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R&D WORKS OF THE *LVIVSKA POLITEKHNIKA* NATIONAL UNIVERSITY

R&D works of Lviv Polytechnic National University researchers for the last five years, which outline the level of accomplishments and the capacity of the University to work effectively for meeting the needs of market economy have been summarized. More information on R&D works of Lviv Polytechnic National University can be found at nauka.lp.edu.ua.

Keywords: semiconductor materials, nanoelectronics, chemistry, energy saving, and information technologies.

The *Lvivska Politekhnika* National University is implementing the national R&D policy and its own strategy aimed at facilitating the establishment of innovative model of economic and social development of Ukraine and a more efficient use of intellectual potential and at raising the national economy competitiveness. The cooperation with international R&D institutions, educational centers, and foundations, as well as the formation of innovation infrastructure and the commercialization of research results are among the main priorities of the National Lviv Polytechnic University.

The staff of *Crystal* R&D Center for Solid-State Electronics and Sensors (supervisor: *I.A. Bolshakova*, Dr. Tech. Science) has developed **a technology of radiation induced modification of $A_{III}B_{V}$ semiconductor materials for sensor electronics**. The researchers have defined optimal technological modes of sensor radiation induced modifications based on heterogenic structures InSb/i-GaAs and InAs/i-GaAs for obtaining sensors with parameters that can be kept stable during the operation in accelerators and fusion reactors and developed a new version of software for measurement system, which provides a high-accuracy control of parameters of radiation-modified semiconductor materials and temperature of sensors during their exposure to radiation. The technology for radiation induced modification makes it possible to obtain materials with a given level of doping and homogeneous distribution of dopants suitable for radiation-resistant sensors with high sensitivity to magnetic field. Unlike the existing techniques, the developed technology for radiation induced modification allows the researchers to apply modification process to both thin-film materials and to finished sensors, which not only simplifies the manufacturing process itself, but also makes it possible to receive radiation-resistant sensors with a wide range of operating temperatures, high sensitivity to magnetic field, and sustainable parameters. The total cost of its implementation is UAH 1.5 million. The payback period is 5—7 years. Among potential customers, there are research centers dealing with operation or construction of research reactors and accelerators of charged particles in the USA, Germany, Russia, Japan, France, and in other countries. The international nuclear research centers CERN, JINR (NICA project), GSI (FAIR project), as well as ITER, JET, and TORE SUPRA fusion reactors require hundreds of magnetometers for cont-

rolling and monitoring the magnetic field. Magnetometers based on radiation-resistant Hall sensors can be used in the growing rapidly market of cyclotron medical devices. Today, equipment for *in-situ* measurements of parameters of materials and sensors during their exposure to radiation has been designed and manufactured. Experimental samples of radiation-modified sensors have been manufactured and tested. Three-coordinate magnetometers based on radiation-resistant Hall sensors have been made for the Joint Institute for Nuclear Research (Dubna, Russia).

Researchers of Lviv Polytechnic University are involved in studying the most important problems of chemistry and chemical technologies. Under the direction of Dr. Tech. Science, Prof. *S.A. Voronov* they have created **highly effective polymeric nucleic acid carriers, fluorescent markers, and medical products for rapid diagnosis and treatment of proteinopathy**. The methodology of synthesis and effective techniques for obtaining new classes of functional monomers have been developed. For the first time, new classes of acrylate, maleate, and malemide surface active monomers have been obtained. The colloid-chemical properties of synthesized monomers and their solutions, as well as the emulsion and dispersion copolymerization with peroxides and other monomers of traditional structure have been studied. The colloid-chemical properties and adsorption capacity of obtained functional oligomers have been researched as well. For the first time, the carriers whose complexes with oligonucleotides overcome the blood-brain barrier have been obtained, which is very important for the treatment of prion infections and other diseases of the brain. An advantage of created materials is that their conjugates with nucleic acids and other drugs, in contrast to the known carriers, are able to overcome the blood-brain barrier to deliver drug to the brain where the nidus of prion infection is located. The synthesized carriers ensure 28- time more effective delivery of nucleic acids to the yeast cells as compared with branched polyethyleimine and are 79-time more effective than polyethylene glycol manufactured by *Sigma-Aldrich*. Their efficacy exceeds 15 times the traditional lithium acetate delivery and 2 times the electroporation. The materials are based on compounds of natural origin and industrial monomers. Their use several times increases the therapeutic effect of specific oligonucleotides. Thanks to the versatility of this method for obtaining oligomers their cost significantly decreases. Experimental samples have been tested at the Institute of Animal Biology and at the Institute of Cell Biology of the NAS of Ukraine as carriers of drugs and genes in the course of their *in vitro* and *in vivo* research.

New «smart» oligomeric carriers of drugs and nucleic acids and nanoscale systems for their target delivery in cells and organisms have been created and studied *in vitro* and *in vivo* (supervisor: Dr. Tech. Science Assistant Professor *O.S. Zaichenko*). Anticancer drugs based on them have successfully passed laboratory and preclinical testing; clinical trials are prepared. The synthesis technology has been protected by patents of Ukraine and the USA. The research was made in cooperation with the Institute of Cell Biology of the NAS of Ukraine, the co-holder of title to this innovation. The idea of research is that new low toxic carriers provide drug delivery to the target organ, its controlled release there and extension of its effect thereby making possible to reduce toxic doses of anticancer drugs and overcoming natural biological barriers in the organism. The R&D product has the following advantages: 1) methods for new carriers and delivery systems provide targeted control of functionality, molecular-mass characteristics of carriers, colloid-chemical and rheological properties, as well as the ability to immobilize drugs and DNA; 2) lower cost and toxicity as compared with the existing synthetic analogs; 3) the ability to create different formulations for oral, parenteral, transdermal, and other routes of administration; 4) the ability to overcome the natural biological barriers, higher efficacy, and prolonged therapeutic effect.

Regulations and technical specifications for obtaining effective **biocide for the protection of pa-**

ints and primers of thiosulfonate type (TT) with a broad spectrum of antimicrobial activity have been drafted (supervisor: Dr. Tech. Science, Prof. *V.P. Novikov*). Pilot tests of biocidal effect of emulsion paint (UP-131) and varnish (339) (both manufactured by IRCOMECT) containing TT biocide at concentrations of 0.1—1% have been made. The samples of UP-131 paint and 339 varnish containing TT biocide have been established to provide antimicrobial and antifungal protection of different materials from destructive action of biological organisms both exterior and interior spaces of buildings. The samples of wood and plaster painted and coated with varnish containing TT biocide have neither *Aspergillus niger* nor *Penicillium chrysogenum* fungi. A sterile zone has been observed in the nutrient medium, which is explained by diffusion of TT biocide to the medium. The proposed TT biocidal substance is a highly active biocide against bacteria and fungi that cause biodeterioration of paints and varnishes and is more effective than *Grotan F-15* (S&M). An estimated demand for thiosulfonate biocide that can be used for the protection of not only paints and varnishes, but also various petroleum products from biodeterioration is about 150 tons annually. An expected economic effect of the production and use of biocides is, at least, UAH 200 million annually. Potential customers are car- and machine-building corporations, civil engineering and construction companies, petrochemical industry.

Among the R&D products in the field of innovative technologies for the production of chemical substances it is necessary to mention **a technological framework for the production of stabilized polymeric sulfur and hydrogen by sulfide plasmolysis.** This product has no parallel in the world and makes it possible to get special types of sulfur with predetermined properties and to effectively address the problem of hydrogen sulfide disposal (team leader: Dr. Tech. Science, Prof. *V.T. Jaworski*). The experimental samples of stabilized polymeric sulfur have been obtained; their physical, chemical, and mechanical properties have been studied; quick-hardened sulfur cement samples with high hydrophobicity, mechanical strength, and frost resistance have been obtained. The technological scheme of manufacturing process has been designed and the process parameters for major technological stages have been calculated. The technology ensures selective production of given special type of sulfur (polymeric or fine), together with hydrogen, and carbon disulfide in one installation only by changing the parameters of raw materials and manufacturing process. The technology provides for complete processing of raw materials and production of desired specific sulfate products that have been in short supply in Ukraine. It should be noted that these sulfate products have not been synthesized in Ukraine so far. The technology makes it possible to cheapen the product by 50—60% due to reducing energy consumption and synthesizing hydrogen, and to improve working conditions. The received samples of stabilized polymeric sulfur surpass the world best examples by certain parameters. The technology ensures 70% thermal stability of polymeric sulfur (as compared with 55% thermal stability of its counterparts), which makes it possible to obtain polymeric sulfur with controllable properties and to extend the scope of its application. The cost of the project (depending on the performance of technological object) is UAH 2—5 million. The payback period is 2—3 years. Potential users are oil- and gas-processing companies, chemical, coke, food, rubber, and tire industries, construction industry, agriculture, and energy sector.

New types of fuel, waste heat, renewable and alternative energy sources, and heat pump technologies are extremely promising research area. Researchers of Lviv Polytechnic University have created **an electric and mechatronic energy conversion system for gearless wind turbines with vertical axis of rotation** (supervisor: Dr. Tech. Science. Sci. *I.Z. Schur*). The system has been patented. A method for simplified and refined calculation of parameters of the generator has been proposed; a software package for calculating the magnetoelastic properties of multipolar synchronous machines of different configurations based

on 3D-modeling of magnetic field has been developed to design high-performance electric machines with set parameters, which surpass the existing counterparts. A microcontroller automatic control system has been designed for optimizing the operating point in order to get a maximum output power, to ensure a correct operation of batteries for extending their service life, and to protect the wind farm from emergency situations. The team has proposed systemic, schematic, and algorithmic solutions for a gearless autonomous wind farm based on two-anchor multipolar synchronous motor with permanent magnets and semiconductor energy converters on the basis of electrical step-up DC-DC-converter and voltage rectifier regulated by microcontroller. These solution provide much better energy and performance indicators as compared with the existing wind turbines due to an effective use of low winds, an optimal control of electrical load, and an effective protection of batteries.

In the field of solar energy, a pilot sample of **three-dimensional n-CdS/p-CdTe solar cell** has been manufactured and tested in the laboratory (supervisor: Dr. Phys. and Math., Prof. *G.A. Ilchuk*). The developed technology for the production of textured solar cells has an important practical and economic value, since it makes it possible to obtain elements with greater effective surface without changing their area; multiple light reflection on micro-relief surface provides increased efficiency of solar cell; the use of silicon for the manufacture of micro-relief pads facilitates the mass production. The technology requires a small amount of high-purity materials (expensive cadmium and tellurium) for the manufacture of solar cells and, consequently, cheapens the production costs. It should be noted that cadmium and tellurium bound in the compound are harmless and environmentally friendly. Increasing efficiency of solar cells without changing their size makes it possible to reduce the payback period of solar panel projects.

Physical and technological principles for the formation of hierarchical and supramolecular structures in molecular power engineering and nanoelectronics have been developed for the corporations operating in the fields of electricity, instrumentation, micro- and nano- photoelectronics, spintronics, and electronic materials (supervisor: Dr. Tech. Science, *Prof. I.I. Hryhorchak*, project: the creation and application of nanotechnologies and nanomaterials). As of today, equipment has been designed and process operations for manufacturing generators and energy storage devices in a composite body have been developed. Pilot samples of solid nanostructured ionistors with functional radio frequency hybridity have been manufactured. New energy sources, the ionistors (nanogenerators) have been developed. For the first time, the approach of supramolecular ensembles of hierarchical architecture has applied to these devices. Supramolecular nanostructures of one- and two-matrix hierarchical architecture (graphite-nanodispersed bismuth selenide and graphite-nanodispersed iron disulfide) have been designed for lithium batteries with the intercalation mechanism for current-generating reactions. This increases capacity up to 6 times as compared with the existing large-scale homologues. A new class of nanostructured elements, such as magnetic DC blockers and coilless delay lines have been designed. First developed intercalation method of forming nanostructures. A nanostructure of new configuration, with alternating 2D-semiconductor and 2D-ionic nano-layers, which features functional hybridity has been obtained for the first time. At low frequencies, it operates as ionistor (supercapacitor), while at high frequencies, it can be used as high-Q RF capacitor. The supramolecular ensembles of hierarchical architecture synthesized for the first time ensure a tremendous increase in photo-capacity at room temperature as compared with the existing materials. Discovered new effects and phenomena provide a wide application of nanostructures to RF capacitors that have much higher specific capacity as compared with the existing ones and nano-photo-ionistors (the supercapacitors) that have no comparable counterparts in the market.

The research team led by Prof. Hryhorchak also has developed methods and modes of **intercalation modification of environmentally friendly minerals** and designed a technological framework and software for their implementation. The formation of supramolecular and double-matrix nanostructures based on minerals modified by intercalation has been established to significantly improves power output of lithium current sources. The specific capacity is much higher than that of the cathode material of lithium power sources, with a functional hybridity making it possible to reach a huge pseudo-capacity of ~8000 F/g. The researchers have designed an active configuration system of double matrix-roocking chair which allow them to reach a specific energy ~9 kJ/g. Design solutions have been simplified in order to increase energy capacity 2 times and the number of charge-discharge cycles 10 times. This enables the replacement of all lead, nickel-cadmium, and nickel metal hydride batteries. The availability of resources, environmental friendliness, and ease of technology that ensures high energy output and low cost of unit of energy make this R&D product attractive for investors. Potential customers are corporations of instrumentation industry, particularly for ensuring autonomous power generation: power supply to calculators, remote control panels, computer-volatile memory, mobile devices, flashlights, etc.) as well as for producing energy blocks for hybrid vehicles. Samples of nanohybridized structures prone to super-capacitive charge accumulation have been manufactured and tested. Technologies for molecular energy accumulators with aqueous and non-aqueous electrolytes and those for lithium batteries with intercalation mechanism of current producing reactions have been ready for implementation. The supercapacitors are supposed to be used for the manufacture of electric bus at *Electron* corporation (Ukraine), the hybrid energy accumulators are planned to implemented at MWH (Slovakia), and the lithium-ion capacitors are expected to be used for gadgets and redox batteries for mobile phones by *LG Electronics* corporation (South Korea).

Burshtyn HEP, OJSC *Lvivoblenergo*, OJSC *Zakhidenergo* and *Kalush* open distributing substation of the Western Electricity System have introduced **tools and ways to improve controllability and quality of electric power systems** (supervisor: Dr. Tech. Science, Prof. *Yu.O. Varetskyi*). A set of software modules has been developed: for analyzing the impact of characteristics of higher harmonic filters on performance of non-sinusoidal mode of power grid; for calculating the elements of power grids that can adequately simulate ferro-resonance processes in real grids with electromagnetic voltage transformers; and for simulating the static excitation system SSTE-2100-465-2.5 UHL4 of TGV-200 turbogenerator. The following databases have been created: for indicators of non-sinusoidal modes of power grids with different types of nonlinear loads and means of compensation for reactive power, which have been obtained from experimental and model studies and enable the creation of a new system for monitoring of non-sinusoidal modes of power grids with non-linear loads and for design parameters of basic types of electromagnetic voltage transformers that enable an adequate simulation of ferro-resonance processes in electrical systems. Technological instructions for telemetry verification based on generalized independent variables for the operational remote control of power grids, which significantly reduce inaccuracy of information caused by errors on the path from the source of information to the operator. The product complies with international standards. Practical application of the proposed models, methods, techniques for analysis and calculation significantly improves the controllability, quality, and reliability of electric power systems and enables the optimization of strategies for the development and improvement of controllability. A computer simulator for testing and diagnosing the static systems for controlling excitation of power turbine generators has been designed; an anti-resonance voltage transformer for power grids with isolated neutral; voltage transformer protection system against damage ferroresonance proc-

esses in electrical networks with isolated neutral point has been developed; pilot sample of device for the protection of voltage transformers from ferro-resonance processes has been manufactured.

The intelligent system of optimum control of the arc furnace electric modes by criteria of energy saving patented in Ukraine is to be implemented at Novovolynsk Foundry, TZOV *Razlet* Research and Manufacturing Association and *Motor Sich*. The engineering prototype of this system passed the test in furnaces of small capacity (a research group of D.Sc. in Engineering, Prof. *Lozynsky O. Yu.*, which works in the direction «Technologies of Power Industry»). Operating control of melting modes and adaptation to the change of axial and parametric disturbances is carried out by a neural network of the upper level. The input vector of a neural network which elements are integral criterion of coordinates and disturbances of the melting mode is quickly calculated by the subsystem of information support. Local subsystems of rapid control and qualitative stabilization of coordinates of the electric mode function on a lower level. The developed hierarchical multiloop system has expanded functionality concerning realization of strategy of multiobjective optimum control, in particular by the generalized criteria of conservation of energy. Unlike dual-phase system of the Italian firm *Danieli* the developed system of neural network control has great opportunities with rapid multiobjective strategies of adaptive optimum control of the melting modes, 1.4 times less installed rating of power supply equipment and, respectively, smaller cost, and also smaller distortions of sinusoid of arches electricity and line voltage. With the offered system the accuracy of implementation of the optimum master schedule of working the heat increases which guarantees receiving electric furnace steel and alloys with standard indicators of chemical composition and physical properties, the quantity of off-analysis heat decreases, the probability of accidents and emergency situations decreases, the cost of steel and alloys decreases. In furnaces with a capacity of 0.5–3 t it is possible to reach reduction of the cost per unit of electric power for 4–6%, decrease the active energy losses for 4.5–7%, and consumption of jet energy for 17–24%. The average power factor for the heat increases from 0.79 to 0.85, metal loss through evaporation is less for 4.5–5.5%, and productivity of the furnace increases for 6–7%.

Under the leadership of D.Sc. in Engineering, Prof. *Duryagiva Z.A.* **functional properties of constructional materials by surface engineering methods with use of computer modeling have been optimized**. The engineering prototype of a USB-adapter of the vibration magnetometer for unification, modernizations and increase of accuracy of measurements of magnetic properties of surface layers has been made. The program complex Solid Works has been developed for creation of simulation models which enables to carry out determination of optimum parameters of a microstructure of surface layers of metal products which meet the requirements of operation. T-ControllerUserManual software product has been developed. The authors have developed new technologies for restoration and repair of machine components to increase their wear resistance, contact strength and corrosion resistance, as well as methods of determination of optimum parameters of microstructure. Ways of creation of functional barrier layers through a laser surface modification of corrosion-resistant steel have been offered. They have the properties of new materials capable to work effectively in friction couples under conditions of static and dynamic loads at simultaneous impact of working environments. Optimum combinations in the system «*steel – the elements modified into a surface*» taking into account kinetics and the mechanism of physical and chemical phenomena on the interface have been established. The optimum modes of methods of a surface engineering have been developed. Smart sensors with functions of recognition, classification, forecasting and prediction have been created. Unlike world analogs the developed technology enables to choose optimum technologies of surface layers formation of different functional

purpose depending on morphology of their structure. To increase contacting durability of friction couples analytical dependencies have been established which connect effective mechanical properties and quantitative parameters of surface layers microstructure. Application of methods of neuro-fuzzy modeling enabled to create smart sensors which can be embedded in the equipment for monitoring of destructive changes in surface layers of constructional materials.

A research group of D.Sc. in Engineering, Prof. *Melnik A.O.* that works in the scientific direction «Supercomputer program and technical means, telecommunication networks and systems. Grid- and cloud-technologies» has developed the **technology of multiport computer memory on the principles of data concurrency** – theory, models and technology of architecture of devices of parallel multiport memory (PMM) of the computer. The technology includes a new image of the ordered access to data that provides parallel access to data from multiple ports, enables to perform parallel calculations and increases productivity of computer systems. A new type of the computer memory and new architecture of the memory device in which this image is realized have been offered. The developed models of PMM devices can be realized with the use of the developed technology in FPGA (Field Programmable Gate Array) as separate computer memory devices or components of computer systems on a chip. Presently there are no memory devices with parallel conflict free access to data from multiple ports. In comparison with memory devices with consecutive access, memory with parallel conflict free access is, at least, n times faster (n – number of memory ports), does not require storage of memory locations where the data is recorded, and has wider functionality. Application of the offered memory device will increase efficiency of computational means for the memory device with 16 ports – 1/16 nanoseconds or 60 picoseconds that is impossible for the known types of memory. For comparison: the fastest semiconductor memory of *Micronsdram* company CT32M64S4W7E works at frequency of 133 MHZ, i.e. for a record/selection of one piece of data from this memory one needs 8 nanoseconds – 128 times more than in the developed multiport memory. The following computer devices can be built on the basis of multiport memory: parallel buffer memory, parallel processors of signals and images processing, shared memory of computer systems and networks, etc.

The development of **information technology for protection of securities on the basis of new methods of digital processing of graphic information** (research supervisor D.Sc. in Engineering, Prof. *Medykovskiy M.O.*) is quite perspective. The developed technology solves a problem of creation of domestic innovative images of protection of securities, as today practically there are no similar methods and means developed on the basis of mathematical apparatus and realized with the use of standard equipment for publishing and printing systems. The working results have been implemented at *Ukraine* Printing and Publishing where the essentially new technology of building of guilloche elements of securities protection has been mastered. Technology and specialized software for production of protective elements through images coding with the use of acyclic Hadamard matrices have been implemented at Banknote Factory of the National Bank of Ukraine. Scientists of Medykovskiy group have developed information technology for realization of complex protection of securities on the basis of vector graphics and images coding, as well as the specialized software which increases efficiency and level of protection of securities through increase of accuracy of graphic elements creation. Use of the developed information technology at the stage of pre-printing processes provides unique elements of protection. Besides, possibilities of parametric identification of documents extend. The developed complex method of securities protection unites a method of design of thin graphics and a method of graphics coding. Association of the method of creation of thin graphics on the basis of Ateb-functions and the method of graphics

coding became a basis for the created new information technology of securities protection. The offered technology of securities protection does not require the use of new materials and special equipment. There is no similar technology of protection and the corresponding software for its implementation in Ukraine.

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НАУКОВІ РОЗРОБКИ НАЦІОНАЛЬНОГО УНІВЕРСИТЕТУ «ЛЬВІВСЬКА ПОЛІТЕХНІКА»

Представлено розробки науковців Національного університету «Львівська політехніка» за останні п'ять років, що дають загальне уявлення про рівень наукового доробку та свідчать про здатність університету ефективно працювати відповідно до потреб ринкової економіки. Докладніше з науковими розробками Львівської політехніки можна ознайомитись на сайті nauka.lp.edu.ua.

Ключові слова: напівпровідникові матеріали, наноелектроніка, хімія, енергоощадність, інформаційні технології.

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Ключевые слова: полупроводниковые материалы, наноэлектроника, химия, энергосбережение, информационные технологии.

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