ACHIEVEMENTS IN SCIENCE 2019

THEORETICAL SCIENCE

I Theoretical calculations allow to explain how graphene enhances the photoelectric conversion efficiency of dye sensitized solar cells

One of the 2019 year Nobel Prize winners in Chemistry John B. Goodenough (USA) in 1980 discovered the cathode material for a 4V Li ion batteries; but that it is possible to design also 5 Volt batteries was demonstrated in the theoretical calculations for the cathode material $Li_2CoMn_3O_8$ [1] carried out by the joint Latvian–Chinese research team. Theoretical calculations allowed to explain how the graphene enhances the photoelectric conversion efficiency of dye sensitized solar cells [2]. Large amount of calculations for eight technologically most important ABO_3 perovskite neutral (001) and polar (011) surfaces and developed a theory was performed, which explains the systematic trends in behaviour of ABO_3 perovskite surfaces [3-8]. The effects of boron (B) and nitrogen (N) substitutions in 4,12,2-graphene on its geometric structure and mechanical as well as electric properties have been calculated from first principles [9,10]. The piezoelectricity induced by B/N atom substitutions in 4,12,2-graphene owing to the deformation of the pristine graphene symmetry [9] was discovered.

Research team: LAS corresponding member Roberts Eglītis, LAS academician Juris Purāns, Dr.phys. Jānis Kleperis, Dr.phys. Anatolijs Popovs, and Dr. Ran Jia (PRC). Institute of Solid State Physics, Latvian University, Institute of Theoretical Chemistry, University of Jilin (PRC).

II New reagent for organic synthesis with potential application in medicinal chemistry discovered

More then quarter of the currently used drug molecules contain at least one or more fluorine atoms. Analysis of recent trends in medicinal chemistry displays that almost half of the registered drugs by the US Food and Drug Administration contain at least one fluorine atom in their structures. This tendency shows, that also in the future synthesis of fluorinated derivatives will be a perspective approach for the design of new pharmaceutical drugs and important part of the manufacturing process. This is a constant challange for chemists requiring development of new methods and reagents for the synthesis of fluoroorganic compounds. We have developed a new reagent for the fluoromethylene - an important organic fluorine containing buildingblock incorporation. Most of the currently used methods invole the use of, for example, ozone depleting reagents or gasouse compounds which involves various technological issues for their application in the laboratory. Our method and the reagent will allow more straignthforward synthesis of new fluorine containing molecules and it has a good potential for the application in a manufacturing of active pharmaceuticals.

Research team: Mg. chem. Renāte Melngaile, Bc. chem. Armands Kazia, Artūrs Sperga, Dr.chem. Jānis Veliks. Latvian Institute of Organic synthesis.

III The new double volume III of the academic publication “Art History of Latvia” presents the so-far most comprehensive research-based overview of the development of fine art, book art, architecture, professional applied art, folk art and artistic life in the territory of Latvia from the late 18th century until 1890

The new double volume III of the academic publication "Art History of Latvia" presents the so-far most comprehensive research-based overview of the development of fine art, book art, architecture, professional applied art, folk art and artistic life in the territory of Latvia from the late 18th century until 1890, revealing the particularity, achievements and activities in the period of Classicism and Romanticism (1780–1840) and the period of Historicism and Realism (1840–1890). The text is illustrated with 1164 images, and a parallel English edition makes the whole study available to international audience. Supervised by director of the Institute of Art History (IAH) of the Latvian Academy of Art (LAA) *Dr.habil.art.* Eduards Kļaviņš, the team of authors includes seven other members – IAH senior researchers *Dr.art.* Elita Grosmane, *Dr.art.* Kristiāna Ābele and *Dr.art.* Daina Lāce, LAA teaching staff members *Dr.art.* Silvija Grosa, *Dr.art.* Inese Sirica and *Dr.h.c.* Valdis Villerušs as well as the ex-director of the Rundāle Palace Museum *Dr.h.c.* Imants Lancmanis. English translation was prepared by IAH senior researcher *Dr.art.* Stella Pelše. The publication was supported by the State Culture Capital Foundation and the Zuzāns family.

Eduards Kļaviņš, Elita Grosmane, Valdis Villerušs, Imants Lancmanis, Inese Sirica, Kristiāna Ābele, Daina Lāce, Silvija Grosa. "Art History of Latvia III: 1780–1890". Edited by Eduards Kļaviņš. Riga: Institute of Art History of the Latvian Academy of Art; Art History Research Foundation, 2019. Book 1, 424 pp., 627 ill.; Book 2, 392 pp., 537 ill. ISBN 9789934882401 (Latvian), 9789934882418 (English).

IV Within the context of the international academic thought for the first time the notion of the migration of cultures, its types and relation to different approaches in culture studies is defined

The collective monograph "Latvia: Migration of Cultures" ("Latvija: kultūru migrācija". Rīga: LU Akadēmiskais apgāds, 2019, pp. 808) is an innovative and unique interdisciplinary study that represents the interaction of several cultures since the first people settled in the present day territory of Latvia. Within the context of the international academic thought the study for the first time defines the notion of the migration of cultures, its types and relation to different approaches in Culture Studies. Researchers of the migration of cultures describe various areas of human activities: material culture (historians), interaction of languages (linguists), migration of myths and other elements of folklore (folklorists, literary scholars), history of ideas and religion as a manifestation of the migration of cultures (philosophers, scholars of religion, historians), boundaries between aesthetic culture and national identity, ideology, politics, and nationhood (philosophers, historians), reflections of the migration of culture in literature and other forms of art.

Research team includes the researchers from the Institute of Philosophy and Sociology, Latvian Language Institute, Institute of Literature, Folklore and Art, Institute of Latvian History of the University of Latvia.

V The monograph discusses the World War II trauma and historical memory including cross-disciplinary studies and successfully integrating various research methods

The monograph "Waiting for the Boat: Latvian Authors as Refugees in Sweden" by LAS corresponding member *Dr.philol.* Inguna Daukste-Silaspro̧ge focusses on a chronologically

and geographically narrowed view of political and historical developments through a prism of an individual's distress, echoed in documents, correspondence, testimony and literary texts. The period covered in the monograph symbolically forms a vector from (1) the coast of Kurzeme and the way in a refugee boat across the sea; to (2) the new country of residence in Sweden as *a refugee*, where one has to reassert their skills and knowledge by leading two parallel lives – the Swedish and the Latvian. The Latvian life turns out to be surprisingly plentiful and allows the refugee to survive emotionally both the foreign land and being cut off from Latvia, where the Baltic Sea is the border. The everyday and working life, the periodicals, social and cultural events in Latvian writers' life, even the literary process itself have been characterised. The theoretical basis of the monograph consists of the works of Latvian and foreign researchers discussing the World War II trauma and historical memory, including cross-disciplinary studies, successfully integrating various research methods. The author of the monograph has produced a unique methodology for her own research, a set of self-accredited research tools supplemented with a viewpoint from literary history. The monograph is also accompanied by a variety of attachments and extensive photographic material. In 2019, the monograph received the Egons Līvs Memorial Award "Krasta ļaudis" (Coast People).

Inguna Daukste-Silasproģe. Waiting for the Boat: Latvian Authors as Refugees in Sweden ("Gaidot laivu. Latviešu rakstnieki bēgļu ceļos": LU LFMI, 2019). Institute of Literature, Folklore and Art of the University of Latvia.

APPLIED SCIENCE

VI The new technology enables better technical solutions for improving energy efficiency by bi-directional implementation power flow into the DC power grid

The developed and approved unique system in cooperation with the German car manufacturer Daimler AG for use in the Mercedes-Benz automobile industry. The new technology enables better technical solutions for improving energy efficiency (saving up to 15% of electricity) by bi-directional implementation power flow into the DC power grid. The first step towards the idea of tomorrow's factories, where energy-efficient and sustainable robotic production through the use of innovative tools, methods, and technologies that take place. Based on this technology as part of the move to the green industry, a new concept factory casing has been built - Factory56 in Sindelfingen, which also uses a developed system (DC network and robotic recuperative energy recovery) to reduce CO2 emissions. It will also power the building's climate systems. (https://www.daimler.com/innovation/case/connectivity/industry-4-0.html)

Research team: LAS academician Leonīds Ribickis, Dr.sc.ing. Oskars Krievs, Dr.sc.ing. Pēteris Apse-Apsītis, Dr.sc.ing. Dāvis Meike, Dr.sc.ing. Andrejs Stepanovs, Mg.sc.ing. Ansis Avotiņš, Mg.sc.ing. Armands Šenfelds, Mg.sc.ing. Kristaps Vītols, Mg.sc.ing. Maksims Vorobjovs, Mg.sc.ing. Mārcis Priedītis, Mg.sc.ing. Artūrs Paugurs, Mg.sc.ing. Oskars Bormanis. Rīga Technical University, Institute of Industrial Electronics and Electrical Engineering.

VII The functionality of visual system has been investigated for people working with an innovation in information visualization – the volumetric 3D image display produced in Latvia

Within the successful collaboration between science and industry, the functionality of visual system has been investigated for people working with an innovation in information visualization – the volumetric 3D image display produced in Latvia. The display opens up new opportunities to use the high-quality spatial images and reduce visual discomfort. The research explored how the depth perception, visual functions and work efficiency benefit when using the volumetric display compared to everyday 2D image displays. Due to the wide support of Latvian medical professionals and students, the properties of visual perception of specific users working with the innovative visualization device have been determined. The findings of the research contribute to the development of innovative 3D image displays not only in Latvia, but also in the world. The obtained results demonstrate that its implementation and scientifically based application in the professional fields can significantly improve the work ergonomics and efficiency.

Research team: Mg. Tatjana Pladere, Mg. Karola Panke, Mg.math. Māra Delesa-Vēliņa, Bc. Viktorija Andriksone, Bc. Vita Konošonoka, Bc. Gunita Jankovska, student Kristaps Kļava, student Marina Seļezņova, resident Reinis Pitura, Dr.phys. Gunta Krūmiņa in collaboration with Dr.sc.ing. Krišs Osmanis, Mg.sc.ing. Ilmārs Osmanis, Dr.phys. Roberts Zabels, Mg. sc.comp. Rendijs Smukulis, Mg.sc.ing. Una Kandere. Faculty of Physics, Mathematics and Optometry of the University of Latvia, Ltd."LightSpace Technologies", Faculty of Medicine of Rīga Stradiņš University.

VIII Previously unreported pathogenic variants that affect a specific region of the slow Myosin Binding Protein-C (sMyBP-C) and are associated with a neuromuscular disease phenotype – mild myopathy together with a myogenic tremor are found

Within the framework of the Neuromuscular disease project, the research team has managed to find previously unreported pathogenic variants that affect a specific region of the slow Myosin Binding Protein-C (sMyBP-C) and are associated with a neuromuscular disease phenotype – mild myopathy together with a myogenic tremor. Such a combination of symptoms has not yet been described for any one disease, furthermore, until now it was considered that tremor is caused only by neurogenic defects. In collaboration with the partners from USA (University of Maryland, National Institute of Health), data is still being gathered from biochemical and molecular biology experiments, as well as from the evaluation of the created mouse model, in order to fully characterize this novel phenotype. This research is providing new insights into previously not described biological mechanisms and might help in understanding and solving similar clinical cases.

Research team: Mg.biol. Jānis Stāvusis, Dr.med. Baiba Lāce, Mg.biol. Dita Kidere, Dr.biol. Inna Iņaškina. Latvian Biomedical Research and Study Centre.

IX Conceptually new approach to achieve high solid state emission

In artificial light sources and in various everyday devices (telephones, computer and TV screens) light is emitted by solid luminophores that typically possesses low emission efficiency. A conceptually new approach to design highly emissive solid state organic luminophores has been developed at Latvian Institute of Organic Synthesis. The new concept is based on the use of intermolecular electrostatic interactions, which are well known in organic chemistry but have not yet been used in the design of organic luminophores. This new approach helps to: 1) Increase the emission efficiency of solid organic luminophores; 2) Facilitate the design of light emitting materials and simplify architecture of light-emitting devices (e.g. OLEDs), thus significantly reducing their production costs; 3) Create new

optical sensors, luminescent materials for biomedical applications and sunlight resembling artificial light sources.

Research team: Mg.chem. Kaspars Leduskrasts, Dr.chem. Artis Kinēns, LAS academician Edgars Sūna. Latvian Institute of Organic Synthesis.

X Interdisciplinary study of even aged spruce stands in Latvia

An interdisciplinary study on spruce forests in Latvia has been completed at the Latvian State Forest Research Institute "Silava", covering forestry and breeding, genetics and phytopathology, as well as technological and economic aspects. Opportunities and risks for the management of planted even aged spruce stands growing in least 200 thousand hectares of the most fertile forest lands of Latvia have been studied. In the 1970s and 1980s, overly dense spruce stands were extensively planted, which currently have grown to be stunted and weakened middle-aged stands. Planted spruce forests, as opposed to unmanaged forests, are very productive at a young age, but subsequently tree growth decreases, and trees are damaged by wind and decay. As a result of the research, the Latvian forest sector was provided with knowledge of optimal management models when renewing spruce stands, as well as information about the significant risks associated with the deterioration of growth potential in overly densely-planted 40-50 year old stands. By repeatedly assessing (after 12 years) 285 spruce stands throughout Latvia, it was confirmed that their growth has not improved but significantly deteriorated. In such situations, declining stands should be cleared and purposefully renewed, ensuring regulatory changes to enable this. In correctly managed spruce stands, it is possible to grow saw logs well within a human lifespan – 40-50 years. The study was initiated by the Latvian forest sector, and was started in 2014 within the framework of the National Research Program. The results of the research are summarized in a monograph "Even aged spruce stands in Latvia", published in 2019 (Daugavpils University Academic Press "Saule", ISBN 978-9984-14-853-3), presented to the Latvian forest sector on Forest Science Day organized by LSFRI Silava on the 30th of May 2019 in the Gulbene region and Jaunkalsnava, attracting more than 120 participants. The scientific team involved in the study received a letter of gratitude from the President of the Latvian Academy of Sciences on Forest Science Day.

Research team: Dr.silv. Jurģis Jansons, Mg.silv. Jānis Donis, LAS academician Tālis Gaitnieks, LAS corresponding member Āris Jansons, Dr.silv. Dagnija Lazdiņa, Dr.silv. Zane Lībiete, LAS corresponding member Dainis Edgars Ruņģis, Latvian State Forest Research Institute ''Silava''.

DIPLOMA OF THE PRESIDENT OF THE LATVIAN ACADEMY OF SCIENCES

I Technology for time measurement with pico-second precision for use in spacecraft

The need for very precise recording of time instants of events exists in many scientific research and technologies. For example, in the field of signal processing, in the satellite laser ranging, in LIDAR systems and for time scales synchronization in distributed measuring systems. The technology for measuring the time of events developed in the IECS was previously used in these systems only in the ground segment. However, measurements of time moments with the possible high precision are also necessary in space equipment, including

LIDAR systems, ranging systems, as well as time and data transfer systems. Thanks to the project of the European Space Agency (ESA), IECS scientists were able to modernize their time measurement technology in such a way that it could be used in accordance with the conditions and requirements of spacecraft engineering. A specialized module has been developed and, in cooperation with the Czech Space Research Centre, was duly tested. ESA rated it as the best contender for use in future space missions and recommended to continue work with potential partners (in Portugal, the UK, and the Netherlands) on the development of various versions specialized for the respective missions (landing of the spacecraft on the moon, research of asteroids, etc.).

Research team: Dr.comp. Vladimir Bezpalko, Dr.comp. Eugene Boole, Mg.sc.ing. Vadim Vedin. Institute of Electronics and Computer Science (IECS).

II Theoretical modelling of self-assembling processes in prospective perovskites for green energy applications

Functional oxide materials with perovskite structure and explicit dielectrical, piezoelectrical, pyroelectrical and electrochemical properties play an essential role in the technologies of the future. Applying nature-inspired principles of self-assembling, properties of nanodevices can be significantly enhanced, including optimization of the electrochemical processes in such devices. It is of a high importance to create a truly ordered structure. As a result of the performed research, for the first time, a systematic description of the topology of the polar perovskite surface, dynamics of the surface defects, molecular and atomic chemisorption, dissociation and migration on the surface has been given. A complex cascade of the surface electrochemical reactions was discovered and described in details. Based on the electron structure of the surface, the study showed how ordering appears in self-assembling mesoscale objects, growing from a disordered solution of nanoparticles, and how surprisingly sensitive the thermodynamics of the process to the peculiarities of the nanophysics of the polar surface appears to be. Obtained results are important for development of the new generation devices for „green" energy such as piezoelements and fuel cells.

Research team: Dr.rer.nat. Jurijs Mastrikovs, Dr.phys. Dmitrijs Zablockis, Dr.rer.nat. Guntars Zvejnieks, Dr.phys. Leonīds Rusevičs, Dr.habil.phys. Vladimirs Kuzovkovs, LAS academician Jevgēņijs Kotomins. Institute of Solid State Physics of the University of Latvia.

III New methods in maxillofacial surgery with the use of innovative bioceramic materials that provides bone density and volume restoration in patients with osteoporosis and bone atrophy

Introduction of new methods in maxillofacial surgery with the use of innovative bioceramic materials that provides bone density and volume restoration in patients with osteoporosis and bone atrophy. Experimental studies of biomaterials for local treatment of osteoporosis using morphological, biomechanical and radiological bone tissue analyses were performed. Clinical trials in oral and maxillofacial surgery demonstrated the efficacy of the developed operative methods for alveolar bone augmentation in peri-implant patients using biomaterials produced in Latvia. These bone replacement materials can be used not only in oral and maxillofacial surgery, but also in other areas, such as traumatology and orthopaedics, where bone regeneration is required.

Research team: LAS corresponding member Andrejs Skaģers, Dr.med. Ilze Šalma, Dr.med. Ģirts Šalms, LAS corresponding member Māra Pilmane, Dr.med. Ingus Skadiņš, Dr.med. Juta Kroiča, LAS corresponding member Jānis Ločs, LAS corresponding member Dagnija Loča, Dr.sc.ing. Līga Bērziņa-Cimdiņa, Dr.sc.ing. Vita Zālīte. Rīga Stradiņš University, Rīga Technical University.

IV New mechanisms and efficacy markers for the treatment of type 2 diabetes in the gut microbiome of patients discovered

The Human Genetics and Molecular Medicine group of the Latvian Biomedical Research and Study Centre has conducted a complex, multidimensional, and several years long study of the effectiveness of type 2 diabetes therapy. It included extensive molecular analysis, as well as obtaining phenotypic and clinical information, in newly diagnosed patients with type 2 diabetes mellitus who for the first time started treatment with the most commonly used antidiabetic drug, metformin. Experiments in the diabetic mouse model have also been conducted to obtain more detailed information. The results provide information on both metformin-induced changes in intestinal microbiome and RNA expression levels, as well as on genetic and epigenetic background. In addition, the data obtained are used to identify molecular markers for predicting the frequently observed gastrointestinal side effects of metformin, as well as to provide missing explanations of the molecular mechanisms of metformin action. In patients with diabetes who are not responding to metformin therapy, no changes in the gut microbiome have been observed during treatment, thus providing further evidence of the important role of the microbiome in the functioning of this drug. The unique discovery of potential biomarkers for predicting treatment efficacy is with widespread use, since on average 20-40% of patients receiving metformin fail to achieve their glycaemic target. In addition, the composition of the microbiome has been shown to be largely population-specific, so the results obtained have the greatest potential for the development of personalized medicine approaches specifically for the Latvian population.

Research team: Mg.biol. Ilze Elbere, Mg.biol. Monta Ustinova, Mg.biol. Ivars Silamiķelis, Mg.biol. Laila Silamiķele, LAS corresponding member Ilze Konrāde, LAS academician Valdis Pīrāgs, LAS academician Jānis Kloviņš. Latvian Biomedical Research and Study Centre, Human Genetics and Molecular Medicine Group, Rīga Stradiņš University.

V Genome-Wide Association Study of Diabetic Kidney Disease Highlights Biology Involved in Glomerular Basement Membrane Collagen

Although diabetic kidney disease demonstrates both familial clustering and single nucleotide polymorphism heritability, the specific genetic factors influencing risk remain largely unknown. To identify genetic variants predisposing to diabetic kidney disease, we performed genome-wide association study (GWAS) analyses. Through collaboration with the Diabetes Nephropathy Collaborative Research Initiative, we assembled a large collection of type 1 diabetes cohorts with harmonized diabetic kidney disease phenotypes. We used a spectrum of ten diabetic kidney disease definitions based on albuminuria and renal function. Our GWAS meta-analysis included association results for up to 19,406 individuals of European descent with type 1 diabetes. We identified 16 genome-wide significant risk loci. The variant with the strongest association (rs55703767) is a common missense mutation in the collagen type IV alpha 3 chain (COL4A3) gene, which encodes a major structural component of the glomerular basement membrane (GBM). Mutations in COL4A3 are implicated in heritable nephropathies, including the progressive inherited nephropathy Alport syndrome. The

rs55703767 minor allele (Asp326Tyr) is protective against several definitions of diabetic kidney disease, including albuminuria and ESKD, and demonstrated a significant association with GBM width; protective allele carriers had thinner GBM before any signs of kidney disease, and its effect was dependent on glycemia. Three other loci are in or near genes with known or suggestive involvement in this condition (BMP7) or renal biology (COLEC11 and DDR1). The 16 diabetic kidney disease-associated loci may provide novel insights into the pathogenesis of this condition and help identify potential biologic targets for prevention and treatment.

Research team includes international authors and Latvian researchers: Dr.med. Jeļizaveta Sokolovska, LAS academician Valdis Pīrāgs, Dr.biol. Vita Rovīte. Faculty of Medicine of the University of Latvia, Latvian Biomedical Research and Study Centre.

VI New approach towards phosphorescent organic materials for use in solution processed organic light emitting diodes

Due to the unmatched image quality, the vast majority of commercially available mobile smart devices use integrated organic light emitting diode (OLED) displays. Implementation of low-cost solution-based production methods would promote the use of this technology in such areas as OLED TVs and lighting panels. Chemists of Rīga Technical University and physicists of Institute of Solid State Physics, University of Latvia have developed novel organometallic phosphorescent materials that can be integrated in solution processed devices and show competitive performance characteristics. It was demonstrated for the first time that an attracting interaction between the active molecules and attached functional groups can be used to enhance light emission efficiency of the materials.

Research team: Dr.chem. Kaspars Traskovskis, LAS academician Valdis Kokars, Mg. Ilze Māliņa, Mg. Armands Rudušs, Dr.phys. Aivars Vembris, Mg. Natālija Tetervenoka, Mg. Igors Mihailovs, LAS corresponding member Sergejs Beļakovs. Faculty of Materials Science and Applied Chemistry of Rīga Technical University, Institute of Applied Chemistry, Institute of Solid State Physics of the University of Latvia, Latvian Institute of Organic Synthesis.

VII Unique perspective on the Baltic cultural space is created where this space is viewed as a united cultural region, the formation of which has been strongly influenced by German culture

For the first time in the history of European and Latvian science, a unique perspective has been created on the Baltic cultural space, where this space is not viewed separately (Latvian / Estonian cultural space as separate from Lithuanian cultural space), but as a united cultural region the formation of which has been strongly influenced by German culture. The study provides a broad insight into previously unexplored aspects of Baltic cultural history - in the areas of text, institutions, educational institutions, everyday material culture, acting persons, music, museums and societal transformation. It was sponsored by the Heidelberg Academy of Sciences. It is a unique and innovative event in the field of humanities in Latvia in recent years. Latvian researchers have made significant contributions to the development of new theoretical and conceptual tools to take a new and fresh look at the transfers, contacts, and shared history of the Baltic and German cultural space ("Baltijas–Vācijas kultūru sakari no 16. līdz 19. gadsimtam: mediji – institūcijas – personas". "Baltisch-deutsche Kulturbeziehungen vom 16. bis 19. Jahrhundert: Medien – Institutionen – Akteure". Bd. II:

Zwischen Aufklärung und nationalem Erwachen. Winter Verlag Heidelberg, 2019, 588 seiten).

Research team: Dr.phil. Raivis Bicevskis, Jost Eickmeyer, Dr.hist. Andris Levans, Anu Schaper, Björn Spiekermann, Inga Walter. Faculty of History and Philosophy, Department of Philosophy and Ethics, Department of History and Archaeology of the University of Latvia.