Latvian Academy of Sciences

ACHIEVEMENTS IN SCIENCE 2023

FUNDAMENTAL SCIENCE

1. Optical modulator on a silicon photonics chip for high-speed data transmission.

LAS full member Oskars Ozoliņš, *Mg.sc.ing.* Armands Ostrovskis, *Ph.D.* Aleksandrs Mariņins, *Mg.sc.ing.* Ints Murāns, *Mg.sc.ing.* Arvīds Sedulis, *Mg.sc.ing.* Kristaps Rubuls, *Ph.D.* Toms Salgals, LAS corresponding member Jurģis Poriņš, *Ph.D.* Xiaodan Pang, LAS corresponding member Sandis Spolītis, *Dr.sc.ing.* Vjačeslavs Bobrovs. Telecommunications Institute, Riga Technical University.

Silicon photonics is an innovative direction that is rapidly developing, making a significant contribution to the efficiency of data centers, 5G and 6G networks, and the development of artificial intelligence. The silicon photonics optical modulator technology developed by RTU stands out for its high energy efficiency and ability to provide greater bandwidth in micrometer-sized devices, ensuring data transmission speeds up to 170 Gbit/s, which allowed it to achieve a world record result in the ERAF RINGO project. The advantages of this solution include dense integration with existing microelectronics platforms and energy-efficient data transmission. This achievement strengthens Latvia's position in the global science and technology market, offering high value-added products and services, promoting economic growth, and supporting sustainable development.

2. Computer modelling of perovskite nanomaterials for efficient hydrogen production.

LAS full member Eugene Kotomin, *Dr.phys.* Yuri Mastrikov, *Dr.phys.* Leonid Rusevich, *Ph.D.* student Maksim Sokolov, *Dr.phys.* Guntars Zvejnieks. Institute of Solid State Physics, University of Latvia.

Since the industrial revolution, global energy demand has increased 26-fold, and fossil fuels account for over 80% of the total energy source. However, as humans fire fossil fuel power plants to power all sorts of activities, worldwide CO_2 production has accumulated up to 36 Gt, causing a significant impact on both the environment and human health. As global warming becomes one of the most urgent issues of this century, efficient alternatives to produce clean energy are required.

In particular, hydrogen is a promising primary energy carrier due to its abundance and high energy density. Photocatalytic water splitting that utilizes abundant solar energy has attracted substantial attention. Studies have shown that several metal oxide-based materials like TiO_2, MoO_3, and perovskites (e.g., $SrTiO_3$) present remarkable potential in the field of photocatalytic water splitting because of their high stability, resistance to photo corrosion, and tunable structure that allows precise modifications of the surface morphology and active sites of the catalyst. Nevertheless, despite appropriate band edge positions for the water-splitting reaction, many of these metal oxides exhibit wide band gaps, and consequently, they absorb predominantly in the ultraviolet region of the solar spectrum. The typical examples are metal titanates, including TiO_2 and $SrTiO_3$, with a band gap of around 3.2 eV. Additionally, photocatalytic efficiency is lowered by fast recombination of

photoinduced electron−hole pairs. Several strategies have been developed, first to extend the utilization of sunlight in the visible range and second to enhance the charge carrier separation.

Using the state of the art methods of quantum chemistry, a series of our computational modelling of SrTiO3 nanoparticles, the optimal positions of water molecule splitting at different faceted surfaces were identified, and kinetics, and thermodynamics of the hydrogen formation upon nanoparticles were studied . We predicted that nanoparticle doping with N and Al impurities could greatly improve formation of hydrogen. The atomistic calculations show that these impurities trap holes and prevent electron-hole recombination.

The cycle of our papers summarized our main achievements in 2023 on hydrogen production from sunlight stimulated water splitting upon perovskite nanoparticles. These studies were performed in the framework of three European projects:

- FLAG-ERA JTC project To2Dox (Transferable two-dimensional correlated oxide layers);
- EC COST Action OC-2018-2-23544 Computational materials sciences for efficient water splitting with nanocrystals from abundant elements;
- M-ERA-NET project SunToChem (Engineering of perovskite photocatalysts for sunlight-driven hydrogen evolution from water splitting).

Our predictions were confirmed by M-ERA-NET project partners: nanoparticles were grown in Slovenia and hydrogen production increase demonstrated in Taiwan University. Thus, new efficient nanomaterials were developed as the results of international collaboration which has great industrial potential. The results were published in high rank Open Access international journals.

3. Analytical research about the lives of Latvian emigrants in Britain at the beginning of the 21st century.

Mārtiņš Kaprāns. Latvieši tur. Latvijas emigrantu mobilitāte un iesakņošanās Lielbritānijā 21. gadsimteņa sākumā ("Latvians there. The mobility and rootedness of Latvian emigrants in Great Britain at the beginning of the 21st century"). Riga: University of Latvia Press, 2023. 136 pp. Institute of Philosophy and Sociology, University of Latvia.

Mārtiņš Kaprāns', *Dr.sc.comm.*, monograph focuses on Latvian labour migrants who have settled in Great Britain over the last 20 years. The book focuses on how Latvians have managed to put down roots in their new homeland. Using a wide range of sociological data and immersing himself in the space of Latvians in Great Britain, the author uncovers migrants' subjectivity and practices of settling in – finding their place in the British labour market, setting up a home, integrating into a multicultural neighbourhood and maintaining national belonging. The monograph highlights the ability of Latvians to take advantage of the opportunities provided by international mobility and to build a livable life. At the same time, however, objective social and economic conditions are analysed, which determine migrants' social position and fate in British society.

4. Basic research of great importance for the history of painting and cultural heritage studies in the Baltic Sea region.

Vija Strupule. Dekoratīvā gleznieciba Rīgas interjeros: 16. gadsimts – 18. gadsimta trešais ceturksnis ("Decorative Painting in Riga's Interiors. 16th century – 3rd quarter of the 18th century"). Riga: Art History Institute of the Art Academy of Latvia; Art History Research Support Foundation, 2023. 408 pp., 226 figs.

The monograph by art historian *Dr.art.* Vija Strupule is based on several decades of persistent work in practical architectural and artistic research of Riga's historic buildings, on theoretical analysis and interpretation of the evidence obtained, exploration of stylistic features and iconographic motifs, and identification of international analogies and sources of influence. Working with particularly difficult material, the author has created a high-quality basic research of great importance for the history of painting and cultural heritage studies not only in Latvia, but also in the Baltic Sea region as a whole.

5. The first scientific work in Latvia to analyse and explore the legal and human rights implications of artificial intelligence.

Irēna Barkāne. Cilvēktiesību nozīme mākslīgā intelekta laikmetā. Privātums, datu aizsardzība un regulējums masveida novērošanas novēršanai ("The Role of Human Rights in the Age of Artificial Intelligence. Privacy, Data Protection and Regulation for Preventing Mass Surveillance"). Riga: University of Latvia Press, 2023. 328 pp.

The monograph by *Dr.iur.* Irēna Barkāne "The Role of Human Rights in the Age of Artificial Intelligence. Privacy, Data Protection and Regulation for Preventing Mass Surveillance" is the first scientific work in Latvia to analyse and explore the legal and human rights implications of artificial intelligence (AI). AI is a technology undergoing rapid development and has become one of the most powerful drivers of social transformation. AI can bring great benefits in many areas, such as health care, education, culture, employment, transportation, environment, safety and national security and provide opportunities for economic, social, scientific and cultural development. At the same time, AI raises many challenges in all those areas as well as presenting serious ethical, legal and social issues. One of the most serious concerns is AI-based surveillance technologies that pose significant threats to human rights, the rule of law and democracy.

The monograph examines the use of AI surveillance technologies in law enforcement in Europe and worldwide and assesses their impact on the right to privacy and data protection, freedom of expression, the principle of non-discrimination and other human rights, as well as on society and democracy in general. The monograph provides an extensive analysis of the development of AI regulation at the international and European level and of the European data protection framework applicable to facial recognition technologies and other AI systems. The study makes recommendations for the further development of AI regulation and policy at the international and national level in order to address the threats posed by AI and to enhance its credibility.

APPLIED SCIENCE

6. Nanostructured topological insulators for applications in energy and quantum nanoelectronic devices.

LAS full member Donāts Erts, *Dr.phys*. Jana Andžāne, *Dr.chem.* Gunta Kunakova, *Dr.phys.* Raimonds Meija, *Dr.phys.* Yelyzaveta Rublova, *Mg.* Kiryl Niherysh, *Mg.* Vitālijs Lazarenko, *Mg.* Raitis Sondors, Prof. Floriana Lombardi. Institute of Chemical Physics, University of Latvia, Chalmers University of Technology, Sweden.

Researchers from the University of Latvia (UL) in cooperation with Chalmers University of Technology have developed economical and easy-to-implement methods for the synthesis of nanostructured topological insulator materials. The resulting materials (nanowires, thin films, nanolaminates, and heterostructures) have improved surface conductivity, and the UL group has conducted extensive fundamental research on prospective applications of these materials in single-electron transistors and charge pumps, superconducting devices, and nanoelectromechanical switches. In addition, the UL group of researchers also demonstrated that the unique properties of the developed materials make them perfectly suited for the fabrication of flexible thermoelectric generators for waste heat conversion to electricity, as well as electrodes for Li+ and Na+ ion batteries. This research has resulted in 43 scientific articles and 7 patents.

7. Innovative reagent that significantly expands the possibilities for chemists to incorporate fluorine atoms.

LAS corresponding member Jānis Veliks, *Ph.D.* Nagarajan Ram Kumar, *Dr.chem.* Larisa Baumane, *Dr.chem.* Dzintars Začs. Latvian Institute of Organic Synthesis.

The introduction of fluorine atoms into organic molecules enables the targeted manipulation of their biological properties. Consequently, synthetic methods for facilitating this transformation serve as crucial tools in the construction of novel pharmaceuticals. Although fluorine atoms are already prevalent in the structure of every fifth active pharmaceutical ingredient, the range of synthesis methods for their incorporation remains significantly limited, often involving the use of aggressive and contaminating reagents. These factors pose substantial challenges in both the development of new drugs and the subsequent creation of technologically convenient manufacturing methods.

A research group led by Dr. Jānis Veliks at the Latvian Institute of Organic Synthesis has developed a new, stable, and non-aggressive reagent. In the presence of a catalyst and under the influence of blue LED light, this reagent generates fluoromethyl radicals – active particles containing fluorine that readily attach to organic molecules. This innovative reagent significantly expands the possibilities for chemists to incorporate fluorine atoms, paving the way for the construction of potential new drugs and the development of novel technologies for obtaining well-known substances.

8. The principle of self-adaptation of the structure used in design of new medicinal agents.

Dr.chem. Jekaterīna Ivanova, *Dr.chem.* Ilona Domračeva, LAS corresponding member Raivis Žalubovskis. Latvian Institute of Organic Synthesis LAS full member Kaspars Tārs, *Dr.biol.* Jānis Leitāns, *Dr.biol.* Andris Kazāks. Latvian Biomedical Research and Study Centre.

Cancer is still one of the most common causes of death worldwide, which has taken nearly 10 million lives in 2020 alone, therefore the search for novel treatment approaches of this disease is of high interest. Affecting the activity of enzymes essential for the growth of cancer cells with anti-cancer agents is a general principle used in the design of new therapeutic agents. However, until today it has not been possible to solve a fundamental problem of selectivity – how to target among similar enzymes only those essential for the functioning of cancer cells.

The group of scientists lead by prof. Raivis Žalubovskis at the Latvian Institute of Organic Synthesis in collaboration with the researchers from Latvian Biomedical Research and Study Centre has demonstrated that the principle of self-adaptation of the structure can be used to solve the problem. When constructing new drug molecules, scientists have incorporated elements of limited flexibility into their chemical structure. Those molecules are able to adapt to the spatial structure of the affected enzymes ensuring interaction with the enzymes essential for the development of cancer cells at the same time not affecting the activity of other enzymes in normal cells. Although this phenomenon is known in organic chemistry, until now it has not been used in the design of new medicinal agents. The discovery not only marks new opportunities in the design of anti-cancer drugs, but will also help to explain differences in the selectivity of action of already known medicinal agents.

9. Studies on the use of wastewater-based epidemiology for investigating the public health and predicting the possible spread of infectious diseases.

Ph.D. Brigita Dejus, *Dr.sc.ing.* Sandis Dejus, *Mg.sc.ing*. Mārtiņš Strods, LAS full member Tālis Juhna. Riga Technical University. *Mg.* Pāvels Cacivkins (*Exponential Technologies Ltd.*). *Mg.biol*. Dita Gudrā, *Mg.biol*. Maija Ustinova, *Mg.biol*. Ance Roga, *Mg.biol.* Līga Birzniece, *Bc.biol*. Edmunds Skinderskis, LAS corresponding member Dāvids Fridmanis. Latvian Biomedical Research and Study Center. *Mg.biol.* Juris Ķibilds, *Mg.biol.* Guntis Boikmanis, *Mg.biol.* Karīna Ortlova, *Mg.biol.* Laura Krivko, *Dr.chem*. Iveta Pugajeva, *Dr.chem.* Vadims Bartkevičs, LAS full member Aivars Bērziņš. Institute of Food Safety, Animal Health, and Environment BIOR. *Dr.med.* Uga Dumpis. University of Latvia.

The Water Research and Environmental Biotechnology Laboratory of the Riga Technical University (RTU), together with partners from the Latvian Biomedical Research and Study Center (BMC) and the Institute of Food Safety, Animal Health, and Environment "BIOR" carried out a series of studies on the use of wastewater-based epidemiology (WBE) for investigating the public health and predicting the possible spread

of infectious diseases. In 2023, the first study demonstrated the potential of wastewater in evaluating the consumption of various medicines and biomarkers of population size; the second study evaluated the possibility of using WBE for monitoring changes in COVID-19 incidence, and the third – for predicting the number of COVID-19 cases. The studies served as the basis for creating a permanent wastewater monitoring system in Latvia, which is currently used to monitor the spread of diseases and prevent SARS-CoV-2 variants in Latvian cities. Throughout the various stages of the studies, researchers from the University of Latvia (LU) and the Latvian University of Life Sciences and Technologies, as well as industry partners *Exponential Technologies Ltd* (xT) and *Latvian Mobile Telephone* (LMT) were involved. Representatives from 16 different cities actively participated in the collection of wastewater samples used in the studies and within the monitoring system.

10. Advanced farming systems for environmentally friendly and efficient crop production in Latvia.

Dr.agr. Inga Jansone, *Dr.agr.* Līvija Zariņa, *Ph.D*. Inga Morozova, *Dr.oec*. Alberts Auziņš, *Dr.oec.* Agnese Krieviņa, *Dr.geogr.* Pēteris Lakovskis, *Dr.sc.ing.* Aivars Āboltiņš, *Mg.soc.sci.* Ieva Leimane, *Mg.agr.* Solveiga Maļecka, *Mg.geogr.* Dace Piliksere. Institute of Agricultural Resources and Economics (AREI). *Mg.oec.* Astra Varika (EDO Consult Ltd.).

We live in an era characterized by global challenges related to climate change, resource scarcity, and food security issues. Economic activity in all sectors has garnered increased attention regarding the interplay between environmental sustainability and economic viability. In this context, agriculture is at the epicenter of events, and a new paradigm sets strict requirements for agricultural activity. For the first time, the profitability of agriculture, encompassing both economic and environmental effects, was evaluated for the different crop rotation, thus emphasizing the need for systemic thinking both in the selection of elements of the agricultural system and in making other decisions related to farming. The research results have been summarized in five scientific papers and five popular scientific publications. Fourteen reports were presented at the scientific conferences and also showcased at the project final conference in January 2023.