Institute of Energy Crops and Sugar Beets, operating under the NAAS of Ukraine, for assessing the impact of stress factors on the condition of sugar beets.

The development is protected by the utility model patent "Device for determining the condition of native chlorophyl" (#141975, O.V. Voronenko, I.B. Galelyuka, V.O. Romanov).

V.O. Romanov

Producing Biologically Active Substances from Seeds by Extraction with Liquefied Gas

Along with current trends towards improving life standards, the requirements to the quality of food and cosmetic products with maximum preservation of their valuable components also rise. One of the most efficient methods of obtaining such products is the extraction of lipophilic biologically active compounds and essential oils with liquefied isobutane gas, since it is non-toxic and chemically inert, while its use requires comparatively low energy consumption.

The State Institution "Institute of Evolutionary Ecology of the NAS of Ukraine", in collaboration with the *Native Oil* company (Odesa) developed a generalized scheme of the technological process of preparing raw material samples, depending on quantitative and qualitative characteristics of plant seeds, the modes and sequence of extraction, filtration and degassing, which is basic for industrial plant seed oil extraction using liquefied gas.

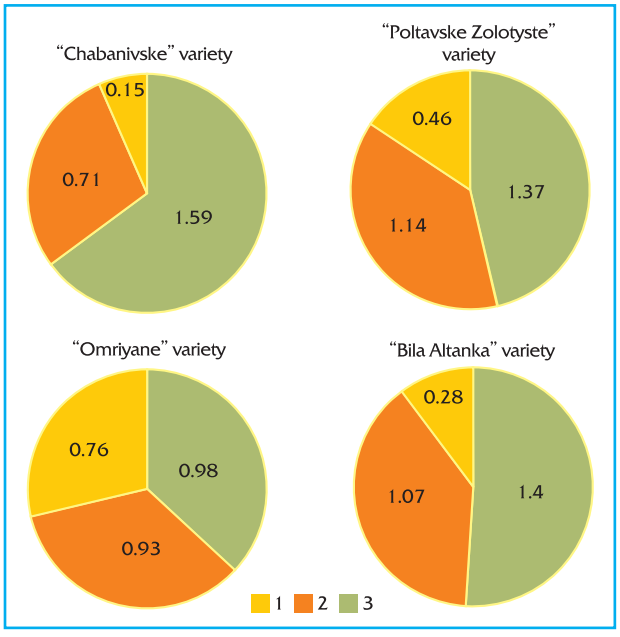
With reliance on the analysis of amaranth and millet seed oils obtained in that way, it was found that in terms of main characteristics their quality meets current standards. It was determined that carotenoid content in the products of seed extraction with liquefied gas makes a positive impact on the quality characteristics of the end product, in particular, its acid and peroxide numbers.

The highest carotenoid content was determined in the oil from seeds of "Bila Altanka" and "Omriyane" millet varieties, the largest amount of miliacin was present in the oil of "Omriyane" (1.3%) and "Poltavske Zolotyste" (1.6%) millet seeds, while the highest content of squalene was in the oil from the seeds of amaranth variety "Lera" (6.8%).

According to the amount of oil obtained from amaranth and millet seeds, the content of chlorophylls and carotenoids, the acid and peroxide numbers, the content of squalene and miliacin, the best varieties were identified and the stages of product obtaining were optimized. The oils of these plants have anti-oxidant and bactericide properties, an anti-tumor effect, are used in the treatment of burns, skin and gastrointestinal diseases.

The recommendations developed were tested in the conditions of small-scale extraction on the production line of the *Native Oil* company. In terms of qualitative biochemical characteristics, these products meet international standards and are competitive on the European market.

Low cost, relative simplicity and safety of the production make them highly relevant and promising. Due to the global trends towards broadening the range of agricultural products and the availability of zoned high-yield domestic varieties of agricultural crops and medicinal plants, the processing of vegetable raw materials is becoming strategically important.



Vegetable oils of the Native Oil company (Ukraine) produced by the technology of liquefied-gas extraction, which was developed in collaboration with scientists of the State Institution "Institute of Evolutionary Ecology" of the NAS of Ukraine

Yield of plant oil from millet seeds after triple extraction (the absolute values of the total oil amount related to the dry mass of vegetable raw material, %)

V.G. Radchenko, R.K. Matyashuk, S.Y. Bilous, A.F. Likhanov, I.K. Teslenko, I.V. Tkachenko, I.V. Sergeyeva

Method of Accelerated Bioremediation of Household Organic Waste Dumps with Biofuel Production

Natural gas and coal are among the most widely used resources in our everyday life and economy. However, industrial development results in an ever-increasing need for their use and dramatic depletion of their reserves. One of alternative sources for generating thermal and electric energy is biomethane, for whose production the processes of organic compounds fermentation are employed.

D.K. Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine developed a method of biological remediation of organic household waste, which was successfully tested on organic waste at a solid waste storage field in the city of Kamianets-Podilskyi (Khmelnytska Oblast). High efficiency of the method was determined — the period of complete organic waste decomposition was 30 days, and the evolution of fuel gases (methane and hydrogen) amounted to 200 m^3 per ton of waste. Using this method and the microbiological preparations in the system of dump gas accumulation and recycling provides a 1.5 time increase in the efficiency of gas accumulation and power generation. It also reduces the project payback period by a year.

In the case of uncontrollable fermentation of organic dump waste, this process is ineffective and is completely suppressed over time. Respectively, methane is not synthesized while the volumes of dumps increase. The rise in the efficiency of dump organic waste fermentation became possible due to recurrent regulation of microbial metabolism and mass transfer, along with solid organic waste shredding.

High efficiency of the decomposition of solid organic waste in 14 days due to its shredding, mass transfer and regulation of microbial metabolism: a – initial waste volume; b – waste after 14 days; reduction in mass by a factor of 27 and energy output of 1 kilogram of waste: 27 l of H_2 and 12 l of CH_4

Relying on the results obtained, Institute's scientists elaborated technological recommendations for improving the efficiency of organic waste destruction in dumps, with producing methane, which can then be converted into electricity. To use the biotechnologies of controllable organic waste fermentation is also a way of future bioremediation of dumps, which would aid in turning environmentally hazardous dumps into economically promising methane hyper tanks of the useful work volume of several cubic kilometers.

O.B. Tashyrev, V.M. Hovorukha, G.V. Gladka, O.A. Havryliuk

Drug Scent Imitations

Scientists of the NAS Institute of Organic Chemistry, in collaboration with experts of the State Research Institute of the Ministry of Internal Affairs of Ukraine and the Cynology Training Department of the National Police of Ukraine, developed imitation scents of drugs: cocaine, heroin, amphetamines, cannabis, poppy straw extract and raw opium. *UKRORGSYNTEZ* R&D Enterprise Ltd produced a pilot batch of scent imitations, whose efficiency was confirmed by the cynological service of the National Police of Ukraine. The developed imitation scents of raw opium and poppy straw extract have no counterparts in the world and had been commercially unavailable earlier. The results of the research work received 6 utility model patents of Ukraine. The production of the "Set of drug scent imitations" was established in collaboration with the State Research Institute of the Ministry of Internal Affairs and with the contribution of *IPO4YOU* company at the *UKRORGSYNTEZ* R&D Enterprise Ltd.

Set of drug scent imitations

This product of Institute's scientists not merely provides the respective units of the National Police of Ukraine with domestic, more affordable, drug scent imitations but also expands the range of such imitations, which, undoubtedly, would produce a positive effect on combating illicit traffic of drugs, in particular, those that make up the current assortment of "street" narcotic drugs.

The results of the research were published in *Nauka ta innovatsii — Science and Innovation* — journal (2020, vol.16, 5, 77—85).

T.M. Sokolenko, L.V. Sokolenko, Yu.L. Yagupolskii

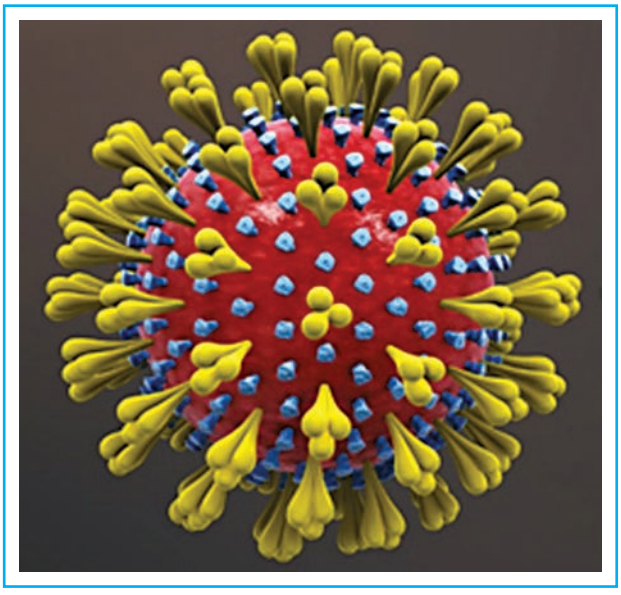
NAS OF UKRAINE IN COUNTER-ACTING *COVID*-19

The epidemic of a new type of coronavirus started in December 2019 in Hubei province and Wuhan city. Along with its spread in other regions of China, the disease began to be detected in other countries. And although China managed to take the disease under control by introducing strict anti-epidemic measures, in other countries, Ukraine in particular, the rate of *COVID*-19 propagation increased.

The National Academy of Sciences of Ukraine did not stay aside from this problem and immediately joined the work towards its solution.

The NAS Institute of Molecular Biology and Genetics, having received the respective task from the National Security and Defense Council of Ukraine, back in February 2020 developed a PCR test system for *COVID*-19 diagnostics. And although, eventually, the governmental order from the Ministry of Health of Ukraine did not arrive, scientists of the institute, at the proposal of the ministry finalized the development of test systems and supplemented them with certain reagents and other components.

In March, the Academy set up the Working Group for the problems (consequences) of the spread of the *SARS-CoV*-2 coronavirus in Ukraine, which was headed by NAS Academician S.V. Komisarenko. Later it was joined by the group performing mathematical simulation of the epidemic-related problems induced by the coronavirus in Ukraine. The group weekly sent its forecasts to respective government departments and publicized them on the NAS website.



Somewhat later, scientific institutions of the NAS of Ukraine started their work on developing domestic vaccines against *SARS-CoV*-2 coronavirus. E.g., this research was organized at the NAS Institute of Cell Biology and Palladin Institute of Biochemistry. That is a difficult and time consuming effort and it is too early to speak about concrete results, but certain progress in this area has already been achieved.

Important studies towards counteracting *COVID*-19 propagation were carried out by scientists of chemical and physical institutions of the NAS of Ukraine. "Research and Production Company DIAPROF-MED Ltd.", involving scientists of D.K. Zabolotny Institute of Microbiology and Virology, developed a number of tests for detecting antibodies in human blood, the so-called immunoferment analysis (IFA) tests. Such assays do not require special equipment, they can be carried out in standard clinical laboratories that are available to nearly every hospital and polyclinic. Besides, they permit a much larger number of daily assays to be performed and enable doctors to identify those who have already recovered and, respectively, cannot be diagnosed with PCR test systems. The enterprise launched the manufacture of such test systems, which are widely used by medical laboratories in Ukraine.

The National Science Center "Kharkov Institute of Physics and Technology" and "RADMA" State Enterprise, operating within L.V. Pisarzhevsky Institute of Physical Chemistry of the NAS of Ukraine, under the orders of manufacturers, carry out radiation sterilization of over 500 items of medical products — bandages, applique bandages, protective face masks, surgical drapes, suture materials, pharmaceutical products, systems for infusing medicinal solutions and blood transfusion, syringes etc. This method of industrial sterilization is up-to-date and safe for users and the environment. These Academy institutions provide the treatment of over 60% of all Ukrainian-made products that require radiation sterilization.

Scientists of the Institute of Plasma Physics of the NSC "Kharkov Institute of Physics and Technology" developed ozonators that were scrutinized to determine their effect on various microorganisms, tested in hospitals for infectious diseases and have been implemented in production, however, at a small-scale as yet. Plasma ozone generators are used to disinfect premises, ambulances, hospitals, public transport etc.

PILOT PROJECT OF SCIENTIFIC RESEARCH FUNDING

In 2020, the budget-funded program 6541230 "Support to developing priority areas of scientific research" was continued. It implements a new model of funding, which widely uses the results of evaluating the efficiency of the scientific institution work and competitive principles to identify priority research projects that are of importance for science and society. The program is aimed at providing targeted support to the scientific teams that carry out research of international quality, in particular, to the teams of young scientists, collaborative international projects, as well as procuring state-of-the-art equipment for these investigations.

Four directions of allocating budget finance were chosen. Within the first direction — "Support of scientific studies and R&D (experimental) works of top priority for the state", funding was provided for scientific subdivisions that received the highest estimates according to the results of evaluating the efficiency of their activities (category A). In total, 407 scientific subdivisions of NAS institutions were provided funding for implementing 173 projects (146 projects in basic science and 27 projects in applied research) — the total of ₴ 298.3 million.

Within the second direction — "Conducting R&D by young scientists through setting up, on the competitive principles, laboratories (groups) of young scientists" were organized. According to the 2020 contest, 36 teams of young scientists were set up: 9 research laboratories and 27 research groups. The research is to be carried out in 2020-2021. The total annual budget of youth laboratories/groups amounted to ₴ 21.2 million. The results of the research conducted by young scientists were published in 219 scientific papers, 87 of those — in foreign professional periodicals. They were also presented to broad scientific community at 137 conferences and workshops.

Within the third direction — "Conducting competitive joint international scientific research", financial support was allocated to the projects selected through joint contests of the NAS of Ukraine and the NAS of Belarus (research was started under 15 new projects), as well as those of the NAS of Ukraine and the National Centre for Scientific Research of France (*CNRS*) (3 projects). The total funding of these projects amounted to ₴ 4.0 million. The notable feature of these contests is that respective applications get independent parallel expert assessment of contest organizers, and the winners are funded according to the principle: each side finances its part of the work. The research results obtained during the year were presented in 36 works published in professional editions, of which 17 were published in international journals. Besides, 2 patent applications were submitted. Scientific achievements were also presented at 38 conferences, including 16 foreign forums.

Within the fourth direction — "Procurement of new state-of-the-art equipment and upgrading the available facilities", 35 NAS institutions were provided with earmarked funds of ₴ 33.739 million for the procurement of scientific equipment and accessories necessary for implementing the research projects supported within other directions of budget-supported program 6541230. ₴ 27.083 million were capital expenditures channeled to the procurement and upgrading of research equipment, while ₴ 5.656 were allocated as running costs channeled for the repair of 12 scientific facilities and instruments. Procured with the funding of the abovementioned budget-provided finance were: laser *DxFLEX* flow cytometer, *AMI*-300Lite automated system for determining catalyst characteristics, *Burehler VibroMet* 2 vibration polisher, Photron *FASTCAM NOVA* S9 — a system for microwave digestion of samples etc.

INTERNATIONAL COLLABORATION IN THE FACE OF PRESENT-DAY CHALLENGES

Last year was a year of challenges and trials for scientists of the entire world, rather difficult for organizing international cooperation. It significantly changed the habitual frameworks of international collaboration due to strict limitations on travels between countries, which resulted in cancelling both the visits of scientists and numerous public events. Despite such objective limitations, the National Academy of Sciences of Ukraine introduced new forms of collaboration with foreign partners, in particular those relying on the present-day remote work tools.

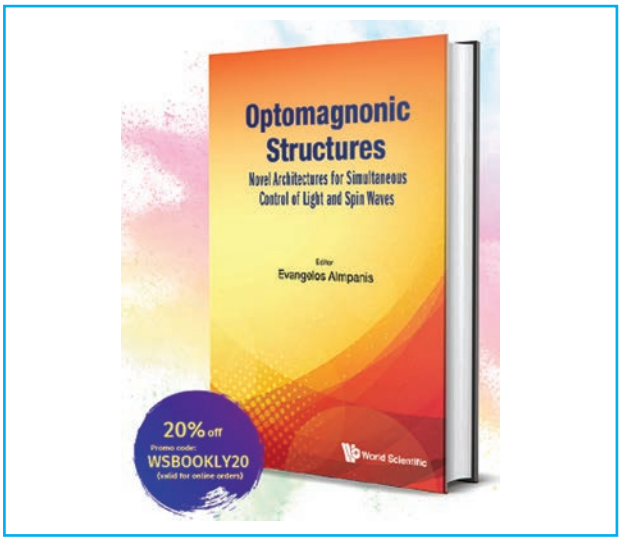
An important step in integrating into the European research space was the accession to the recently established **European Open Science Cloud (EOSC)**, where Ukraine is represented by Bogolyubov Institute for Theoretical Physics of the NAS of Ukraine. The participation in the international organization of digital platforms and infrastructures provides for Ukrainian structures (from scientific proper to business ones) the access to using all respective instruments and services.

Of considerable importance are strategic documents of influential international organizations elaborated with the contribution of Ukrainian scientists. The open session of the Council of the European Organization for Nuclear Research (CERN), attended by the heads of the academic program for high energy physics, declared an **update of the European Strategy in Particle Physics**. That was the result of nearly two years of preparatory work led by the European Strategic Group involving the representatives of CERN member states and associate members, observers in the CERN Council and directors of large national laboratories in Europe. The document presented the scientific vision of the community of elementary particle physicists in Europe and covered two top-priority future initiatives: "Electron–positron 'Higgs factory'" and "Feasibility study for a next-generation proton–proton collider with the energy of nearly 100 TeV", which would exceed the energy achieved in the Large Hadron Collider by a factor of 7.

The holding of one of the most ambitious scientific forums — **the 8th International Scientific and Practical Conference "Nanotechnologies and Nanomaterials" (NANO–2020)** was a successful combination of the traditional format of international scientific events and the employment of on-line broadcast on the Zoom platform and through the *YouTube* channel. The conference was organized by the NAS Institute of Physics jointly with the National University "Lvivska Politechnika", the Universities of Turin (Italy), Pierre and Marie Curie (France), Tartu (Estonia), and the Agency of the Polish Academy of Sciences in Kyiv with the support of the *EEN-Ukraine* Consortium. It was attended off-line by nearly 100 Ukrainian scientists and leading scholars of 20 countries, while the conference was watched by over 1500 users. The zest of the event was the on-line speech of Roald Hoffmann, 1981 Nobel Laureate in chemistry, professor of Cornell University (USA). The conference also hosted the Information Session of *Horizon*-2020 and *COSME* programs, as well as *Virtual NANO*–2020 event promoting innovation support and international cooperation.

Significant results were obtained during the implementation of projects under **EU *Horizon*-2020 Program and its Euratom complementary program. *EUROfusion* Consortium**, which consisted of 30 scientific organizations of EU member states and associate countries, and where Kharkov Institute of Physics and Technology as the Ukrainian participant of the project united the potentials of 3 NAS institutions and 3 leading Ukrainian universities, carried out a number of investigations under the thermonuclear research project; it was supported by the national programs of consortium members. That provided an opportunity of taking part in joint theoretical and experimental research employing powerful facilities: tokamaks, stellarators and plasma accelerators, and of professional training of the next generation of researchers in this extremely important field. With reliance on the results of basic research in plasma physics, a number of important applied developments were elaborated as well: novel methods of applying functional coatings, materials modification with plasma flows, environmentally safe plasma technologies for industry, medicine, environment protection etc.

The implementation of the project **"MagIC – Magnonics, Interactions and Complexity: multifunctional aspects of spin wave dynamics" of the EU program "Horizon–2020" according to the MSCA-RISE scheme of academic exchanges** was completed. In the framework of this project, scientists of O.O. Galkin Institute for Physics and Engineering of Donetsk, the Institute of Magnetism of the NAS of Ukraine and the MES of Ukraine, Vasyl Stus National University of Donetsk, V.N. Karazin National University of Kharkiv, Igor Sikorsky Polytechnic Institute of Kyiv, in collaboration with their European partners from Adam Mickiewich University (Poznan, Poland), the universities of Exeter (Great Britain), San Sebastian (Basque Country, Spain) investigated the propagation of spin waves (fluctuations of magnetization) and electromagnetic waves in magnonic crystals — man-made periodic structures composed of at least two materials with



Monograph based on the results of MagIC project

Signing of the Memorandum of Collaboration in cross-border cooperation by the leaders of the Institute of Economic and Legal Research of the NAS of Ukraine, the Department of Law of Uzhhorod National University and CESCI in the presence of the Consul General of Hungary in Uzhhorod

different magnetic properties. Magnonic crystals are promising media for a new generation of devices for saving and transmitting information. Several dozen articles in leading professional journals and a chapter in the collective monograph were published using the results of research under the *MagIC* project.

Extending the projects of transborder collaboration is of importance for dealing with the issues of the regional development of Ukraine and it conforms to the main principles of the European Neighborhood Policy. Scientists of V.K. Mamutov Institute of Economic and Legal Research of the National Academy of Sciences of Ukraine and its Center for Prospective Studies and Collaboration in Human Rights in the Sphere of Economy took part in such projects. They joined the Consortium within the project **"Development of Cross-Border Collaboration for Europeanization of Ukrainian Borders"** of the Visegrad Fund, which also involves Central Europe Service for Cross-Border Initiatives (CESCI, Hungary), academy institutions of the Visegrad Group states — Poland, Slovakia, the Czech Republic, Hungary. The International Workshop for the legislative provision, current status, challenges and prospects of developing the cross-border cooperation between Ukraine and member states stressed the importance of cross-border collaboration in the framework of the new policy of the EU Eastern Partnership. The workshop was attended by representatives of the Polish Academy of Sciences, the Association of European Border Regions and the Slovak Foreign Policy Association, the EC Directorate-General for Neighborhood and Enlargement. It outlined peculiarities of the Visegrad countries Europeanization through cross-border cooperation over the recent 15 years and the necessity to determine the needs for improving the relevant legislation, enhancing the competences and abilities of the central authorities, local government bodies and other Ukrainian subjects of cross-border cooperation.

Scientists of the NAS Institute for Market Problems and Economic and Ecological Research acquired the widest experience of cross-border cooperation due to their involvement in seven projects under Interreg programs for the Danube Region countries and the countries of the Black Sea Basin. The Memorandum on Collaboration in the sphere of scientific, business and social activities between this Institute and Ankara University (Turkey), which was signed on 21 February 2020 by Salik Kai, professor of the University, during his visit to the Institute, is to play an important role in extending collaboration with institutions and organizations of Turkey. The program of professor Salik Kai's visit included his open lecture "New investment opportunities of the economy real sector for Turkey and Ukraine", communication with representatives of scientific and business communities, as well as a tour of business infrastructure of the Odesa Oblast. During those meetings, they achieved agreements on the academic exchanges between Ukrainian scientific institutions and the Turkish University, accreditation of Ukrainian institutions of higher education in the Turkish Ministry of Education. Also discussed was the potential for attracting foreign investments to Odesa Oblast enterprises and concrete future scientific projects.

SCIENCE AND SOCIETY

The proper informing of the public about the achievements, significant results of scientific, R&D and innovative activities of NAS scientists is an important area of Academy's work. Over the recent years, it has continuously searched for new, better forms of supporting and deepening the ties between the scientific community and the society.

Scientists of numerous Academy institutions are active promoters of and participants in educational events and actions involving broad circles of public. The NAS of Ukraine is an organizer and co-organizer of numerous exhibitions, where it demonstrates the results of its research. In 2020, much effort went into the widest possible presentation, through various mass media, of the outcomes of Academy's work, as well as of the resonant scientific events taking place in the NAS of Ukraine and generating public interest. Besides, many leading scientists of the Academy take pro-active civic stand, carry out educational work, form scientific outlook, denounce pseudo-scientific theories by expressing their ideas in blogs on various Internet sites, publishing articles in mass media and placing information in social networks etc.

Unfortunately, last year the pandemic of coronavirus disease made adjustments in Academy's efforts towards popularizing science. The quarantine restrictions imposed in Ukraine made scientists postpone public events or change their format.

The science popularization activities of the largest scale — the All-Ukraine Science Festival, which is traditionally held in May, had to be put off till the next year. Another grandiose project for popularizing science, which had been launched by young scientists of the National Academy of Sciences of Ukraine, — "Science Days"— did not take place last year due to sanitary and epidemiological measures introduced in the country.

At the same time, *COVID*-19 made us look for new opportunities and broadly use on-line communication facilities.

E.g., the Brain Awareness Week, which is annually held in many places across the planet to inform the society on research in neurosciences and examine the structure and functioning of human brain, was held online. Every day, online events involving Academy scientists took place in the framework of this global popular-science campaign.

A number of activities were held by Academy institutions on the occasion of the Mathematics Year, which was announced by the President of Ukraine to draw attention of the whole society to enhancing mathematical literacy.

During the quarantine, the State Natural History Museum of the NAS of Ukraine (Lviv) invited all those willing to watch the exhibitions "Glacial Epoch: Return of Mammoth to Lviv" and "Symphony of Life" in virtual tours. And the National Scientific Museum of Natural History of the NAS of Ukraine (Kyiv) offered online excursions on its *YouTube* channel.

The lectures of NAS scientists continued to be delivered online. Among the most interesting were the cycles of online lectures within projects "Real science", "Scientific meetings", "Palladin Lecture Series".

The most prominent event of the year was the launch of the first interactive area "Museum of Science" by the Junior Academy of Sciences of Ukraine in the Science Pavilion at the Exhibition of National Achievements. The museum holds over 120 interactive exhibits and

Excursion to old Vyshhorod in the framework of archeological lecture series "What archeology tells us about", provided by the Archeological Museum of the NAS Institute of Archeology

Street exhibition "Ordered to be ignorant: Ukrainian archeologists in the grip of totalitarianism" in Kyiv (materials for the exhibition were provided by 6 NAS institutions)

Integrated lesson of mathematics for schoolchildren of 2nd form of Secondary School № 10 of Sloviansk Town in Donetska Oblast, held in the framework of the Year of Mathematics in Ukraine. The lesson was organized by PhD Yevhenia Savelieva (The NAS Institute of Applied Mathematics and Mechanics)

"Festival of Constructivism" on the territory of Museum Site "Ukrainian Institute of Science and Technology. Kharkiv" of the Kharkiv Institute of Physics and Technology of the NAS of Ukraine

Science Museum of the Junior Academy of Sciences of Ukraine

installations brought from various countries — there one can ride a bicycle with square-shaped wheels, set out in a space travel, see a 2-meter hologram and a 60-kilogram crystal, make up water and salt from atoms in the augmented reality, and get an insight into the functioning of human body.

In the previous year, NAS scientists continued their close collaboration with Ukrainian media, in particular, with TV channels *UA: Pershyi, Rada, Priamyi, Inter, 5 Kanal, TRK Kyiv, Espreso, Ukraina 24, ATR, Internet channels Hromadske Telebachennia, Ya-UA, UKRLIFE.TV,*

Nana Voitenko, Sci. Dr. (Biol.), (Left) and Victor Dosenko, Sci. Dr. (Med.) – researchers of Bogomoletz Institute of Physiology of the NAS of Ukraine – in "Doctor knows" program of Kyiv TV channel

radio stations *UA: Ukrainske Radio* (*Pershyi Kanal Ukrainskoho Radio, Promin, Kultura*), *Hromadske Radio, Radio Svoboda, Radio NV, Holos Stolytsi*. Going on was Academy co-operation with printed periodicals: *Den, Holos Ukrainy, Uriadovyi Kurier, Ukraina Moloda, Svit, Demokratychna Ukraina, Ukrainske Slovo, Ukrainskyi Tyzhden, Kraina, Siohodni, Fakty, Hazeta 2000, Expres, Kunscht* popular-science magazine, as well as electronic resources *Dzerkalo Tyzhnia, Ukrainska Pravda, Livyi Bereh, Apostrof, Glavred, Rubryka, Siohodni, Fokus, The Village Ukraina, Obozrevatel, UKRINFORM* Information Agency etc.

To raise the level of public activity of the NAS of Ukraine, establish effective mechanisms of scientific community communication with the society, inform the general public on Academy's role in dealing with important nation-wide challenges, promote the popularity of scientific activities in Ukraine, early in November 2020 NAS Presidium set up the Commission for Communication with the Society and Popularizing Scientific Activities. Its principal tasks are to enhance the communication actions of the Academy and its institutions in the information space; to form the positive image of the Academy; to extend the use of available channels of delivering information to the general public for showing the role of science in today's world, presenting the activities, achievements and problems of the Academy; to prepare proposals on upgrading Academy's Web site and Web sites of its institutions; to establish systemic co-operation of the Academy with mass media; to facilitate the introduction and development of varied forms of popularizing science with the involvement of Academy's scientists.

The Commission has already started its active work and prepared proposals towards enhancing the communication activity of the Academy, forming its positive image.

PUBLIC RECOGNITION OF NAS SCIENTISTS' ACHIEVEMENTS

NAS Academician L.I. Anatychuk and Prof. Yu.M. Gryn, Director of Max Plank Institute for Chemical Physics of Solids (Dresden), were awarded with V.I. Vernadsky Gold Medal of the NAS of Ukraine for their outstanding achievements in the field of thermoelectric materials science.

In 2020, 17 employees of NAS institutions, organizations and enterprises were honored with state awards of Ukraine. Awarded for their personal contribution to the state upbuilding, socio-economic, S&T, cultural and educational development of Ukraine, significant labor achievements, conscientious work were:

NAS Academician A.G. Naumovets, First Vice-President of the NAS of Ukraine, — with Order of Prince Yaroslav the Wise 2nd Class;

NAS Corresponding Member V.I. Tsymbaliuk, member of NAS Presidium, — with Order of Prince Yaroslav the Wise 5th Class;

NAS Corresponding Member V.L. Mazur, Chief Research Associate of the NAS Physico-Technological Institute of Metals and Alloys of the NAS of Ukraine, — with Order "Of Merit" 1st Class;

NAS Academician I.M. Mryglod, Director of the NAS Institute for Condensed Matter Physics, and NAS Corresponding Member V.A. Ustymenko, Director of V. Mamutov Institute of Economic and Legal Research of the NAS of Ukraine, — with Order "Of Merit" 3rd Class.

Awarded for their considerable personal contribution to the advancement of Ukrainian science, strengthening S&T potential of Ukraine, conscientious work of many years and high professionalism were:

NAS Academician O.M. Ponomarenko, Academician-Secretary of the NAS Department of Earth Sciences, Director of M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the NAS of Ukraine, — with Order of Prince Yaroslav the Wise 5th Class;

V.K. Taradii, Director of the International Center for Astronomical and Medico-Biological Research of the NAS of Ukraine, — with Order 'Of Merit' 2nd Class;

Ya.V. Vermenych, department head of the NAS Institute of the History of Ukraine, — with Order of Princess Olga 3rd Class.

For a considerable personal contribution to state establishment, strengthening national security, socio-economic, S&T, cultural and educational progress of the Ukrainian state, considerable labor achievements, conscientious work of many years, awarded were:

NAS Academician O.V. Kyrylenko, Academician-Secretary of the NAS Department of Physical and Technological Problems of Power Engineering, Director of the NAS Institute of Electrodynamics, and NAS Academician V.V. Petrov, Director of the NAS Institute for Information Recording, — with Order of Prince Yaroslav the Wise 5th Class;

NAS Academician V.F. Chekhun, Director of R.E. Kavetsky Institute of Experimental Pathology, Oncology and Radiobiology of the NAS of Ukraine, — with Order "Of Merit" 1st Class;

NAS Corresponding Member L.A. Dubrovina, Director General of V.I. Vernadsky National Library of Ukraine, I.M. Todurov, Director of the State Scientific Institution 'Center for Innovative Medical Technologies', NAS Corresponding Member O.M. Trofymchuk, Director of the NAS Institute of Telecommunications and Global Information Space, — with Order "For Merit" 3rd Class.

For a significant personal contribution to the state upbuilding, socio-economic, S&T, cultural and educational progress of Ukraine, considerable labor achievements and high professionalism, NAS Academician I.R. Yukhnovsky, People's Deputy of Ukraine of I–IV convocations, Advisor to NAS Presidium, was awarded with Order of Prince Yaroslav the Wise 3rd Class.

For a considerable personal contribution to the development of forestry in Ukraine, renewal and conservation of state-owned forests, courage and professionalism shown during the liquidation of a fire on the territory of the Exclusion Zone and the Zone of Unconditional (Mandatory) Resettlement, selfless work of many years, S.M. Stoyko, Principal Research Associate of the NAS Institute of Ecology of the Carpathians, Academician of the Forestry Academy of Ukraine, was awarded with Order of Prince Yaroslav the Wise 5th Class.

For a significant personal contribution to the development of national education, training of highly qualified specialists, fruitful pedagogical work and high professionalism, NAS Corresponding Member M.O. Kyzym, First Deputy Minister of Education and Science, was awarded with Order "Of Merit" 2nd Class.

Honorary titles "Merited Figure of Science and Technology" were granted to five scientists, "Merited Inventor"— to one scientist, "Merited Jurist" — to one scientist, "Merited Culture Worker" — to one person, "Merited Doctor of Ukraine" — to two scientists.

The State Prize in Science and Technology of Ukraine was awarded to 6 NAS scientists for the work "Structure and interaction of atomic nuclei in elastic, inelastic and radioactive processes"; for the work "Novel methods of mathematical simulation of complex processes and systems, based on high-efficiency calculations" — to 5; for the work "Ensuring functional security of critical information and control systems" — to 2; for the work "Lithos-

phere deep structure and seismic hazard of the territory of Ukraine" — to 7; for the work "Development of rotors for high power turbines" — to 2; for the work "Scientific fundamentals of the innovative technologies of anthracite substitution in heat power engineering and their implementation" — to 4; for the work "Obtaining polymer materials and structures made of them under the action of physical fields" — to 3; for the work "Highly selective methods of synthesizing heterocyclic compounds for developing functional materials components and producing new medical agents" — to 5 researchers.

7 Academy researchers became the winners of the Cabinet of Ministers Prize for "The development and implementation of innovative technologies", 39 researchers — of the Prize of the President of Ukraine for young scientists, 16 researchers won the Verkhovna Rada Prize for young scientists.

For a considerable personal contribution to the development of national science, fruitful science management, conscientious work of many years and high professionalism, 2 NAS employees received Certificates of Honor of the Verkhovna Rada of Ukraine and 1 employee — the Certificate of Honor of the Cabinet of Ministers of Ukraine.

54 researchers won NAS prizes named after prominent Ukrainian scientists and scholars.

NAS Corresponding Member Elisabeth Kordyum, head of cell biology and anatomy department of M.G. Kholodny Institute of Botany, the founder of the scientific school in space biology, was included in the Hall of Fame of the International Astronautical Federation for her personal contribution to the development of world astronautics.

Academician Anatolii Zagorodny, President of the NAS of Ukraine, was conferred the title of Honorary Scholar of the Institute for Applied Systems Analysis (*IIASA*) for his significant contribution to the work of the Council of this international scientific institution, where he represented Ukraine since November 2011, to acknowledge his distinguished service aimed at strengthening ties between *IIASA* and Ukrainian scientific and political community, as well as to express the gratitude for his constant support and personal allegiance with *IIASA* ideals and goals.

Maria Rybak, PhD, researcher of the department of protein synthesis enzymology at the NAS Institute of Molecular Biology and Genetics, was honored with the Prize of Kostyuk Foundation. This prize was founded by the disciples of Academician Platon Kostyuk (1924-2010), world-renowned Ukrainian biophysicist and neurobiologist. It is traditionally awarded to young scientists who carry out biomedical research in Ukraine.

Olena Vaneyeva, senior research associate of mathematical physics department of the NAS Institute of Mathematics, was awarded with the National Prize "Woman of Ukraine" in "Science" nomination. The Prize was established by Edipress Ukraine media holding to recognize

Olena Vaneyeva, senior research associate of mathematical physics department of the NAS Institute of Mathematics, the winner of 'Woman of Ukraine' prize in "Science" nomination (Left)

In the framework of the 2nd Annual Conference Women in Nuclear Ukraine, Tamara Kuznetsova, employee of NSC Kharkov Institute of Physics and Technology, receives WiN Ukraine Award from Igor Garbaruk, Deputy Minister of Education and Science of Ukraine (Right)

the role of women in all spheres of the present-day Ukrainian society and enhance the self-realization of women.

The winners of the 3rd Ukrainian *L'ORÉAL–UNESCO* Prize "For Women in Science" were Olga Kopach, Doctor of Science (Biology), Senior Research Associate of Bogomoletz Institute of Physiology of the NAS of Ukraine, and Marina Nesterenko, PhD, Senior Research Associate of the mathematical physics department of the NAS Institute of Mathematics.

Tamara Kuznetsova, the head of the physical protection department of the NSC "Kharkov Institute of Physics and Technology" of the NAS of Ukraine, won the *WiN Award Ukraine* of the global network of non-commercial organizations *Women in Nuclear Global*, intended for women who made a considerable contribution to the development of Ukrainian nuclear industry, in the "Woman Professional" category.

Last year, R.E. Kavetsky Institute of Experimental Pathophysiology, Oncology and Radiobiology of the NAS of Ukraine received the Scopus Award Ukraine Prize in the "Best Journal" nomination for publishing *Experimental Oncology* journal.

209 people were awarded with NAS honors: "For Scientific Achievements" — 35 employees, "For Training Young Scientists" — 48, "For Professional Accomplishments" — 92, "For Promoting Science Advancement" — 12, with "Talent, Inspiration, Work" prize for young scientists — 22.

103 people and labor collectives received NAS acknowledgements.

77 people and labor collectives were awarded with certificates of honor by NAS Presidium and the Central Committee of NAS Trade Unions.

BACKGROUND INFOFMATION. 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. Research-and-production organizations (design offices, pilot production facilities etc.) operate within some scientific institutions. 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, cell banks, 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 National Scientific Library of Lviv
- 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),
- Prydniprovskyi Science Center (Dnipro),

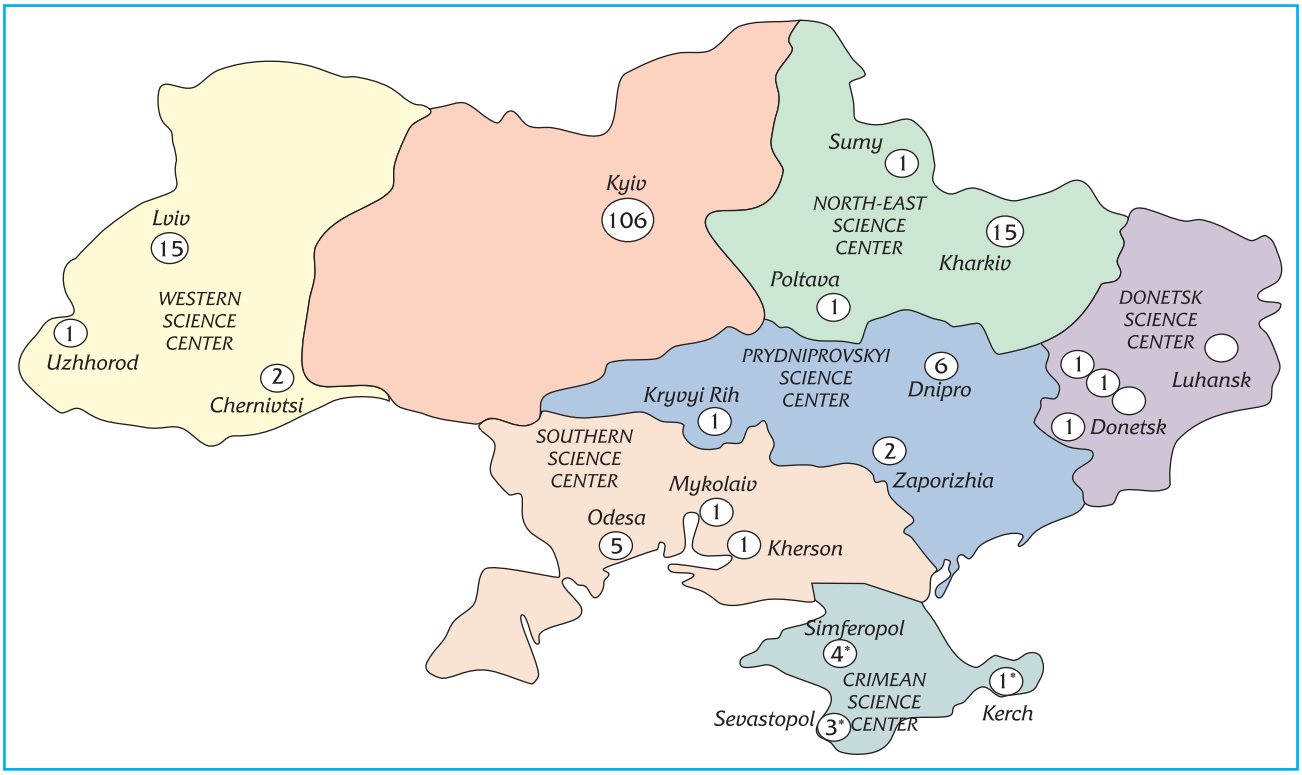
as well as the Center for Evaluating Research Institutions and Scientific Support to Regional Development (Kyiv).

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

DISTRIBUTION OF INSTITUTIONS ACROSS SECTIONS AND DEPARTMENTS

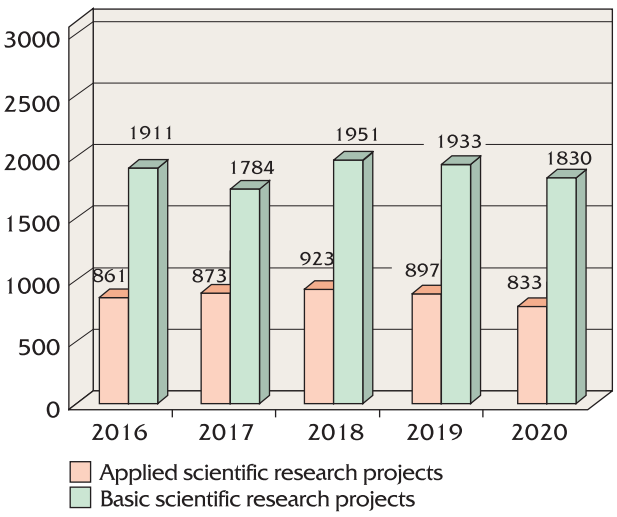
Department	The number of scientific institutions	The number of R&D organizations	Objects with the National Asset status	Centers of the shared use of equipment
CeSection of Physical, Engineering and Mathematical Sciences				
Mathematics	4	—	—	—
Informatics	8	—	—	1
Mechanics	6	3	3	3
Physics and Astronomy	16	2	8	14
Earth Sciences	15	1	1	5
Physical & Engineering Problems of Materials Sciences	11	19	1	12
Physical & Technological Problems of Energy Engineering	11	1	2	4
Nuclear Physics & Energy Engineering	6	2	2	4
Section of Chemical and Biological Sciences				
Chemistry	13	6	—	11
Biochemistry, Physiology & Molecular Biology	8	2	5	9
General Biology	22	1	19	14
Section of Social Sciences and Humanities				
Economics	9	—	—	—
History, Philosophy & Law	15	3	5	—
Literature, Language & Art Criticism	9	—	4	—

Regional structure of the NAS of Ukraine

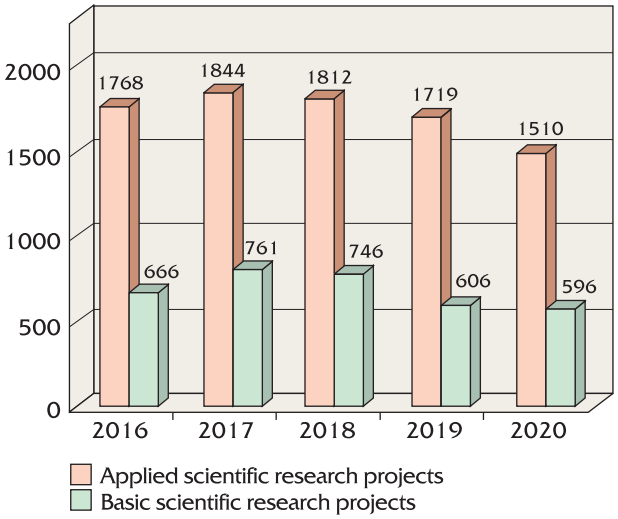


The figures in the map show the number of research institutions
** The status of NAS institutions located in the Autonomous Republic of Crimea is defined by the Law of Ukraine "On guaranteeing the rights and freedoms of citizens and legal regime on the temporarily occupied territories of Ukraine"*

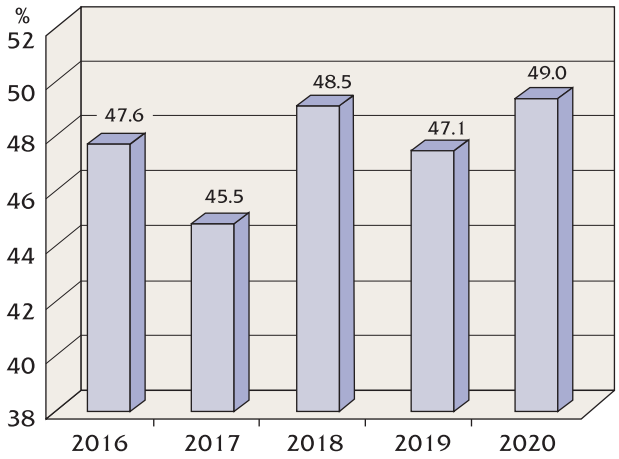
Conducting scientific research



The number of implemented research projects financed from 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

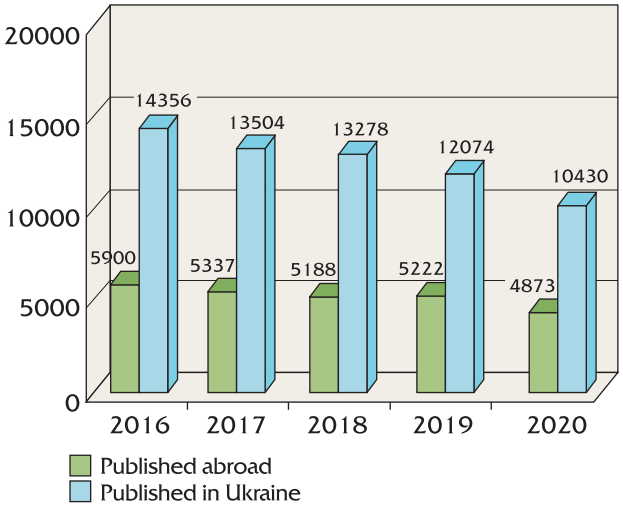
Targeted-program and contest-based research projects of the NAS of Ukraine in 2020 involved the research conducted under:

- 8 NAS targeted programs of basic research;
- 15 NAS targeted programs of applied research;
- 2 separate targeted projects;
- 15 research programs of NAS departments;

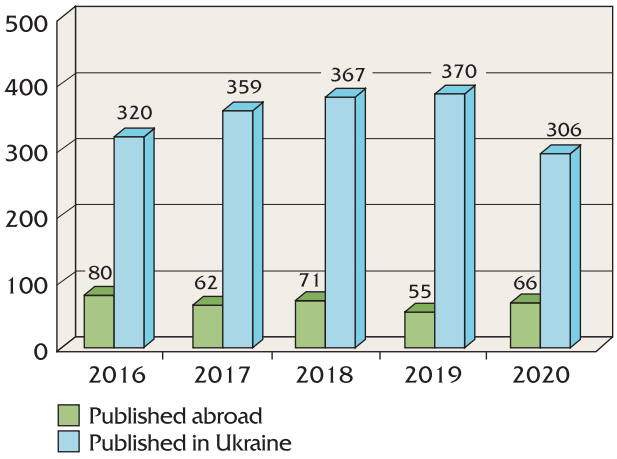
and were based on the results of:

- joint contests with foreign and international organizations;
- a contest of S&T (innovation) projects;
- a contest of scientific and S&T projects implemented in the area 'Support to scientific and S&T (experimental) developments that are of top priority for the state;
- a contest of research projects in socio-humanities;
- contests of research projects of young scientists of the NAS of Ukraine.

Publication activity



The number of papers by NAS scientists in periodicals



The number of scientific monographs

Publishing activities

- **the total number of Academy journals:**

86 scientific journals, 1 popular-science journal (*Svitohliad — Worldvision*), and *Dzherelo* abstract journal 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

- **16 journals are published in English abroad:**

by Springer Publishers

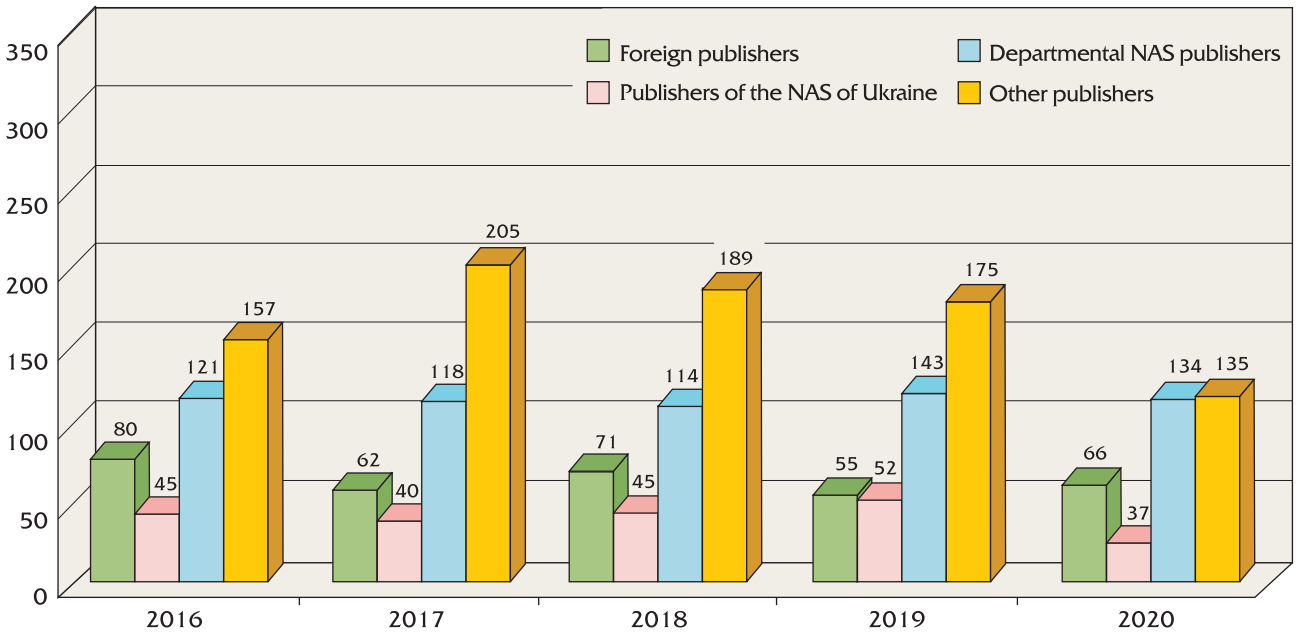
1. Ukrainian Mathematical Journal
2. Cybernetics and Systems Analysis
3. International Applied Mechanics
4. Strength of Materials
5. Materials Science
6. Theoretical and Experimental Chemistry
7. Neurophysiology

by Allerton Press 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. International Journal on Algae



Distribution of scientific monographs across groups of publishers

3. Hydrobiological Journal
4. International Journal of Physiology and Pathophysiology

by other publishers

1. Low Temperature Physics (American Institute of Physics)

Scientific expertise

In 2020, NAS experts were involved in preparing:

- Strategy of the national security of Ukraine;
- Strategy of the economic security of Ukraine;
- Strategy of the development of Defense and Security Sector;
- Strategy of food security till 2030;
- Strategy of Economic Reconstruction of Donbas;
- Annual report to the President of Ukraine, Verkhovna Rada and the Cabinet of Ministers of Ukraine on the situation of youth in Ukraine

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

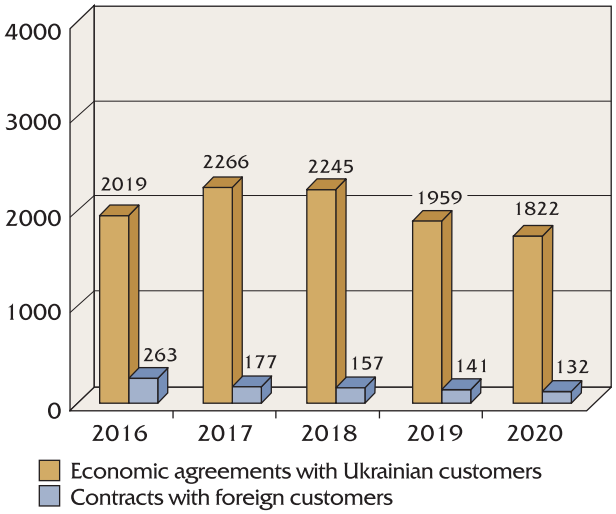
- On introducing amendments to the Law of Ukraine "On Scientific and S&T activities";
- On introducing amendments to the Law of Ukraine "On higher education";
- On electronic communications;
- On the list of non-privatized state property objects;
- On introducing amendments to the Tax Code of Ukraine concerning the balancing of budget receipts;

Expert conclusions	2016	2017	2018	2019	2020
Concerning normative legal acts and program documents, information and analytical materials on various issues of socio-economic development provided for state power bodies	2160	2200	2320	2330	1850
Concerning the expediency of funding basic research projects from the State Budget	606	393	378	428	1081

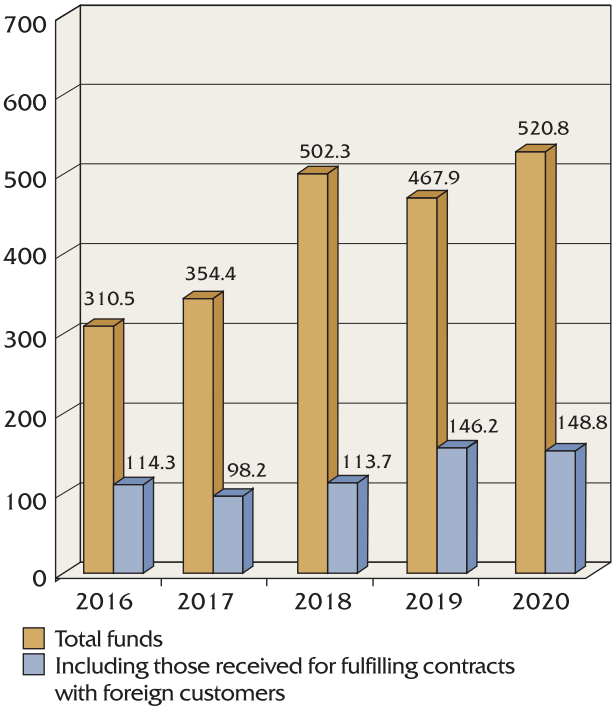
• On introducing amendments to certain legislation acts on ensuring the right of the workers of state-owned and municipal agricultural enterprises, institutions and organization for receiving a land share;

• On introducing changes to some legislative acts of Ukraine concerning the acquisition, exercising and protection of intellectual property rights.

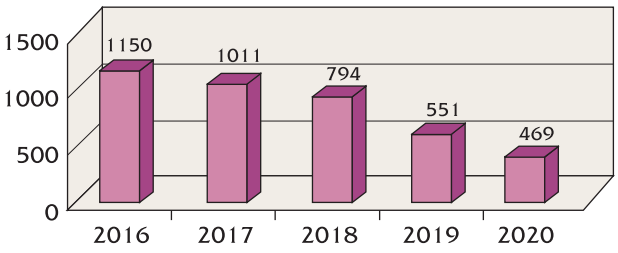
Innovation activities



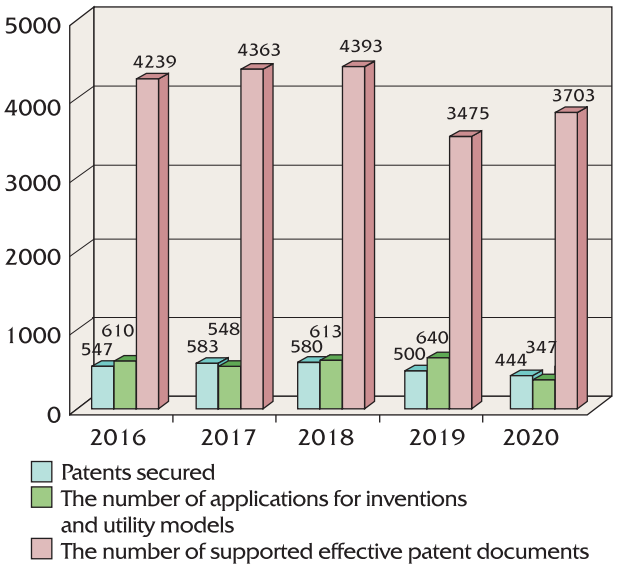
The number of economic agreements and contracts



Funds received by NAS institutions for fulfilling economic agreements and contracts, ₴ million



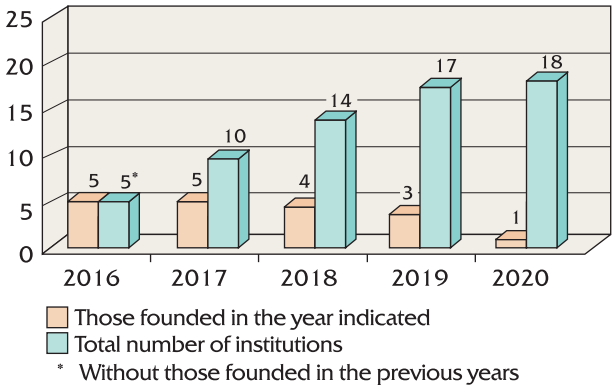
The number of commercialized scientific products



Protection and use of intellectual property objects, the 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	202
Research topics and projects implemented collaboratively with academics	205
Published monographs co-authored with academics	92
Research scientists who worked in education:	1255
including:	
NAS academicians	36
NAS corresponding members	85
Published textbooks and manuals for institutions of higher education	90
Scientists at the head of chairs in higher education institutions	65
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 2019/2020	421
in academic year 2020/2021	329

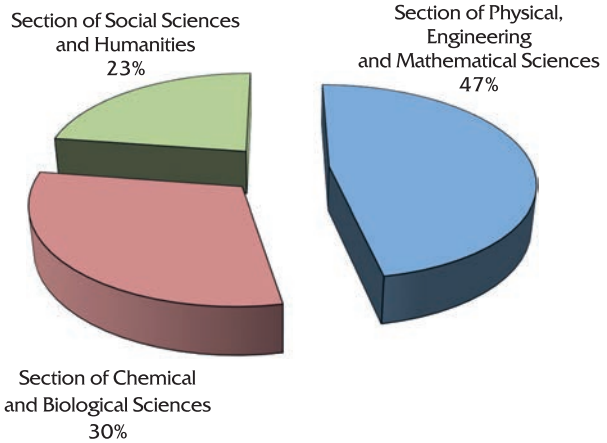


Joint research-and-education structures

Students who wrote their graduate papers at research institutions	797
Academics incorporated to specialized academic councils of research institutions	520
Scientists of research institutions incorporated to specialized academic councils of higher education institutions	537
Newly employed graduate specialists who attended study groups of the Junior Academy of Sciences in their school days	8
Research scientists and lecturers of higher education institutions and MES organizations who upgraded their professional skills at research institutions	294
Theses of academics defended at specialized academic councils of scientific research institutions	138

International ties

Legal contractual framework for the international collaboration of the NAS of Ukraine (effective agreements, contracts, memorandums etc.) — the total of 139 documents..



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

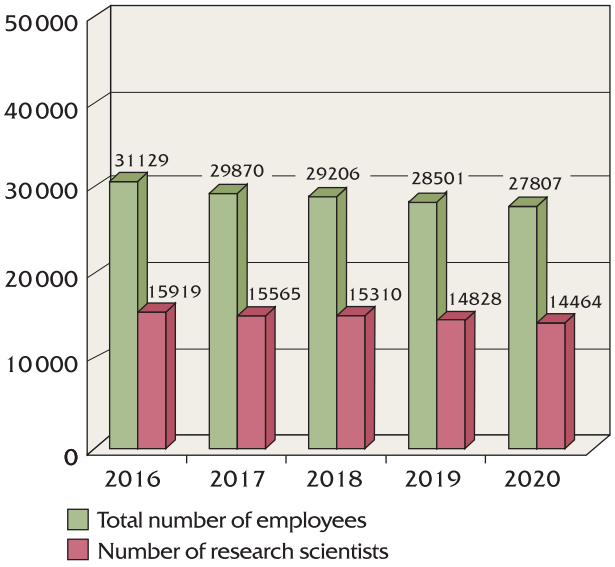
In 2020, the Academy signed a new collaboration agreement:

• Memorandum of the scientific and technological collaboration between the NAS of Ukraine and the Administrative Committee of Guangzhou High-Tech and New Technologies Zone (PRC)

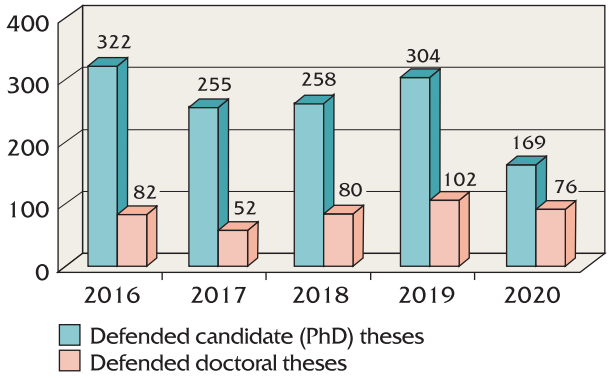
Nearly 680 direct agreements and contracts, concluded by NAS institutions with international partners are in force.

Employment figures (as of 01.01.2021)

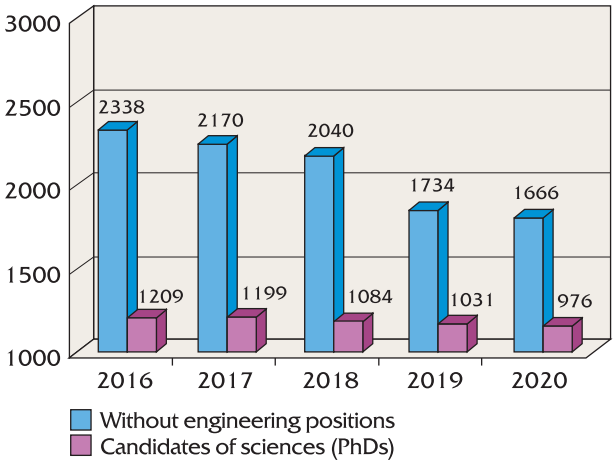
Total number of employees	27807
of them:	
in research institutions	26347
in research-and-production facilities	1133
in service organizations	327
Number of research scientists	14464
of them:	
doctors of sciences	2395
candidates of sciences (PhD)	6585
researchers without an advanced degree	5484
The number of young specialists recruited in 2020	298
The number of those who pursued post-graduate studies	1186
including full-time studies	1002
Defended PhD theses	169
Doctoral fellowships	97
Defended doctor-of-science thesis	76



The number of employees

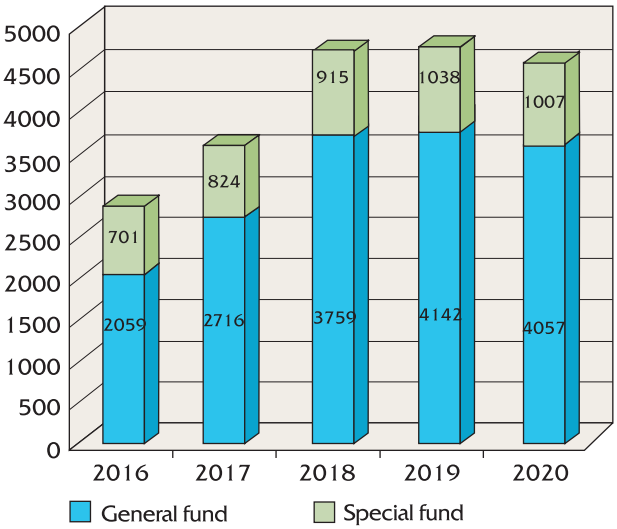


Training of scientific personnel, the number of people

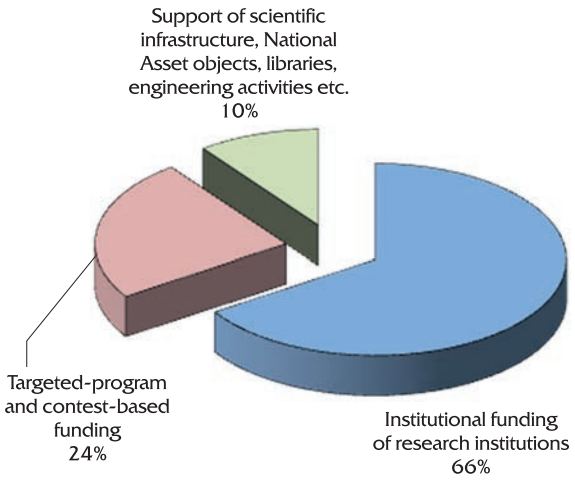


The number of young scientists

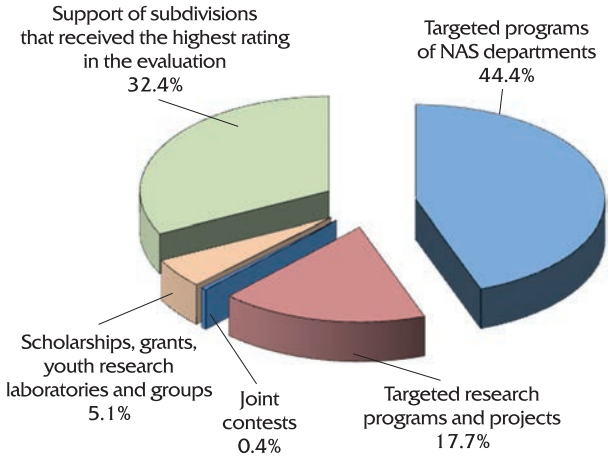
Financial provision



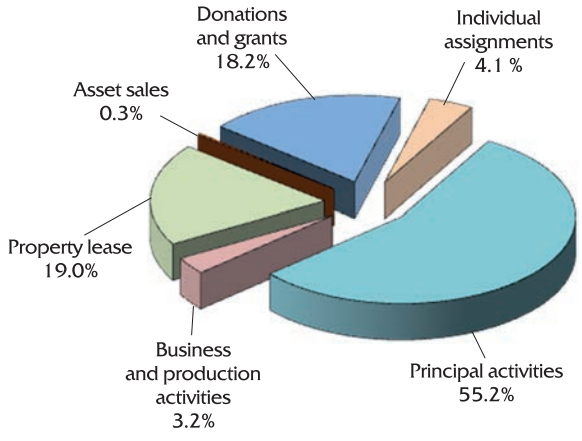
The total amount of NAS funding, ₴ million



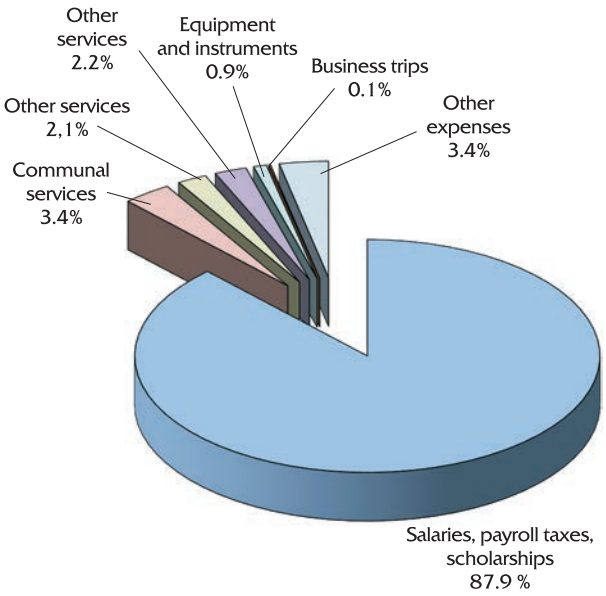
Distribution of finance from the general fund for conducting scientific research



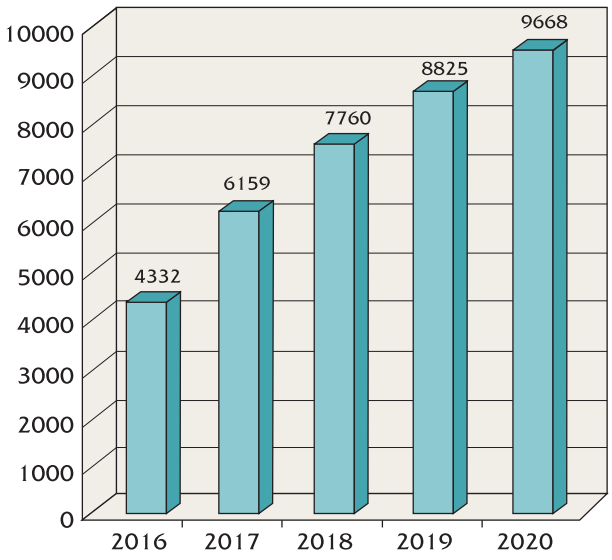
Targeted-program and contest-based funding



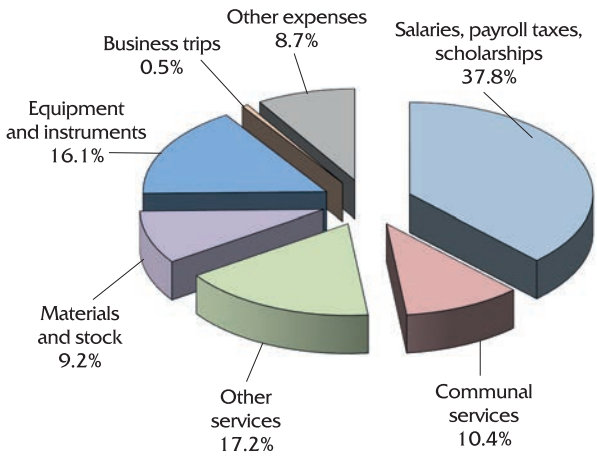
Structure of revenues to the special fund



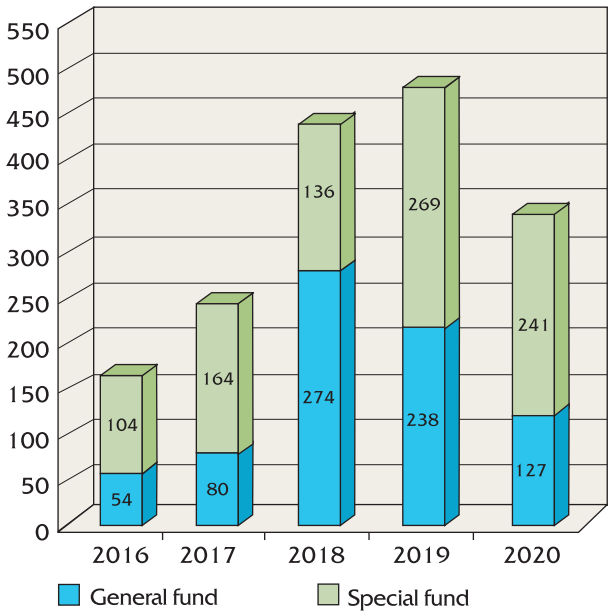
Structure of general fund expenses



Average monthly salaries of employees, ₴



Structure of special fund expenses



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