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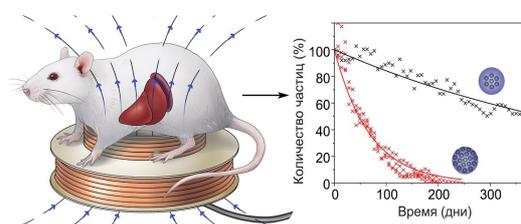
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## BIO-TECHNOLOGY & MEDICAL

### 1. Russian Scientists study the fate of magnetic nanoparticles in a living organism

Source: MIPT, 13 July 2021



*Drawing. Scheme for measuring the aging of magnetic particles in the liver and spleen of mammals*

A group of scientists from the Institute of Bioorganic Chemistry, Moscow Institute of Physics and Technology, Sirius University, GPI RAS, NRNU MEPhI and RNRMU were the first to investigate the long-term fate of magnetic nanoparticles in animals. They are used for targeted drug delivery and are already approved for use in medicine. But for a long time it was not known what happens to the nanoparticles after they undergo therapy. Thanks to the new development of Russian biochemists, it became clear, how magnetic nanoparticles "age" and disintegrate in mammals' bodies.

**Targeted drug delivery is one of the breakthrough directions in the development of modern diagnostics and therapy of various diseases.** Ideally, "smart" nanoparticles that transport drugs should find, recognize, and treat the disease on their own. A common object of research in the field of targeted therapy is magnetic nanoparticles; they are widely used for

controlled drug delivery and are already being used in medical practice. In particular, they are bright contrast agents for magnetic resonance imaging (MRI) - one of the most popular functional diagnostics tools today. In addition, a number of formulations of magnetic particles with sugars are used to treat iron deficiency anemia. For a long time, it remained unclear how nanoparticles behave in the body after they have fulfilled their function.

A team of Russian biochemists have developed a new spectral magnetic method for the detection of materials. It allows you to separate the signal of magnetic nanoparticles from iron, which is normally found in the body. The mouse is positioned in the region of the liver and spleen above a magnetic coil that acts on the nanoparticles, and the magnetic response measures how much iron is left in the particles and how much has already been included in the mammalian proteins.

The high sensitivity of the method and the ability to carry out measurements without the death of animals made it possible for the first time to conduct such a large-scale research in the field of nanobiotechnology. Scientists were able to compare the rate of degradation of 17 types of nanoparticles among themselves, studied the effect on biodegradation in the body of their size, dose, surface charge, coating and internal structure. After being introduced into the bloodstream, nanoparticles accumulate in lysosomes and slowly dissolve under the action of acid and enzymes. Scientists have shown that the speed of this process is highly dependent on the internal structure of the material: with the help of the design of nanoparticles, it is possible to accelerate the time of complete degradation from several years to one month. For example, small particles with a negative charge degraded the fastest. Among the various polymers covering the particles,

“This work would not have been possible without the creation of an approach for non-invasive detection of magnetic particles in the body. The measurements were carried out for over a year. The use of classical approaches would require more than a thousand mice for such an experiment, which is unreasonable both for ethical reasons, and for financial and human labor costs,” says **Maxim Nikitin**, one of the authors of the article, head of the laboratory of nanobiotechnologies at MIPT, head of the Nanobiomedicine direction of Scientific Technological University "Sirius".

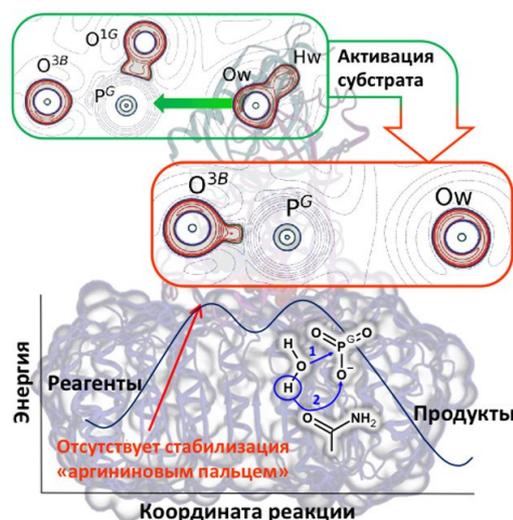
Then the scientists tried to understand what was happening with the remnants of the nanoparticles. They found that the excess iron that was formed when they were dissolved was not excreted from the body. Instead, animals have decreased absorption of the iron that comes from food. As a result, iron from the particles completely changed into low-toxic forms, was deposited in the liver and spleen, and was probably used by the body at its own discretion: to create erythrocytes, regulate metabolic processes, and other uses. An important discovery was the absence of long-term toxicity of magnetic particles to the body. The only changes that were found were a temporary increase in the population of immune cells involved in particle recognition and processing, as well as long-term deposition of excess iron in the liver and spleen.

“The fact that the magnetic particles are converted into biogenic iron is an important feature. It can be used to treat some forms of anemia,- says **Ivan Zelepukin**, the first author of the article, junior researcher at the Laboratory of Molecular Immunology at the Institute of Bioorganic Chemistry of the Russian Academy of Sciences, a graduate of the Moscow Institute of Physics and Technology. "Our research is shedding light on the intelligent design of nanomaterials with controlled iron release rates."

The study was carried out with the support of the Russian Science Foundation and the Russian Foundation for Basic Research and is a continuation of a series of works in which the mechanisms of interaction of particles with the body are studied.

## 2. Revealed the secret of an enzyme without an "arginine finger", but effectively transmitting cellular signals

Source: Federal Research Center of Biotechnology, RAS, 13 July 2021



Employees of the Federal Research Center for Biotechnology RAS, together with colleagues from Moscow State University and the Institute of Bioorganic Chemistry, RAS, have found out how the complex of the Ran GTPase enzyme and its activator works during the hydrolysis of GTP, a process underlying the transmission of a number of cellular signals. It turned out that "arginine fingers", which were considered critical for this family of proteins, are not needed at all, while it remains very effective. The discovery of the mechanism will help in

research on cancer diseases, which often progress due to failures in the GTPase information transmission system. More information about the research results can be found on the pages of the ACS Catalysis journal.

Guanosine triphosphate (GTP) is one of the nucleotides on the basis of which RNA molecules are assembled on a DNA matrix. It also serves as a source of energy in various biological reactions, for example, protein synthesis, and is involved in specific signaling processes in the cell. In the latter case, special enzymes, the so-called small GTPases, cleave off a fragment of the phosphate tail of the nucleotide, converting guanosine triphosphate into guanosine diphosphate (GDP). Without an assistant, the rate of this reaction is very slow, but with the activator protein of the GAP family, it occurs about five orders of magnitude faster.

“Failures in this system can provoke the development and metastasis of cancerous tumors, and therefore it is being actively studied. Small GTPase Ras from rat sarcoma is often used in studies. In the complex of this protein with its accelerator, the most important role is played by the "arginine finger" - the amino acid residue of arginine located in the GAP accelerator protein and penetrating into the active center of GTPase as a result of their complex formation. It is this residue that is believed to be critically important for accelerating the GTP hydrolysis reaction. Another GTPase from this group, Ran, interacts with its mate with the same acceleration, but there are no "arginine fingers" here. We decided to figure out what the secret of her work is.", - explains Maria Khrenova, Doctor of Physical and Mathematical Sciences, head of the molecular modeling group of the Federal Research Center of Biotechnology RAS.

Scientists from FRC Biotechnology RAS, together with colleagues from the Moscow State University named after M.V. Lomonosov and

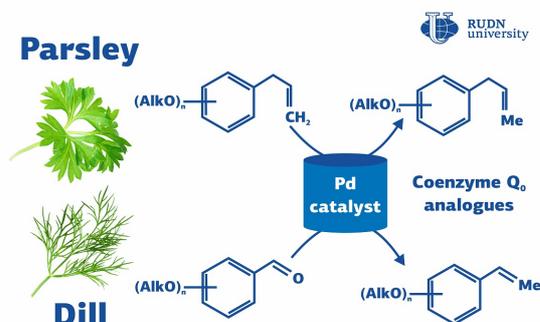
the N.M.Emanuel RAS, simulated on a computer the interaction of the GTPase Ran with the corresponding activator protein and the reaction of this complex with GTP. The simulation was done using the methods of quantum and molecular mechanics: this approach allows one to describe that part of the system where a chemical reaction takes place using the methods of quantum chemistry (molecule - nuclei and electrons), and the rest of the protein complex - within the framework of classical concepts (molecule is a set of related atoms). The movements of the fragments of the system and the state in which they are "fixed" are determined by energy maxima and minima.

Based on these principles, the researchers modeled step by step all the processes occurring during GTP hydrolysis, including the behavior of Ran without a helper protein. It turned out that the secret of the complex is that the activator is needed in order to clamp the active center of the GTPase. The result is a cavity in which the amino acids and water molecules responsible for the reaction, which inevitably come from the environment, are located in the most convenient way. Thanks to this, the Ran enzyme and the assistant do without "arginine fingers", without losing their effectiveness in comparison with other members of the family.

“Understanding the underlying mechanisms of how GTPases work during hydrolysis will help in cancer research. Many specific drugs are aimed at either blocking active sites or preventing contact between the enzyme and its helper. Perhaps our discovery will form the basis for the development of such a drug, ”concludes Maria Khrenova.

### 3. RUDN University Chemists obtained coenzyme from Parsley and Dill seeds

Source: RUDN University, 12 July 2021



Scientists from RUDN University have developed a new method for converting plant hydrocarbon radicals into substances that can be used to synthesize coenzyme Q<sub>0</sub>.

Coenzymes of the Q group in mammals and plants are responsible for maintaining the energy metabolism of cells. They are powerful antioxidants and regulate the permeability of mitochondrial membranes. Coenzyme Q<sub>0</sub> is known to reduce and even suppress metastasis in breast, skin and ovarian cancers.

A scientist from RUDN University proposed a simple way to obtain the necessary element from parsley and dill extract. The main stage on the way of obtaining a coenzyme is hydrogenation to allylpolymethoxybenzenes fragments. This process takes place in a special apparatus with a fluoroplastic insert using a porous palladium catalyst. After use, the reaction mixture is separated from the catalyst without additional filters.

The minimum reaction time is 4 to 8 hours. However, with an increased hydrogen pressure, the reaction takes 2-4 hours. Even with

accelerated production, no methylbenzene by-products remain after hydrogenation, which simplifies further purification. The catalyst can then be used up to 40 times.

“With the help of X-ray diffraction analysis, we have confirmed the spatial structure of the resulting compound. This allows further study of its antitumor and antioxidant properties,” explained Viktor Khrustalev, Doctor of Chemistry, Head of the Department of Inorganic Chemistry of the Peoples' Friendship University of Russia.

### 4. TPU scientists find method to double rate of fracture healing

Source: TPU University, 20 July 2021



Samples of calcium phosphate coated implants

Scientists of Tomsk Polytechnic University were able to find a method to double the recovery rate of damaged bones. The scientists proposed to use implants produced using a 3D printer. The technology of applying bioactive coatings on the implant surface proposed by the TPU scientists also distinguishes by significant saving of time and resources. The research findings are published in the Modern Technologies in Medicine academic journal.

According to the scientists, now a days, rehabilitation medicine is mainly successful due to the development of composite biomaterials

imitating living tissues. They consist of elements of various chemical and mechanical properties. It allows imitating functions of damaged tissues in an organism more accurately. The most efficient technology of implant production is 3D printing that allows receiving individual implants for every patient taking into account his anatomy. The technology of applying bioactive coatings on such implants has just begun to develop.

The TPU scientists were able to determine optimal structural parameters of titanium implants produced by 3D printing. They also proposed technology of their improvement using a bioactive calcium phosphate coating providing accelerated recovery of damaged bones.

“Our coating has already been used in the worldwide known Russian Ilizarov Scientific Center for Restorative Traumatology and Orthopedics. Calcium phosphate coated implants were inserted into more than 400 patients from 6 to 50 years from Russia, France and other countries. These implants are successfully used in veterinary practice as well.

According to the results of the joint research with the Center experts, no one implant failure has been observed, while the recovery rate of the structure of bones and muscles doubled due to the coating,” Sergey Tverdokhlebov, Associate Professor of the TPU Weinberg Research Center, told to the journalists of the Sputnik international news agency.

The development feature of the TPU scientists lies in combining several methods of material modification. It allows embodying implants not only in a shape but also in biological properties what is required to treat complicated pathologies and traumas.

“In this research work, we combined a number of methods: plasma electrolytic oxidation allowed forming the porous calcium phosphate coating on the titanium surface. Then, the

coating was saturated with biodegradable material that serves as a container for medicine and drugs improving implant survival. Ultimately, plasma processing using sputter deposition gave optimal properties to the material for the growth of living cells on it,” Sergey Tverdokhlebov explained.

To optimize the properties of the implant and to reduce the number of expensive experiments, the TPU scientists used computer simulation of the release process of medicine put on the implant. According to the researchers, it will hasten the entry of new types of implants into the market.

The research work is being conducted within the Federal Target Program jointly with OSTOMED-M, an industrial company partner.

The research team is intending to develop a bioactive coating technology for titanium and polymer implants for the treatment of osteoporosis and other complicated pathologies of bone tissue.

## 5. Lactobacillus active against COVID-19 detected

Source: RIA Novosti news, 19 July 2021



The Nizhny Novgorod Institute of Epidemiology has identified an active agent against COVID-19 strain of lactobacilli.

The strain of lactobacilli, active against coronavirus infection, was identified by specialists of the State Scientific Center "Vector" and the Blokhina Institute of Nizhny Novgorod, according to the Rospotrebnadzor website.

According to the website, the Nizhny Novgorod specialists together with the staff of the FBSI SSC VB "Vector" studied the antiviral activity of six strains of lacto- and bifidobacteria, which are part of the author's probiotics, against swine flu, the H5N6 avian influenza virus and coronavirus.

"It has been established that probiotic strains of lactobacilli and one strain of bifidobacteria exhibit pronounced activity against influenza viruses, and one of the strains of lactobacilli is also active against the SARS-CoV-2 virus," the message says.

It is added that the research results have been formalized in a joint scientific article, which was published in the foreign scientific journal Biomed Research International.

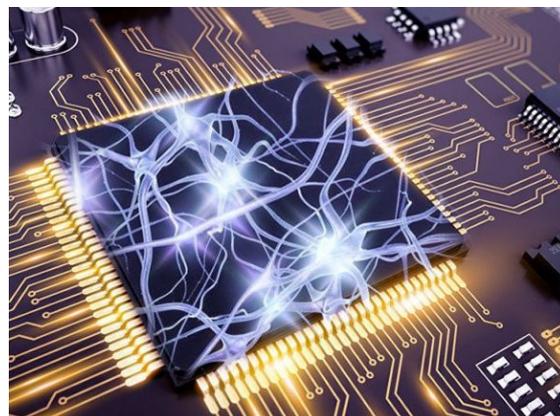
## COMPUTER SCIENCE & DATA SCIENCE

### 6. Semiconductor strain control method brings the electronics of the future closer

Source: Skoltech, July 14, 2021

Skoltech researchers and their colleagues from the United States and Singapore have created a neural network that can be used to tune the properties of semiconductor crystals and obtain components for electronics with unrivaled performance. This work opens a new direction in the development of microcircuits and solar cells of the next generation through the use of

controlled deformation, with which you can literally change material properties on the fly.



Nanomaterials withstand severe deformations quite successfully. Being in a deformed state, they exhibit unusual optical, thermal, electronic and other properties associated with changes in interatomic distances. Deformation can also change the conductivity of a material: for example, silicon, known for its semiconducting properties, in a deformed state turns into an effective conductor.

In addition, it turned out that the properties of the material can be changed as needed by varying the degree of deformation. This concept laid the foundation for a whole line of research - elastic deformation engineering (ESE). The new approach can be a way out as the efficiency limit of microcircuits according to Moore's law is steadily approaching. Another area in which this method can be used is in the development of solar cells. "This allows you to create elements with custom properties that can be changed as needed to maximize performance and adapt to external conditions," explains study co-author Alexander Shapeev.

In their previous work, Skoltech graduate and postdoc graduate Yevgeny Tsymbalov, Skoltech associate professor Alexander Shapeev and their colleagues, using the ESE method, transformed

diamond nano-needles from an insulator into a highly conductive metal-like material, which indicates the broad applied capabilities of the technology. In their new study, the scientists presented a convolutional neural network architecture that allows ESE techniques to be applied to semiconductors.

“The neural network we have created uses the strain tensor as input and predicts the electronic band structure - this is a kind of physical 'snapshot' describing the electronic properties of a deformed material. It can be used to calculate any properties of interest, including the band gap, its properties and the effective electron mass tensor,” explains Shapeev.

This work continues and develops previous studies. “We have already gone beyond the previously used approaches. We have developed and implemented a special model based on the architecture of a convolutional neural network for solving ESE problems, - notes Tsymbalov. “We also take into account physical properties and symmetries to improve the performance of the model.”

In order to improve the accuracy and convergence of the model, the proposed method uses various data sources: on the one hand, these are data that are not computationally expensive, but have low accuracy, and on the other, they are computationally expensive, but accurate data. “Another distinctive feature of the method is active learning: our model independently determines which data is most expedient to obtain at the next stage of training, and then learns from them. At the final stage, the network is trained on a set of computationally expensive data obtained by the method of precise GW calculations. With the help of this procedure, we manage to reduce the number of necessary calculations,” says Evgeny Tsymbalov.

The researchers note that compared to other modern solutions, the neural network they

created is "more versatile, accurate and efficient in terms of enabling autonomous deep learning in relation to the electronic band structure of crystalline solids", which provides a higher speed and accuracy of the method when searching and optimization in the deformation space and, consequently, obtaining the optimal deformation values for the given quality indicators.

In a previous paper, scientists tested an earlier version of the model in a series of in situ experiments with diamond. “Unfortunately, no device has yet been invented that could deform a diamond with an arbitrary deformation tensor in 6D, but some research teams and laboratories are already conducting experimental developments in this direction,” comments Evgeny Tsymbalov.

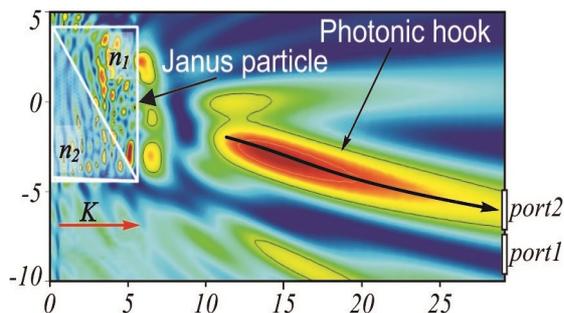
This work was carried out as part of a long-term collaboration between Skoltech, Massachusetts Institute of Technology (USA) and Nanyang Technological University (Singapore). During the project, Skoltech scientists were mainly engaged in computational problems and machine learning methods, while their foreign colleagues were responsible for the physical aspects of the research. “We are currently working on the next article, which will consider the limits of permissible elastic deformations. The importance of this topic is due to the fact that the theoretical limits of safe elastic deformation for ESE have not yet been determined,” notes Evgeny Tsymbalov in conclusion.

## **7. Scientists propose new optical switch for high-speed computers**

*Source: TPU News, 19 July 2021*

Scientists of Tomsk Polytechnic University jointly with their colleagues from Great Britain have proposed a physical concept of a new optical switch that forces to change light wave

guidance. The switch is a small glass particle of an unusual form. Its size is only about 1  $\mu$ . The research findings are published in the *Annalen der Physik* academic journal (IF: 2,276; Q1). According to the authors, such a simple switch can be used in high-speed optical computers in the long run.



Information is transferred by electrons in all currently existent calculating machines, including computers. Scientists believe if electrons inside the computers are replaced with photons, i.e. light quanta, then the data can be transferred literally at lightspeed. Researchers and companies of different countries are working on creating an efficient optical quantum computer. Prototypes of such computers have already been presented in the USA and China, however, these computers are capable to solve a very limited range of tasks. To widely apply optical computers, researchers still have to overcome a lot of obstacles.

“In such machines, it is essential to switch a signal at very high speed, i.e. to change the light guidance. Therefore, efficient switches are required. Researchers solve this task in different ways. Some researchers propose mechanical switches, however, these switches do not provide the required switching speed. While the others use specific crystals based on the nonlinear effects, which require developing new

special materials and methods of controlling them. We proposed another principle in our article: particles of special forms from dielectric material can change the light guidance efficiently. In this case, we considered glass. Moreover, the proposed method does not require the application of metals,” Oleg Minin, Professor of the Division for Electronic Engineering of the TPU School of Non-Destructive Testing, a supervisor of the project, says.

The proposed switch is a small cube-shaped glass particle with a prism attached to it. Its operation is based on the effect of the photonic hook that was previously discovered by the research authors.

“It is a matter of a particle shape. Previously, we discovered that the light percolating a dielectric particle of this shape twists as a hook at the output. Due to its physical properties, the photonic hook possesses a very wide range of potential application. In this case, the calculations show if we change the light wavelength percolating the particle, then it is possible to change hook guidance. That is the core of switching the signal, in changing the guidance,”

Oleg Minin explains that the researchers are currently preparing to conduct a series of experiments, which will prove the results of the simulation and calculations. The experiments will be conducted at Bangor University (Great Britain).

The research was conducted with the partial support of the Russian Foundation for Basic Research and the TPU Competitiveness Enhancement Program.

## 8. A new method for training computer vision algorithms on limited data sets

Source: *Scientific Russia News*, 17 July 2021



Skoltech scientists have developed a method for training computer vision algorithms that increases the accuracy of data processing in the presence of limited initial samples. Thanks to the new method, solving various problems of remote sensing will become easier not only for computers, but in the future also for data users. The research results are published in the journal *Remote Sensing*.

Methods of computer vision and machine learning have long been used in solving problems of environmental monitoring: with the most time-consuming of them, which, moreover, are prone to human errors, algorithms cope with great ease. However, the problem is that the neural network first needs to be trained so that it can, for example, successfully distinguish between tree species in forest areas.

A significant difference between satellite images and ordinary photographs, dozens of which can be taken every minute on a smartphone, is that not so many frames can be obtained in one satellite pass, and not always with sufficient

resolution. In addition, cloudiness affects the quality of shooting. Obtaining a sufficient number of well-labeled images suitable for training a neural network can be an extremely difficult task to solve which scientists and engineers use, in particular, image augmentation techniques.

“A neural network is a very powerful system that requires large training data sets to produce quality results. Unfortunately, when solving practical problems, we often face the problem of lack of data, so data processing specialists have to use various methods to artificially increase the initial samples. One of the most popular methods is data augmentation - transforming images to increase sample variability,” says one of the authors of the article, Skoltech graduate student Sergey Nesteruk.

Skoltech professor Ivan Oseledets and his colleagues have developed a MixChannel data augmentation method that can be applied to multispectral satellite images. It is based on the principle of data substitution: instead of a strip in the original image, a strip of an image of the same area of the earth's surface obtained at another time is substituted.

“Using the data augmentation method in the case of regular RGB images is not particularly difficult, but there has not yet been an effective means of augmentation of complex multispectral data. MixChannel is a fundamentally new method of data augmentation, designed specifically for working with multispectral data,” notes the co-author of the article, Skoltech graduate student Svetlana Illarionova.

To test the new method, scientists used images of boreal coniferous and larch forests of the Arkhangelsk region, obtained from the Sentinel-2 satellite. On them, the researchers trained the convolutional neural network to classify these types of forests. “The direct method of training a

classification model based on a convolutional neural network is to use a set of satellite images of a given area obtained during the active growing season. To create a training dataset, a fragment is randomly selected from a large image, the authors note. "However, if you test the resulting model on an image taken on a day that was not included in the training set, the accuracy of the model can drop dramatically."

Since cloudiness is often present over the territory of the Arkhangelsk region, there were very few suitable satellite images - only six, but even with such a limited sample, the new method, based on the results of testing on three neural networks, surpassed the most modern solutions. As the authors emphasize, the method developed by them can be used in combination with other augmentation methods, which will allow obtaining even more training data.

The new method can also be used to solve other problems related to the use of Earth remote sensing data, in particular for environmental research, precision farming and any other tasks where there is a limited number of images with medium spatial resolution. In the future, scientists plan to refine their method, providing the ability to process images of various types of land cover and more extensive territories with different natural conditions.

Scientists from the Space Center, the Center for Scientific and Engineering Computing Technologies for Large Data Problems (CDISE) and the Skoltech Digital Agriculture Laboratory (DAL) took part in the study.

## ELECTRONICS & COMMUNICATION

### 9. Electro-Technical University initiates development of a biochip for the diagnosis of COVID-19

Source: RIA Novosti News, 21 July 2021



Scientists of LETI initiate biochip development to diagnose COVID in 5-10 minutes

Biochip for detection of coronavirus, being developed at the St. Petersburg State Electrotechnical University "LETI", will be able to diagnose for 5-10 minutes, Scientists told RIA Novosti leading researcher Engineering Center microtechnology and diagnostics. Candidate of Physical and Mathematical Sciences, Tatiana Zimina announced this breakthrough.

Earlier, Federal agency Rospotrebnadzor also announced the development of a biochip for testing for coronavirus, noting that another development in this area is being carried out by LETI, where for a number of years the direction of research and development of multimodal biosensors for the rapid determination of biomarkers, viruses and microorganisms, including biomarker diagnostics of acute heart

attack myocardium, stress, rapid diagnosis of SARS-CoV-2 coronavirus using peptides.

As Zimina said, work on the creation of diagnostic methods based on peptide biochips has been carried out at ETU since 2005. In January 2020, work began on the study of digital twins to the S-protein (spike) of the SARS-Cov-2 coronavirus; by March 2020, two peptides complementary to the S-protein were developed by computer modeling.

“By the summer of 2020, partners have created two peptides based on the principles of combinatorial chemistry and database analysis. All peptides have been synthesized. At present, laboratory models of flow-through miniature biochips and a compact reader have been developed. - added Zimina.

According to her, it is assumed that by the end of 2021 a sample of the biochip will be ready. She clarified that the support of Rospotrebnadzor and the allocation of funding, as well as ensuring cooperation with organizations licensed to work with coronavirus cultures for testing, can significantly accelerate the introduction of biochips into clinical practice.

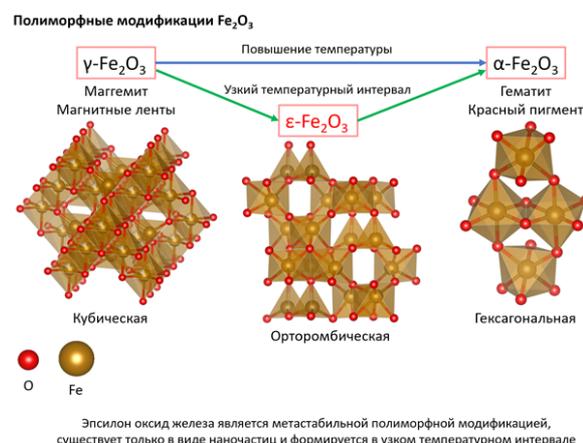
"The biochip we are developing will allow diagnostics within 5-10 minutes," Zimina noted.

## 10. Scientists have developed magnetic nanopowder for 6G technologies

Source: *MIPT News*

Material scientists have developed a fast method for producing epsilon iron oxide and demonstrated its promise for use in new generation communication devices. Its outstanding magnetic properties make it one of the most desirable materials, for example for next generation 6G communications devices and highly reliable magnetic recorders. The work is

published in the Journal of the Royal Chemical Society Journal of Materials Chemistry the C .



*Drawing. Crystal structures of iron (III) oxides. Courtesy of Evgeny Gorbachev*

Iron (III) oxide is one of the most abundant oxides on the planet. It is most commonly found in the form of the mineral hematite (or alpha-iron oxide,  $\alpha\text{-Fe}_2\text{O}_3$ ). Another stable and widespread modification is maghemite (or gamma modification,  $\gamma\text{-Fe}_2\text{O}_3$ ). The first material is widely used in industry as a red pigment, and the second is used as a magnetic recording medium. Both modifications differ not only in the crystal structure (alpha-iron oxide has a Photo. The authors of the experiment Lyudmila Alyabyeva and Evgeny Gorbachev at the terahertz spectroscopy laboratory of the Moscow Institute of Physics and Technology

“Despite the fact that the epsilon iron oxide phase was obtained in its pure form a relatively long time ago, in 2004, due to its complex synthesis, it still does not find industrial application, for example, as a medium for magnetic recording of information. We managed to significantly simplify the technology,” says Evgeny Gorbachev, a graduate student at the Faculty of Materials Science at Moscow State University and the first author of the work

hexagonal system, and gamma-oxide has a cubic one), but also in magnetic properties.

In addition to these forms of iron (III) oxide, there are more exotic modifications, for example epsilon-, beta-, zeta- and even amorphous. The most attractive phase is precisely epsilon iron oxide,  $\epsilon\text{-Fe}_2\text{O}_3$ ... This modification has an extremely high coercive force (the ability of a material to resist an external magnetic field). The force reaches 20 kOe at room temperature, which is comparable to the parameters of magnets based on expensive rare earth elements. In addition, this material absorbs electromagnetic radiation in the sub-terahertz frequency range (100-300 GHz) due to the effect of natural ferromagnetic resonance. The frequency of such resonance is one of the criteria for the use of materials in wireless communication devices - the 4G standard uses megahertz, and 5G uses tens gigahertz. The subterahertz range is planned to be used as a working band in sixth generation (6G) wireless technologies, which is preparing to be actively introduced into our lives since the early 2030s.

The resulting material is applicable for the production of converting or absorbing devices at these frequencies. For example, using composite nanopowders  $\epsilon\text{-Fe}_2\text{O}_3$ , it will be possible to make paints that absorb electromagnetic waves, and thus shield the premises from extraneous signals and protect the signal from being intercepted from the outside. The very same  $\epsilon\text{-Fe}_2\text{O}_3$  can be used in devices for receiving a 6G signal.

Epsilon Iron Oxide is an extremely rare and difficult form of iron oxide to obtain. Today it is received in very small quantities, and the process itself takes up to a month. Of course, in such a situation, we are not talking about widespread use. The authors of the study developed a technique for accelerated synthesis of epsilon iron oxide, which allows to reduce the synthesis time to one day (that is, to carry out a

full cycle more than 30 times faster!) And to increase the amount of the resulting product. The technique is easy to reproduce, cheap and can be easily introduced into industry, and the materials necessary for the synthesis - iron and silicon - are among the most widespread elements on Earth.

“Despite the fact that the epsilon iron oxide phase was obtained in its pure form a relatively long time ago, in 2004, due to its complex synthesis, it still does not find industrial application, for example, as a medium for magnetic recording of information. We managed to significantly simplify the technology,” says Evgeny Gorbachev, a graduate student at the Faculty of Materials Science at Moscow State University and the first author of the work.

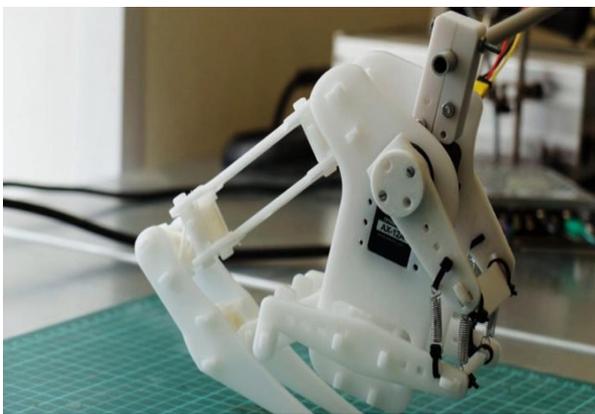
The key to the successful application of materials with record characteristics is the study of their fundamental physical properties. Without a detailed study, the material can be undeservedly forgotten for many years, as has happened more than once in the history of science. It was the tandem of materials scientists from Moscow State University, who synthesized the compound, and physicists from MIPT, who studied it in detail, that became the key to successful development.

Such high ferromagnetic resonance frequencies have enormous potential for practical applications. Today there is a rapid development of terahertz technologies: this is the Internet of Things, this is ultra-fast communication, these are scientific devices of a narrower application, these are medical technologies of a new generation. The 5G communication standard, which has become so sensational in the last year, operates at frequencies of tens of gigahertz, but with our materials we open up prospects for the transition to significantly higher frequencies (hundreds of gigahertz), that is, we are already dealing with 6G and higher standards. Now it's up to the

engineers, we are happy to share the information we have received with them and look forward to the opportunity to hold our 6G phone in our hands,” notes Lyudmila Alyabyeva, Senior Researcher, Terahertz Spectroscopy Laboratory, Moscow Institute of Physics and Technology, where terahertz studies were carried out.

## 11. ITMO scientists create a hopping robot using morphological computation

Source: ITMO News, July 2021



The International Laboratory of Biomechatronics and Energy-Efficient Robotics has created a prototype of an energy-efficient hopping robot. The design is based on flexible joints and a series elastic actuator.

A team consisting of Kirill Nasonov and Dmitry Volyansky, Master’s students of the Faculty of Control Systems and Robotics, supervised by Ivan Borisov, a research associate at ITMO University, is working on a galloping robot with unique morphological characteristics. The main task of the team is to develop a light, flexible, energy-efficient, and functional system. To achieve that, they use principles of biomimetics and morphological computation. According to Ivan Borisov, the goal is to create a device that

would require as little control effort (energy) as possible, while being able to overcome uneven terrain, overcome obstacles, and be resilient to physical harm.

As a platform for the approbation of methods and design principles, we are developing a galloping robot that can move fast and consume little energy. Modern legged robots such as Spot or Unitree usually look something like a stool with legs – an absolutely rigid body with open-kinematic legs. They have proved their efficiency: they can walk, run, climb, and do flips but they also waste a lot of energy. Running is a periodical motion. When they run, the mechanisms of their open-kinematic legs perform oscillatory motion. So they waste energy at every phase of the running cycle: they need it to accelerate, decelerate, accelerate in the opposite direction, decelerate again, and the cycle goes on.

What we want to achieve, however, is energy-efficient motion. We apply the principles of biomimetics, e.g. we observe how nature has been solving similar tasks during millions of years of evolution and transmit unique characteristics of living systems into robotics. One of the most energy-efficient and evident ways of motion is kangaroo jumps. The kinetic energy of these animals is transformed into potential energy stored in tendons and muscles when they hit the ground. When they jump again, it’s transformed back into kinetic energy. We have used a similar principle in our prototype,” comments Ivan Borisov.

### Morphological design

Energy efficiency means using a limited energy budget most effectively. To minimize the control effort of motors, it is possible to create a robot, for which much of the desired behavior is already present in the inherent dynamics of the mechanical system, while the control algorithms are only needed to excite, stabilize and augment

natural dynamics with little effort. Such a design principle is called morphological computation, when computation of control signal is carried out not only via algorithms but via a mechanical structure, e.g., its morphology. Thanks to the optimal distribution of mass, elasticity, and optimization of mechanical parameters, it's possible to achieve the required dynamics with fewer and less powerful motors.

“The main actuator in this system is an extension spring: when the robot hits the ground, it stretches and accumulates potential energy, and when it jumps up again, the stored energy is transformed back into kinetic energy. Thus, energy gets recuperated and the motor only has to compensate for energy losses caused by impacts and friction,” explains Ivan Borisov.

### **Flexible elements**

Moreover, the robot's body had to be made significantly lighter, which meant getting rid of weighty elements such as gear wheels, metallic axes, and bearing parts. In order to do that, the team used the research results of ITMO's partner, the University of Twente (the Netherlands).

“We had a hypothesis about flexible joints: they can rotate at a certain angle, they are light, and they have no friction and backlash. Then we had to think about how to design them. The very task of designing joints is non-trivial – we can't just take some plastic parts and connect them at an angle – it should be calculated mathematically. The University of Twente has a laboratory that works in this field, and fortunately for us, their research is open to the public. We can see how they do it and, based on it, find our solution,” says Kirill Nasonov.

At the University of Twente's Laboratory headed by Prof. Dannis Brouwer, mechanisms with flexible joints are synthesized mostly for the sake of high-precision motion. In ITMO's

project, the mechanism was synthesized to reach the robot's physical interaction with the environment. The joints were 3D printed from polyurethane – a flexible plastic with a stretching structure. They have a geometric three-part shape that provides the mechanism with flexibility, resilience, and resistance to deformations.

The rest of the parts are also plastic: body's elements and links were cut from polyacetal with a laser and put together using plastic clips.

### **Testing prototype**

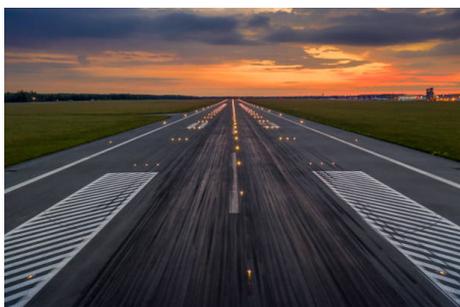
The hopping robot isn't the final product but more of an object for testing the methods of morphological design and flexible joints in particular. No similar robots have been designed in such a way before. Moreover, the galloping robot is a good example for research to study control methods and how a highly dynamic system interacts with the environment.

“We used series elastic actuators and implemented a method of control not by the error of position, but by the error of potential energy stored in the spring. Our team's students are at the end of their first year of Master's studies and this is the result of their work during this period. They were able to test in practice the skills of innovative modeling, non-standard methods of control, design, production of parts, and also got skills of programming a controller,” says Ivan Borisov.

The team plans to create a robot that not only jumps on the spot but can also move on uneven terrain. For that, they would need to synthesize a more complex mechanism that will be able to configure motion trajectory.

## 12. LETI proposes a way to avoid plane crashes on the runway

Source: ETU "LETI" News, July 2021



The method for assessing the presence of obstacles on the runway in conditions of limited visibility, proposed by a young scientist of ETU "LETI", is based on classical methods of digital image processing and the use of neural networks.

Airplanes today are equipped with synthetic vision systems that allow pilots to compensate for poor visibility in various weather conditions. Such systems make the "picture" clearer, increasing the contrast of the contours of objects. However, there are often accidents on the runway associated with the presence of foreign objects on it. These can be all sorts of obstacles - both moving and static: upholstery, luggage, vehicle, animal. Just because of the puncture of aircraft tires on the runway, airlines lose about \$ 13 billion a year. This explains the relevance of segmentation of objects on the runway to alert the crew, which should complement the existing functionality for improving visibility.

Denis Andreev, a post-graduate student of the Department of Television and Video Equipment of the St. Petersburg State Electrotechnical University "LETI", suggested expanding the functionality of the synthetic vision system. He has developed a cascade of methods that assess

visibility conditions, compensate for them, increase visibility and visibility of objects, and segment objects on the runway. The methods proposed by the scientist are also capable of communicating the trajectory of a moving object. The research results are published in the journal "Questions of radio electronics. Series: Television Techniques".

"There are ground systems that are installed on the runway. They are quite effective and find obstacles of rather small dimensions - about 10x10 cm. The disadvantages of such systems are the need to modernize the entire airport infrastructure and the high cost of such transformations, which only large airports can afford. Now such systems are installed only in the largest airports in the world - in Bangkok, Tel Aviv, Vancouver," says Denis Andreev.

The new method does not require major changes in the operation of on-board computers: it is supposed to change the software of the module responsible for the operation of cameras, and add connections for correct display on the multifunctional display.

"In my work I have applied classical methods of digital image processing: methods of increasing local contrast, segmentation of objects, a modernized method of background subtraction. Also, neural networks are used to track points, build a projection of an object. With their help, we fix reference points on the runway in order to track the change in the camera angle relative to the runway and thus compensate for the object," says the young scientist.

The project is being implemented as part of a postgraduate dissertation under the guidance of Professor of the Department of Television and Video Technology at ETU "LETI", Doctor of Technical Sciences Nikolai Vladimirovich Lysenko and is at the final stage: the cascade of methods has already been fully implemented in the software package.

## EARTH SCIENCE & ENVIRONMENTAL SCIENCE

### 13. The development of LETI scientists will help to improve the accuracy of earthquake prediction

Source: SpbGETU "LETI" News, 27 July 2021

*Employees of the Department of APU SPbGETU "LETI" created an algorithm for adjusting the coefficients of the adaptive digital filter in the residual class system (ROC) and proposed a methodology for its application, depending on the length of the filter and signal.*

In many applications that use modern methods and algorithms for digital signal processing, adaptive digital filters (ADF) are widely used, including a digital filter and an adaptation system. The most widely used digital finite impulse response (FIR) filters are used in ADF. Adaptive filtering is used in acoustic systems, image processing, equalizers designed to equalize the characteristics of communication channels, systems using adaptive antenna arrays.

The efficiency of the ADC is largely determined by the algorithm that allows adapting the coefficients of the FIR filter to obtain a reference signal, while the algorithm for correcting the vector of coefficients of the FIR filter should, at a given stage, implement the adjustment procedure with minimal software and hardware costs.

In order to increase the speed of signal processing in various applications, the use of RNS is justified. This improves the performance of digital signal processing systems (including digital filters) and reduces hardware costs due to parallel and independent processing of low-bit residuals when performing arithmetic operations such as addition, subtraction, and multiplication. The disadvantage of RNS is the high

computational complexity when performing non-modular operations, including division, sign determination and comparison of numbers. These limitations are due to the fact that the RNS is a non-positional number system, and comparison of the values of numbers in the form of RNS is impossible - for example, the division operation consists of the operation of comparing values, which is also a problematic operation.

*“Attempts to solve this problem are still being undertaken by various scientists in different directions, but there is still no universal solution suitable for any task. As a result, there are currently no algorithms for adjusting the ADF coefficients implemented in the RNS. Therefore, the development of a new adaptation algorithm - adjusting the filter coefficients - using the RNS and ensuring the specified requirements for the quality and speed of adaptation is the most important task of digital signal processing ”.*

Scientists from the St. Petersburg State Electrotechnical University "LETI" together with colleagues from the North Caucasus Federal University and the University of Gauhati (India) have created a new algorithm for adjusting the coefficients of the adaptive digital filter in the residual class system. It turned out that this algorithm can be used to solve the most important problem of digital signal processing. It will increase the speed of signal processing due to noise reduction without loss of quality. The research results are published in one of the most prestigious interdisciplinary journals - IEEE Access.

*“To correct each coefficient, it is necessary to perform one operation of subtraction, one operation of multiplication and one operation of addition modulo RNS, that is, the recalculation time is proportional to the order of the filter. A fundamentally new algorithm is proposed that surpasses the existing LMS and RLS algorithms and their modifications in a number of parameters: the quality of adaptation (noise*

reduction), ease of implementation, execution time, etc. The main difference of the developed algorithm is the sequential adaptation of each coefficient with zero error. In the well-known algorithms, the entire vector of coefficients is iteratively adapted to a certain specified accuracy. The number of iterations (steps) is determined by the length of the input signal for all algorithms . "

Scientists also proposed a method for applying the developed algorithm depending on the filter length and signal length. They performed mathematical modeling of the considered algorithms, and also demonstrated how the proposed methodology can help the designer in adjusting the filter coefficients without the need for extensive trial-and-error procedures. Scientists analyzed the quality of noise reduction and computational complexity on the example of synthetic and real seismic data.

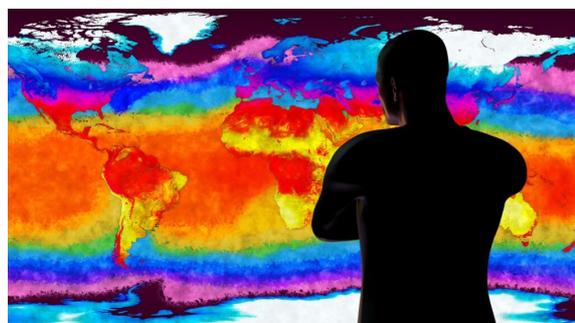
The proposed algorithm can find application in the work of seismologists for a better and faster determination of seismic activity, for example, an earthquake or an explosion; will be in demand in hydroacoustics, bioinformatics and other areas of human life.

#### **14. Scientists ensure accurate measurements for carbon diplomacy**

*Source: MIPT News, 19 July 2021*

MIPT has developed a multichannel heterodyne spectroradiometer for remote sensing of greenhouse gases. In recent years, the problem of anthropogenic impact on the climate has moved from the scientific plane to the economic and foreign policy. On Wednesday, July 14, the European Commission published the first official proposals for the introduction of cross-border carbon regulation in the EU. From 2023, the European Union plans to introduce a carbon tax and technologies that allow precise

measurements of the concentration and fluxes of greenhouse gases that Russia needs to determine the carbon balance at the macroregional level. Development article published in Remote Sensing magazine.



According to the UN, the last decade has been the warmest in the history of mankind. The European Union is actively pursuing a strategy to decarbonize its economy. Countries commit to zero emissions by the middle of this century. Russia has also joined the process of transition to new industries with a significant reduction in the participation of carbon in any form. From 2023, the European Union plans to introduce a carbon tax. Russia is the world's largest exporter of hydrocarbons, on the one hand, and on the other, there are the world's largest natural and climatic resources on its territory.

Alexander Rodin, executive director of the scientific and technical center for monitoring the environment and ecology of the Moscow Institute of Physics and Technology, explains: " We know quite well how much carbon is emitted by industrial enterprises. The man-made carbon footprint can be calculated and estimated fairly accurately. But the absorption, or, as experts say, the sequestration of carbon by various natural landscapes is a rather poorly studied process, since natural biochemical cycles are by no means more complicated than what mankind still possesses. "



*Multichannel heterodyne spectroradiometer*

Natural landscapes are very diverse, and, depending on the state, they can either absorb or emit, that is, release carbon. It is these uncertainties that allow geopolitical partners to put Russia at a disadvantage. So, from international reporting it follows that the forest in Finland is a carbon sink, and exactly the same forest in Karelia is already an emitter. The question is why? In order to have an evidence base and objective assessments of the absorption or, conversely, the emitting capacity of various natural environments, Russia urgently needs to build up scientific expertise in this area.

Monitoring greenhouse gases requires very high precision. Few types of devices cope with this task. The laboratory of applied infrared spectroscopy of the Moscow Institute of Physics and Technology has created a device with unique characteristics.

Alexander Rodin adds: " Our multichannel heterodyne spectrometer is one example where a small team managed to significantly surpass the global level. The closest competitors in NASA are several years behind us in these developments. As of today, measurements of this class with a resolution of  $10^8$ , that is, one hundred million, in the near infrared range, except for us, no one is doing yet. "

The unique characteristics allow you to measure the concentration of atmospheric pollutants,

including greenhouse gases, with high accuracy. To date, a field device has been developed at the MIPT Center for Environmental and Ecology Monitoring. Now, when carbon polygons are being created in the country, there is a need for such equipment. The device is also interesting because, despite its unique characteristics, it is easy to operate and quite cheap. This is just the case when the saying "the need for invention is cunning" is true.

Alexander Rodin sums up: " We are negotiating on this topic, and I very much hope that our equipment and technologies will be used there. Precision instrumentation today requires very high accuracy. All the equipment currently used in this area is of imported origin, our industry does not produce anything of the kind. But even from a very advanced development to a device that would not only be used, but believed internationally, there is a long way to go. It is necessary to carry out certification, cross-calibrations, obtain international recognition. All this is a very serious work that we are doing now. "

A multichannel laser heterodyne spectroradiometer is also being developed for space applications. In addition to monitoring carbon dioxide, the most important greenhouse gas, the concentration of tropospheric methane and stratospheric water vapor must be accurately measured. The device is capable of simultaneously measuring the vertical profiles of  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$  and  $\text{O}_2$ , as well as carrying out direct Doppler measurements of wind speeds in the range of heights from 5 to 50 km.

The Laboratory for Applied Infrared Spectroscopy has been developing ultra-high resolution heterodyne spectrometers since its inception in 2011. The Scientific and Technical Center for Environmental and Ecology Monitoring, which includes three laboratories and one department, develops integrated

software and hardware monitoring systems in the interests of the Ministry of Natural Resources of Russia, other departments and state corporations, as well as commercial customers.

### 15. Kuzgtu scientists have created an environmentally friendly technology for processing coal waste

Source: *Scientific Russia*, 25 July 2021



Scientists of the Kuzbass State Technical University (a member of the Kuzbass REC) have developed a technology for processing coal waste into a safe gas similar in composition to natural gas. This technology reduces emissions of harmful substances by 2.5-3 times.

As an innovative development, a technological solution was proposed for the processing of coal waste using a binder in the form of dewatered excess activated sludge in order to obtain gaseous fuel. The characteristics of the environmental hazard from the use of the obtained fuel in comparison with the traditional combustion of fossil fuels in terms of the emission of harmful substances turned out to be 2.5-3 times lower.

In the process of research, scientists formed fuel pellets, dried them to determine the abrasion strength. Further, in the process of pyrolysis (thermal decomposition), a gas was obtained.

The studies carried out have shown that the composition of the produced gas is equivalent to that of natural gas. Thus, in the future, it can be used as a gaseous energy carrier in multi-apartment and residential private houses for cooking, heating and heating water, as well as fuel for cars and boilers.

On the basis of the developed technology, it is planned to create installations that will be designed according to the requirements of a specific customer, taking into account the specifics of the generated waste planned for processing. The estimated cost of small-sized plants will vary within 5-6.5 million rubles, depending on the type of raw materials, processing volumes and operating conditions.

### 16. In Conversation :- Russian Climatologist – Prof. Vladimir Semyonov, explains: Climate has always changed, but not as dramatically as it is now

Source: *INTERFAX.RU*, 01 August 2021

The problem of climate change is increasingly called the new global problem of our time. The climate problem is discussed at the summits of heads of state and government. This is clear. So how does the climate affect the occurrence of heat and floods, and, consequently, human health? On the topic of changing climatic conditions on Earth, our special correspondent Vyacheslav Terekhov talks with Corresponding Member of the Russian Academy of Sciences Vladimir Semenov, a Russian climatologist, specialist in the field of diagnostics and modeling of climatic changes, deputy director of

the A.M. Obukhov Institute of Atmospheric Physics.

- More and more often we observe natural paradoxes: in one part of the Earth, even on one continent - heat, drought, hence forest fires, and nearby - rivers overflow their banks, floods occur, which are also catastrophic. Is it related to the dramatic climate change on Earth or to human activity? Moreover, these changes are not global, but in individual areas.

### **FROM THE CANNON ... THROUGH THE CLOUDS!**

- Of course, the problem of climate change is a global problem. It is scientific, philosophical, and purely human.

Let's take a little history. At the end of the 19th century, many people were shocked when the first experiments were carried out to induce artificial precipitation by shooting ordinary projectiles at the clouds. Sometimes it coincided with rain, which caused a lot of noise. There have been many discussions - religious and philosophical: does a person have the right to do such things? Doesn't that contradict God? Previously, this was the prerogative of higher powers.

But we survived. Now, unlike the little-useful experiments of a century ago, effective methods of precipitation initiation have been developed, and we actively use artificial rain during, for example, parades. Now we are experiencing in a psychological state a moment somewhat similar to the end of the 19th century. For the first time in the history of the Earth in 4.5 billion years, a person was able to change the climate by the results of his activities, but already on a global scale! This became noticeable not only at the generation level, but also for young people who lived for thirty years. The climate is changing before their eyes, as a result of this the nature of the weather is changing, including on the territory of Russia. Over the past 50 years, our

temperature has risen by almost two degrees. And this brings about noticeable changes. Moreover, we, climatologists, see all this on instruments.

Data from satellites suggests a strong rise in temperature as a result of human emissions of carbon dioxide (greenhouse gases). Not only greenhouse gases, but also the values of the fluxes of solar radiation coming to the Earth and thermal radiation leaving the Earth are well tracked. So we directly measure not only the increase in the concentration of greenhouse gases in the atmosphere, but also their impact, especially over the past 20-30 years, on the change in the planet's heat balance, and from indirect data we can well judge these changes in the last at least 50 years. And this data is consistent with the observed warming and its estimates made back in the 1970s.

### **THE CLIMATE HAS ALWAYS CHANGED, BUT THE PACE IS DIFFERENT**

- Of course, when the population of the Earth was in the hundreds of thousands or millions of people, the climatic changes, although they were, were not so drastic. They depended not on human activity, but on other factors: on changes in the parameters of the Earth's orbit and axis of rotation, solar activity, on the movement of tectonic plates (which are constantly moving about 5-10 centimeters per year), on changes in the composition of the atmosphere. Along with climate change, there have been changes in the configuration of continents and oceans. And even earlier, the climate depended on processes in the Earth's mantle and on other natural factors.

- The climate has always changed, but the pace of its change accelerated. So?

- Sure. With each period of time, the population on Earth increased and finally approached such a level that it became a factor in climate change. Now the planet is home to almost eight billion

people, mostly in cities with a rich infrastructure. The result of their activity was greenhouse gases, which, as we have already noted, affect the change in the composition of the atmosphere, and hence the climate on the planet. It is quite understandable that in recent decades, at the highest political level, the question has arisen of the need to reduce activities harmful to the atmosphere.

### **OR MAYBE YOU SHOULDN'T "BREAK THE SPEARS"?**

- The fact that a person develops himself by his activity, but has a harmful effect on nature, and thereby on his health, has already become the talk of the town. However, in one of the academic publications, I recently read an article where climatologists, those who are engaged in the Arctic Ocean, as they say, went on land and, together with scientists on the problem of permafrost, came to conclusions, somewhat correcting the position that it is a person who causes the most great harm to the atmosphere. They found that the carbon dioxide emissions in the Arctic, in the permafrost region, are much higher than from industry. Does it mean that nature itself adds, if not surpasses, the harmful effect on the atmosphere? Is it worth it then to "break lances" in the struggle to reduce harmful industries?

- This is, first of all, not so. We see changes in concentration, we know the balance of how much is emitted by humans, how much (roughly estimate) the Ocean and terrestrial ecosystems can absorb. All this is at the level of hypotheses, according to which methane hydrates on the shelf release methane flows during the thawing of permafrost. I repeat, these are just hypotheses. But analyzing satellite data of methane and carbon dioxide measurements, we see trends in these values over the past fifteen to twenty years. And they do not record any additional growth in the high latitudes of the Northern Hemisphere!

- Then how to explain their data?

- Very simple. Specialists pass on ships over some kind of cut, get a fixation of the increase in methane on the instruments. They believe that these indicators indicate the beginning of the process of methane release from the permafrost, which is affecting climate change. But these are local indicators, and the results of other studies indicate that the change in methane concentrations in this area is due to crustal faults - where the temperature is higher, methane hydrates begin to melt there. This has nothing to do with the process of global warming - these are local processes and in the global balance they have no significant effect on the total content. These are just speculations, hypotheses that have not been confirmed by anything, except for such local experimental data.

### **HEAT IS ASSOCIATED WITH RAINS!**

- How can one explain the simultaneous and completely opposite manifestation of weather phenomena: in one part of the country or continent, the strongest excess of the temperature norm, causing drought and fires, and in another - floods with catastrophic consequences?

- As for the simultaneous floods and heat waves, these are generally processes related to each other. The heat that has established in our territory of the European part of Russia is associated with a blocking anticyclone (an anticyclone is an atmospheric mass, a vortex movement of air with high pressure in the center. one wind vortex air flows over a certain part of the planet (it has huge dimensions and low pressure in the center - IF). In our middle latitudes, there is a constant transfer of air masses from west to east. This feature is associated with atmospheric circulation due to the south-north temperature difference. And if an anticyclone arises, then it does not allow this flow to spread. But in summer, along with the transfer of air masses, humid and cool air

currents come to us from the Atlantic. The continent, under the influence of the summer sun, heats up faster and stronger, and the ocean is inertial and the temperature, roughly speaking, remains about 18-20 degrees. When an anticyclone appears, it seems to block the passage of cool air masses from the ocean and causes us heat! Plus the anticyclone is a clear sky and all solar radiation passes along the surface of the earth and heats it up.

This is one side of the coin. The other concerns Europe: those cyclones that used to pass through Europe to our territory and went further, they also get stuck in a traffic jam. All this moisture freezes, and instead of just passing through heavy rainfall for one day, it pours in the same place for several days!

- I remember at the same time a phrase from a Soviet comedy: "the weather is good on Deribasovskaya, it is raining again on Brighton Beach!" So it is here: the heat in central Russia in Western Europe causes rain. So?

- Almost. But our South is also connected by the "games" of the cyclone and anticyclone. In particular, wetter and warmer air masses over the Black Sea, which has warmed by 2.5 degrees over the past 40 years, when the cyclone passes along the coast, in the foothills pour out more abundant rains than before.

### **IN SOME WAYS, A PERSON IS POWERLESS ...**

- Can a person somehow influence this formation?

- Man cannot influence the formation of cyclones and anticyclones. This requires colossal energies. According to some estimates, the energy of one cyclone, not the largest, is equal to the amount of electricity that a person generates at one time! This is a huge energy and it is absolutely impossible to somehow influence the formation and dynamics of such processes.

### **... AND IN SOME WAYS REAPS THE FRUITS OF CARELESSNESS AND EVEN GREED!**

- Is it possible to foresee floods and droughts in advance?

- This is a good and important question. The predictability of such events on a scale from a week to a month is now being intensively studied at our institute. The fact is that the usual weather forecast gives us a reliable forecast for about three to five days, maximum - a week, but after this period the weather is already random. Methods of prediction on a longer scale are now being developed; this is, as it were, a new, different science. In this regard, we are trying to move forward. And not only us. Over the past ten years, intensive research on this topic has been carried out, in particular, at the European Forecast Center. They recently published an article where they report that they were able to predict the heat of 2010 about a month before it came to Moscow.

But here we must also understand that we are all strong in hindsight. Therefore, so far this is just a new and important direction, which is intensively developing. But, frankly, there are no significant successes yet. We need to apply other methods that we want to develop.

### **AND YET - NATURE IS NATURE, AND IT WILL NOT HURT A PERSON TO THINK!**

- And yet, I would note that there was a forecast for Germany before the flood: meteorologists predicted the intensity of precipitation and its localization. That is, the amount of precipitation that will pour out was known very accurately during the day. This is enough time to take emergency measures. But for some reason this did not happen. Knowing the nature of the impending events, no one took any serious measures. This is strange. And in this direction, you can also work, somehow take more

seriously the forecasts and risks of such phenomena.

- We talked about floods. And what about the fires?

- In the heat, I would say the same. We cannot predict when we will have such a blocking anticyclone. It was suddenly installed, fixed. But we don't know when it will collapse. That is, by the nature of the circulation, we can say: yes, this blocking anticyclone will most likely last for at least a week. But then other processes are already switched on - it can self-support and freeze in one place - say, two or three weeks, or even a month - and in such conditions, of course, the risk of fires increases. Here, again, the antecedent conditions must be taken into account. If the soil is moist, for example, then this is good, because the moist soil, evaporating moisture, does not allow the surface to warm up, if the soil is initially dry, then a week and a half is enough, the soil dries up, and the earth begins to warm up, soil drought occurs.

In such conditions, we have fires - peat, forest, the most negative consequences occur as in 2010 - severe air pollution, fires, etc. But here, I repeat, just like with floods, you just need to take measures to prevent exactly the consequences of such hot periods. Much has been written about this. In 2010, the same peat areas of the Moscow region were previously reclaimed, there were canals where water could be let in to moisten them. Everything was started. It is the same with forestry - clearings, cutting down old dry forest, exporting it, etc. - this should be actively pursued. That is, this is a complex problem and it is connected not only with the weather, climate, but also with the actions of people on the surface of the earth, how they prepare forests and infrastructure for such possible events.

- We reap the fruits of our carelessness and indifference to nature.

- Yes Yes. But not only that. We also reap the fruits of our, shall we say, greed and desire to make big profits.

#### **WHAT IS THE COMING DAY FOR US?**

- What can we expect in the next ten years?

- Warming will continue in the next ten years. At about the same pace that it continued in the previous 20 years. That is, over the past 30 years, the temperature in Russia has increased by about 1.2-1.5 degrees. This is, in principle, a lot, well, accordingly, over a decade, somewhere on the order of 0.4-0.5 degrees, warming still needs to be added. That is, the climate will be approximately the same as now, but noticeably warmer than at the end of the 20th century. Warming should be expected to continue until the middle of the century. Therefore, some measures for adaptation need to be taken now.

I constantly say that climate change is absolutely not fatal to humans. It will survive warmer and colder weather. The problem is in the costs that the economy, human activity, health will receive, if you do not prepare for changes!

### **17. Russia has created a unique material to protect buildings from earthquakes**

*Source: RIA Novosti, 01 July 2021*

A scientist at Vyatka State University has developed a viscoelastic material that has no analogues, which is capable of providing additional seismic safety of buildings during earthquakes. The material was successfully tested at the Madrid Polytechnic University and was highly appreciated by Spanish experts, the press service of Vyatka State University reported.



*Sample of a new viscoelastic material connecting surfaces*

Researchers from around the world are looking for effective ways to protect buildings and structures from destruction during earthquakes. In recent decades, an approach based on passive energy dissipation has been developing. In special systems, the energy of earthquakes in them is supplied to special devices - seismic shock absorbers. These are, for example, viscoelastic dampers, which control vibration of a structure due to shear deformation and the corresponding energy dissipation of the viscoelastic material.

Another type of seismic damper includes hysteresis dampers, which increase the lateral rigidity of the structure and can dissipate a large amount of energy due to plastic deformation of metals.

One of the promising developments was created by scientists from the Polytechnic University of Madrid: they proposed a new clamp-type seismic damper designed for seismic protection of structures. This tube-in-tube damper consists of two hollow structural sections. The outer one has a number of strips formed by the device of slots in the wall, and is welded to the inner hollow section so that when the damper brace, undergoing forced displacement in the direction of its axis, the strips dissipate energy due to bending / shear deformation.

Spanish developers have proposed to design a seismic damper that combines the advantages of hysteresis and viscoelastic dampers. To do this, they decided to place a special viscoelastic material in the hysteresis damper, which will be the first to perceive seismic loads and provide additional losses of vibration energy.

## **18. Scientists are investigating the contribution of continental waters to the Barents sea due to permafrost degradation**

*Source: Scientific Russia News, 16 July 2021*



The sea expedition on the Dalnie Zelentsy research vessel in the Barents Sea near the Kola Peninsula, organized by the Murmansk Marine Biological Institute of the Russian Academy of Sciences, has come to an end. During the expedition, Evgeny Yakovlev, a young Arkhangelsk scientist, head of the laboratory of ecological radiology at the Federal Research Center for the Comprehensive Study of the Arctic of the Ural Branch of the Russian Academy of Sciences, took samples for further analysis, which will make it possible to assess the presence of thawed continental waters in seawater due to permafrost degradation. The work is carried out within the framework of a grant from the Russian Science Foundation.

As the head of the research project Evgeny Yakovlev explained, to isolate the thawed permafrost component and quantify the contribution of continental waters to the chemical balance of the Arctic basin, data from isotope tracers (indicator isotopes)  $^{234}\text{U} / ^{238}\text{U}$  (uranium) and  $\delta^2\text{H} + \delta^{18}\text{O}$  (deuterium and oxygen-18). Their presence in seawater is due to global warming and the degradation of permafrost.

Studies previously carried out by scientists from FITSKIA UB RAS within the framework of the Roshydromet project "Transarktika-2019" showed that the isotopic composition of uranium ( $^{234}\text{U} / ^{238}\text{U}$ ) in the Barents Sea differs significantly from the average for the World Ocean.

- The data available to date on variations in the isotopic composition of uranium in the waters of the World Ocean, as well as in corals, shells of molluscs and carbonate deposits, confirm the hypothesis that the increase in the flow of uranium-234 in the ocean is due to an increase in the runoff of melt water formed during the degradation of permafrost on continents during warm climatic eras. The data on the Barents Sea showed that the enrichment of ocean water with uranium-234 is manifested the stronger, the more isolated the sea area from the general oceanic circulation, the greater the relative length of the coastline and the contribution of continental waters to the chemical balance of the reservoir, - Yevgeny Yakovlev notes.

In addition, the expansion of the database on the isotopic composition of uranium in ocean waters, sediments, carbonate formations will clarify the possibility of using this parameter for paleoreconstructions.

## **19. The development of a research work from ETU "LETI" will improve the operation of navigation systems**

Source: *SpbGETU "LETI" News, 03 Aug 2021*

To orient objects in space, various navigation systems are used - a set of algorithms, software and devices capable of responding to changes in the orientation angles of the body. These changes are recorded using gyroscopes - special devices that measure the angular velocity of rotating objects. Such devices often operate in unstable conditions of overload, which can significantly affect the quality of work and the accuracy of the result obtained.

The project "Development of Sensitive Elements of Angular Velocity Sensors on Bulk Acoustic Waves" by Yasemin Durukan, assistant of the Department of Electroacoustics and Ultrasonic Engineering (EUT), will allow creating sensitive elements that are distinguished by their ability to function under vibration and overload conditions and have a wide dynamic range of the measured value.

"The ability of the elements to function under vibration and overload conditions is due to their high strength - the product body is solid, and due to the high dynamic range of the measured value, there are no restrictions for measuring both low angular velocities and high angular velocities," says Yasemin, a postgraduate student of the ETU Department of ETU "LETI" Durukan.

Today there are no analogues of the device being created - the element being developed by the LETI researcher operates on bulk acoustic waves, while the closest analogs, mass-produced at enterprises, use surface acoustic waves.

The operation of the angular velocity sensor element is based on a change in the polarization

of the waves. “At the ends of the solid-state body of the device there is a radiator that excites a volume acoustic wave and a receiver of these vibrations. When rotation appears, the wave begins to propagate with a large rotation. The informative signal caused by the rotation is a change in polarization, ” Yasemin Durukan describes the principle of operation .

The girl has already created a full-fledged working model - a cylindrical glass body with an oscillator and oscillator. Further plans include the development of a competitive sample with minimum dimensions and maximum output signal level.

At the ETU Department of ETU "LETI", research in the field of studying acoustic waves began in 2006 with a description of the theory of propagation of surface waves in rotating media. Thus, the scientists of the department formulated acoustic principles and technical solutions for creating a sensitive element of an angular velocity sensor based on the features of the propagation of volumetric acoustic waves of circular polarization in solid media.

The development was highly appreciated by the American Acoustic Society, for which the researcher received an award.

## INNOVATION

### 20. TPU Scientists find method to save over 50 percent of fuel at refineries

Source: *TPU News*, 26 July 2021

Scientists of Tomsk Polytechnic University have developed a method to reduce refinery energy consumption. Using this method, the scientists were able to save more than half of the fuel at the researched manufacturing site. The university experts believe that these results can

be achieved at almost any industrial manufacturing facility. The research findings are published in the *Energy Conversion and Management* academic journal (IF: 9,709; Q1). Journalists of the Sputnik international news agency told more about the conducted research.



The scientists used hydrocracking, the processing of high-boiling oil fractions to generate fuel at the refinery. They proposed to reduce the spend of energy resources using the optimization of a structure of technological and heat fluxes. The specific sequence of heat exchangers led to increasing energy efficiency. As a result, the consumption of fuel gas and heavy fuel oil was reduced by 54 percent, while the consumption of electrical energy was reduced by 20 percent at the refinery.

“For instance, there are three heat fluxes. The first flux is heated by steam, the second one is cooled by water and the third is heated in the oven. To save energy resources, we can heat the first and third fluxes by the second one. There are dozens of such fluxes at any operating refinery,” Stanislav Boldyrev, Research Fellow of the TPU Research School of Chemistry and Applied Biomedical Sciences, said.

According to the researcher, the proposed method can be used both for the renewal of operating enterprises of the secondary sector of the economy and for designing new more

energy efficient manufacturing facilities with a minimal impact on the environment. Such renewal will allow refineries to reduce costs for manufacturing final products and to reduce the environmental impact.

Fuel saving at the refinery where the experiment was conducted led to the reducing carbon dioxide emissions by 19 t per year. It is linked with the overall reduction of burning fuel.

“This technology can already be used for improving processes in chemical and gas processing industries, food handling. The technology can be used everywhere where raw materials are used and it deals with heating, cooling and chemical transformations,” Stanislav Boldyrev notes.

To create an optimal flux structure, the researchers used pinch technology, integration principles of seamless process flows, graph theory and fundamentals of heat and mass transfer.

Fuel saving at the refinery where the experiment was conducted led to the reducing carbon dioxide emissions by 19 t per year. It is linked with the overall reduction of burning fuel.

“Pinch technology lies in minimizing gross energy in any system where there are fluxes which must be heated and cooled. Using these fluxes, it is possible to recuperate thermal energy, i.e. to use this energy one more time.

In its turn, graph theory allowed optimizing the structure and forming a mathematical task. The graph theory helped to reduce the number of required heat exchangers, i.e. to select a structure of a heat exchanger network, in which there will be two heat exchangers instead of ten additional ones. Thus, it is possible to reduce capital expenses for manufacturing renewal,” the scientist added.

## **21. NSTU NETI scientists can refine oil from water with the help of current**

Source: NSTU NETI News

Scientists of Novosibirsk State Technical University NETI have created and patented a technology to reduce the time of oil refining from water at the deposit immediately after production. The technology is based on the combination of electric and magnetic fields.

When oil is extracted from the field, it rises to the surface together with the oil waters. The amount of water and oil in the mixture may vary depending on the deposit and production conditions. With traditional refining technology, the mixture is settled, water and oil are stratified and then the oil is fed into the pipeline. However, such a natural process can take a long time.

“The settling rate is related to the water properties, such as density, viscosity and surface tension. We decided to increase the density of water, to carry out a quasi-weighting operation, which will reduce the settling time, ” said Yevgeny Porsev, associate professor of the Department of Electrotechnological Units, NSTU NETI.

The essence of the technology is the combination of electric and magnetic fields. Magnetic induction is created in a magnetic field using electromagnets with cores and a winding through which an electric current is passed.

“We can direct magnetic forces downwards, and electric forces across the movement of the water. Thus, we create conditions for increasing the water density; as a result, the floating of fat balls of oil accelerates, ” the scientist noted.

The increase in productivity depends on a variety of conditions at a particular deposit. According to Porsev, the technology is most expediently applied directly at the oil production site. It requires installing an electric power source and electromagnets near the deposit.

From the point of view of costs, the use of the NSTU NETI scientists' technology is comparable or slightly more expensive than the traditional method of separating oil and water. But taking into account the gain in time from the moment of production to sending to the oil pipeline, the economic benefits of the invention for the oil production industry are evident.

The patented technology can also be used for wastewater refining from oily impurities.

## **22. Flexible optical sensor made of nanodiscs can detect deformations in structures**

*Source: SB RAS News*

Krasnoyarsk scientists theoretically investigated the optical properties of a two-dimensional lattice of nanodisks and proposed a model of an optical strain sensor based on it. The idea of using the lattice arose when observing the microstructures of plants responsible for photosynthesis. The research results are published in the journal *Nanomaterials*.

Two-dimensional periodic arrays of nanoparticles have unique optical properties that can be used in the design and creation of optical sensors and sensors. The sensitivity of such devices is determined by the geometry of the lattice and the shape of its constituent elements, which imposes certain requirements on the technology of its manufacture and, as a consequence, on the cost of the final product.

Scientists from the Federal Research Center "Krasnoyarsk Scientific Center of the Siberian

Branch of the Russian Academy of Sciences" and the Siberian Federal University theoretically investigated a two-dimensional lattice of dielectric nanodisks and proposed a sensor model based on it. The principle of operation of a real device will be based on the change in the resonant wavelength of the structure during its deformation. Scientists have found that the optical response of the grating when it is compressed and stretched in two mutually perpendicular directions is different: in one case, the resonance wavelength does not change, in the other, its shift is observed. The sensitivity of such a device is determined by the difference in resonant wavelengths related to the coefficient of deformation of the structure.

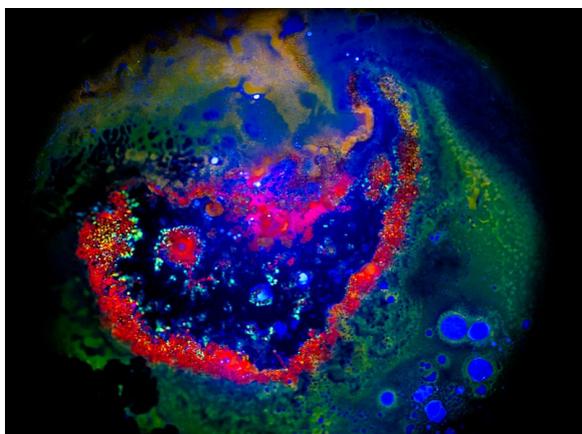
Such devices must have a high elasticity, which determines their operating range. Therefore, scientists propose placing nanoparticles in gel matrices or deposited on a flexible substrate, for example, on a film of polydimethylsiloxane. The elasticity of the material will prevent cracking when the structure is stretched or compressed. The use of such materials makes these structures look like soft matter or living tissue. It will allow the sensor device to behave like a "living plant" and, based on the behavior of the lattice and the corresponding spectral shifts, determine deformations in the structures on which it is located.

Similar lattices arise in the microstructures of plants responsible for photosynthesis. Inside the plant's leaf cells are chloroplasts filled with a thylakoid membrane containing chlorophyll, which gives plants a green color. However, the pigment is unevenly distributed in the green part of plants. The thylakoid gathers in folds, disc-shaped in shape, oriented towards the light source and arranged in lattices. It is possible that in this way the plant manages to concentrate the light flux in the area necessary for photosynthesis, or, on the contrary, to get rid of excess radiation.

“Such structures can form the basis of optical sensors or detectors that allow determining the presence of mechanical deformations and their magnitude. Such devices have high sensitivity, which is provided due to deformation of the lattice without additional changes in the shape of the nanoparticles themselves. This approach greatly simplifies the technological side of the implementation of the device and makes it much cheaper, ”- said one of the authors of the study, a researcher at the Institute of Physics. L.V. Kirensky FRC KSC SB RAS, candidate of physical and mathematical sciences Rashid Gelmedinovich Bikbaev.

### **23. "Cut" of Perovskite: ITMO Scientists have shown how to shape microscopic single crystals without loss of quality**

Source: ITMO News,



A group of scientists, which included ITMO employees, proposed a new method for processing tiny fragments of Perovskite. It allows you to cheaply and accurately shape microcrystals into the desired shape for creating lenses and other optoelectronic elements. This can bring closer the widespread introduction of this material into the industry. The researchers'

work is published in Laser & Photonics Reviews.

Today, one of the most actively studied materials is the perovskite family. The first perovskite was the calcium titanate mineral, discovered in 1839 in the Urals mountains, and has long been regarded as a material for capacitors. Then, in the 1980s, more complex perovskites began to be used for high-temperature superconductors. However, at the beginning of the XXI century it was rediscovered, this time as a valuable raw material for photonics.

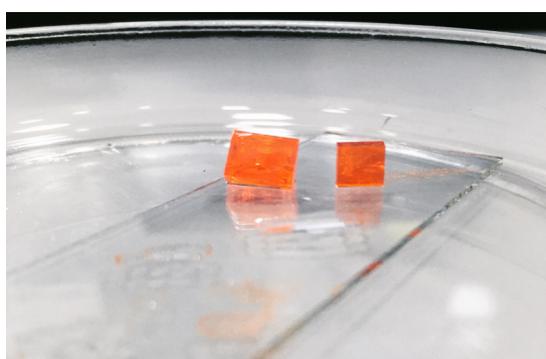
The so-called halide perovskites have great potential for use in optical systems. Lasers based on them can emit very clean and bright light. Perovskite efficiently absorbs light energy, which opens up the potential for its use in solar energy.

However, there are still a number of problems for the large-scale commercial use of perovskites. One of them is the search for a cheap and effective way to shape the microcrystals of this material into the desired shape.

*“One can draw an analogy with jewelry, where not only the quality of the diamond is important, but also its cut,” says **Sergei Makarov**, Dean of the Faculty of Photonics at ITMO University.- It is necessary to process the stone so as to give it the desired shape, preserving its properties. So here, it is necessary to process the perovskite in order to obtain from it, for example, a microlens or other optical element. At the same time, we must not damage its functional properties, first of all, optical transparency and luminescence efficiency. ”*

### Disadvantages of existing methods

Scientists today know a number of ways to process semiconductor materials. They allow you to cut, extrude or etch the required pattern on the surface of the sample or to give the microcrystal of the material itself the necessary shape. However, these methods are poorly suited for working with micro- and nanoscopic perovskite particles.



*Cube-shaped perovskites. Photo courtesy of the researchers*

*“For example, one of the most accurate nanolithography methods is lithography with a focused ion beam,” explains Sergey Makarov, “an ion flow is directed to the material and “removes ”the excess part of the material from the sample. But this technology doesn't work with perovskite. The gallium ions used for processing break the crystal structure and are incorporated into it. We're just messing up the stuff. Even if after processing it looks good in shape, in reality its optical properties are hopelessly damaged. ”*

The fact is that gallium ions embedded in the structure of the crystal begin to absorb light, rather than transmit it through themselves. As a result, it is no longer possible to make an active element for a laser from such a crystal. Therefore, scientists experimented with

various methods of processing perovskite. The methods gave results, but were difficult to apply and often also led to material spoilage.

*“For example, multistage lithography using photoresistors,” explains Sergey Makarov, “implies the application of liquid materials to protect the sample. But we are working with microcrystals that do not adhere very reliably to the substrate. By applying liquid, we can move them or wash them off altogether. It is possible to use nanoimprint lithography, when a pattern is applied to a crystal using a press mold under pressure. But here, too, a problem arises, because the pressure can displace the microcrystal, which again will lead to its deterioration during processing. ”*

### Laser treatment

An international group of scientists, which included scientists from ITMO University, the Far Eastern Federal University, the Institute of Image Processing Systems of the Russian Academy of Sciences and the Japanese Tokai University, proposed a different way to give perovskite single crystals the desired shape.

*“In our previous works, we tested the technology of laser ablation of thin films consisting of many nanocrystals of perovskite,” recalls **Alexander Kuchmizhak**, senior researcher at the Pacific Quantum Center of the Far Eastern Federal **University** and IAPU FEB RAS, co-author of the work. “We have shown that it is possible to cut microstructures of various shapes from the film with a laser. Moreover, this treatment did not lead to degradation of the optical and light-emitting properties of the obtained structures as a result of laser action. Based on this work, we decided to try a similar method for processing single micro- and nanocrystals of perovskite. ”*

To do this, the scientists used ultrashort (femtosecond) laser pulses. Due to the fact that

perovskite has a relatively poor thermal conductivity, the scientists managed to burn out the necessary parts of the crystal without damaging its structure in neighboring areas. Thus, the scientists managed to "cut" lenses and other elements from monocrystals that can be used in optical systems.

*“Using the developed laser recording method, we managed to form various functional optical microstructures from perovskite microcrystals - various microlenses,“ subwavelength ”diffraction gratings with a period significantly less than the wavelength of optical radiation, and so on. However, perovskite optical elements can be used not only as passive devices - for deflecting the beam or focusing it to the diffraction limit, they can also act as functional elements of more complex active optical devices - microlasers, ultrafast modulators and other elements of new generation optical chips ”- says another co-author of the work, senior researcher at IAPU FEB RAS and FEFU **Aleksey Zhizhchenko.***

## NEW MATERIALS

### 24. Researchers have taught the neural network to correctly name organic molecules

Source: *Scientific Russia News*, 31 July 2021

Researchers from Skoltech, Moscow State University named after M.V. Lomonosov and Syntelly have developed and trained a neural network to generate the names of organic compounds in accordance with the IUPAC chemical naming system. Using this example, they showed that modern neural networks are capable of solving exact algorithmic problems. An article describing the study was published in *Scientific Reports*.

In chemistry, there is a generally accepted language for recording the names of organic compounds - the nomenclature of IUPAC, the International Union of Pure and Applied Chemistry. For example, sucrose familiar to everyone is called (2 R , 3 R , 4 S , 5 S , 6 R ) - 2- [(2 S , 3 S , 4 S , 5 R ) - 3,4- Dihydroxy-2,5-bis (hydroxymethyl) oxolan-2-yl] oxy-6- (hydroxymethyl) oxane-3,4,5-triol, and the popular drug paracetamol is N - (4-hydroxyphenyl) acetamide .



This name of a substance fully reflects its chemical structure, therefore, for complex molecules, the names according to the IUPAC nomenclature can be very cumbersome. At the same time, an error even in one symbol will be critical, that is, the use of the IUPAC nomenclature requires the chemist to be attentive and well aware of its numerous rules. There are commercial software products on the market for computer generated IUPAC names, but no software under a free license.

“We originally wanted to create an IUPAC name generator for Syntelly, our AI platform for chemistry. Realizing that creating an algorithm by digitizing IUPAC rules could take more than a year, we decided to take advantage of our experience in creating neural network solutions, ”says Sergei Sosnin, research leader, Skoltech researcher and co-founder of Syntelly startup.

The researchers took as a basis Transformer, one of the most powerful modern neural networks

created by Google for machine translation from one language to another. The team trained Transformer to "translate" a molecule from structural representation to IUPAC name and vice versa.

To train and test the network, the study authors used the world's largest open source PubChem database, containing about 100 million connections. The neural network, created in about a month and a half, was able to "translate" with almost the same accuracy (about 99%) as algorithmic solutions based on chemical rules.

In addition, the study showed that neural networks are capable of solving algorithmic problems with sufficient accuracy. "Both humans and neural networks will do well, for example, with the task of distinguishing between photographs of cats and dogs, for which an efficient algorithmic solution is impossible without machine learning. At the same time, a person does not multiply multidigit numbers well, and the simplest calculator does it instantly and with absolute accuracy - this is an example of a purely algorithmic problem, as well as the generation of names according to the IUPAC nomenclature," Sosnin explains.

"Previously, the paradigm prevailed that neural networks should not be used to solve such" exact "problems, but we have shown that this can be a reasonable alternative to complex algorithmic solutions. in one letter leads to a completely wrong molecule. And nevertheless, the Transformer successfully copes with this task ", - adds the scientist.

The developed solution is implemented in the Syntelly platform and is available online . The researchers hope that their method can be applied not only to translate between chemical notations, but also to other technical notations, such as generating mathematical formulas or translating computer programs.

## 25. Scientists synthesize a material which can completely replace natural gypsum in the construction industry

Source: MISIS News, 02 Aug 2021



An international team of scientists has proposed a method of production of high-quality gypsum binders based on synthetic calcium sulfate dihydrate produced from industrial waste. Tests of the obtained material have shown that it not only meets all the requirements for materials of this class, but also surpasses binders based on natural gypsum in several parameters. The work has been published in the Journal of Industrial and Engineering Chemistry.

Gypsum binders are widely used in construction. They have valuable properties such as low weight, low heat and sound conductivity, fire resistance, and they are easy to shape. In addition, gypsum-based binders are hypoallergenic and do not cause silicosis, an occupational disease for builders and repairmen caused by inhalation of dust containing free silicon dioxide. At the same time, the cost of gypsum materials is low, as are the costs of heat energy for their production.

A group of scientists from NUST MISIS, Belarusian State Technological University,



University of Limerick and the Institute of General and Inorganic Chemistry of the National Academy of Sciences of Belarus has proposed an innovative method of producing high-strength binders based on synthetic gypsum obtained from industrial waste by neutralizing spent sulfuric acid and carbonate components. Researchers mixed sulfuric acid from waste heat-resistant fibers with water and limestone. The content of calcium sulfate dihydrate in the obtained synthetic gypsum was at least 95% of the mass of the final product.

In the course of the study, scientists obtained three types of synthetic gypsum samples: building gypsum, high-strength gypsum and anhydrite. The building gypsum was made using traditional technology in a gypsum boiler. Anhydrite was also produced according to the traditional technology for this type of gypsum material by firing followed by cooling. An autoclave was used to synthesize high-strength gypsum.

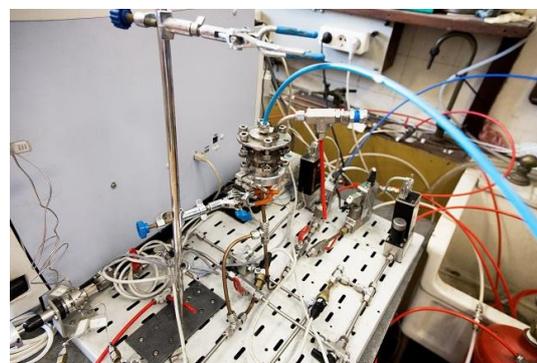
The researchers point out that one of the advantages of producing building gypsum materials from synthetic calcium sulfate dihydrate is that the synthetic gypsum is obtained immediately in the form of a powder product. In the traditional production of gypsum powder, gypsum has to be crushed to the desired

state, which requires a significant amount of electricity. Thus, the method proposed by scientists for the production of binders based on synthetic gypsum will significantly reduce production costs by simplifying the production technology. At the same time, the building gypsum obtained in the course of the study fully meets the requirements for gypsum binders of the G5 — G7 grades, for high-strength gypsum — the requirements for gypsum grades G10 — G22.

Synthetic gypsum, obtained from waste sulfuric acid and limestone waste, can completely replace natural gypsum for the production of gypsum binders in countries that do not have gypsum stone deposits.

## 26. Chemists have found the perfect Graphene oxide for drying membrane

Source: *Scientific Russia News*, 05 Aug 2021



*Reactor for studying membrane properties*

The staff of the Faculty of Chemistry and the Faculty of Materials Science of Moscow State University, as part of an international group of researchers with the participation of employees of the German synchrotron center DESY, showed that in order to create efficiently drying air membranes, it is necessary to use graphene

oxide with the maximum oxidation state. Membranes based on graphene oxide can be used both in household ventilation and air conditioning systems and in industry. The article was published in *Carbon* - the leading journal in the study of the structure, properties and applications of various carbon materials.

Two-dimensional materials are considered by scientists as a promising basis for very high quality membranes. The hopes are based on the fact that the thickness of two-dimensional materials is only a few atomic layers. Due to this, layer defects can be created in them, allowing only a certain type of molecules to pass through. For example, graphene oxide has a two-dimensional structure and is well wetted with water due to the large number of oxygen-containing groups. As a result, materials based on graphene oxide can adsorb up to 60% of water relative to their weight. The increased ability of the material to absorb and remove water vapor determines their high permeability through the membrane. The presence of water between the layers also blocks the transport of other gases. That is, water will pass through the membrane, but everything else will not.

“For the first time, the possibility of using membranes based on graphene oxide for gas drying was shown in 2012 in the work of Nobel laureate Andrei Geim ,” said Dmitry Petukhov , the author of the study, senior researcher at the Department of Inorganic Chemistry at Moscow State University . “ However, in this and in subsequent studies, the authors did not study the effect of the chemical composition and content of various functional groups on the rate of transport of gases and water vapor, which was done within the framework of our work.”

Graphene oxide is not one but a whole class of compounds with different ratios of carbon and oxygen atoms and the presence of different functional groups. Therefore, many of its properties are determined by the chemical

composition, which is set at the stage of synthesis. Dmitry Petukhov and his colleagues showed that to create highly efficient drying membranes, graphene oxide with the lowest possible ratio of carbon atoms to oxygen is needed.

“With a larger number of oxygen atoms, the hydrophilicity of the surface of the material increases, and therefore the membranes pass water better, ” explained Dmitry Petukhov. - To study this process, we obtained graphene oxide by treating graphite powder with potassium permanganate. Various oxidation states were achieved by changing the ratio of graphite and permanganate. Next, membranes were formed from the resulting suspension by deposition on a substrate and their transport properties were studied. A comprehensive study of such membranes required the use of a variety of physicochemical methods, therefore, studies were also carried out at the Udmurt Scientific Center of the Russian Academy of Sciences and at the DESY synchrotron center. ”

Membranes based on graphene oxide can be used both in household ventilation and air conditioning systems and in industry, for example, in the preparation of natural and associated petroleum gas for pipeline transport. True, there are still a number of problems associated with the deposition of graphene oxide over large areas, increasing the stability and durability of membranes. Therefore, chemists at Moscow State University are now actively working to increase the resistance of membranes to pressure drops, experimenting with the introduction of various compounds into the interlayer space.

## 27. TPU scientists have developed a technology for producing hydrogen from solid waste

Source: *Scientific Russia News*, 17 Aug 2021



*Thermal conversion plant*

Scientists of Tomsk Polytechnic University have developed a technology that allows to obtain synthesis gas with a high, from 20% to 40%, hydrogen content from solid waste - sawdust, coal dust, sludge, old tires. The peculiarity of the technology is that not one useful product is obtained from waste, but three at once. During processing, a minimum volume of CO<sub>2</sub> is released - no more than 5% of the total volume of synthesis gas. In the future, scientists expect to reduce this value to zero and find the most efficient way to isolate pure hydrogen from the mixture.

At Tomsk Polytechnic, the technology was developed on the basis of the Ecoenergy 4.0 Research Center of the School of Power Engineering. A line of installations has already been created here, which allows you to work with different volumes of the initial product - from a few grams to 20 kg. On the basis of Tomsk CHPP-3, a complex test stand was created for developing the technology, here you can work with the volume of the initial product already 4 tons per hour.

The technology is based on the method of steam thermal conversion. The original product is exposed to steam at high temperatures - from 500 to 1200 degrees Celsius, depending on the material.

“The global goal that we pursue in this and our other research is to find really working methods that will make it possible to obtain high-margin products from unnecessary waste that is not used in the energy sector in any way, and in the most environmentally friendly way. We set the task of not recycling, but recycling waste, - says the project manager, deputy director for development of the TPU Power Engineering School Vladimir Gubin . - We work with sawdust, old tires, waste from the coal industry - this is wood chips, slag, sludge, coal dust. Experiments have shown that it is from the latter that the synthesis gas with the highest hydrogen content is obtained. ”

In installations developed at TPU, the raw material in compressed form is destroyed by the action of water vapor in the presence of oxygen or without, depending on the material. There is a process that scientists call "underfiring", because only the organic part of the material is destroyed.

“We end up with three products in different phases. In hard - carbon chips, it can be used in road surfaces or as a filter for additional cleaning. If the starting material was pine sawdust, after processing we get excellent biochar for cooking. In the liquid phase, we obtain liquid hydrocarbon fuel, which can be used for heating. In gaseous form - synthetic gas, consisting of hydrogen, a minimum percentage of carbon dioxide and nitrogen compounds. Synthesis gas burns well, so it can also be used for heating, return to the technological cycle and extract hydrogen from it, ”explains Vladimir Gubin .

Next, scientists intend to find the most effective way to release hydrogen and reduce the content of carbon dioxide or its environmentally friendly disposal.

“Thermal conversion is the main method for obtaining synthesis gas from a solid material. This method is being actively developed today in the United States and China, and Russia is still lagging behind in terms of the scale of technology implementation. However, we are significantly ahead of our foreign colleagues in terms of fundamental research of the process, which already gives us practical advantages: we get more useful products,” the scientist explains.

## SCIENCE & TECHNOLOGY INITIATIVES

### 28. A neural network developed at Samara University predicts equipment failures with almost 100% accuracy

Source: Samara University News, 16 July 2021



Scientists of the Samara National Research University named after academician S.P. Korolyov have improved the previously developed diagnostic complex capable of

automatically predicting possible failures, malfunctions and failures in the operation of complex technical systems. Thanks to the use of a new neural network architecture, the accuracy of detecting possible faults has exceeded 99%. The research results are published in the renowned international journal Sensors .

*"We have developed a new neural network architecture for a diagnostic complex for detecting technical anomalies. The work was carried out jointly with the Institute of Machine Acoustics. The new neural network architecture is more accurate, experiments on the test bench showed that the accuracy of correctly predicted equipment states exceeds 99%," said a senior researcher at the Institute of Artificial Intelligence Samara University Evgeny Minaev . "In addition, the new architecture is more flexible and makes it easy to increase the number of potentially recognizable faults. The main feature of our development is that now only 0.2% of the data from the test bench is required to fully train the system of the complex, the rest of the data is generated using the digital twin of the system. This approach significantly reduces the cost of training the diagnostic complex using real technological equipment "*

The modernization of the predictive diagnostics complex did not require significant changes in its hardware component. In addition, scientists have made the source codes of their development available to the whole world by posting them on the Internet.

*"Despite the modernization of the architecture have remained modest demands on the hardware platform. Moreover, our neural network was the most lightweight among competitive developments, which are compared in this article in Sensors Journal. Another important point, the neural network source code and datasets we have put in open access , researchers from all over the world can test their algorithms on our data, or vice versa -*

check our program on their data , "said Evgeny Minaev.

In 2020, scientists from the Samara National Research University named after academician S.P. Korolyov created a prototype of an intelligent diagnostic complex capable of warning in advance of possible failures, malfunctions and failures in the operation of complex technical systems. The development is based on deep learning technology. The complex self-learns in the process of operation and, diagnosing the state of technology, informs the person which element of a particular system is in a pre-failure state and may soon fail.

The uniqueness of the diagnostic method invented by scientists lies in the software comparison of the so-called "dynamic portraits" of nodes and systems: the real, current state of equipment, data on which is collected using a set of sensors, is constantly compared with the ideal state of technology - the "ideal portrait" in the program database. The complex detects deviations from this "ideal portrait" - for example, it can be changes in the pressure indicators in the oil system, the difference in temperature levels or fuel consumption, and the indicators are recorded at each section of a node or system, after which a neural network program based on the learning algorithms decides on the likelihood of a problem.

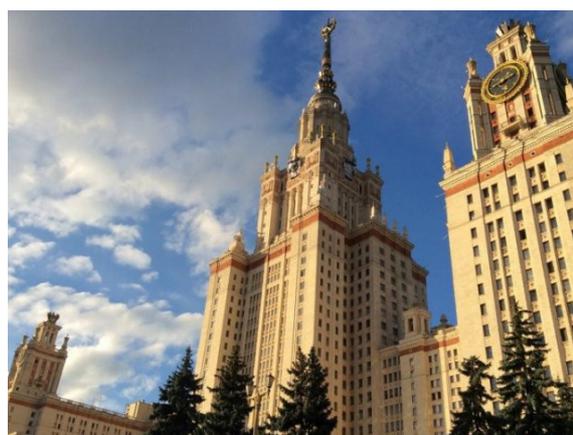
As conceived by the developers, in the future, such diagnostic complexes can be used to improve the safety of air transportation, but already now the obtained characteristics make it possible to use them in industry, in unmanned aerial vehicles and cars.

“The next step is to create a software and hardware complex for diagnostics of technical systems based on a neuroprocessor module, developed jointly by the Faculty of Electronics and Instrumentation and the Institute of Artificial Intelligence,” said Director of the

Institute of Artificial Intelligence Artem Nikonorov about the development plans.

## 29. Moscow State University and Yandex to collaborate in areas of Inter-disciplinary Modern science

Source: *Scientific Russia News*, 16 July 2021



Society of Young Scientists of Moscow State University named after M.V. Lomonosov Moscow State University on Yandex.Q announces a competition for the best essays on topical issues of modern science, which are studied in the interdisciplinary magistracy of Moscow State University. Authors of the best works will have the opportunity to become curators of five areas of the service: Geography, Geology, Economics, Chemistry and Jurisprudence. Among the jury members are Dean of the Faculty of Chemistry of Moscow State University, radiochemist Stepan Kalmykov, Head of the Financial Literacy Laboratory of the Faculty of Economics of Moscow State University Rostislav Kokorev, Dean of the Faculty of Geography of Moscow State University Sergei Dobrolyubov, Head of the Department of Criminalistics of Moscow State University Yevgenia Kryukova and

Professor of the Faculty of Geology Yuri Ampilov.

Participants of the competition will have to fully answer the questions that are studied in the master's programs at Moscow State University. Future curators of the Ekonomika community on Yandex.Q will tell you what rules exist for financing budgetary organizations and how politicians are guided in practice when making budget decisions. These and many other questions are the subject of study at the master's programs "Fundamental Economics" and "Economic Policy" of the Faculty of Economics of Moscow State University. Focus "Fundamental Economics"- research and academic career of students. "Economic policy", in addition, is focused on the education of a new generation of managers - who understand the structure of the economy from the point of view of modern science, the possibilities and limitations of economic policy, including ethical ones.

In 2021, Moscow State University will open a set for 37 new unique interdisciplinary master's programs in 7 scientific and educational schools. The programs are aimed at training specialists in breakthrough areas of science and technology: space exploration, the brain, cognitive systems, artificial intelligence, the future of the planet and the preservation of ecosystems, the preservation of the world cultural and historical heritage, digital medicine, molecular technologies of living systems and synthetic biology, mathematical methods of analysis complex systems. In their implementation, 27 faculties of Moscow State University, institutes of the Russian Academy of Sciences, enterprises and employing organizations are involved. MSU is also opening a set for 5 master's programs of a new branch of MSU in Sarov, which will open its doors for the first time on September 1, 2021.

Moscow State University named after M.V. Lomonosov - a leader among Russian

universities in world rankings. Moscow State University includes 41 faculties, 7 branches, 50 thousand students. On the basis of Moscow State University, there are advanced research centers, including computing, laser, biotechnological, oil and gas, agricultural, as well as the Science Park, medical research and educational center, satellites, observatories, museums and scientific stations throughout Russia and abroad. The list of Nobel laureates includes 11 names of scientists and graduates of Moscow University. In 2020, **Moscow State University formed 7 interdisciplinary scientific and educational schools in breakthrough areas: "Fundamental and Applied Space Research"; "Preservation of the World Cultural and Historical Heritage"; "Brain, Cognitive Systems, Artificial Intelligence"; "Molecular technologies of living systems and synthetic biology"; "Mathematical methods for the analysis of complex systems"; "Photonic and quantum technologies; "Digital medicine" and "The future of the planet and global environmental changes"**. Schools are designed to combine the educational process of the university and its scientific potential to create new unique educational programs, train specialists with the most modern knowledge and skills, to develop promising interdisciplinary areas of science and achieve breakthrough scientific results. Yandex.Q is a community of experts in science, medicine, economics, education, art and many other spheres of life. Yandex.Q experts share knowledge in a Q&A format. The service has a data verification system: experts check each other's answers so that only reliable information is displayed in Yandex search.