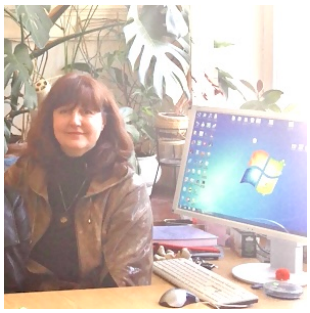

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P.L. Kapitza Institute for Physical Problems, Russian Academy of Sciences, Moscow, leading researcher

***Specialist in the field ofnanoarchitectonics, thin film nanomaterials, and X-ray diffraction***

**The area of scientific interests** is the development of fundamental experimental and theoretical foundations for the production of nanomaterials based on nanoarchitectures obtained through controlled self-assembling of bioactive compounds, including drugs, in confined space at the nanolevel: at the water-air interface, in thin films and in nanocarriers.

**The author of the concept** of nanostructuring of compounds at the air-water interface, according to which the structural units of the layer, in the general case, are not individual molecules (Langmuir's approach), but M-nanostructures formed as a result of self-assembling. Such layer on water is a nanocosm, where, at a critical density, ensembles work as nanoreactors in which the transformation of the original matter occurs and, as a link in the chain of evolution of parent molecules, supermolecules – nanoarchitectures of a special type with strong non-covalent intermolecular interactions, capable of solving problems more complex than the original compounds are formed.

**Education.** Faculty of Physics, Ivanovo State University (diploma with honors), PhD student at the Institute of Crystallography (A.V. Shubnikov) of the Russian Academy of Sciences, Moscow (Laboratory of Small Angle Scattering). Subject of PhD thesis "Formation and X-ray small-angle study of Langmuir-Blodgett films of discogens: tetra-alkanoyloxyhydroquinones, copper carboxylates and hexaalkoxytriphenylenes" (1993). Subject of doctoral dissertation “Controlled self-organization of azaporphyrins in 2D and 3D nanostructures in Langmuir layers and Langmuir-Blodgett films” (2012).

**Experience.** In 1993-1994 – postdoc at the University René Descartes (Paris-V), Laboratory of Physics and Biophysics, Paris, France, and in 1997-1998 – at the Institute of Physics of the University of Ancona, Italy. In 1999 – scientific research using synchrotron (*Trieste S.C.p.A., Austrian SAXS beamline at Elettra*) and neutron *(Laboratoire Léon Brillouin, CEA-CNRS, G2-3 Small Angle Neutron Scattering Facility PAXY and G3-BIS: Time of Flight Reflectometer EROS emissions)* at the European Research Centers in Trieste, Italy and Saclay, France. Invited lecturer at three International Schools on Nanotechnology and New Materials (Italy, 2002, 2003, 2005). Until 2008 – scientific work and teaching at the Ivanovo State University (ISU). In 2001 – secondary scientific work at the Institute of Chemistry of Non-Aqueous Solutions of the Russian Academy of Sciences. In 2003, by decision of the Higher Attestation Commission, was awarded the academic title of Associate Professor in the specialty "Condensed Matter Physics". Since 2008 – a leading researcher, and since 2018 – the head of the Langmuir-Blodgett Technology Laboratory at Ivanovo State University of Chemistry and Technology (ISUCT). Member of the Dissertation Council for the defense of doctoral and PhD theses (ISUCT), chairman of the State Examination Commission of ISU in the field of study "Physics". Visiting scientist at the Università Politecnica delle Marche,

Department of Materials, Environmental Sciences and Urban Planning SIMAU, Italy. Leading international research teams and conducting research on two projects at the International Synchrotron Research Center in France *(Synchrotron Radiation Facility, Grenoble, ESRF).* From 2008 to 2019 – periodic work and lecturing in Italy (Universities of Ancona, Genoa, Parma, Bologna, Lecce, Catania) and in China (Shenxi University, Xi'an). Since 2021 – secondary scientific work at the Federal Research Center "Informatics and Control" of the Russian Academy of Sciences, Moscow (Department of Nanotechnology and Information Technology of the Russian Academy of Sciences, Department of Mathematical Sciences of the Russian Academy of Sciences). Since 2025 – leading researcher at the P.L. Kapitza Institute for Physical Problems, Russian Academy of Sciences, Moscow.

**Author of two monograph, chapters in five books (published in Italy and Russia) and more than 100 scientific articles in journals:** *ACS Langmuir, Colloids and surfaces B: Biointerfaces, Journal of Applied Crystallography, Biosensors and Bioelectronics, Applied Surface Science, Colloids and Surfaces A, Material Science and Engineering C, Journal of Inclusion Phenomena, Molecular Crystals and Liquid Crystals, Thin Solid Films, Electrochimica Acta, BioNanoScince, Journal of Porphyrins and Phthalocyanines, Macroheterocycles, Journal of Experimental and Theoretical Physics, Biological Membranes, Colloid Journal, Physico-chemistry of Surface and Material Protection, Izvestiya RAN, Physical series; Surface, X-ray, synchrotron and neutron studies, etc.*

**Reviewer of projects in the Russian Science Foundations, dissertations and articles in journals:** *ACS Langmuir, Journal of Applied Crystallography, Journal of Inclusion Phenomena, Applied Surface Science, Journal of Nanoscience and Nanotechnology, Inorganica Chimica Acta", "Journal of Physical Chemistry", "BioNanoScince", "Macroheterocycles", etc.*

**Participant (with oral and plenary reports) of twenty-one international conferences**: *Organized Molecular and LB films (Germany, Italy 2000, 2001 and 2008); Chemistry of Porphyrins and Their Analogues (Russia 2003, 2011, 2019), Supramolecular Architectures (Russia 2014); Molecular Electronics (Russia 2018); Porphyrins and Phthalocyanines (ICPP-7, Korea, 2012; ICPP-8, Turkey, 2014; ICPP-9, China, 2016; ICPP 10, Germany, 2018; ICPP-11, USA, 2021), Synthesis and application of porphyrins and their analogues (ICPC: Russia 2003, 2011, 2019, 2024), etc.*

**Head of twelve scientific projects and grants in physics:** grants of the Russian Science Foundation No. 20-12-00175-p (2023-2024) and No. 20-12-00175 (2020-2022); international projects Russia-Italy-France and Russia-Italy of the European Synchrotron Research Center (ESRF), Grenoble, France; Project of the Ministry of Education and Science of the Russian Federation within the framework of the federal target program "Scientific and scientific-pedagogical personnel of innovative Russia", in the direction of "Nanotechnologies and nanomaterials", State. contract No. 14.740.11.0268; two Grants of the Ministry of Education of the Russian Federation under the scientific program "Universities of Russia"; Five Grants of the Russian Foundation for Basic Research.

**The amount of funds attracted for scientific research (under grants for 2008-2024) is 55.1 million rubles.**

## Main directions of scientific research

– Nanoarchitectures of metal organic compounds in confined space at the nanolevel: at the air-water interfaces, in thin films and in nanoengineered capsules
– Supermolecular nanomaterials based on vitamin $B_{12}$ and porphyrin derivatives
– Reactions in 2D and 3D layers at the liquid-gas interface (polymerization, complex formation, etc.)

– Thin-film sensors and catalysts
– Structure of floating layers, films and capsules according to small-angle X-ray scattering, X-ray reflectometry (XRR) and grazing incidence X-ray diffraction (GIXD and GISAXS)
– Theory of condensed state (generalized equation of state of the nanostructured M-layer at the air-water interface)
– Drugs for nanomedicine; nanoparticles and targeted drug delivery systems (vitamin $B_{12}$, chlorin e6, etc.)

**Fundamentally new experimental results obtained**

– Supermolecules of tetrapyrroles were discovered *(Langmuir 2018*).
– The first (a) supermolecular nanostructures of vitamin $B_{12}$ derivatives *(Langmuir 2023)*, (b) nanostructures of water-soluble compounds (vitamin $B_{12}$ and phthalocyanines), stable on the water surface, (c) vitamin $B_{12}$ nanostructures in nanoengineered polymer capsules *(Colloids and surfaces B: Biointerfaces, 2019)* were obtained.
– A hypothesis has been put forward about the possibility of generalization of the electron density of molecules in tetrapyrrole nanoparticles (X-ray diffraction studies, *Langmuir 2008*).
– In nanostructured monolayers on water at room temperature, reactions that take place in solutions only under harsh conditions (high temperature, acid, catalysts) were carried out.
– For the first time, it is proposed to dissolve nanostructured films on solid substrates and obtain nanoarchitectures that work not only in films, but also in solutions of organic solvents.
– Thin films of vitamin $B_{12}$ derivatives are recommended for use as active layers in adsorption-resistive sensors for ammonia and hydrogen sulfide. The detection limits for $NH_3$ (0.1 ppm) and $H_2S$ (0.06 ppm) are lower than those of known sensors based on most other tetrapyrrole compounds (*Sensors and Actuators B, 2024*).
– For the first time, by coating the working element of an organic memristor with a thin film of a vitamin B12 analogue, the switching potential of the device was significantly reduced – by 100 mV. This result represents a significant step toward neuroprosthetics – integration with biological systems operating at potentials of 50-100 mV (*IOP Nanotechnology 2024*).

**Theoretical results**

– A concept for nanostructuring complex organometallic compounds under conditions of spatial restrictions at the nanolevel has been proposed and developed: at the water-air interface, solid-air interface, and in nanocapsules *(Colloid Journal 2008, Langmuir 2023,39,9*).
– A model of a layer formed on the water surface was constructed. The physical basis of the model is to represent the layer as a real gas, the structural units of which are not individual molecules (Langmuir's approach), but M-nanostructures. The model parameters are quantitative characteristics of the structure and properties of the layer. A variable parameter, in particular, is the initial surface concentration. Quantitative relationships between the layer characteristics and the conditions of their formation are established. A generalized model of the layer state has been proposed that adequately describes experimental data and is applicable to layers of both 2D and 3D nanoparticles, including those formed under high surface pressures *(RSF Project 2020-2022*). It has been shown that calculating the layer compressibility allows us to identify phase transition points and determine precise boundaries for the developed generalized model of the layer state *(RSF Project 2023-2024, extension).*

**From 2020 – within the framework of Russian Science Foundation projects,** when solving complex interdisciplinary problems in the fields of physics, biophysics, chemistry, the science of nanomaterials and nanomedicine, considerable attention has been paid to research not only of a fundamental, but also of an applied nature. In particular, the first supermolecular nanoparticles of a derivative of vitamin $B_{12}$ have been obtained, the multifunctional properties and activity of which, not only in films, but also in solutions of these films, exceed the properties of both the initial

compounds and vitamin $B_{12}$ itself. Thin films of vitamin $B_{12}$ derivatives were recommended for use as active layers of highly sensitive optical and adsorption-resistive sensors for ammonia, hydrogen sulfide and cyanides. The detection limit for $NH_3$ (0.1 ppm) and for $H_2S$ (0.06 ppm) is lower than the detection limits of known sensors based on most other tetrapyrrole compounds. Uses: reusable poison gas sensors, bifunctional multinuclear nanoelectrocatalysts, highly stable toxicant destruction catalysts. The reduction in operating potential by 100 mV achieved by introducing a vitamin $B_{12}$ analogue into the active layer of an organic memristor brings the devices closer to being implemented in biological systems. It has been established in vivo experiments that vitamin $B_{12}$ derivatives not currently registered as drugs, including those delivered in nanocapsules, work as antidotes for acute and chronic, including drug poisoning, as well as neuroprotectors. Pyridylporphyrin and its reduced forms, chlorin and bacteriochlorin, are promising for use as photosensitizers for photodynamic, including antimicrobial, therapy.

***The main provisions of the concept and the most important scientific results are presented in the following works***


- *Maiorova L.A. Controlled self-organization of azaporphyrins in 2D and 3D nanostructures in Langmuir layers and Langmuir-Blodgett films, Dissertation for the degree of Doctor of Physical and Mathematical Sciences (in Russ.) 2012, 328 p.*
- *Maiorova L.A., Koifman O.I. The concept of nanostructuring of macroheterocyclic compounds at the liquid-gas interface and nanomaterials based on supermolecules formed on the surface of water, Chapter 18, 701-740 in the monograph "Functional materials based on tetrapyrrole macroheterocyclic compounds" edited by Koifman O.I., M .: LENAND (in Russ.), 2019. URSS. 2019. 848 p. ISBN 978-5-9710-6952-2.*
- *Valkova (Maiorova) L.A., Glibin A.S., Valli L., Casilli S., Giancane G., Borovkov N.Yu., Sibrina G.V., Koifman O.I. et al. Nanoaggregates of copper porphyrazine in floating layers and Langmuir-Schaefer films. Langmuir 2008, 24, 4857-4864.*
- *Maiorova L.A., Kobayashi N., Zyablov S.V., Bykov V.A., Nesterov S.I., Kozlov A.V., Devillers Ch.H., Zavyalov A.V., Alexandriysky V.V., Orena M., Koifman O.I. Magnesium porphine supermolecules and two-dimensional nanoaggregates formed using Langmuir-Schaefer technique. Langmuir, 2018, 34, 9322-9329.*
- *Maiorova L.A., Erokhina S.I., Pisani M., Barucca G., Marcaccio M., Koifman O.I., Salnikov D.S. et al. Encapsulation of vitamin $B_{12}$ into nanoengineered capsules and soft matter nanosystems for targeted delivery. Colloids and surfaces B: Biointerfaces, 2019, 182C, 110366.*
- *Maiorova L.A., Kobayashi N., Salnikov D.S., Kuzmin S.M., Basova T.V., Koifman O.I., Parfenyuk V.I. et al. Supermolecular nanoentities of vitamin $B_{12}$ derivative as a link in the evolution of the parent molecules during self-assembly at the air-water interface. ACS Langmuir 2023, 39, 3246-3254.*
- *A. Sorokin, L. Maiorova, M. Zavalishin Dimethyl sulfoxide in a Langmuir trough Applied Surface Science, 2024, 670, 160636. DOI:10.1016/j.apsusc.2024.160636.*
- *Darya Klyamer, Dmitry Bonegardt, Pavel Krasnov, Tamara Basova, Larissa Maiorova*
*Chemiresistive NH3 and H2S sensors based on thin films of vitamin B12 derivatives. Sensors and Actuators B, 2024, 418, 136268. https://doi.org/10.1016/j.snb.2024.136268.*
- *N.V. Prudnikov, A.V. Emelyanov, M.V. Serenko, I. A. Dereven'kov, L.A. Maiorova, V.V. Erokhin.*
*Modulation of polyaniline memristive device switching voltage by nucleotide-free analogue of vitamin B12, IOP Nanotechnology 2024, 35, 335204. DOI 10.1088/1361-6528/ad4cf5.*
- *I.A. Dereven'kov, L.A. Maiorova, O.I. Koifman, D.S. Salnikov High Reactivity of Supermolecular Nanoentities of Vitamin B12 Derivative in Langmuir-Schaefer Films Toward Gaseous Toxins.*
*ACS Langmuir 2023, 39, 48, 17240–17250. DOI:10.1021/acs.langmuir.3c02317.*
- *LA. Maiorova, OA Gromova, IYu Torshin, TV Bukreeva, TN Pallaeva et al. Nanoparticles of nucleotide-free analogue of vitamin B12 formed in protein nanocarriers and their neuroprotective activity in vivo. Colloids and Surfaces B: Biointerfaces, 2024, 244, 114165. DOI:https://doi.org/10.1016/j.colsurfb.2024.114165.*



**The work is being carried out in accordance with the Direction of the Strategy for Scientific and Technological Development of the Russian Federation** – H1: transition to advanced technologies for the design and creation of high-tech products based on the use of intelligent manufacturing solutions, robotic and high-performance computing systems, new materials and chemical compounds, the results of processing large volumes of data, machine learning technologies, and artificial intelligence. The priority area of scientific and technological development in the Russian Federation – preventive and personalized medicine, ensuring healthy longevity. **Critical**

**technology** – technologies for developing next-generation drugs and platforms (biotech and high-tech drugs). End-to-end technology – technologies for creating new materials with specified properties and performance characteristics.

**The fundamental and practical significance of the problems being solved** is determined by the fact that the processes of nanostructuring of biological compounds or their functional core compounds, the most important functions of which, in particular derivatives of vitamin $B_{12}$ and chlorophyll, in nature are carried out precisely in ensembles, are studied. Their properties are determined by the structure of the ensemble. In addition, compounds are actively used in catalysis and medicine, where their aggregative behavior directly determines the properties of the drugs. The possibility of forming nanoparticles of compounds – their own nanoforms of drugs – is relevant for the purposes of nanomedicine.

The results obtained make it possible to use the Langmuir-Blodgett technology as a tool for the formation and study of 2D and 3D nanoarchitectures, including supermolecules of the compounds, and the production of nanomaterials and own nanoforms of drugs of a fundamentally new type on their basis.

The main fundamental and still open problem, the solution to which is the focus of current research, is the nature of strong non-covalent intermolecular interactions in supermolecules, which does not fit into the framework of traditional concepts.

**The main areas of practical application of the results** (1) nano- and biotechnologies – new methods for producing medical and biological nanomaterials based on the nanoarchitectures of bioactive compounds; (2) photonics – optical nanomaterials and photosensitizers; (3) electronics – organic memristors; (4) ecology – water purification and control of harmful emissions, food industry; (5) pharmacology and nanomedicine - new drugs and express sensors for toxins.

**Language skills** *English, Italian, (French), Russian - native.*