



Наука. Инновации. Производство

Сборник материалов
2-го Белорусско - Корейского форума

Science. Innovation. Production

Proceedings of the 2nd Belarus - Korea Forum

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В сборник включены материалы 2-го Белорусско-Корейского форума «Наука. Инновации. Производство» по следующим направлениям: биотехнологии, новые материалы, нанотехнологии и энергетика, информационные технологии.

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CONTENTS

Session: Biotechnology	5
The Multifunctional Nanocomposites for Theragnosis. <i>Seungjoo Haam</i>	7
Nanomedical Technology in Personalized Cancer Medicine. <i>Yong-Min Huh</i>	8
Short Chain Fatty Acids as Markers of Physiological State of the Body. <i>V. Sedakova, A. Klebanova, N. Klebanov</i>	8
Subcellular Control Mechanism of the Myocardial Reperfusion Injury. <i>N. Akulich, N. Efremov</i>	9
The Regulation of Angiogenesis in Tumor Nodules by Oxygen with Laser Radiation. <i>M. Asimov, R. Asimov, A. Rubinov</i>	11
Optical Method and Devices for Elimination of Carbon Monoxide Toxic Effect on Human Body. <i>M. Asimov, R. Asimov, A. Rubinov, V. Plavskii</i>	13
Spectral-Kinetic Properties and Pharmacological Treatment of Methylene Blue in Endoscopy and Photodynamic Therapy of Precancerous Lesions. <i>E. Zenkevich, T. Gin'ko, M. Parkhats, A. Stashevsky, A. Stupak, Jin Young Jeong, Bong Hyun Chung</i>	15
The Development of New High-Tech Technologies and Innovative Equipment for Phototherapy of Hyperbilirubinemia (Jaundice) Newborns. <i>V. Plavskii, A. Mikulich, A. Ryabtsev, I. Leusenko, G. Mostovnikova, A. Tretyakova, A. Mostovnikov, L. Plavskaya</i>	17
Enriching Compositions for the Functional Products in Nutrition of School-Children. <i>T. Madzievskaya, S. Dalidovich, Yu. Romanovets, E. Gusev</i>	19
Innovative Technologies of Ecological Nutrition for the Cultivated Fruits and Berries. <i>T. Madzievskaya, R. Pleskatsevich, O. Krot, V. Markovnik, S. Dalidovich, Yu. Romanovets</i>	20
Development of the Technology of Transplantation of Embryos of Carnivorous Animals (dogs). <i>N. Shapekova, B. Kurmanov</i>	21
Molecular Genetic Characterization of Pathogens Onychomycosis and Creation of a Collection of Microorganisms-producers of Specific Antigens. <i>N. Shapekova, E. Kuchar</i>	22
Session: New Materials	23
Graphene-based Layered Nanostructures for Electronic and Optical Applications. <i>G. Panin</i>	25
Development of Physical/Technological Fundamentals or Production of Composite Metal-Semiconductor-Insulator Nanostructures with Tunable Electric and Magnetic Properties. <i>A. Fedotov, J. Fedotova, E. Streltsov, P. Zukowski, Yu. Kalinin</i>	26
Testing of Refractive X-Ray Optics for Focusing and Imaging at the Pohang Light Source. <i>Yu. Dudchik, Jae-Hong Lim</i>	27
The Formation of C-49 Modification Titanium Disilicide. <i>A. Chaplanov, M. Markevich, V. Zhuravleva, E. Shcherbakova, V. Stelmakh</i>	29
Study on Magnetic Domain Dynamics of Magnetocalorimetric Thin Film Materials. <i>Dong-Hyun Kim, Tran Dang Thanh, Suhk Kun Oh, Seong-Cho Yu, A. Petrov, S. Demyanov, N. Kalanda, M. Yarmolich, L. Kovalev</i>	31
Development of New Carbon Nanomaterials for Photodynamic Therapy and Investigation of their Photophysical Properties. <i>A. Stashevski, Jinyoung Jeong, B. Dzhagarov, Bong Hyun Chung</i>	33
Diamond-Like Carbon Coatings for Friction Units. <i>N. Chekan, I. Akula, I. Vasilevich</i>	35
Mesomechanical Principles of Form-Stable Composites Development by Nano-Disperse Reinforcement of Metals and Polymers. <i>S. Shilko, Yu. Pleskachevsky, Choe H., Choi H</i>	36
Science Basis of Strengthening Treatment to Create High Performance Materials with Nanostructure, Nano-Composite and Composite Structures. <i>A. Shmatov</i>	38
New treatment Nanotechnology for Hardening Steels, Ceramics and Diamond Materials. <i>A. Shmatov, A. Salamianski</i>	39

Low-Temperature Technology Dispersing Refractory and Raw Materials. <i>A. Shmatov</i>	41
High-Strength Submicrocrystalline Electrotechnical Bronzes Obtained with the Use of Mechanically Alloyed Nanostructured Modifying Ligatures. <i>F. Lovshenko, I. Lozikov, G. Lovshenko</i>	42
Nanostructural Mechanically Alloyed Powdersf Gasometrical Spraying Method and Coatings of them. <i>F. Lovshenko, G. Lovshenko, A. Fedosenko</i>	44
Optical Films of Polyvinyl Alcohol withSilver Nanoparticles or Carbon Nanotubes. <i>V. Agabekov, O. Daiineko, N. Ivanova, A. Potapov, V. Dlugunovich</i>	46
Liquid Crystal Photoalignment Materials Based on Reversible Intermolecular Bonds. <i>A. Muravsky, V. Mikulich, A. Murauski, V. Agabekov</i>	47
Local Modification of Graphite Films by Atomic Force Microscopy. <i>E. Skopcov, G. Zhavnerko, V. Agabekov</i>	48
Layer-by-Layer Biopolymer Nanocapsulesfor Biologically Active Compounds. <i>T. Shutava, O. Masalova, A. Kraskouski, V. Agabekov</i>	50
Session: Nanotechnology and Energetics	51
Nanotechnology for Energy Technology Application. <i>Tae Won Kang</i>	53
Energy Sector of the Republic of Korea: Ideas for Studying. <i>T. Prokharchyk</i>	54
Energy Recovery from Natural Gas Letdown Stations. <i>K. Levkov, V. Romanuk, T. Bubyr</i>	56
Development of Metal Composite Materials with Macroheterogeneous Structure for the Application in Friction Pairs Working in Heavy Conditions. <i>U. Kalinichenko</i>	58
Wye-Connected Current Transformers Mathematical Model Implementation in Simulink-Simpowersystems Environment. <i>I. Novash, Y. Rumiantsev</i>	60
Features of Implementation of Microprocessor Transformer Differential Protection. <i>M. Loman</i>	61
The Main Economic Problems of the Energy Sector of the Republic of Belarus. <i>V. Nagornov, Y. Tymul</i>	63
Regional Peculiar Features Pertaining to the Use of Renewable Energy Sources. <i>Y. Tymul, Ngo Anh Tuyet</i>	65
Determination of Optimal Load Factors for Transformers of Distributive Electrical Networks. <i>M. Fursanov, N. Petrashevich</i>	67
Improving the Efficiency of Biomass-Fired CHP.A. <i>Sednin</i>	69
New Power Efficient Industrial Technologies for Induction Heating. <i>I. Viahera, A. Michliuk, A. Palysajeu</i> ..	71
Fuel, Efficiency and Electricity Price. <i>A. Biahliak</i>	72
Session: Information Technologies	73
Parallel Processor for Pattern Recognition. <i>M. Tatur</i>	75
Application of Artificial Intelligent Systems in Real-Life Tasks. <i>V. Golovko</i>	77
Low Power XOR Gate Decomposition. <i>I. Murashko</i>	78
Open Semantic Technology for Intelligent Systems. <i>V. Golenkov, N. Guliakina, D. Shunkevich. M. Yatskou, Y. Lisitsa, T. Apanasovich, V. Apanasovich</i>	80
Software Package Celldataminer for Processing Luminescence Microscopy Images of Cancer Cells. <i>E. Azarov, M. Vashkevich, D. Likhachov, A. Petrovsky</i>	82
Voice Conversion Systems with Web Interface. <i>E. Azarov, M. Vashkevich, D. Likhachov, A. Petrovsky</i>	83
Optimal Routing Based on Service-Oriented Architecture Approach. <i>N. Listopad, A. Hayder</i>	85
Physical Unclonable Functions as Entropy Source to Build True Random Number Generator. <i>S. Zalivaka, A. Ivaniuk</i>	87
Computer Aided Program of Mechanical Calculation of Flexible Conductors. <i>Y. Bladyko, I. Sergey</i>	89



2nd Belarus-Korea Forum
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Session:

Biotechnology



The Multifunctional Nanocomposites for Theragnosis

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The successful medical practices comprise early and accurate diagnosis of disease, patient condition-specific treatment, accurate assessment of the treatment, and application of preventive measures against potential complications after cure. While personalized medicine, ideally, refers to medical care tailor-suited to individual patients, patients are, in practice, segmented to several subgroups under a general disease; for example, breast cancer patients are catalogued into several subgroups depending on molecular markers and/or signatures reflecting underlying tumor biology as well as anatomical staging and the patients within a subgroup would be subjected to the same treatment including conventional and/or molecularly targeted therapy. Notably, many of these fields are greatly benefited by recent developments in nanotechnology. While cancer remains as a major medical challenge, recent years we saw a decrease in the mortality due to better understanding of tumor biology and improved diagnostic devices and treatment. Catalogued patients following both tumor biology driven and classical anatomy-driven classification are subjected to personalized cancer therapy, namely administration of patient condition-specific drugs (molecularly targeted drugs) along with other conventional therapies including chemo-/radio-therapy or surgery. While this new paradigm shift in cancer treatment and recent success leading to mortality decrease are very welcome, there remain a number of great huddles to be overcome for successful cancer treatment; accordingly, the recent nanomedicinal technological advances are focused on topics such as simultaneous multimodal imaging to document molecular events for accurate patient cataloguing at earliest possible stage, simultaneous diagnosis and treatment for early intervention, drug targeting and release control to circumvent multiple-drug resistance, and etc. These advances invariably adopt nanocomposites with multiple functions incorporated, because biologically relevant nanocomposites with their relatively large size of 3~200 nm under physiological conditions, as compared to molecular drugs, can easily take various payloads of chemicals and nano-objects for desirable functions like molecular imaging and cancer-killing.

In this talk, I describe some of functional components in the bio/medicinal nanocomposites as well as their required properties, and, furthermore, noteworthy recent advances in the formulation of multifunctional nanocomposites which led to great technological thrusts are introduced. Finally, I offer an outlook on the direction which this field is heading to and technical huddles which should be overcome for successful biomedical applications.

Nanomedical Technology in Personalized Cancer Medicine

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In vivo understanding of target molecules via molecular imaging with nanoprobe is crucial to assess indication of targeted drug and to monitor its efficacy in patients, which are the key factors in planning personalized cancer therapies. In the smart contrast agent, target contents is the cornerstone to cataloguing patient subgroups and evaluating targeted anticancer drug efficacy as well as its resistance. Further, the ultrasensitivity from high crystallized monodiverted metal oxide nanoparticle enables us to image very small sized tumor via MRI. On the other hand, *in vitro* measurement of target contents has a critical role to optimize personalized cancer medicine. These contents promise various nanoplatfroms and nanodevices to translate precise and sensitive nanobiosensor into personalized clinical settings. Thus it is necessary to develop *in vivo* and *in vitro* diagnostic tools to measure multiple targets and/or signaling pathways of cancer toward personalized medicine.

Short Chain Fatty Acids as Markers of Physiological State of the Body

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Modern views on the functioning of the human intestinal microflora can take into account an independent body with its own features that have a significant impact on the maintenance of homeostasis of the body. In recent years special attention is paid to investigation of such metabolites of intestinal microflora, as well as short chain fatty acids that are produced from heteropolysaccharides by anaerobic bacteria. Each acid has a physiological effect on the body: ethanoic acid - participates in the supply of substrates for lipogenesis and energy supply of the epithelium, and also exerts an antimicrobial effect, regulates the pH level, the motor and secretory activity of the bowel; propionic acid - regulates microcirculation in the mucosa and supports trophic processes, participates in gluconeogenesis, blocks the adhesion of pathogens to the epithelium; butanoic acid is the main factor in the regulation of proliferation and differentiation of the epithelium of the colon, which is the reason of its antitumor activity. The qualitative composition of short-chain fatty acids and their quantitative ratio can be a reliable criterion, pointing to the well-being of bowel.

Mogilev State A.A. Kuleshov University with Mogilev Regional Cancer Center as one of the promising directions of research carried out work on the definition of short-chain fatty acids in human serum in norm and in pathology.

Developed a method of qualitative and quantitative determination of short-chain fatty acids by capillary gas-liquid chromatography, which allows to carry out qualitative and quantitative definition of acids in the blood serum with a high degree of sensitivity and accuracy. Further studies are on the path of accumulation of statistical data on the concentration of acids in the blood serum of healthy people and people with some malignant tumors of the gastrointestinal tract.

Subcellular Control Mechanism of the Myocardial Reperfusion Injury

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Coronary Heart Disease (CHD) has become main cause of death for adult population. The most dangerous sign of CHD is myocardial infarction (MI) with everyday lethality of 10%. The zone of myocardial ischemic damage is the main ending predicament for patients with acute myocardial infarction.

The optimal strategy is a direct approach to decrease acute myocardial infarction in fast and effective coronary reperfusion.

Improvement of coronary intervention technology and medical support has made possible to normalize epicardial blood flow for 95% of patients after first percutaneous coronary intervention.

Nonetheless the earlier and full recovery of epicardial blood flow into infarct-related artery, in 25% of events when it doesn't come to optimal tissue perfusion and contractile function normalization.

Most possible causes of unsatisfactory patient results by endovascular treatment with acute myocardial infarction and ST segment uprising could be microvascular dysfunction or lethal reperfusion injury.

An achievement in endogenous cardioprotection mechanism was an experimental work by Zhao L. Z. et al. (2003), which showed us that series of consecutive shortcycles which create occlusions/opening in coronary artery lumen projected after modeled myocardial infarction and accomplished reperfusion of ischemic tissues, which leads to significant decrease of necrosis from 47% to 11%. This phenomena was titled an ischemic postconditioning (IPC).

The differences in IPC conduction, researched in groups of patients without accounting comorbidities and drugs taken, and also experimental results of discrepancy and clinical research that won't let you analyze given data and are preventing the wide use of this strategy in clinic.

Knowing the importance and significance of AMI patient treatment problems, we are presented with an actual and significant research accomplishment, directed by development of interventional therapy for patients with AMI technology and ST segment uprising with purpose to augment closest and furthers treatment results.

Patients with acute myocardial infarction and ST segment uprising have the most unfavorable prognosis in all ACS cases. The hospital lethality of this group in countries of EU ranges 6-14%. According to the recommendations of American Heart Association and European Society of Cardiology, the main objective of this patient category treatment is early reperfusion therapy. Duration of coronary ischemia is the main determinant for necrosis prevalence and the bigger the zone of ischemic myocardial damage is bigger risk of development of left ventricular remodeling, heart insufficiency and life-threatening arrhythmias. The zone decrease of ischemic myocardial damage is the main mission in patient treatment with acute myocardial infarction.

A priori ischemia is the most important cause of irreversible myocardium damage, the main researchers efforts at the time of last three decades were directed on development of therapeutic strategies for the most early coronary reperfusion. We can suggest that reperfusion therapy has improved the results and prognosis for patients, with acute myocardial infarction and ST segment uprising, which could have reached it's maximum level of effectiveness.

Despite for those positive effects of reperfusion therapy, reperfusion has significant threat for myocardium ("double-edged sword") and comes with its temporary contractile dysfunction (stunning), microcirculation disturbance (phenomena «no-reflow») and life threatening rhythm disturbance (Yellon and Hausenloy, 2007) Those specific manifestations of reperfusion can be characterized as functional and reversible myocardial reperfusion injury (MRI).

But irreversible forms of MRI, which count in microvascular obstruction and LRI (lethal reperfusion injury), give their contribution in ending sizes of myocardial infarction and negate the positive effects of early reperfusion. Irreversible LRI specifically for cell death after episodes of prolonged ischemia which can be prevented by intervention during reperfusion. Size irreversible myocardial injury case, consists of two different types of damages -ischemia-reperfusion-induced and induced. Thus, the LRI can be considered one of the causes of death of cardiomyocytes, which is closely associated with reperfusion.

Mechanisms of ischemic preconditioning are considered as a complex of signaling cascade that includes three successive stages-a trigger, mediator and effector:

a) Preconditioning triggers:

1) receptor-dependent: adenosine, opioid peptides, bradykinin, catecholamines, etc.

2) receptor-independent: oxygen free radicals, ions, calcium oxide, nitrogen.

b) Preconditioning mediators: protein kinase C, G, A, B (Akt), tyrosine kinase, kinase, extracellular signal-regulated (ERK), PI3K, GSK-3 β , etc.

c) Latest preconditioning effectors: (sarcolemmal Kchannel, mitochondrial channel).

Various biologically active substances like adenosine, bradykinin, endogenous opioids, IL 6, tumor necrosis factor and other are triggers and release at IPC process. They attach to G-protein-coupled receptors of cell membrane and other receptors and activate them. Those can activate protein kinases of phosphorylating enzymes (PI3K)-Akt, ERK, endothelial NO-synthase and STAT3 protein family RISK and SAFE (Tsang et al., 2004), which leads to inhibition of the mitochondrial channel opening (Hausenloy and Yellon, 2003).

Some of the physiological effects, like the decrease of oxidative stress, reduction of intracellular calcium overload, prevention of apoptosis of cardiomyocytes and endothelium damage, deceleration of pH renewal and neutrophil accumulation in myocardial infarction zone and etc., they can show cardioprotective effects, which are independent from molecular mechanisms.

EndoG is a member of pantheon proteins that regulate apoptotic cell death in cardiovascular disease, including heart failure and ischemia/reperfusion. Attempts to define the specific role of EndoG in either cell death or life in mammals have produced contradictory and controversial results. The purpose of this project is to analyze structural and functional role of EndoG in order to understand its mechanism in DNA fragmentation and degradation. In vivo investigation for the functional role of EndoG in Cardiomyocyte death after ischemic and pharmacologic preconditioning will be investigated in Belorussian side. In vitro structural and functional analysis at the molecular level will be carried out in Korean side. The combined link between the in vivo and in vitro data analysis would help to understand the EndoG function as a whole on the DNA degradation and provide molecular basis for the development of its regulator in pharmaceutical application.

This research is to understand the mechanism and involvement of EndoG in chromatin condensation and degradation on apoptotic pathway by using the cellular and molecular biology techniques and crystallographic information based on protein structure. To do this:

1. We are to investigate the regulatory effect of EndoG in DNA degradation mechanism in molecular basis

2. We are to characterize the EndoG biochemical properties with respect to the placement and positioning in complex structures either with oligonucleotide substrate or with various interacting proteins that is involved in DNA fragmentation and condensation.

3. We are to analyze EndoG function in cellular compartment and visualize the EndoG activity by comparative assessment in vivo in the primary coronary angioplasty of 250 patients with heart failure.

The Regulation of Angiogenesis in Tumor Nodules by Oxygen with Laser Radiation

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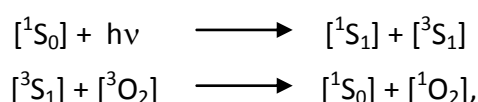
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Hypoxia in solid tumor is the major problem [1] that limits the efficiency of therapeutic methods, in particular, the method of photodynamic therapy (PDT). Hypoxia in cancer tissues occurs due to the fast growth of cancer cells and disordered angiogenesis. That why solid tumor is located in the regions with reduced oxygen concentration. Large hypoxic area within human solid tumor has been detected in measurements of oxygen tension directly inserting the oxygen electrode in tumor tissue.

In the method of PDT mechanism of tumor destruction is based on photochemically generation of singlet oxygen (¹O₂) and its toxicity for tissue cells. It makes oxygen a key component in the method of PDT. Generation of ¹O₂ involves the following process:



where [¹S₀] - is the concentration of photosensitizer in solid tumor; [³O₂] and [¹O₂] - are concentrations of molecular oxygen and its singlet form in tumor cell. The first stage of photochemical reactions involves excitation of the molecule of sensitizer by laser irradiation in its triplet state ³S₁. Second stage includes generation of singlet oxygen - ¹O₂ due to interaction of triplet molecules of sensitizer ³S₁ with the oxygen molecules in ground state ³O₂. It makes oxygen a key component in the method of PDT. Rapid decrease of oxygen concentration in cancer tissue during the generation of ¹O₂ in PDT is the main factor that induces a local tissue hypoxia. Improving the oxygenation of solid tumor masses to eliminate tissue hypoxia is remained as actual problem in modern Oncology.

In present two main methods of oxygenation are used. The oldest method is based on ventilation of lung with pure oxygen at normal pressure. This method is not selective in terms of local tissue oxygenation. An alternative the method of hyperbaric oxygenation (HBO) has been developed. The method of HBO based on inhalation of 100% oxygen greater than one atmosphere. This method is not selective and may cause oxygen toxemia that limit its application.

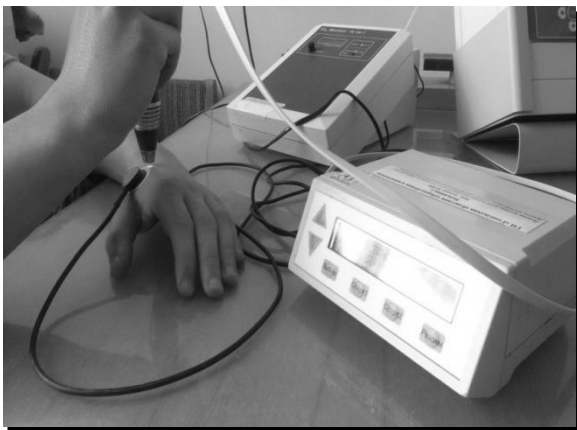
One of important abnormal characteristic found in most solid tumors is its location in the regions with reduced oxygen concentration. The role of hypoxia in developing of solid cancer remains unclear. The ability to vary local oxygen concentration by laser induced photodissociation of oxyhemoglobin opens unique possibility to investigate this problem.

In this paper the evaluation of our basic conception [2] and experimental study of laser-induced photodissociation of oxyhemoglobin for elimination of hypoxia in cancer tissue is proposed.

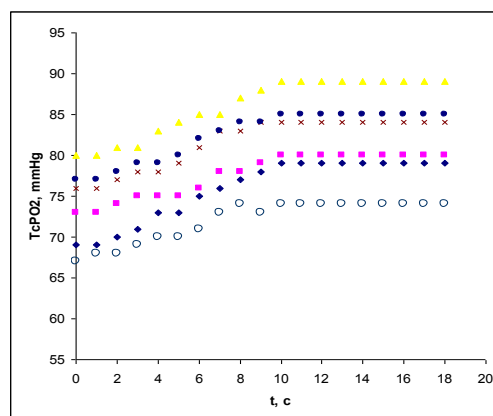
Laser-induced enrichment of tissue oxygenation allows use an effective optical method for therapy of pathologies where elimination of local tissue hypoxia is critical.

Basic principle of measuring the oxygen tension PO₂ in arterial blood is direct method of registration of gas that dissolved in blood plasma. For this usually is used Clark-type polarographic sensor ("TcPO₂ electrode"). When the sensor is exposed to oxygen, it creates an electrochemical reaction (O₂ + 2H₂O + 4e⁻ → 4OH⁻) that causes current to flow through the cathode. The amount of current flowing in electrochemical cell is proportional to the value of oxygen tension PO₂ in blood

plasma or $TcPO_2$ that indicates oxygen tension in tissue. Transcutaneous oxygen monitor (TCOM) - "Radiometer" TCM-2 - is used for measuring the value of tissue oxygenation tension.



Experimental procedure



Kinetics of tissue oxygenation

In direct in vivo measurements of the tissue oxygen tension $TcPO_2$ electrode was placed on hand. First, initial oxygen tension was measured. Then He-Ne laser radiation at the power of 1,5 mW was applied. Kinetic of oxygen tension in tissue was investigated. Obtained results were normalized to initial oxygen tension value. Six set of measurement were carried out with the six voluntaries.

The value of oxygen tension during laser irradiation increases with the different rate and reaches saturation level approximately after 10 minutes of exposure. The value of $TcPO_2$ is increases about 1.6 times compare the initial one.

It should be noted that in order to reach experimentally observed the rise of $TcPO_2$ by 1, 6 times at the surface of tissue, the calculation indicates the increase of oxygen release rate from arterial HbO_2 into blood plasma should increase about 4,3 times.

It is exiting that the value of PO_2 in blood plasma reached by laser-induced photodissociation of HbO_2 is comparable to that one typically reaches by the method of HBO. The distribution of $TcPO_2$ in the volume at the irradiation zone is depended on the time of exposure and the properties of tissue.

Monitoring the kinetic of $TcPO_2$ gives unique possibility to control the process of laser-induced tissue oxygenation. Thus, a new method of optically elimination tissue hypoxia could be developed. This is an important in increasing the efficiency of solid tumor therapy by the method of PDT.

The obtained results give scientific background to develop new effective method of two colors Photodynamic Therapy of solid cancer.

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Optical Method and Devices for Elimination of Carbon Monoxide Toxic Effect on Human Body

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The problem of effectively eliminating the toxic effect of carbon monoxide is an urgent and socially significant task. Up to the present, the capabilities of modern medicine remain quite limited and therefore losses as a consequence of poisoning are serious.

Presently we proposed and developed optical method of elimination the toxic effect of carbon monoxide based on the phenomenon of laser induced photodecomposition of blood carboxyhemoglobin - HbCO.

It is well known that gas carbon monoxide (CO) forms strong bind with blood hemoglobin (Hb) The decay rate of HbCO complexes is extremely low, and at it concentration in the blood about 20%, the period of its half decay time takes more than eight hours.

For elimination of poisoning effect of CO in clinical practice usually uses ventilation of lungs with pure oxygen. This method is used usually in the cases no strong intoxication, but at concentrations of HbCO in the blood higher than 60% it becomes useless.

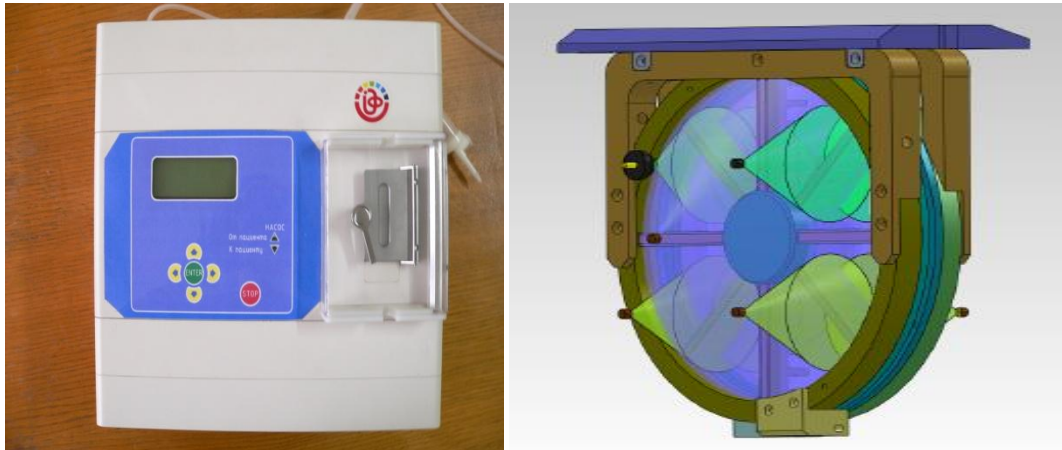
Currently, the method of hyperbaric oxygenation (HBO) based on the effect of pure oxygen on human body at the pressure of several times higher than atmospheric is used for detoxification. The method of HBO increases the concentration of oxygen in the blood and at the same time results a higher risk of oxygen toxemia. Thus, the problem of eliminating the toxic effect of CO remains urgent and solving it requires new approaches to developing modern, highly effective therapeutic methods.

We proposed and developed an optical method for eliminating the toxic effect of carbon monoxide, which is based on laser induced photodecomposition of blood HbCO (Asimov M.M., Asimov R.M., Rubinov A.N., "Method of deactivation of blood carboxyhemoglobin", //Patent, №2408400. 2011).

In addition to this, photodissociation of carboxyhemoglobin makes it possible to restore hemoglobin's function of transporting oxygen to tissue cells. Despite the fact that the bond in the CO complex with Hb is significantly stronger than in the case of O₂ complex with Hb, the effectiveness of photodissociation of HbCO is almost an order of magnitude higher than HbO₂: 98 and 10% in the visible range of the spectrum, respectively [6]. Such a large difference in the quantum yield of photodissociation opens the possibility of destroying the blood HbCO complex with high selectivity, essentially not touching the useful HbO₂ component. At the same time as the effectiveness of known methods of eliminating the toxic effect of CO is limited by the time of natural decay of the HbCO complex, mandatory destruction of HbCO by photodissociation under simultaneous saturation of the blood plasma by molecular oxygen makes it possible to substantially hasten the removal of CO from the body.

The basis of the suggested method is irradiation of blood vessels and capillaries by optical irradiation of a certain wavelength. As well, the majority of energy absorbed by blood HbCO will be expended on photodissociation. We present here the results of investigation the effect of optical radiation with HbCO in cutaneous blood vessels and capillaries and the method of its effective photodissociation.

On the basis of research results, obtained both in the numerical simulation of the interaction of laser radiation with blood HbCO and experimental measurements in vivo it is developed the apparatus for phototherapy the poisoning effect of carbon monoxide (see photo).



This apparatus provides in vitro irradiation of blood by optical radiation in the wavelength range of 530 – 560 nm. Wavelength and the output power of the radiation chosen in accordance with the maximum of absorption bands of blood HbCO.

The device has the following main specifications:

- Operation mode setting time installation after the inclusion of not more than 5 min.
- The speed of the flow of the blood of 5, 10 and 15 ml/min.
- Accuracy of flow rate of blood is no more than + / 20 %.
- Spectral range of the radiation from 530 to 630 nm.
- Time of continuous work of the installation is not less than 8 hours.
- Information on the modes of operation of the installation is displayed on the alpha-numeric display.

- Power supply voltage 230 ± 22 Century, with frequency of 50 Hz.
- Power consumption is not more than 80 VA.
- Overall dimensions not more than $260 \times 250 \times 143$ mm.
- Weight of installation of not more than 7 kg.

Apparatus for extracorporeal blood irradiation is a compact device with three main modules: a spiral cassette with a sample of blood irradiation; peristaltic pump for blood circulation and the optical system, which provides two-side blood irradiation with LED sources. Light sources are selected in accordance with the maximum of absorption bands of blood HbCO in the visible spectral range. Apparatus is equipped with the system of protection against removing the cassette during the work.

In this apparatus a planar LEDs with the selected spectral range and the output power of radiation is used. The algorithm of operation of the apparatus provides selective activation and deactivation of each LEDs that allows one to vary the different parameters of the light effects (such as the pumping wavelength of light, or a combination of wavelengths, optical radiation power, etc.) to achieve the desired therapeutic effect. It is also possible increase or decrease in the «dose» of exposure by changing the speed of pumping blood.

Developed apparatus for extracorporeal blood irradiation on the bases of the phenomenon of laser induced carboxyhemoglobin photodissociation may find wide application in modern medicine and could also be useful in emergency situations in elimination the consequences of fires or anthropogenic disasters.

Spectral-Kinetic Properties and Pharmacological Treatment of Methylene Blue in Endoscopy and Photodynamic Therapy of Precancerous Lesions

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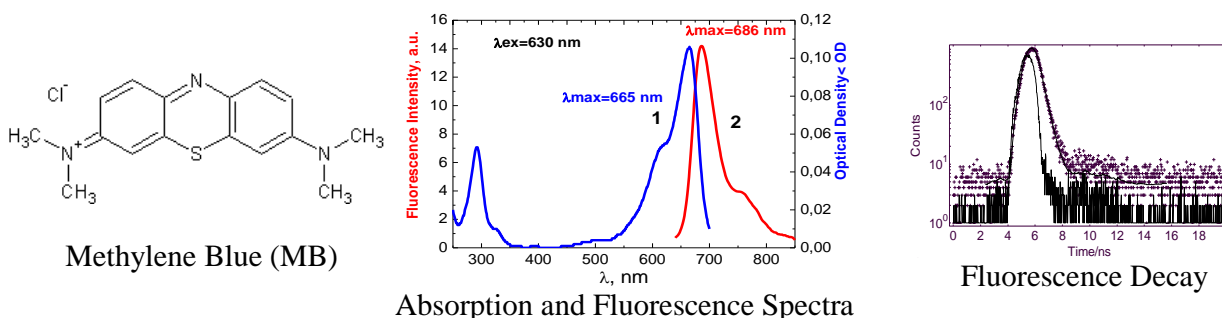
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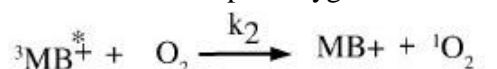
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Methylene Blue (MB) is a molecule that has been playing important roles in microbiology and pharmacology for some time. It has been widely used to stain living organisms, to treat methemoglobinemia, and lately it has been considered as a drug for photodynamic therapy (PDT). In this talk, we present the fundamental photophysical, photochemical and photobiological characteristics of this molecule and evolve to show for the first time *in vivo* applications related to PDT of precancerous lesions (stomach upper gastrointestinal tract) based on endoscopic technique.



It is well-known that PDT is a promising modality for the management of various tumors and nonmalignant diseases based on the combination of a photosensitizer (PS) that is selectively localized in the target tissue and illumination of the lesion with visible light, resulting in photodamage and subsequent cell death. The main photophysical process leading to the singlet oxygen ($^1\Delta_g$) formation is the energy transfer from the triplet excited PS to the triplet oxygen:



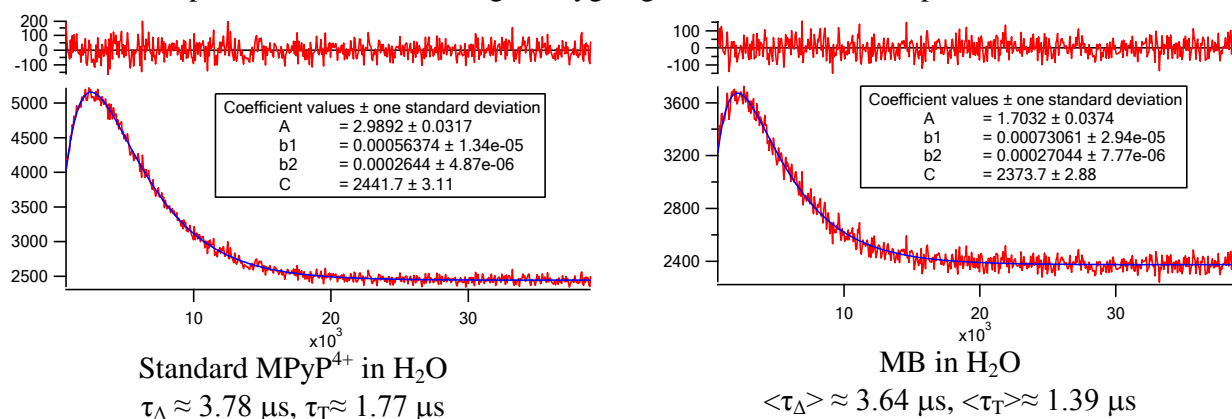
Measurements of spectra and decays (using TCSPC approach) of the singlet oxygen emission ($\lambda_{\text{max}} = 1270 \text{ nm}$) as well as quantum efficiencies of $^1\text{O}_2$ generation (γ_{Δ}) have been performed on laboratory highly sensitive laser NIR spectrometer [1-3]: laser excitation by STA-01SH Nd:LSB laser ($\lambda_{\text{exc}} = 531 \text{ nm}$, energy of $4 \mu\text{J}$, FWHM = 0.7 ns , repetition rate of 1 kHz . STANDA Ltd.), monochromator MS2004i, (registration range of $950\div 1400 \text{ nm}$, SOLAR TII Ltd.), computer photon counting board P7888-2 board (time resolution of 1 ns/channel , FAST ComTec GmbH), PMT Hamamatsu H10330-45, (experimental response $\Delta t_{1/2} = 1 \text{ ns}$). The main procedure for the measurement of $^1\text{O}_2$ generation quantum efficiency γ_{Δ}^x is based on the comparison of emission intensity of singlet oxygen ($\lambda_{\text{max}} = 1.27 \mu\text{m}$) photosensitized by a standard compound (intensity I_0) and by MB (intensity I_x) in the same solvent

$$\gamma_{\Delta}^x = \gamma_{\Delta}^0 \frac{I_x \times \beta_0}{I_0 \times \beta_x},$$

where γ_{Δ}^0 is the quantum efficiency of singlet oxygen generation by a standard, $\beta_0 = (1 - 10^{-D_0})$ and $\beta_x = (1 - 10^{-D_x})$ are fractions of absorbed exciting light by the standard and MB, respectively, at a given excitation wavelength. I_x and I_0 values were averaged and extrapolated to the maximal pulse intensity after more than 32 laser pulses for every measurement.

It was shown that in homogeneous solution where no dimers are present (ethanol or diluted aqueous solutions) MB produces triplets with high quantum yield ($\gamma_{ISC} = 0.52$), working as a 1O_2 photogenerated source ($\gamma_{\Delta} \sim 0.5$) in comparison with a standard (water-soluble porphyrin TMPyP⁴⁺ having the efficiency of singlet oxygen generation $\gamma_{\Delta}^0 = 0.77$ [4]). In aqueous solution the efficiency of 1O_2 is dependent on the pH. MB triplets are excited state bases, so that its pK_a increases from a negative value in the ground state to around 7.5 in the triplet state. Therefore, the pH of the solution may certainly affect the efficiency of type I and type II photosensitization mechanisms. From PDT treatment point of view the MB main absorption band are in the therapeutic window like a lot of photosensitizers based on tetrapyrrolic compound.

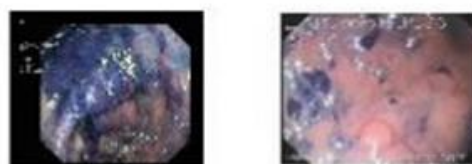
Some experimental results on singlet oxygen generation *in vitro* are presented below:



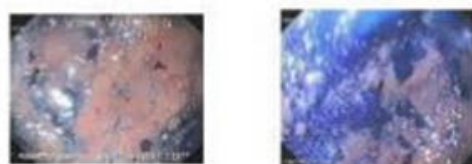
PDT of precancerous lesions for patients has been carried out using endoscopic technique (GIF «OLYMPUS», type XQ-30, Q-40, video informative system V-70, two-channel endoscope with frontal optics). Efficiencies of singlet oxygen $^1\Delta_g$ generation (in water solutions) as well as diagnostics abilities and PDT efficiencies in precancerous lesions (stomach upper gastrointestinal tract) have been compared for MB (widely known histological dye) and for Photolon (developed by the Scientific Pharmaceutical Center of RUE Belmedpreparaty, Belarus). It has been shown that with respect to Photolon, MB has interesting characteristics (high water solubility, low toxicity, high efficiency of singlet oxygen emission $\gamma_{\Delta} = 0.43$ in water) conferring to this molecule a great potential for application in PDT.

We have found also that in addition to a pronounced diagnostic factor, MB is effectively concentrated in cancer cells and upon laser excitation at $\lambda_{exc} = 670 \text{ nm}$ and 630 nm triggers the photosensitization mechanism of necrosis. It was estimated that the necessity of the chromoscopy and PDT of the precancerous lesions of stomach upper gastrointestinal tract with Photolon and MB is $\geq 26\%$.

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Laser endoscopic treatment with MB



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The Development of New High-Tech Technologies and Innovative Equipment for Phototherapy of Hyperbilirubinemia (Jaundice) Newborns

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The phototherapy of hyperbilirubinemia (jaundice) of newborns is one of the clearest examples of the effective use of optical technologies in medicine. According to the data of various authors, the jaundice syndrome is observed in 50–60% of full-term newborns [1] and about 80% of premature infants and is most pronounced by day 3–4 of their life. The indicated noninfectious disease is caused by the excess accumulation in the blood, as well as in subcutaneous fat cells, of bile pigment (a product of the exchange of hemoglobin) – Z,Z-bilirubin IX α – which imparts a characteristic golden yellow color to the skin. For most newborns who manifest the attributes of hyperbilirubinemia, as the operation of the system for excreting bilirubin improves and the biochemical systems of the organism normalize, the jaundice disappears in 1–2 weeks without causing any harm to the child. However, in 6–10% of the infants the jaundice proceeds to a serious form as a consequence of a high bilirubin level and requires intensive therapy. If emergency measures are not taken, the presence of a high concentration of the indicated toxic pigment in the infant's organism can have an effect on his physical and neuropsychic development, as well as being a direct cause of death.

The main methods of treatment aimed at reducing the level of bilirubin in the blood of newborns is phototherapy and exchange transfusion. The standard treatment for neonatal jaundice is phototherapy. And the tactic of therapeutic interventions is usually aimed at achieving a favorable clinical outcome with the help of phototherapy, without resorting to the methods of interventional therapy. Exchange transfusion was the first successful therapy for severe neonatal jaundice. This technique rapidly eliminates bilirubin from the circulation. Circulating antibodies that target the erythrocytes are also removed. Exchange transfusion is especially beneficial in infants who have ongoing hemolysis from any cause. One or two central catheters are placed, and small aliquots of blood are removed from the infant and replaced with similar aliquots of red cells from a donor, mixed with plasma. This procedure is repeated until twice the blood volume has been replaced. During the procedure, serum electrolytes and bilirubin should be measured periodically. The amount of bilirubin removed from the circulation varies according to both the amount of bilirubin stored in tissues that reenters the circulation and the rate of hemolysis. In some cases, the procedure needs to be repeated to lower the serum bilirubin concentration sufficiently.

Typically, invasive methods are only applicable if using phototherapy fails to reduce the concentration of bilirubin in the blood of newborn babies to a safe level. It should be noted that the operations of exchange transfusion of large amounts of blood (to an infant from an adult donor) are heavily beared by the babies, and in some cases exacerbate intoxication of child's body. Mortality of children under this procedure ranges from 0.3% to 5.2% [1]. Thus, one of the main objectives of phototherapy of neonatal hyperbilirubinemia of newborns is the reduction to a safe level of bilirubin in the blood, without resorting to the methods of interventional therapy, potentially causing organism infection and infant mortality.

The principal and most widely used method of treating hyperbilirubinemia of newborns is phototherapy consisting of the total action on the child's body surface of light with a power density of $P = 0.3\text{--}2 \text{ mW/cm}^2$, whose spectral composition corresponds to the long-wavelength absorption band of bilirubin ($\lambda = 400\text{--}530 \text{ nm}$). The method began to be widely used in medical practice in the 1970s, and, according to the data of the American Academy of Pediatrics, more than a million infants throughout the world have by now been treated. It is assumed that the determining role in lowering the bilirubin level in the organism of newborns who undergo phototherapy is mainly

played by the processes of photoisomerization of the pigment – the formation of its configurational isomers (*Z,E*-bilirubin IX α , *E,Z*-bilirubin IX α , and *E,E*-bilirubin IX α) and structural isomers (*Z*-lumirubin and *E*-lumirubin). The indicated isomers, and above all lumirubin, being more hydrophilic compounds than native *Z,Z*-bilirubin IX α , are characterized by an elevated excretion rate.

Along with a pronounced therapeutic effect, long lasting influence on the infant with fluorescent, halogen and metal halide lamps light may have an adverse side effect on him. Besides the ultraviolet and infrared components, present in the emission spectrum of these lamps, negative impact on the baby can also be made by intense visible light through photosensitized processes involving endogenous pigments (including bilirubin photoproducts) and pharmacological agents.

Currently there is no alternative to the use of LED sources in the devices for phototherapy of neonatal hyperbilirubinemia. Radiation sources of this type of blue-green region of the spectrum correspond to the range of absorption of bilirubin and significantly exceed the widespread lamp sources (mercury, halogen, metal halide) on the set of optical and operational characteristics. The devices for phototherapy of neonatal hyperbilirubinemia (*i*) does not contain the ultraviolet and infrared components (having side effects on the newborn); (*ii*) provides adjustment of the intensity of effecting radiation, depending on the severity of the newborn; (*iii*) allows a uniform distribution of light intensity on the surface of the child's body; (*iiii*) dozen times exceeds lamp on the work resort; (*iiiii*) resistant to mechanical damage and does not represent (in contrast to the mercury vapor lamps) environmental concerns in violation of its integrity and while disposal.

An increase (in comparison to the analogues) in the efficiency of the phototherapy of jaundice is attained due to the

- more high density of the radiation power on the surface of the body of a child;
- possibility to regulate the intensity of the acting radiation depending on the gravity of the disease;
- uniformity of distribution of the radiation-power density over the surface of the body of a child;
- choice of a spectral range, in which the screening action of haemoglobin is lower than in the case where a wide-band radiation of lamps for phototherapy is used;
- increase (due to the definite ratio between the intensities of the blue and green components of the LED radiation) in the content of lumirubin – a photoproduct of bilirubin characterized by a maximum rate of extraction.

Objective: development of equipment and technologies that improve efficiency and reduce (eliminate) the adverse side effects of phototherapy of hyperbilirubinemia (jaundice) newborns through the use of LED light sources, optimizing the spectral range of radiation and its intensity based on the study of photonic bilirubin

Urgency of the problem: Traditional methods of phototherapy based on the use of fluorescent and halogen lamps, are ineffective and have a number of adverse side effects (erythema of the skin, bronze baby syndrome, overheating of the body, etc.). For this reason, the duration of phototherapy is 100 hours or more, can not be avoided procedures exchange transfusion of blood. In the course of the project will be developed photophysical approaches and prototypes were made to ensure efficiency of phototherapy and the exclusion of adverse side effects

The main stages of work:

1. Elucidation of the optimal spectral range for effective phototherapy with the optical properties of the baby's skin and the quantum yield of photoisomerization bilirubin wavelength.
2. The study of photonic bilirubin and its effectiveness self-sensitized destruction.
3. Optimizing LED illuminator, which provides a uniform intensity of the effect of light on the surface of the baby's body.
4. Creating innovative LED apparatus for implementing the method.
5. The development of efficient methods for phototherapy of neonatal hyperbilirubinemia.

Enriching Compositions for the Functional Products in Nutrition of School-Children

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Well-balanced nutrition is most important for health life of the young people who represent the future of any country.

Due to the accelerated growth, intensive physical and psychological development of school-children, stresses of maturity, and strains of educational process, nutrition of the young must meet the stringent requirements for such vital ingredients as vitamins, amino acids, mineral salts, bioflavonoids.

According to the data of medical studies [1], the ration of the Belarusian population is characterized by a great deficiency of vitamins A, B, E, C, and D and of minerals (calcium, magnesium, iodine, selenium) lowering the vital forces and increasing the sickness rate due to the inadequate nourishment. Two thirds of the school-children under 14 have chronic diseases.

With the scope of realization of the Republican Program «Child nutrition 2011-2015», the specialists of the Unitechprom of BSU, jointly with the concern Beltechnokhleby, the Foodstuffs Research Center of the National Academy of Sciences of Belarus, have performed the research activities associated with the task «Investigation, development, approval and validation of enriching additives for bakery and confectionary flour products».

To develop the enriching additives, a model has been proposed for compensation of the deficient micronutrients in nourishment of school-children on the basis of the following principles:

1. Selection of the products systematically used for food with regard to the national traditions, availability, and preferences of school-children.
2. In Belarus these requirements are fully met by the bakery and confectionary goods.
3. The functional significance of the nutrients and compensation for the real micronutrient deficiency of teenagers.
4. In the process of work the activities were aimed at the design of enriching additives for normal functioning and development of locomotor apparatus, for the immune system strengthening. The enriching ingredients include compounds of calcium and magnesium; vitamins A, E, and D.
5. Provision of an adequate supply of the enriching components with due regard for the physiological consumption rate of school-children.
6. Selection of the components having a maximal biological availability and compatibility.

As a result, two enriching additives have been designed and tested, which include the compounds of Ca and Mg; vitamins A, E, D; and plant ingredients (apple powder, oats, buckwheat, cinnamon, inulin).

Calcium, being the principal structural element of a skeleton, is very important for its formation.

Magnesium is involved in the process of nervous agitation, of the water, carbon, phosphate metabolism.

Vitamin A is one of the most important antioxidants. It is required for protection against infections and for the immunity strengthening. Its deficiency results in retardation of growth, in the teeth deformation.

Vitamin E possesses the antioxidant properties, stabilizes cell membranes. Its deficiency leads to degenerative changes in skeletal muscles, in myocardium.

Vitamin D influences the mineral composition and bone forming. Its deficiency may result in rickets [2-6].

The developed enriching additives have been studied by physical and chemical methods; their antioxidant properties have been examined at the temperature 253 K. To characterize the antioxidant properties in general, a dimensionless quantity has been chosen. This quantity is denoted as the «efficiency» and determined by the ratio between the peroxide number of pure lipid and that with the use of an enriching additive. It has been found that the use of the additives improves stability of lipids to oxidation.

The package of the standard technical documentation for the production of the proposed enriching additives has been elaborated.

In conclusion it should be noted that organization of the research-grounded nourishment of school-children, adapted to their nutritional needs in the process of growth and influencing the development process of the young people, is very important both from the medicinal viewpoint and from the social aspects.

Innovative Technologies of Ecological Nutrition for the Cultivated Fruits and Berries

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A long-term experience of truck gardening, fruit and berry cultivation in Belarus points to the fact that the principal factors of stress negatively affecting the development and productivity of the cultivated cultures are as follows: drastic temperature drops; air and soil humidity; inadequate or excessive nutrients; sunscalds. Unfortunately, plants are under the effect of the concurrent stress-factors leading to a considerable decline in efficiency of the agricultural technologies used. For the intensified technologies, there is an additional problem associated with degradation of the ecological situation due to the increased area of agricultural farming and to the necessity for the extensively used pesticides and other protecting chemicals.

Within the scope of the realized State Program «Innovative Biotechnologies», the science-production enterprise «Unitechprom of BSU» in association with the Fruit Growing Institute, Plant Protection Institute, local foundation of the Scientific-Technological Park, and Belarusian State University, has obtained the results demonstrating that these problems may be easily solved by means of the foliar nutrition of plants used together with the conventional agricultural techniques.

During realization of the Program, the new balanced water-soluble compounds of the complex regenerative action which are based on humic, citric, and succinic acids; chelates of copper, iron, zinc, and manganese have been developed. These compounds are highly effective in regeneration and reinforcement of the protective and growth stimulating biochemical processes in the plants at the critical vegetation stages. Also, the innovative technologies have been developed to produce these compounds and to use them at the agricultural enterprises.

As demonstrated by the data of ICP-AES (inductively-coupled plasma atomic-emission spectroscopy) and spectrophotometry, the balanced composition of the complex-effect compound «Volat-6» includes the active functional groups and stable chemical structures with active bonds, offering the photoprotective, genoprotective, and sorption capacities for a long period of time.

The complex-effect compounds «Volat-8» and «Volat-9» represent an open nonstationary system of a great number of monocrystalline particles in the state of thermodynamic equilibrium, characterized by active autohesion, well-developed specific surface, and good solubility.

As shown by the agricultural tests carried out in Belarus, owing to the well-balanced composition of the substances adopted to the metabolic processes in the cultivated fruits and berries, the cases of intolerance, sunscald and allergic complications are excluded. There is no cumulation of the components within a plant; their dose is determined by the systematic effect on the vital activities of cell structures in the plant both in normal and extreme conditions. In total the components are more effective than used separately.

The efficiency of the proposed means is supported by numerous laboratory, field, and operating tests performed by the accredited organizations. To illustrate, an increase in the harvested crop of black-currants was 23-25%, a size of the berries increased by a factor of 1.7, increase of shoots was up to 40%; compared to the control lots, the crop capacity of apple trees increased by 18-20%; the yield of standard products was 83-90%.

Considering such properties of the developed compounds as complete solubility in a process solution; good absorbability by the leaf organs of plants; formation of rich leafage; low consumption and small dosage; ecological safety (no adverse effects for microflora, no toxicity, safe use for people, animals, birds, and bees); wholesome influence on the plants; multipurpose usage; compatibility with other prophylactic-treatment means; simplicity of use; good dispersibility with the use of commercial equipment, the developed innovative technologies and compounds look very promising for implementation at the intensive-production agricultural enterprises in different regions of Belarus and in other countries.

Development of the Technology of Transplantation of Embryos of Carnivorous Animals (dogs)

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Object of research are purebred and purebred dogs belongs to residents of Astana.

The purpose of work is Development of technology of leaching and transplantation of embryos in carnivorous. In the interim period studied the causes of abnormalities of sexual system function in dogs and their correction.

Methods of work – clinical and laboratory research methods been used. Research equipment had been used: a stethoscope, sphygmomanometer, vacuum-timers, artificial vagina for sheep producers, microscope slides, cover glasses, test tubes, Goryayev counter, biochemical analyzer, «Indesit» refrigerator, «Adventurer» electronic balance, bactericidal irradiator.

In the process of studies aimed establishing the concentration level of sex hormones in the blood of dogs, for the corrections of the manifestation of the sexual cycle.

In experiments semen were taken by artificial vagina used eight males for testing techniques (five mongrel, two German shepherds and one Doberman Pinscher). In the period of development of a technique received 28 experiment samples from ejaculation. After the test the technology for obtaining sperm by artificial vagina from among the most trained left five dogs (shepherd - 8 years, Doberman 9 years and three purebred dogs, age not known). From five dogs ejaculation carried out two times a week in the first week (Tuesday, Friday), from next week received sperm three times a week (Tuesday, Thursday, Saturday).

After each of the fence ejaculating males were in a state of rest. The food consisted of porridge, boiled meat - 150-200 g each and fortified food. Animals in the period of experiments were fed twice a day (morning and evening).

As a result of the studies, 19 dogs were allocated worm infestation and 14 dogs with metabolism disorders, in the result of violations of feeding and as the effects of supplementation infections, 6 of them with inflammation of the mucous membrane of the uterus. All 19 dogs were held deworming. As a treatment used drugs replicating in the body content of micro and macro elements, vitamins, restoration of a mucous membrane of the uterus and improve its contractility. The course was held repeated sampling urine, faeces, blood on comparative studies.

The essence of the novelty of the results of the study is that the dog training market of Kazakhstan does not have a wide choice of breeding dogs. Population cannot satisfy their desires in keeping dogs, due to the lack of interested breeding or their high price. Results will for the first time in the national biotechnological practice to develop a domestic technology embryo-engineering process in this area; to prepare specialists for transplantation work in dogs; ensure the needs of the population in the wide choice of purebred dogs for home detention; monitor and genetic characterization of breeding dogs; create a database of various dog breeds.

The major biotechnology indicators: methods for the treatment of pathologies with the use of new highly effective pharmacological means.

The degree of implementation is developed and proposed for scientific and practical purposes of a comparative analysis of the pathological and physiological state of individual morpho-biochemical indicators of urine and blood, reflecting the state of the reproductive system. It is planned the edition of methodical guidelines for the diagnosis and treatment of diseases affecting the sexual system of dogs.

Field of application - medical and veterinary biochemistry, medical biotechnology, in particular, the biological research Institutes, medical and veterinary profile, veterinary clinics.

The efficiency of development is determined by the detection of internal changes in the organism of dogs, affecting the normal functioning of the reproductive system of dogs.

Prognosis proposals on the development of research objects – taking sperm, artificial insemination, leaching and embryo transfer will be tested and developed by further research.

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Molecular Genetic Characterization of Pathogens Onychomycosis and Creation of a Collection of Microorganisms-producers of Specific Antigens

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Object of research are antigens isolated from clinical strains of fungi - agents of onychomycosis person; immune serum-obtained by the use of these antigens.

The purpose of work - Molecular-genetic researches and development of a rapid test system for the detection of dermatomycetes antigens in order to improve the diagnosis of onychomycosis. At the intermediate stage: Obtaining of antigens and antibodies and checking of immunochemical characterization. To solve these problems: Obtain biomass, antigens isolated and purified, allocated the most frequent representatives of the fungi - agents from onychomycosis; get hyper-immune serum to specific antigens and to determine the diagnostic value of antibodies in different serological tests; examine the properties of the activity, specificity, and immunogenicity of the antigens, determine the working titer of the antigens in the different serological tests.

The methods of work – biochemistry, biotechnology, immunological and statistical methods of research have been used.

In the process of studies aimed obtaining biomass of dermatomycetes *Trichophyton rubrum* and *Trichophyton interdigitale* as the most frequent representatives of the fungi - agents of onychomycosis; the isolation and purification of antigens filtration methods of low-speed centrifugation, dialysis; obtaining Hyper sera to specific antigens and diagnostic evaluation of antibodies in various serological reactions: RA, RP, RAC, ELISA; analysis of the properties, activity, specificity and immunogenicity of antigens, determination of their working titer.

During the reporting period, the company conducted the cultivation of two strains of the underlying conditions for accumulation of biomass from which received 4 soluble antigen and 2 corpuscular antigen. Determined the concentration of the components of the antigens, polysaccharides and 0.125-0,500 mg/ml, proteins up to 0.6-0.25 mg/ml Concentration of polysaccharides of particular antigens reached values as 2.0 to 4.0 mg/ml Antigens used for immunization of laboratory animals and in the formulation of serological reactions.

The laboratory animals were immunized with various schemes and obtained immune serum. Testing of sera in various serological reactions allowed to find agglutination properties of particular antigens *T.rubrum* and *T. interdigitale* with a titer of antibodies in the range of 1:64-1:256. Statement of the precipitation reaction is finding precipitation properties of the protein antigen *T.rubrum* strain №146. Other antigens do not have precipitation properties. In ELISA analysis revealed a high activity of antigens with titers of specific antibodies to 1:1600-1:3200. Complement binding properties are defined due to the effect of anti-complement. The optimal concentration and the working titer of components for setting serological reactions: RMA - 100 thousand cells/ml, ELISA 10,0 mcg/ml.

As a result of research antigens obtained from two strains of pathogens onychomycosis *T.rubrum* and *T. interdigitale* performed checking of immunochemical characterization. It has been established that corpuscular antigens have agglutination properties, are active in the ELISA, do not have precipitation properties. Soluble polysaccharide and protein antigens are active in ELISA, identify specific antibodies in high dilutions. Protein antigen *T. rubrum* has precipitation properties.

The essence of the novelty of the results of the study is that there have been antigens of *T. rubrum* and *T. interdigitale* and immune serum to them, carried out comprehensive studies of their immunochemical characteristics.

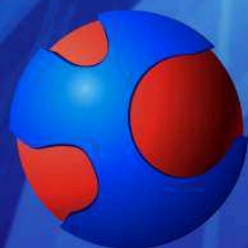
The major biotechnology indicators: the methods for the selection of antigens of agents of onychomycosis and the method of obtaining immune sera.

The degree of implementation - selected 10 strains dermatomycetes to create collections of microorganisms, which was the basis for the edition of the «Concise Atlas of mushrooms of the genus *Trichophyton* - typical agents of onychomycosis», 2 strains allocated antigens and immunochemical characterization was tested.

Field of application – biotechnology, medical and veterinary Mycology. The efficiency of development is determined by the application of the proposed method of obtaining the antigen from the agents of onychomycosis, which will be proposed as a component of the diagnostic test-systems.



2nd Belarus-Korea Forum
"Science. Innovation. Production"



Session:

New Materials

Graphene-based Layered Nanostructures for Electronic and Optical Applications

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Graphene-based layered heterostructures have a great potential for high-performance optoelectronics due to its fascinating electrical, thermal, mechanical and optical properties. Actually, it has arisen a new class of materials called—two dimensional crystals which are stable in the free state. The first, and perhaps the most striking evidence of validity of the theoretical concepts of graphene has become a half-integral or "relativistic" quantum Hall effect, in which the Hall conductivity is quantized in half-integer values of Klitzing constant. Another unusual feature is the fact that the graphene remains finite conductivity even when the carrier concentration is approaching zero, and furthermore, is close in magnitude to the quantum of conductivity. Such behavior is attributed with the effect of the so-called Klein paradox and the lack of localization of relativistic electrons. On the basis of graphene can be synthesized the new class materials so-called two-dimensional crystals with desired electronic and optical properties using chemical functionalization. For example, it was demonstrated that graphene can react with atomic hydrogen, fluorine or oxygen, which makes this a highly conductive semimetal with zero band gap into dielectric (graphane, graphone or graphene oxide). Another promising direction is the creation of quasi-2D layered structures consisting of alternating monoatomic planes of different materials, such as graphene, boron nitride, molybdenum disulfide etc. Graphene/graphene oxide (G/GO) heterojunctions were demonstrated to be promising for fabrication of nonvolatile resistive memory devices. After the forming process the nanostructure shows the reliable and reproducible unipolar or bipolar resistive switching at room temperature with good on/off current ratio. The 2D layered nanostructures are considered also to be good candidate for high efficient solar cells and ultra fast photodetectors in a broad optical range.

Development of Physical/Technological Fundamentals or Production of Composite Metal-Semiconductor-Insulator Nanostructures with Tunable Electric and Magnetic Properties

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This work is devoted to the results of the study of two types composite metal-semiconductor-insulator (MSI) nanostructures, which can be used for production of sensors, transducers, microminiature electric engineering componentry and memory media.

1. MSI film nanocomposites containing metallic FeCo-based nanoparticles with “core – shell” structures embedded into insulating matrixes (alumina, fluoride, PZT, etc.). Semiconducting “shells” around metallic “core” are composed of FeCo-based oxides which are formed when deposition of the films in argon – oxygen atmosphere in vacuum chamber using ion-beam sputtering of compound targets. The presence of semiconducting FeCo-based oxide “shells” around FeCo-based nanoparticles results in the appearance of inductive-like contribution into reactive part of impedance in form of the so called negative capacitance effect. We analyze the conditions (concentration of FeCo-base phase, type and state – amorphous or crystalline - of insulating matrix, composition of “core-shell” structure, temperature, frequency range, annealing, etc.) when inductive-like contribution prevails over capacitance. The domination of inductive-like contribution (approached the values of 10-20 pH/pm³) in some of composite MSI nanostructures allows to use them in future as miniature planar (non-coil-like) inductive elements with the tunable parameters in hybrid ICs or other electric engineering applications. We offer to use this principle to develop planar microinductors using technology compatible with planar silicon IC-technology.

Some of the composites studied possessed temperature dependences of resistance which are linearized in log-log, Arrheniuse or Mott scales allowing to use them as a low-cost temperature sensors in the wide range of temperatures (2 – 400 K). Nanocomposites FeCoZr-fluorite have found out perpendicular magnetic anisotropy that can be used for the formation of magnetic memory media.

2. Ni/SiO₂/Si composite nanostructures containing array of Ni nanorods, distributed in pores of SiO₂ layer, on Si substrate. These structures were sintered by template-assisted deposition. Porous SiO₂/Si template can be manufactured by two ways. The first way, which was used in our work, includes the irradiation of SiO₂ layer by swift heavy ions with energies of about 50-400 MeV and the following selective etching of template for the formation of vertical cone-like pores. Using under-potential electrochemical deposition, these pores were filled with Ni nanoparticles forming the array of Ni nanorod-like Schottky barriers on Si substrate. After preparation of Ni/SiO₂/Si nanostructure, three electrodes, two of which were situated on the top side of nanostructure and the third - on the back side of Si substrate. It was shown that, at the determined combination of operating current between two top probes and also sign and value of transversal bias voltage (applied between one top and backside probes) Ni/SiO₂/Si nanostructure have found out the huge magnetoresistive effect (tuned by both longitudinal and transversal electric fields) in the temperature range 20 – 30 K (approaching the values up to 35 000 % at H = 8 T) and in the range 200-320 K (up to 500 %).

We offer to fabricate such Ni/SiO₂/Si nanostructures in the ordered pores created using micron or submicron lithography and other methods of planar Si technology to form electric probes to every Ni rod. This will allow to manufacture magnetosensitive matrixes with Ni rod arrays permitting to estimate distribution (visualization) of magnetic fields in space in different magnetic systems like superconducting solenoids, transformers and other magnetic systems.

Testing of Refractive X-Ray Optics for Focusing and Imaging at the Pohang Light Source

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The article represents results of focusing and imaging of X-rays at the beamline 6D – XMI of Pohang Light Source with use of the X-ray optics designed in Belarus.

More than 40 centers of synchrotron radiation operate today, including and so-called synchrotrons of the third generation (ESRF (France), APS (USA), SPring-8 (Japan), etc.) which allow to receive intensive x-ray beams with a cross size about 100 microns and the energy of photons 5-20 keV. Such X-ray beams can be focused into micron sized spots with the use of a number of the optical elements one of which is the compound refractive X-ray lens.

The third generation Pohang Light Source of synchrotron radiation was put into operation in May, 2012 as a result of modernization of existing earlier synchrotron of the second generation. As a result of the modernization the current of electrons in the synchrotron ring increased considerably and the cross section of the electron beam was reduced up to the size of 100-200 microns.

The used for experiments compound refractive X-ray lenses were produced in the A.N. Sevchenko Institute of Applied Physics Problems of Belarus State University [1]. The lens is designed in the form of a glass capillary filled by a given number of epoxy microlenses. Radius of curvature of a separate microlens is equal to the radius of the capillary channel and due to this it become possible to create lenses with the surface curvature radius equals to 10-50 microns that is difficult to realize with other known methods. The number of microlenses may be from 50 to 200. The lens focal length is about 100 mm for 8 keV X-rays.

Refractive X-ray lens works as ordinary lens for visual light. In the case of synchrotron radiation the distance between the source and the lens is high enough and equals, as a rule, to 10-50 m; the size of the source is also, as a rule, less than 1000 microns. When refractive lens with a focal length equal to approximately 10 cm is used, expected size of source image may be equal to some microns. This is a way for obtaining micro and nano-sized X-ray beams.

Two compound refractive X-ray lenses were developed and made for experiments. Lens # 1 consists of 81 biconcave microlenses, with 250 microns surface curvature radius. The calculated focal length of the lens for 8-keV photons is equal to 408 mm. Lens # 2 consists of 126 microlenses. Radius of curvature of the surface for a separate lens is equal to 50 microns. The calculated focal length of the lens for photons with energy 8 keV is equal to 52,5 mm. Fig.1 shows images of the lens #1 and lens #2.

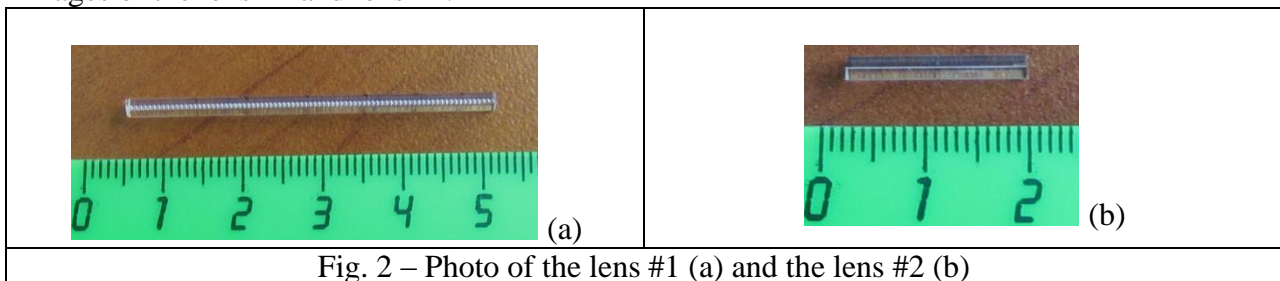


Fig. 2 – Photo of the lens #1 (a) and the lens #2 (b)

Fig. 2 shows photo of experimental setup for measuring lens focal length. 8-keV X-rays from synchrotron source were directed through the X-ray lens on a scintillating crystal. Visual light from the scintillating crystal was collected by objective lens and the lens forms image at the digital CCD-camera. 12-bit CCD camera of 1376 X 1040 pixels format was used. The size of the synchrotron's source at beamline 6D - XMI was equal to 148 microns x 71 microns. The X-ray lens was placed at the distance 31,4 m from the source.

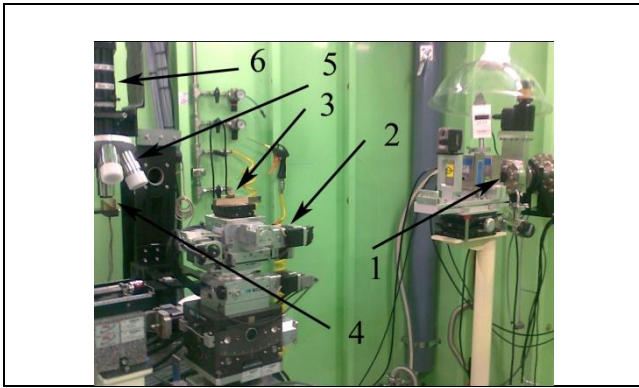


Fig. 2 – Setup for measuring X-ray lens focal length.

1- X-ray beam output system; 2- goniometer; 3- X-ray lens in a holder; 4- scintillator, 5- microscope objective lens; 6- CCD- camera.

Fig.3 shows images of the X-ray beam cross section formed by the lens # 1 at various distances to the lens.

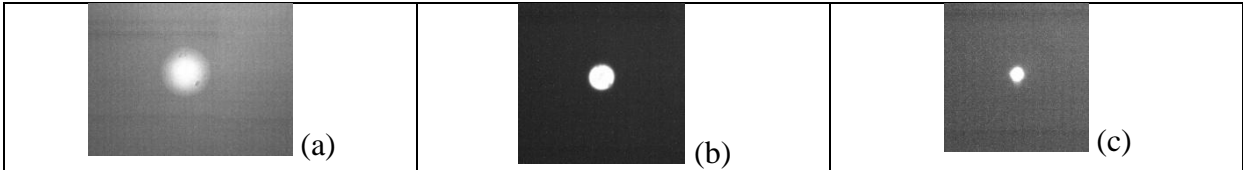


Fig.3- Image of the X-ray beam formed by the lens # 1 at various distances d to the lens.
a) $d= 20$ cm; b) $d= 30$ cm; c) $d=41$ cm.

From Fig.3 it is seen that the smallest cross section of beam is observed when the camera is placed at distance $d= 41$ cm to the lens. This distance coincides with the calculated focal length of the

lens # 1 equals to 40,8 cm. It was established that the beam size in horizontal direction is equal to 4,5 microns, and in the vertical - 5,5 microns. It was impossible to establish the beam size more precisely, because the spatial resolution of this method for the used CCD-camera was in the range of 2-3 microns.

The lens # 2 with focal length of 52,5 mm was used as an objective lens of a simple X-ray microscope which was realized at the station 6D X-ray microimaging of the Pohang Light Source.

The gold mesh # 1500 with a number of cells on one inch equals to 1500 was used as an object; thickness of a wire was equal to 6 microns. The mesh was placed at the doubled focal length to the lens. The scintilator plate was placed at the same distance to the lens: that allows receiving the object image in the ratio 1:1. Fig. 3 shows the image of the grid # 1500 obtained with the use of the lens # 3 with magnification equals to 1.

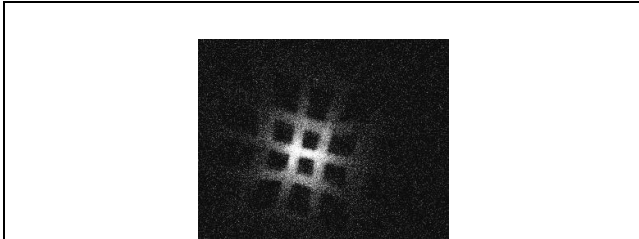


Fig. 3- The image of the grid # 1500 obtained with the use of the lens # 3 with magnification equals 1.

The analysis of the image of a grid No. 1500 showed that spatial resolution of a microscope makes about 2-3 microns. Better resolution may be obtained after optimization of the used X-ray CCD-camera.

The work was partly supported by National Research Foundation of Korea

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The Formation of C-49 Modification Titanium Disilicide

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Due to tougher requirements to photocells used for measuring light fluxes in such knowledge domains like ecology, medicine, chromatography, astronavigation and others, a need arises to expand the range of photocells to meet new sensitivity, spectral range and cost specifications. In particular, the need to fix and analyze the UV and visible light by rather cheap and easy-to-make photocells has led to a broader assortment of such devices [1-3].

The pulse photon processing (= rapid thermal annealing - RTA) has found wide use for technological processes of silicide synthesis to solve the problems of micro- and opto-electronics and development of submicron-size LSI and SLSI [4-7].

Titanium silicides were formed by using the method of hardphase reaction of titanium films with silicon. The general sequence of the process operations was as follows: cleaning of a silicon wafer from natural oxide layers, deposition of Ti films and two-layer Ti/TiN films onto wafer surface and conducting the hardphase reaction to form silicide in the region of metal contact with silicon using pulse photon processing.

The Ti and TiN films were deposited in modular setups for magnetron sputtering such as Varian m2i and Endura 5500 PVD of the Varian and Applied Materials Companies, respectively. The pulse photon processing was carried out using halogen lamps on Heatpulse 8108 commercial installation of AG Associates Company (fig.1).

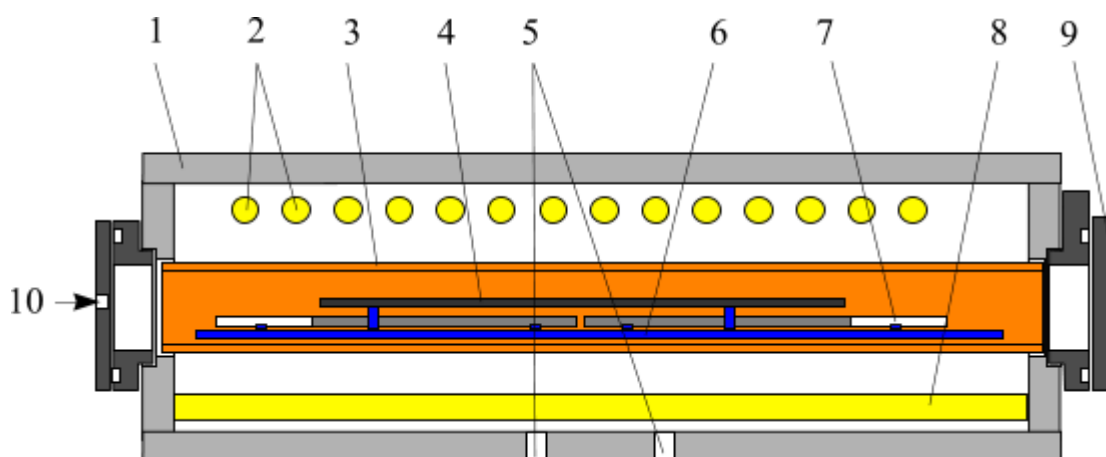


Figure 1. Section of reactor of Heatpulse 8108 setup: (1) water-cooled gold-plated stainless-steel casing; (2) halogen lamps (upper row consisting of 14 pcs), (3) quartz reactor; (4) silicon wafer being processed; (5) optical inputs of temperature control pyrometers (2 pcs); (6) quartz wafer holder; (7) silicon shields (3 pcs); (8) halogen lamps (lower row consisting of 14 pcs); (9) charging door of reactor; (10) gas supply input.

The synthesis of titanium disilicide films was performed on КДБ 12 wafers without implantation as well as on boron doped wafers, 12 Ohm·cm substrates implanted by As (N+) with various implantation doses such as $5 \cdot 10^{15} \text{ cm}^{-2}$, $3 \cdot 10^{15} \text{ cm}^{-2}$ and $1 \cdot 10^{15} \text{ cm}^{-2}$. The alloy was the formation by annealing in a reactor at 600°C, 620°C and 650°C for 30 second.

It possesses luminescent properties and has potential for use in optoelectronics. The band width of luminescence spectrum is determined by the mechanism of radiation in different grain parts in the TiSi₂(C49)/Si nanosized thin-film heterostructure.

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Study on Magnetic Domain Dynamics of Magnetocalorimetric Thin Film Materials

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We have investigated magnetic and magnetocaloric properties of $\text{Ba}_{1.7}\text{La}_{0.3}\text{FeMoO}_6$ and $\text{Sr}_{2-x}\text{Ba}_x\text{FeMoO}_6$ with double Perovskite structure. The samples have been fabricated by a standard solid state reaction technique and structural properties were examined by X-ray diffraction measurement, all of which were carried out by NASB collaborators. The magnetic and magnetocaloric properties have been explored, first by low-temperature vibrating sample magnetometer (VSM). Temperature-dependent $M(T)$ and dM/dT curves under an applied field of 100 Oe are shown in Fig. 1, where ferromagnetic-paramagnetic phase transition is clearly observed around the Curie temperature about 345 K.

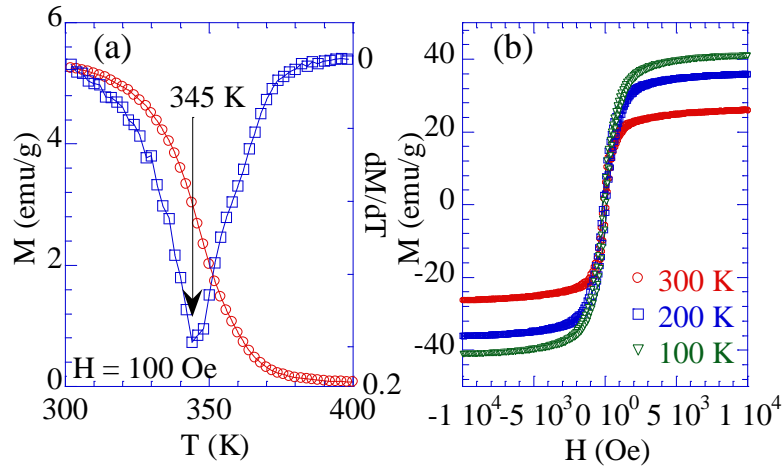


Fig. 1. Temperature-dependent $M(T)$ and dM/dT for $\text{Ba}_{1.7}\text{La}_{0.3}\text{FeMoO}_6$ compound sample. [1]

To further understand the transition behavior, the critical behavior around the T_c has been analyzed by Arrot plot method, where the transition here undergoes with second-order transition, as demonstrated in Fig. 2. The critical scaling exponents experimentally determined are compared to the predicted values from several theories.

Secondly, the target materials of $\text{Sr}_{2-x}\text{Ba}_x\text{FeMoO}_6$ ($x = 0, 0.2, 0.4, \text{ and } 0.6$) have been successfully fabricated by NASB collaborators. The thin films were deposited on SrTiO_3 substrate by the pulsed laser deposition technique at the substrate temperature of 800 °C with Oxygen partial pressure of 150 mTorr. Various magnetic properties will be examined by low-temperature VSM, ferromagnetic resonance, and magneto-optical Kerr effect. Magnetic imaging by means of magneto-optical Kerr microscopy and magnetic force microscopy will be carried out for the samples, thereby providing details of microscopic correlation between magnetic domain structures and magnetocaloric behavior around the T_c .

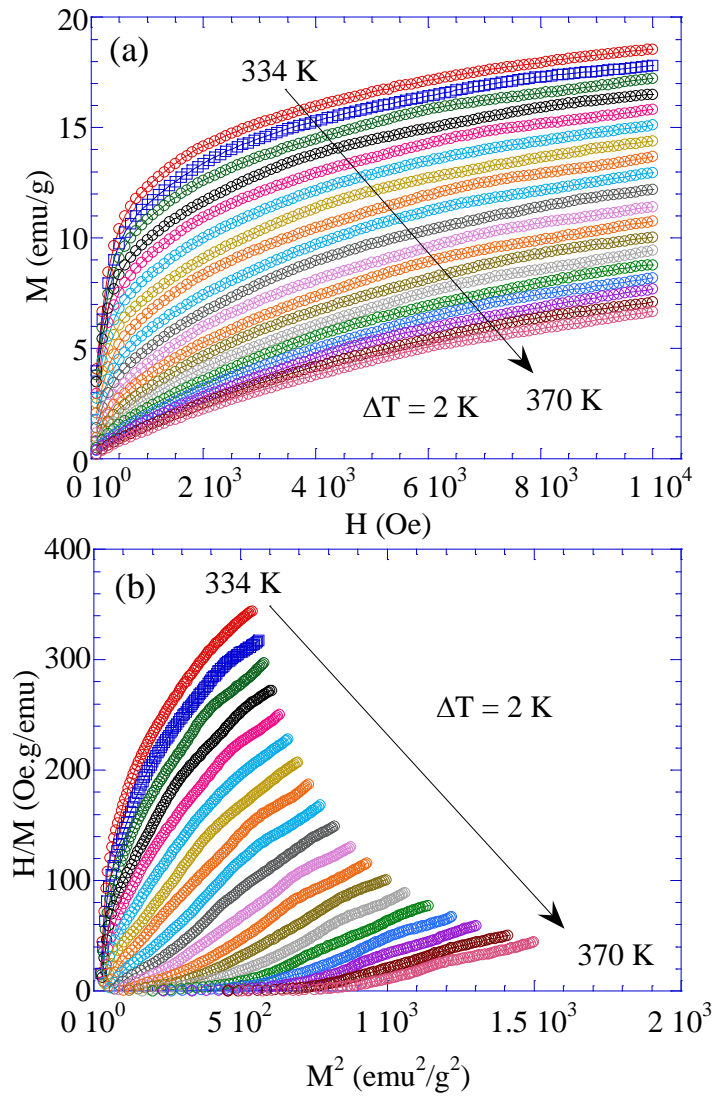


Fig. 2. (a) Field dependent magnetization under various temperature. (b) Arrott plots with H/M vs. M^2 for $\text{Ba}_{1.7}\text{La}_{0.3}\text{FeMoO}_6$. [1]

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Development of New Carbon Nanomaterials for Photodynamic Therapy and Investigation of Their Photophysical Properties

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Since its discovery in 1985, buckminsterfullerene (C_{60}) has stimulated a large body of research due to its unique photophysical properties [1, 2]. Chemical modification allows C_{60} to luminesce [2]. In general, certain carbon nanomaterials exhibit optical emission due to quantum confinement effects [3]. In this way, nano-sized carbon materials have attracted much attention since they are expected to replace conventional cadmium-based quantum dots.

Recently, highly water-soluble fullerene nanoparticles (C_{60} -TEGs) were prepared by conjugating with tetraethylene glycol (TEG) using lithium hydroxide as a catalyst [4]. Here, we studied the photophysical properties of the C_{60} -TEGs by combining various experimental approaches of continuous-wave and time-resolved spectroscopy. In presented fullerene nanoparticles broad emission band arising from a wide-range of excitation energies was mainly attributed to optical transitions from disorder-induced states (Figure 1).

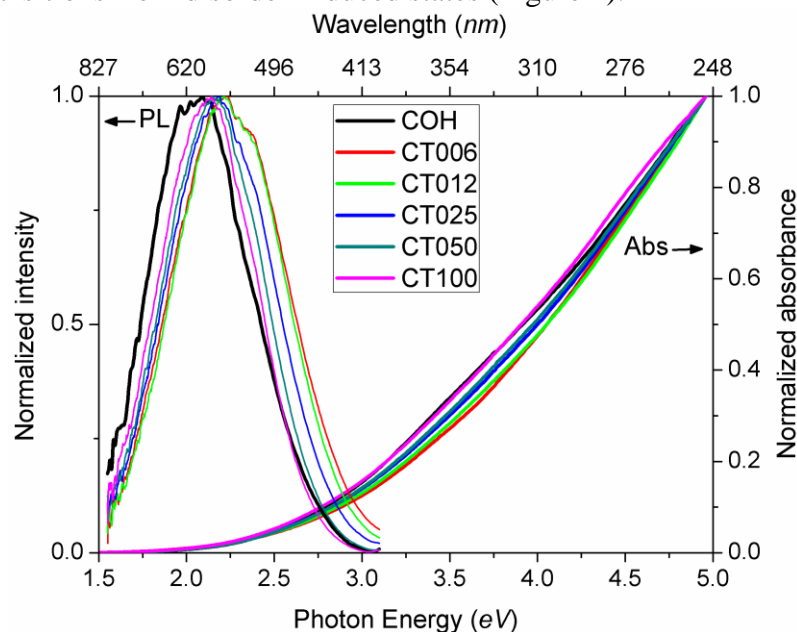


Figure 1 – Normalized photoluminescence and absorption spectra of the $C_{60}(OH)_n$ and C_{60} TEGs water solutions. The luminescent spectra were obtained for excitation at 350 nm (3.5 eV).

Triplet state properties of modified C_{60} should also be promising, since pristine fullerene readily generates singlet oxygen (1O_2) and other reactive oxygen species by illuminating ultraviolet or visible light [5]. Energy transfer from the excited triplet state of fullerene to the ground state of oxygen gives rise to 1O_2 as illustrated in the following triple-step scheme: (1) fullerene + $h\nu \rightarrow ^1\text{fullerene}^*$; (2) $^1\text{fullerene}^* \rightarrow ^3\text{fullerene}^*$; (3) $^3\text{fullerene}^* + ^3O_2 \rightarrow \text{fullerene} + ^1O_2$.

Singlet oxygen is able to irreversibly cause various cell damage including mitochondria, lipid, and nucleus, thus leading to damage of target diseased cells or tissue [6]. However, due to its extremely low solubility in water monomeric C_{60} does not show a significant photodynamic effect in aqueous systems. To overcome the drawback, many efforts have been explored to develop the

water-soluble C₆₀ by various approaches including reaction with hydrophilic moieties, grafting polymers, and applying surfactants [7]. As a rule, such modification of C₆₀ significantly affects its photophysical properties. For example, fullerol (C₆₀(OH)₂₄), a representative water-soluble fullerene, is known to have low activity of ¹O₂ generation compared to that of pristine fullerene [8]. Therefore, it is a challenge to synthesize water-soluble fullerene derivatives with sufficient photosensitizing activity.

Using highly sensitive kinetic spectrometer [9], for the first time the ¹O₂ kinetic luminescence signals produced by polyhydroxylfullerene (C₆₀(OH)_n) and C₆₀-TEGs nanoparticles were detected and described in water (Figure 2).

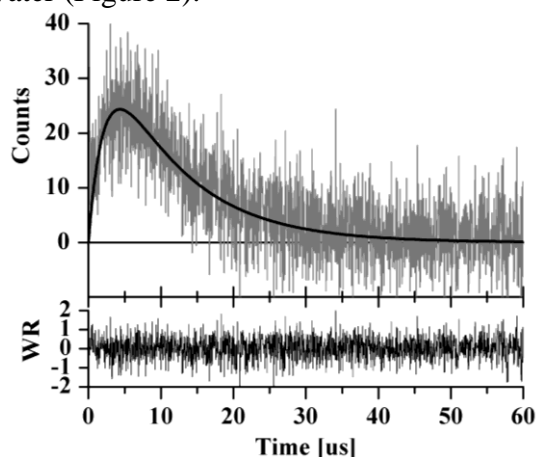


Figure 2 – Kinetics of CT050-photosensitized luminescence of singlet oxygen in water at excitation wavelength 355 nm. A solid line is the two-exponential curve fitting. ¹O₂ luminescence rise and decay times were found to be $2.3 \pm 0.5 \mu\text{s}$ and $10.3 \pm 1.8 \mu\text{s}$, respectively. WR are the weighted residuals

Acknowledgements

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Diamond-Like Carbon Coatings for Friction Units

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It is known that diamond-like carbon (DLC) coating can be used effectively as a solid lubricator, which is characterized by low coefficient of friction and low wear.

We have developed and successfully used a new high-productive combined physical and chemical method of obtaining of the coatings (PVD-CVD method). This method provides a high deposition rate and doesn't require the using of bias voltage, which is important for the dielectric DLC coatings condensed on a conductive and non-conductive substrate.

Raman Spectroscopy and X-Ray Photo Electron Spectroscopy researches allowed to determine the ratio of sp^2 and sp^3 bonds of carbon atoms. Increase in the acetylenes pressure in vacuum chamber leads to enhance of amount of the sp^2 bonding and as a result to diminution of coefficient of dry friction up to 0.08.

It was shown some examples of using PVD-CVD method in the development of technologies of wear-resistant coatings obtaining on WC-Co micro-drills and cutters for PCB proceeding, renovation of punch plungers in high-pressure pumps, obtaining of lapping coating for the pistons of Diesel engines, passivation and hardening of the surface of molds for the plastics industry, obtaining of absorbing coatings for the body parts of space apparatus photodetectors, protective and decorative coatings for watches etc.

It was discussed the experience in cooperation with international organizations in this area accordingly to their demands, in particularly with the Korean Institute of Industrial Technology (impulse plasma source and DLC film technology delivering) and LG Corporation (DLC coatings for friction parts of high-side shell scroll compressor).

Mesomechanical Principles of Form-Stable Composites Development by Nano-Disperse Reinforcement of Metals and Polymers

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Although various nano-structures have been suggested for metals and polymers, using nano-scale boundaries, nano-precipitants, and second-phase particles, these structures are obtained only under the specific thermodynamic conditions and hence the stability of the structures is extremely low. Composites incorporating thermally stable nano-scale reinforcement have captured a great deal of attention due to their exceptional properties and stable structures. Hence, these composite materials are necessary for creation of low-weight and reliable structural elements for aerospace technology, machine building, defense means, medicine (implants and prosthesis) and so on.

The present study first aims to develop metal-based and polymer-based composites containing various types of nano-scale reinforcement, particularly focusing on the 1) uniform dispersion of each of the reinforcement and the 2) strong interface between the reinforcement and the matrix. Difficulties in homogeneous dispersion of the reinforcement in the matrix, sometimes weak interface due to the poor wettability between the reinforcement and the matrix, and easy destruction of molecular structures of the reinforcement are main obstacles.

The second goal of the study is to explore mechanical behavior of the composites. Predicting dramatic improvement of physical and mechanical performances has so far been reported for real metals or polymers containing nanosized fillers (short fibres and/or particles). However, the mechanism of abnormal strength and deformation characteristics of the nanocomposites has yet to be fully understood. When such materials are processed by the current high-energy methods (pressing, pressing with shear, extruding, molding, etc), non-uniform structure is formed with the significant internal stress resulting in distortion and defects of the structure.

For optimization of technological process and increasing competitiveness of products, it is extremely important to study 1) its local mechanical characteristics by means of modeling and 2) to predict the parameters of composites using the corresponding data for matrix, filler and interface layers as well as geometry of these phases. The known fundamental results also need to be adapted for disperse-reinforcing metallic and polymer materials, particularly with nanosized fillers, with taking into account the interface layer and non-linear behavior of matrix phase and, in some cases, filler one. Also, mesomechanical analysis of deforming and failure of such materials is necessary in search of ways of recycling of the products which have exhausted the resource.

First of all, we aim to develop new composites containing nano-scale reinforcement. There have been a fair number of attempts to disperse nano-scale reinforcement in the metal matrix or in the polymer matrix using a liquid-state or a solid-state technique. It has been demonstrated that coating processes, such as plasma spraying, cold spraying, and thermal spraying, can be used to fabricate bulk composites. However, poor dispersion of CNTs and unfavourable chemical reactions between reinforcement and the matrix materials are crucial problems in the liquid-state techniques. One of the great advantages of a solid-state technique is the relatively low processing temperatures enough to avoid the unexpected reactions and to provide fine microstructures. The powder metallurgy technique involving the ball-milling process has been considered one of the promising routes for mechanical dispersion of nano-scale reinforcement. Metal or polymer powder is blended with nano-scale materials, followed by hot consolidation of the mixture. Friction stir processing based on friction stir welding has been increasingly reported as a solid-state joining and microstructural modification process. Interesting ideas using molecular-level mixing and severe plastic deformation have been suggested to provide a better mechanical performance of the composites.

With this scope, we suggest to develop metal-based and polymer-based composites containing various types of nano-scale reinforcement via solid-state techniques; to examine the effects of the morphology of reinforcement and interface structures between the reinforcement and the matrix on the

mechanical properties; to optimize the processing variables to develop the composite with desirable structures and properties.

The materials under consideration are structured as a heterogeneous composites. Nowadays composite materials are usually modelled as a single-phase, usually, elastic medium (continuum) or as an elastic biphasic (matrix and filler) medium. But to predict such important characteristic as form stability, we must take into account the real configuration of the filler's particles, visco-elastic-plastic properties of matrix and filler as well as interface layer influence. Here is the novelty of the suggested theoretical and experimental results:

- to formulate constitutive equations for solid phase under large strains which typical for polymer and elastomer composites;
- to carry out the static mechanical tests to determine model parameters in the wide temperature and velocity range using identification procedure;
- to carry out the dynamic contact indentation to determine visco-elastic characteristics under local non-destructive loading.

Experimental tests should be developed on the micro and macro-scale. In the first case, structural analysis should be developed in order to determine distribution of the various phases in the real materials. Moreover, particularly for micro-mechanical and nano-mechanical properties, the solid phase should also be analysed. On the macro-scale, parameters of phenomenological description should also be determined. Both cases experiment will have to be conducted to verify the developed mathematical models.

The objective of the proposed project is to create adequate mezo-mechanical description of nano-disperse reinforcement of metals and polymers. The combination of mezo-mechanical description and experimental study would realize next advantages:

- uniform dispersion of nano-scale reinforcement and development of strong interface between reinforcement and the matrix.
- development of bulk composites with desired density.
- creation of analytical and numerical meso-models of disperse-reinforced materials at elastic and plastic deformation and original experimental methods of mechanical testing of elastic, plastic, viscous and strength parameters of disperse-reinforced materials.
- mesomechanical analysis of disperse-reinforced composites under tension, compression and shear; the experimental study of samples deformation; the comparison of theoretical and experimental results.
- development of models for composites materials with nanosized fillers and prediction of new deformational effects for these materials.

On the initial two steps of the project the first results have been obtained as given below.

To improve the description of dispersed-reinforced composites, the determination of thermal and viscous parameters of polymer matrix is assumed. It's has been shown that using of hypothesis of stability of relaxation activation energy for the polyfluorene in temperature range 10 ... 200 °C allows to obtain a good accuracy of complex dynamic characteristics calculation in more wide frequency range (1...10 Hertz) than in case of Williams-Landell-Ferry's equation.

Updating of Takayanaga's model, allowing one to analyze uniaxial stress state of the dispersed-filled composite in the conditions of the nonlinear deformation caused by hyperelasticity or a plastic flow is proposed. Variants of model for spherical and cubic reinforcing inclusions are considered. In particular, calculation dependences of axial pressure on longitudinal deformation for polymethylmethacrylate, filled with particles of aluminum oxide have been obtained, at temperature 180 °C and carbon-reinforced plastic based on polytetrafluorethylene at temperature 20 °C. Results of modeling are compared with experimental curves of a stretching and compression.

Science Basis of Strengthening Treatment to Create High Performance Materials with Nanostructure, Nano-Composite and Composite Structures

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Main purpose of the research work is to develop:

- Classification of structural and energy mechanisms for strengthening materials
- Classification of strengthening methods for items, tools and parts
- Synergism of design strength for materials to form nanostructure, nano-composite and composite structures
- Classification of composite structures formed by means of hardening treatment
- Classification of strengthening methods for items, tools and parts
- The simple, inexpensive and high-performance and ecologically clean methods for strengthening materials to form composite structure;

Classification of structural and energy mechanisms for strengthening materials is based on:

- Theory of metastability system
- Dislocation theory
- Friction theory
- Corrosion theory

Classification of strengthening methods for items, tools and parts to form composite structures is based on realization of structural and energy mechanisms and includes:

- Methods for technological treatment
- Metallurgical and other methods for manufacturing materials
- Design and operation methods

Synergism of design strength (between strength and reliability criteria) for materials is based on the creation of composite materials with non-uniform structure, rationally having opposite properties of its macro- and micro(nano) elements. All composite materials can be divided into 3 levels:

- Composite materials from alternating macroelements (matrix, layer) with various properties
- Composite materials from alternating micro(nano)elements (grains, sub-grains, particles) with various properties
- Composite materials from micro(nano)elements which have directed changes of their properties

Classification of composite structures formed by means of strengthening treatment includes:

- Structure of composite materials with interchanging macro-elements (matrix, layer) and various properties
- Structure of composite materials with interchanging micro-(nano-)elements (grains, subgrains, particles) and various properties
- Structure of functionally gradient materials of micro-(nano-) elements that directionally change their properties

The new hydro chemical treatment method for hardening ready-made parts and tools made from steels, hard alloys, ceramics and diamond materials is developed. This treatment permits decreasing the friction coefficient of the tool steel surface in 8,3 and hard alloy surface in 3,9 as compared with untreated. Besides in materials at a depth of 1 mm; a zone of compression stress (180–470 MPa) is formed. As a result the operational resistance of steel, hard alloy and diamond tools has been increased by the factor of 1.5-8.0 in comparison with the standards.

New treatment Nanotechnology for Hardening Steels, Ceramics and Diamond Materials

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The main purpose of this work is the development of simple, inexpensive and high productive method for hardening ready-made parts and tools made from steels, hard alloys, ceramics and diamond materials to obtain high service and anti-friction properties.

The new hydro chemical treatment method (HCT) includes the two processes:

(1) Chemical Treatment of the surface in water dispersive and nanocompositions of superhard, refractory and wear-resistant materials (oxides, carbides, diamond, graphite, etc.) at temperature of 95–100 °C for 20–60 min (2) subsequent Heat Treatment at temperature of 130–200 °C for steel surface and at 1030–1050 °C for ceramic surface during 30–60 min.

The HCT process has a dual strengthening effect. First, solid lubricant nano-structure thin-film (about 0.5 μm) coatings are formed. Second, in materials at a depth of 1 mm; a zone of compression stress (180–470 MPa) is formed. The observed phenomena can be explained within the Rebinder effect and others.

The proposed HCT method has the advantages over the known processes:

1. The process is simple, traditional equipment are used;
2. After processing the initial structure and dimensions of items do not change;
3. The coatings are formed on steels, hard alloys, diamond and other materials;
4. The process has high productivity by using a chemical bath of an arbitrary size;
5. The technology is energy-efficient: electric current on surface is not required;
6. The process is inexpensive: additional expenses are 1–10% of items cost;
7. The friction coefficient of solid coatings without lubrication is 0,07–0,11;
8. High thermal stability of nano and nanocomposite structures for coatings (up to 1050 °C);
9. After resharpening, the tools retain up to 80–100 % of wear resistance.

Optimization of the active composition and temperature – time parameters of the processes were performed for the friction coefficient of the films on tool steel and hard alloy. The diagrams “property vs. process parameters” were plotted using the obtained mathematical expressions. Treatment with optimal regimes permits decreasing the friction coefficient of the tool steel surface in 8,3 and hard alloy surface in 3,9 as compared with untreated (Fig. 1).

Results of the technology testing in industry are the following:

Increase of service life of processed tools and parts	k_w
<i>Item</i>	<i>Company name</i>
mills(HSS)	“Motovelo” (Belarus) etc. 2 – 8
screw taps(HSS)	“VUHZ” (Czechia), “Daewoo”(Korea) etc. 1.7 – 4.8
band saws(HSS)	“VUHZ” (Czechia) etc. 2.5 – 3
drills(HSS)	“Stock” (Germany), “PS” (Slovakia) etc. 1.8 – 4.2
knives(HSS)	“Skloplast” (Slovakia) etc. 1.9 – 2.2
stamps	“ZVL-LSA” (Slovakia) etc. 1.8 – 3
diamond drills, tool-grinding wheels	“BELAZ” (Belarus) etc. 1.8 – 3.5
disposable hard alloy pellets	
used for turning	“SALUT”(Russia), “Dynatherm”(India) etc. 1.5 – 4.5
used for milling	“BELAZ”, “Motovelo” (Belarus) etc. 1.5 – 3
hard alloy draw plates	“BMZ” (Belarus) etc. 1.5 - 2
bushes of dump-track BELAZ	“BELAZ” (Belarus) 1.5 – 2

Application of the process in industry requires minor expenses.
The process is used by several enterprises in Belarus and Russia.

Friction pair: material to be tested (plain surface) - IIIX15 steel ($\varnothing 4$ mm sphere)

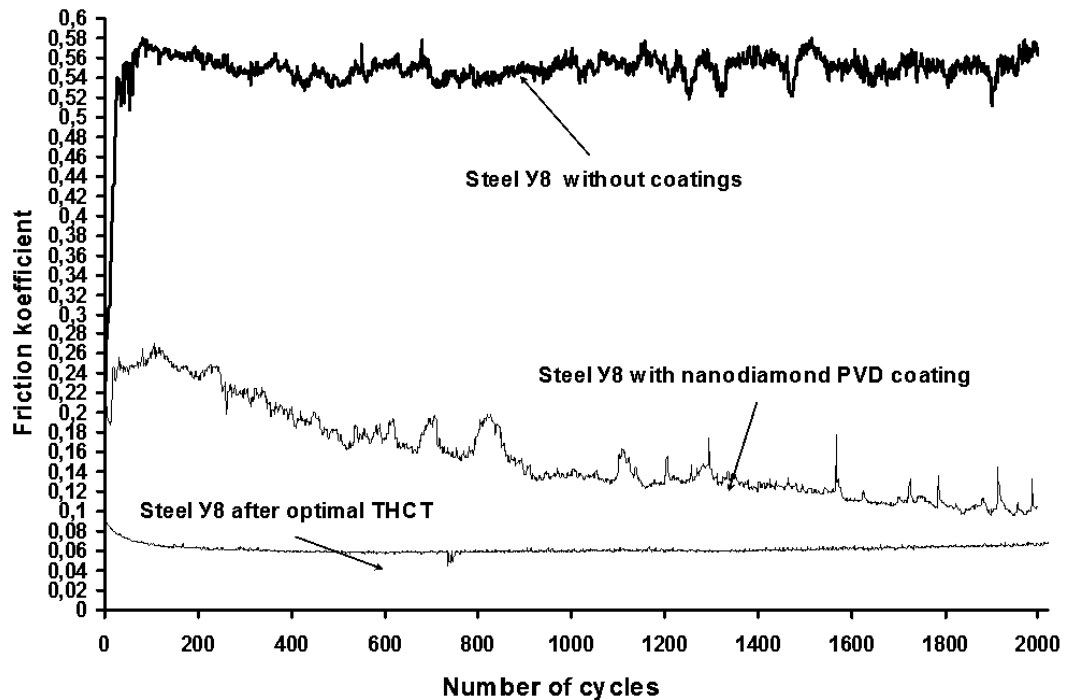


Fig. 1 – Comparative diagram of friction coefficient changes due to wear-and-tear lifespan of (a) tool steel and (b) hard alloy prior to and after THCT at dry sliding friction (without lubrication):
Test conditions: 1 H load; stroke length (track) - 3 mm, speed - 4 mm/s

Friction pair: material to be tested (plain surface) - IIIX15 steel ($\varnothing 4$ mm sphere)

Low-Temperature Technology Dispersing Refractory and Raw Materials

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Main purpose of this research work is the development of simple, inexpensive and high-performance method dispersing refractory and raw materials to produce aqueous media for hardening ready-made parts, tools and to fabricate construction composite materials for industry, building and peaceful life.

The dispersion process can be explained within the Rebinder effect owing to wedging action of polar molecules of surface-active substances in a microcrack of any solids including refractory and raw materials. Dispersing materials is based on temperature gradient ΔT , pressure gradient ΔP , chemical concentrations gradient ΔC and other gradients ΔX_i which are created within materials and outside. The radius of dispersed particle r is mathematically dependent on the following param

$$r = f(\sigma_s \cdot \tau \cdot n / \Delta T \cdot \Delta P \cdot \Delta C \cdot \Delta X_i)$$

wherein σ_s - surface tension; n - number of cycles; τ - duration of change of the gradient

As seen from the formula minimal radius of particle r is provided if:

$$\sigma_s, \tau \rightarrow \min; \Delta T, \Delta P, \Delta C, \Delta X_i \rightarrow \max; n \geq 1$$

For this purpose, an aqueous suspension of refractory and raw materials (silicon carbide, silicon oxide, chalk, sand, clay, etc.) are dispersed by special technology. Maximum process temperature does not exceed 350 °C and the minimum temperature - 0 °C. Varying the regimes (temperature, duration) on a specially developed device for dispersing materials and composition of aqueous suspension, we can reduce the particle size up to 30-500 nm.

The proposed dispersing method has the advantages over the known technologies:

- simplicity of the process because it can be implemented on a simple design equipment and does not require protective atmosphere
- energy efficiency since the process temperature does not does not exceed 350 °C
- high productivity because of the opportunity to make dispersing materials by using a chemical bath of an arbitrary size
- ecologically safe process
- low production cost of dispersing materials

The method can be used in industry, medicine and other fields of human life.

Applications in industry Dispersed silicon carbide and silicon oxide can be used to manufacture plastic and wear-resistant ceramics for end seals in oil and gas industry, heat-resistant ceramic engines and steam-gas turbines, resistant diamond-like ceramic tools and parts. Dispersed raw materials can be used for the building and road construction composite materials: dispersed sand - for concrete, plaster, pavement, and dispersed clay - for tile, brick, etc. Besides membranes for water and wastewater can be made of dispersed clay and sand. The 50-500 nm particle size can be used for these purposes.

Medical applications Dispersed chalk can be used for restoration of hair and tooth enamel, treatment of skin diseases and other cosmetic purposes. The 30-100 nm particle size can be used for these purposes.

High-Strength Submicrocrystalline Electrotechnical Bronzes Obtained with the Use of Mechanically Alloyed Nanostructured Modifying Ligatures

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In the production of low alloy copper materials the specific volume of the chrome-bearing bronzes is more 60 %. About 90 % of them account for alloys of “Cu – Cr” and “Cu – Cr – Zr” systems. They are widely used for the manufacture of both small and large-tonnage structures: heat-exchange units, including crystallizers, electrodes of contact, seam and projection welding; machine armatures using contact and resistance welding; the current supply tips; discontinuous contacts, etc.

Specific features of manufacturing chrome-bearing bronzes relate primarily to their melting and molding and are determined by the following factors: the presence of elements similar to oxygen (Zr, Ti, V, Nb, Cr, Si) in the alloy, a small allowance for alloying (sometimes $\pm 0,003$ %), high purity requirements to the material. Therefore it is necessary to use separately prepared double and complex ligatures as a charge. This results in the high cost of bronze and environmental pollution.

Large-scale research carried out by the authors of the paper reveals that one of the promising methods for solving the problem is to use the reaction of mechanical alloying, excluding high temperature melting from the technological process of production.

The mechanical alloying includes treatment of the powder charge of the given composition in the high-energy mill, mechanoreactor, the resulting product of which is a granular composition with the sub-/microcrystalline basis, strengthened, as a rule, by nano-, submicro- / sized inclusions. The given structure is stable and in most cases is inherited by compact materials produced from mechanically alloyed compositions. It allows a conclusion on their application prospects in a number of cases as modifiers to be made.

A great advantage of the technology is that the use of mechanically alloyed alloys with submicrocrystalline distribution of alloying elements leads to their subsequent rapid dissolution in the copper melt. This reduces the temperature of the basic melting by 150-200 ° and shortens its duration by 2-4 times, it also decreases the loss of alloying elements at least by 1.8 times and improves the sustainability of the whole process. Besides, the technology allows smelting chrome-bearing bronzes in practically any melting units that ensure the necessary temperature conditions. The following pressure and thermomechanical treatment of bronze pilot samples is conducted in accordance with the standard technology. The typical structures of cast chromium and chromium-zirconium bronzes are shown in Figure 1.

Bronzes obtained with the use of mechanically alloyed ligatures have high density, are nonporous and don't have microinclusions. Along with its main purpose (alloying), the developed ligatures also act as a modifier. Their fine structure is inherited by cast bronzes. The average size of the bronze grain basis is less than 1 micron, and their structure relates to the submicrocrystalline type. The alloying elements are uniformly distributed in the base. The strengthening phases after heat treatment are Cr, Zr, and probably, Cu₃Zr. The size of the strengthening phases does not exceed 0.1 μm and they are considered nanocrystalline. The changes in the structure have a positive effect on the properties of materials and they possess the following set of physical and mechanical properties: hardness - HB160 - 180, tensile strength - 500-600 MPa, tensile strain - 20-25 %, electrical conductivity - 80-82 % of the electrical conductivity of copper. In this case, the recrystallization temperature is 50-80° C higher than the recrystallization temperature of the similar bronzes obtained in a conventional way.

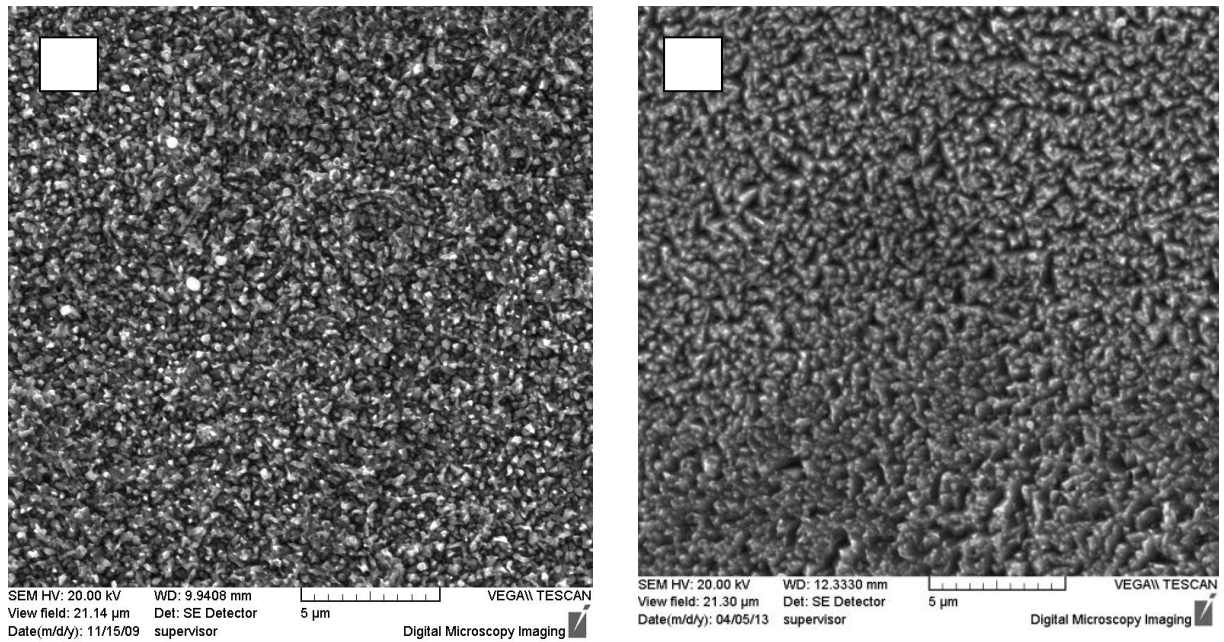


Figure 1 – Structure of chromium-zirconium (a) and chromium (b) bronze

The production tests of contact spot welding electrodes made of alloys using the developed technology were conducted at a number of leading enterprises of the Republic of Belarus ("MAZ", JSC "BelAZ", RUE "MTW", RUE "Mogilevliftmash " and others). They showed the excess of relative resistance by 1.8-2.2 times compared to counterparts in industry today.

The development of the "Technology of obtaining mechanically alloyed nanostructured modifying ligatures for the production of high-strength submicrocrystalline electrotechnical bronzes" was nominated as "The best innovative project in the field of high-tech engineering and metallurgy" at St-Petersburg Engineering Fair and awarded the first degree diploma (the gold medal).

Nanostructural Mechanically Alloyed Powders Gasometrical Spraying Method and Coatings of Them

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Classical powders for thermal spraying are multicomponent systems, complicated in their chemical composition, containing, in most cases, a significant amount of scarce elements. Industrial production technologies require sophisticated and expensive equipment, and the organization of their production demands significant capital investments, chemical methods, besides, are environmentally hazardous.

A progressive way of producing powder materials that provide acquisition of protective coatings with highly operating properties, is the reactionary mechanical alloying; when the basic burden manufactured, there appears interaction between basic substances in mechanoreactor (mechanochemical synthesis). This technology, which is easy and universal, can produce nanostructured, dispersion-strengthened powders for gasometrical coatings of various functional purposes, and it creates a considerable basis for making economically alloyed category of materials as well.

The authors of this work have developed a wide nomenclatorial range of powder materials, used for obtainment of gasometrical coatings of various purposes and possessing a unique structure and properties. The created materials make it possible to get a wide range of economically alloyed cheap powders for gasometrical anti-wear, heat-resistant and temperature-resistant coatings for various applications: for hardening of tools and constructive items that operate at high loads in heavy wear – X, X3, X6, X9, X3-DS; corrosion-resistant – 12X18H10, 15X18H10T, 15X18H10T-DS; for renovation of the structural items for general purpose – 15X2H4. The field of application of the developed nickel powders resembles the counterparts, they are promising for high-temperature corrosion-resistant refractory coatings, whose operating temperature may exceed 0.7 mp. Iron-aluminum alloys are promising materials, which coatings possess high hardness, wear resistance, good workability at higher temperatures in various aggressive gas environments. The basis of mechanically plated composite ceramic powder is a classical batch consisting of aluminum and titanium oxides, alloying components such as nickel and aluminum.

It was found during treatment in mechanoreactor that when processed in powder compositions containing oxygen, carbon, on the one hand, and metals that have high affinity to these elements, on the other, there occur mechanically activated phase transformations that lead to the formation of solid solutions of oxides and carbides, or intermediates of their bonds, and providing a dispersive and dispersed hardening that is preserved when heated to temperatures up to 1000 °C.

Formation of the matrix structure when the batch on the basis of metals being worked, has the same mechanism and occurs as a result of dynamic recrystallization process. The product of mechanical alloying is a granular composition with an average particle size of 30-60 microns. The mechanically alloyed powders are characterized by a homogeneous elements' distribution, nanocrystalline structure with a grain size of its basis less than 100 nm consisting of sub-grains of less than 50 nm, stabilized by nano-sized inclusions of hardening phases; they are unbalanced systems, in which, together with the balanced phases, there exist intermediate bonds and basic alloying components.

The product of mechanical batch alloying based on oxide ceramic containing up to 15 % of metal constituent (Ni and/or Al), is metallized metal ceramics with an average size of its powder

particles of 3-5 microns. In the processing of handling there flow phase and structural transformation which cause the formation of a complex oxide - Al_2TiO_5 and intermetallic $Ni_3(Al, Ti)$, that reduces the amount of the basic components - nickel and titanium oxide in 2 times. There is also a change in the lattice parameters of the phase $\alpha-Al_2O_3$. Manufacturing the batch in mechanoreactor causes the increase in density dislocation approximately in 5 times and the decrease of CSR in 2.5 times.

The studies showed that the steel powders of pearlite, pearlite- martensite and martensite classes as a result of multiple shock actions working bodies on the particles that cause plastic deformation, the heating of microvolumes with their forthcoming cooling, experiences the phase of framework transformation $Fe_\alpha + Fe_3C \rightarrow Fe_\gamma(C) \rightarrow Fe_\alpha(C)$, the final product of which is the unbalanced phase, similar to martensite with a thickness of the plates of a few atomic parameters. The hardening caused by martensitic transformation, is removed when heated to of 500-600 °C.

The annealing of mechanically alloyed compositions leads to transformations approximating phase composition to its the equilibrium, but not reaching it. The presence of the majority of the equilibrium phases is detected during thermal exposure above 700 °C. After annealing, the composite powders retain the nanodimensional type of structure, they become heat-resistant and in their hardness in the temperature range of 20-1000 °C they significantly exceed the counterparts, due to the complex nature of their hardening, combining solid solution, dispersion, grain boundary and dispersed with the decisive role of the latter two. This allows one to make scientifically substantiated conclusions on the prospects of the reaction of mechanical alloying technology of obtaining powders for gasometrical wear-and- heat-resistant coatings that operate in harsh temperature and force conditions.

The optimal values of the mechanical alloying process factors in a vibratory mill that provide maximum hardness of the composite powders based on iron, nickel and metal for gasometrical coatings, regardless of their composition, are practically the same and are found in the following range: the acceleration of working bodies – 135-145 $m \cdot sec^{-2}$, working media and the feedstock – 10-12, the degree of filling the milling cell with working bodies – 70-80 %, the processing time in mechanoreactor – 8-10 hours.

According to the results of experimental research the meaning of the factors of the plasma spraying mechanically alloyed powders based on iron and nickel that provide maximum wear resistance of the coatings are: current strength – 240-250 A, voltage – 190-200 V, power – 45-49 kW, spraying range – 250-300 mm, tube's diameter – 2.0-2.6 mm, the distance from the nozzle to the outlet – 4.5 mm. Optimal conditions for obtaining composite powder coatings based on aluminum oxide are in the following range: spraying distance – 100-150 mm diameter tubes – 1,4-2,0 mm, the distance from the nozzle to the outlet – 6-7 mm.

The results of the study have become the scientific basis for the development of mechanically alloyed nanostructured composite powders' manufacturing processes and the production from them the coatings using plasma spraying. Besides, these results have become the bases for design and creation of the production area for their implementation, where there have been made 12 business bargains ordered by Russian and Belarusian enterprises during the years of 2006-2010. The optimal wear-resistant composition of the coating is 1.3-2.1 times higher than that of the counterparts.

Optical Films of Polyvinyl Alcohol with Silver Nanoparticles or Carbon Nanotubes

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In recent years keen interest in studying of spectral and optical properties of nanodimensional systems of metal nanoparticles (NP) and carbon nanotubes (CNT) as a part of film structures on the basis of substances where effects of superficial plazmonny resonances are observed remains. The last in turn strongly depend on geometry of NP and properties of environment that opens possibility of control of their optical response at change of their size, a form, an environment, etc. [1]. So, the polymeric films modified by nanoparticles of silver or CNT, can be used as transmissive, thermomosture resistant polarizers [2,3], and also diffusion lenses as a part of passive sources of lighting on the basis of LCD indicators which at a certain range of corners of supervision are reflective polarizers [4].

Regularities of change of the spectral and optical characteristics determined by methods of electronic spectroscopy and a laser goniofotometric stokes-polarimetry, films from the polyvinyl alcohol (PVA), modified by silver nanoparticles or CNT by the quarternary ammonium connections (QAC), and also oriented by stretching and irradiated by UV radiation are studied.

Filling of PVA-films by nanoparticles of Ag happens at the expense of course of slow oxidation-reduction reaction when drying forming PVA of the composition containing dosed amounts of nitrate silver (0,01÷0,1 mas.%) and weak reducers: QAC (antistatik SAS) 0,1÷1,0 mas. % or glycerol (softener) 2,6÷2,8 mas. %. Macromolecules of CNT which consisted of the cylindrical tubes of sheet graphite which had diameter of 20-50 nanometers and length to several microns, entered into QAC solution and dispersed at Ultra Sonic. The mass fraction of CNT in the stretched PVA-films varied from 0,2÷2,0 mas. %, and QAC – 1,0÷10,0 mas. %.

"Wave" dependence of character and values of optical density of films on the contents in them colloidal nanoparticles of Ag or CNT, SAS and also from influence of UV irradiation, orientation by stretching is established. Methods of stokes-polarimetry spectral and polarizing (operational) properties of films (transmission, polarizing ability, birefringence, etc.) and their angular distribution were determined. Recommendations about practical use of the developed films for optoelectronics products are made.

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Liquid Crystal Photoalignment Materials Based on Reversible Intermolecular Bonds

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Photoalignment is a non-contact surface treatment that induces surface anisotropy for orientation of liquid crystals, allowing reduction of alignment defects formation upon fabrication of alignment layer. Due to unique ability to provide smooth anisotropic surface the photoalignment materials are perspective for application in novel liquid crystal based devices with low light leakage. However the common problems of known photoalignment materials are low anchoring energy and poor stability towards environmental impacts, i.e. moisture and heat.

We developed new type of photoalignment materials based on reversible intermolecular bonds (RIB) [1], remarkable for its high value of azimuthal anchoring energy above $5 \times 10^{-4} \text{ J/m}^2$ and intrinsic thermo-stability of the photoinduced molecular anisotropy up to 200°C and over. The innovative concept explains the correlation between the molecular structure and its photoalignment properties [2], which enabled flexible modification of properties of the photoalignment materials [3]. Our records of achievements are the water-compatible RIB photoalignment materials: a) water-proof materials washable with de-ionized water [4] and b) water-soluble materials for deposition from aqueous solutions [5].

The application of RIB photoalignment materials for passive liquid crystal refractive interfaces is perspective for future liquid crystal photonic devices.

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Local Modification of Graphite Films by Atomic Force Microscopy

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Graphene has unique properties due to the perfection of its hexagonal crystal structure [1]. It is characterized by low levels of defects and the high mobility of charge carriers [1, 2], which makes it a promising subject of research and makes it possible to improve the performance and reduce the power consumption of devices on its base. However, graphene cannot be practically machined, resulting in the need to find other methods of local changes in the surface properties, including electrical one.

In this paper we present a method for modifying the structure and electrical properties of graphite films by atomic force microscopy [3], which is the basis of the method of local anodic oxidation (LAO).

Electrochemical local anodic oxidation (LAO) film surface of highly oriented pyrolytic graphite (HOPG) with elements of graphene performed by the scanning probe microscope Nanoscope IIIA (Veeco, USA), with a block «C-AFM», allowing to apply a potential difference ± 12 V to the "probe-sample" system, using probes for AFM with constant rigidity 1-5H/m and conductive coatings (platinum-iridium PtIr alloy and cobalt coating with chromium sub-layer Co/Cr).

Pre-LAO HOPG scanned to detect possible defects, and then it was carried LAO process by set up the trajectory and speed of the AFM probe along the surface of HOPG, its bend (the pressure of the probe on the sample) and the voltage applied to the system "probe-surface of the sample". The effectiveness of LAO process evaluated using an atomic force microscope to measure height and width of the relief created on the surface (in AFM contact mode) and its conductivity (in C-AFM conducting mode).

LAO process under air conditions represents electrochemical oxidation of the anode, in a system where the cathode is an AFM probe with conductive coating, and an anode is modifiable surface (in this work - HOPG), the electrolyte is the water adsorbed on the surface of the sample, which is the source of oxygen. In case of LAO in a vacuum, sputtering of carbon is due to rupture of the C-C bonds under the influence of an electric current. The process of LAO is affected by resistivity, the tip radius of the probe, its spring constant, resistivity of HOPG and air humidity.

In graphene, carbon atoms are packed in a hexagonal crystalline structure and the process runs stepwise LAO as discontinuity of the valence bonds (C-C). Moreover, its velocity is very high, the oxygen stands out from the water and reacts with the carbon atoms, whereby the surface is deformed, and joined thereto various oxygen-containing groups. It is also possible the complete destruction of the graphene layer.

Thus, there are two possible modifications of the graphite during the LAO process - "sputtering" and "growth" of the material. "Sputtering" of graphite is an electrochemical oxidation of the carbon leading to carbon oxides removal from the reaction zone.

"Growth" of the surface is to join of oxygen-containing groups to the HOPG surface under the influence of an electric field, which is achieved at high speeds of the AFM probe along the surface when the break is not all the C-C bond. The result of incorporation of one-atom layer of various radicals and residues of "sputtering" materials into the lattice of graphene is an increase of its size, which is registered as an AFM hills.

It should be noted that LAO's products "growing" on HOPG, are firmly bonded to the surface and do not collapse under the influence of the probe. "Sputtering" of LAO's products (oxides and destroyed parts of graphene layer) is rather volatile and they are deposited onto the sample and the probe. Deposition onto the probe is expressed in the deterioration of the conductive

properties of the system, since all the process of LAO's products (carbon oxides, the surface-modified oxygenated groups, residues and "sputtering" materials) are insulators.

The depth range of "sputtering" of graphite was set experimentally (from 2 to 200 nm). Theoretically, maximum depth is only limited by the duration of the process. The height of the oxide formed is in the range from 0.1 to 2 nm.

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Layer-by-Layer Biopolymer Nanocapsules for Biologically Active Compounds

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New polysaccharide-based nanocapsules are of great interest as vehicles suitable for encapsulation of bioactive substances. Encasing molecules in an anocarrier enhances chemical stability and dispersibility of the substance in biological fluids, controls release of the active ingredient, enhances its bioavailability and changes tissue distribution. The nanocore/shell containers are the foundation for targeted delivery systems with enhanced blood circulation and low systemic toxicity.

Non-emulsion syntheses of stable gel nanoparticles of calcium alginate and calcium pectinate with diameters in the range of 100-250 nm and narrow size distribution were recently proposed; the range is hardly reachable by reverse emulsion-gelation technique [1,2]. The use of diluted polysaccharide solutions, permanent ultrasound treatment, certain pH and ionic strength values applied during the syntheses supports the nanosize of the particles. Utilization of stabilizers (Tween 80, polyethylene glycols (PEG)) during the syntheses further decreases the hydrodynamic diameter of nanoparticles with a factor of 1.3-3.0 and prolongs their colloidal stability up to 30 days. The stabilizers are partially remains adsorbed on the nanoparticle surface after syntheses preventing sticking in concentrated colloids. By weight, the obtained gel nanoparticles consist of more than 80 % of water and less than 20% of solid material; the values vary with polymer and synthesis conditions. Admixing bovine serum albumin (BSA) to a polysaccharide solution prior the nanoparticles synthesis allows to obtain protein/polysaccharide nanoparticles containing up to 0.58 mg per 1 mg of polysaccharide [2]; thus cores with tunable hydrophobicity were created for further modification with layer-by-layer (LbL) polyelectrolyte shell. The outer surface of the negatively charged polysaccharide nanoparticles was modified by a layer of chitosan.

Similarly, 150-200 nm soft gelatin cores were prepared and coated with multiple layers of medium molecular weight biopolyelectrolytes (dextran sulfate, poly-L-lysine, poly-L-arginine, carboxymethylcellulose, gelatin, protamine) [3].

The obtained nanocapsules consisting of a soft gel-like interior surrounded by a multilayer polyelectrolyte shell were used for encapsulation of polyphenols((-)-epigallocatechingallate, tannic acid, the aflavin) and 2-aminoarylpyrimidine derivatives (Imatinib and its analogs) with previously proven anticancer activity. The bioactive substances were encased in the developed nanocapsules in a high concentration.

The non-washing LbL assembly technique was proposed for coating soft, gel or otherwise unstable cores with diameters in the nanometer range [4]. The nanoparticle aggregation during the LbL assembly was avoided by using constant ultrasound treatment and PEG-modified polyelectrolytes. It also allows for further increasing colloidal stability of nanocapsules dispersions in salt solutions and attaining modest protein-resistant properties.

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2nd Belarus-Korea Forum
"Science. Innovation. Production"



Session:

**Nanotechnology
and Energetics**

Nanotechnology for Energy Technology Application

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The current Energy Technology (ET) has been evolving in most rapid fashion to meet the world's ever growing demands and needs. But these developments of ET need to be accompanied by the advance of Nano Technology (NT). We have been focusing on ET combined with NT research and it consists of major two topics of optical components and electric devices.

The first topic is about optical components study. We have produced GaN and ZnO by using Nano structure, Light Emitting Diode (LED), FED and Solar cell structure. To fulfill the demands of higher lighting source industry, we tried to increase injection current. But we found that the outcome fall short of our expectations due to *Droop effect*. At present, we consider that we may be able to develop highly effective LED without Droop effect by using Nano rod Multi Quantum Well. In addition, we found out that light emitting can be driven without the existing complicated LED growth and processing by simply folding two boards together. Solar cell with simple structure can be also easily produced and we also expect that it will realize energy harvest for multi-purpose by producing wind energy at nights. For the last few years, multi-functional solar cell has been tried onto clothes, in which a piece of metal functioning as a solar cell is attached on clothes to harness the solar energy. In terms of practicality, it has little practical value. Thus, we made a try to make solar cell clothes. We expect that we are able to make clothes which function as solar cells by turning fiber itself into p-n inosulation.

The above studies are the examples of ET application devices combined with NT, and we will explain each one's motion mechanism and its applicability as well.

Energy Sector of the Republic of Korea: Ideas for Studying

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Today the energy system of the Republic of Belarus is on the stage of reformation while the energy sector of the Republic of Korea experienced rapid industrial sector development during the later decades of the 20th century, also is beginning to make a transition to a service-oriented economy. But the energy systems of both republics have things in common and therefore should be studied in order to analyze the potential for using the Korean experience in the sector reformation.

Energy sector has the vertical structure in both republics. Same as SPA “Belenergo”, the state-owned Korea Electric Power Corporation (KEPCO) dominates all aspects of electricity generation, retail, transmission, and distribution. In 2001, KEPCO's generation assets were divided into six separate subsidiary power generation companies. Although the initial restructuring included plans for their privatization, KEPCO continues to wholly own each of the subsidiaries. Furthermore, KEPCO owns majority shares of KEPCO Engineering and Construction, Korea Nuclear Fuel, Korea Plant Service and Engineering, and Korea Electric Power Data Network.

KEPCO's total generation capacity was 67,005 MW as of the end of 2011, accounting for 88.4% of the country's total capacity. SPA “Belenergo” total generation capacity today is 8,488 MW.

The Korea Electric Power Exchange (KPX), also established in 2001 as part of the electricity sector reform efforts, serves as the system operator and coordinates the wholesale electric power market. KEPCO continues to act as the electricity retailer, and controls transmission and distribution.

The energy sector in both countries is influenced much by the state regulation. The Electricity Business Act of Korea makes the Ministry of Commerce, Industry and Energy (MOCIE) primarily responsible for the economic regulation of the electricity sector. An electricity tariff pricing system is designed to protect low-income residents and industrial consumers. That is why the system of subsidization, same as in Belarus, also exists in Korean energy sector. Electricity tariffs vary on the basis by the voltage. The basic tariff structure is a two-part.

With its lack of domestic reserves South Korea is a major energy importer, importing nearly all of its oil needs and being the second-largest importer of liquefied natural gas in the world behind Japan, the third largest importer of coal, and the fifth largest importer of crude oil.

Total primary energy consumption, which stood at 43.9 million tons of oil equivalent (toe) in 1980, increased more than six-fold to 275.7 million toe in 2011, ranking Korea as the 10th largest energy consuming nation in the world.

Although oil accounted for the largest portion (42 percent) of South Korea's primary energy consumption in 2011, its share has been declining since the mid-1990s, when it reached a peak of 66 percent. This is attributed to the steady increase in natural gas and nuclear energy consumption. The government plans to dramatically increase the nuclear share of total energy consumption in the near future as planned reactors are built.

Oil represents 34% of energy sources for final consumers, followed by heat (28%). Gas accounts for 19% of consumption, electricity for 12%, biomass for 5% and coal for 2%.

Gas represents the largest share of primary consumptions (65%), followed by oil (25%). The gas is primarily used to supply the power plants.

The figures for Belarusian electricity generation in both republics have the tendency to grow.

South Korea has the sixth-highest nuclear generation capacity in the world. Korea Hydro & Nuclear Power Co. currently operates South Korea's four nuclear power stations, with 20 individual reactors. Fourteen additional reactors are scheduled to be completed by 2024, with the goal of

generating nearly half of the power supply from nuclear sources. Emerging as an international leader in nuclear technology, Korea is pursuing opportunities to export its technologies.

Nowadays the nuclear power plant is also being built on the territory of Belarus. Russian company is the contractor to build the nuclear power plant. The first reactor is expected to be operational by 2016-2017, and the second one by 2018-2020. The first two reactors will have the combined capacity of around 2400 MW. It is possible that two additional reactors will be built by 2025.

A renewable portfolio standard for South Korea became effective in 2012 with a beginning renewable electricity quota of 2 percent of total generation. Renewable sources remain a small share of South Korea's electricity generation, with hydropower being limited to small dams on the Han River, and a 1 billion kW pumped-storage facility at Yangyang. In response to global trends, the Korean government came up with the 3rd Basic Plan for New and Renewable Energy Technology Development at the end of 2008 with the goal of replacing 11% of primary energy with renewables by 2030.

The share of renewable energy sources in Belarus is also relatively small but the National program of local and renewable energy sources for 2011-2015 requires further development of the sphere. In 2012 the share of renewable energy sources in the gross consumption of fuel and energy resources in Belarus amounted to 5%.

To summarize the mentioned above it should be said that in order to proceed the sustainable development of the Belarusian energy sector the experience of Korea in the fields of sector reformation and nuclear plants building and further operation is to be studied or partially implemented.

Energy Recovery from Natural Gas Letdown Stations

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Every industrial process creates at least some waste heat or secondary energy sources. A rational solution is to recycle this industrial waste energy in the actual manufacturing process - regenerative usage. Likewise, this waste energy can be used as a secondary energy source, which consists of three main groups: gas overpressure, waste heat and combustible waste.

The main sources of waste heat are technological devices, which are typically energetically inefficient.

One potential secondary energy source is the overpressure that results from lowering natural-gas pressure to meet consumer specifications. In order to be transported through pipelines, natural gas has to have a very high pressure. At this level of pressure, however, it cannot be used by consumers, which means that it has to be forcibly lowered. This creates energy losses. Natural gas pressure is reduced in two steps. First, it is lowered at a gas-regulating station, where the pressure goes from a range of 3,5 – 7,5 MPa to a range of 0,3 – 1,2 MPa. Then, at gas control points, it is reduced to a range of 0,005 – 0,6 MPa. Water steam is treated similarly. Many industrial boilers produce steam with a pressure range of about 1,3 MPa. To make it usable, it needs to be at 0,3 – 0,6 MPa. The pressure has to be reduced through a throttling process.

Secondary energy sources can be recovered by using machines that convert energy streams into a more valuable energy form. Most frequently, the most useful forms are electrical and mechanical energy, due to their widespread use and the need for high exergy value. Low-grade thermal energy does not satisfy modern requirements. Frequently, the secondary energy sources produced by manufacturers significantly exceed their needs for low-temperature heat.

For this purpose, different types of machines can be applied: turbines, piston engines, screw engines, etc. Each year, turbines are getting more popular in small-energy production. This is due to certain advantages, such as the direct transfer of torque to the electric generator, the small number of moving parts, etc.

Turbines with a large capacity (several megawatts) are nowadays applied in industrial systems with large and continuous streams of secondary energy sources. In order to increase the number of possible sources of energy recovery, it is necessary to create low-power machines that can recover small amounts of energy streams with low-potential parameters.

This is made possible by microturbines, which expand the range of objects that allow secondary energy recovery. Existing steam and gas turbines have some disadvantages. It is necessary to improve microturbine designs to make them viable energy recovery machines, while simultaneously increasing the efficiency of the transformations.

The new type of microturbine is developed by the specialists of “Scientific and Technological Park of the BNTU “Polytechnic” is called TurboSphere. It simultaneously combines several units, such as a turbine, a heat exchanger, and a power generator. TurboSphere has only one blade wheel, and its multistage gas-flow expansion is performed by heating gas between stages.

The electrical power of the turbines ranges from 5 kW to 500kW, depending on the characteristics of the energy sources. The TurboSphere is a compact machine, with only one moving part - a blade wheel with a diameter from 300 mm to 700 mm. This blade wheel’s rotational velocity can reach 3000 rpm or more. It requires neither a high-velocity electric generator nor a reduction gear. Its dimensions allow for the TurboSphere to be placed indoors or outdoors.

The turbine's original design and concept allow for earlier implementation of complicated power cycles. Allowing the use of any type of steam or gas as a working fluid, this process creates a wide spectrum of input and output characteristics, including flow rate, pressure, and temperature.

This innovative turbine performs the following tasks:

- 1 Power generation from waste heat using the Organic Rankine Cycle (ORC);
- 2 Electricity production from low-potential fuel, such as trash and wood;
- 3 Recovery of natural gas overpressure at gas stations;
- 4 Conversion of steam overpressure energy into electricity during steam throttling, minimizing energy loss.

It is possible to integrate the TurboSphere into sources of alternative energy, such as geothermal and solar energy.

The energy market requires small, cheap, and highly efficient micro turbines for the recovery of secondary energy sources. In addition to having these traits, the versatile TurboSphere will be compatible with a wide range of energy sources and their necessary parameters.

Development of Metal Composite Materials with Macroheterogeneous Structure for the Application in Friction Pairs Working in Heavy Conditions

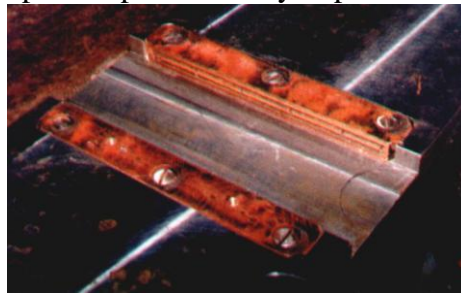
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The development of new materials with improved service is the very important for material science. Metal Composite Materials with Macroheterogeneous Structure (MCMMS) were developed in Belarusian national technical university for usage in heavy working conditions. Here was created new compositions of MCMMS based on the Cu- based matrix reinforced with rapidly solidified iron base granules. MCMMS are able to work under the high specific load matched with low sliding velocities and the elevated temperature when most tribological materials are unable to perform.

The production of MCCM parts is based on the casting technology. As a result the cost of these composite materials are lower compared to ones manufactured via a powder metallurgy route. The additional advantage is that the secondary nonferrous alloys and scrap can be used to cast composite parts. The casting technology is characterized with good flexibility resulting in the production of parts of the complex shape without any limitations in parts' sizes.

Casted composite materials were successfully applied to produce parts for the installation under the frame of the turbine's bearings support aiming the normalization of the turbine's thermal expansion.

Moreover some roller bearings can be replaced in friction units with plain bearings made of MCMMS. It is especially useful when the friction pair is working under the elevated temperature as the composite materials developed keep their ability to perform at the temperature up to 500 °C.



MCMMS plain bearings for the application in the system of the steam distribution

Another attractive feature of the MCMMS is the ability to form the friction film resulting in the considerable reduction of wear and the increase of the service life.

The additional increase in the reliability of friction parts and the service life can be achieved with the application of solid lubricative coatings, which are modified with special additions.

The question of reception of composite materials with macroheterogeneous structure sharply stands in global engineering. The given type of materials can be used both as pairs friction, and for other needs.



MCMMS parts in the friction unit to normalize the thermal expansion of the turbine

Also as an aspect of studying composite materials have been accepted on the basis of the Al- based matrix reinforced with rapidly solidified iron base granules in diameter from 1,0 up to 1,2 mm. The way of introduction grains has been accepted as cast-mechanical.

For revealing optimum technology of reception of the given composition for a basis two kinds of moulding have been accepted, under normal and nonequilibrium conditions. It has been revealed, that at casting in equilibrium conditions incomplete wettability of reinforcing phases is observed, that at drives to formation of emptiness and shrinkable bowls. At use of nonequilibrium parameters this factor is out, thus growth dendrite structures of a matrix goes in a normal mode.

For use of any material as pair friction it should be investigated on tribotechnical properties.

Tribotechnical tests of samples of a composite were carried out on automated triometer unit, equipped by specially developed device for registration of factor of friction. At tests the counterbody made of tempered steel, with average speed of mutual moving $\cong 0,1$ m/s was used.

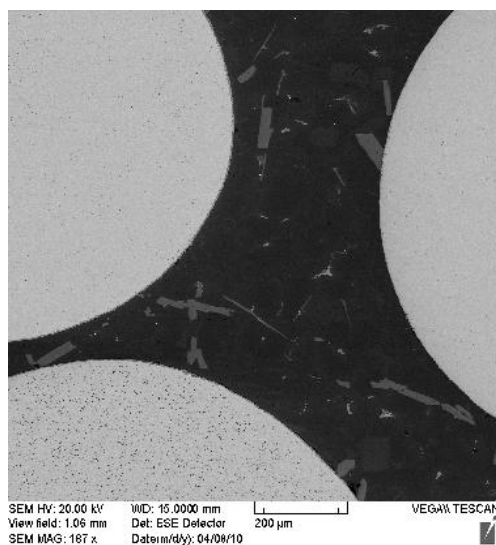


Image of Al – Fe composite Material

Specific loading made 2,0 MPa. Tests were carried out up to achievement of 15000 cycles with intermediate weighings after everyone 2000-5000 cycles. The way of friction for a unitary cycle of test made 0,06 m. The general way of friction at tests made 920 m. The copper counterbody has been revealed, that in process extra earnings of the rubbed pair aluminium samples and, for example, become covered by a film of secondary structures. Thus friction is stabilized at loadings 0,5-2 MPa. Aluminium materials on antifrictional properties come nearer to properties of widely widespread electrocontact materials on an iron basis with lead, and under electric characteristics surpass them in 3 times.

Wye-Connected Current Transformers Mathematical Model Implementation in Simulink – Simpowersystems Environment

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The reliability of power system operation depends on the correct relay operation.

Current transformers (CTs) are used to reduce the value of flowing currents in power system to values, which are convenient to measure and also to ensure the secondary device isolation from the primary system.

Properly selected CT supplies protection devices with undistorted secondary current. Otherwise, there is a CT iron core saturation, which can lead to protection device malfunction. Theoretically, the saturation can be avoided if all affecting the accuracy factors are taken into account during CT parameters selection. In practice, this leads to unacceptable CT dimension increasing.

Modern microprocessor-based protection relays can operate even at certain CT error level. Therefore, the complete CT saturation exclusion is not required, and the choice of CT parameters must be based on recommendations provided in instruction manual for the specific protection device.

Mathematical model of the wye-connected CT's based on the mathematical model of the single CT. The model is implemented in Simulink environment using SimPowerSystems block library, which contains a lot of electrical device models, however standard CT block is absent in it. This significantly limits the Simulink – SimPowerSystems environment usage for modeling a protection device, which obtain the information about the flowing current value from the CT secondary winding.

Wye-connected CT's model includes three models of the single CT, combined into a TA-Y block (fig. 1). Particular attention in the model was paid to the saturation characteristic of the current transformer core.

Studies were carried out using electrical network model (fig. 1).

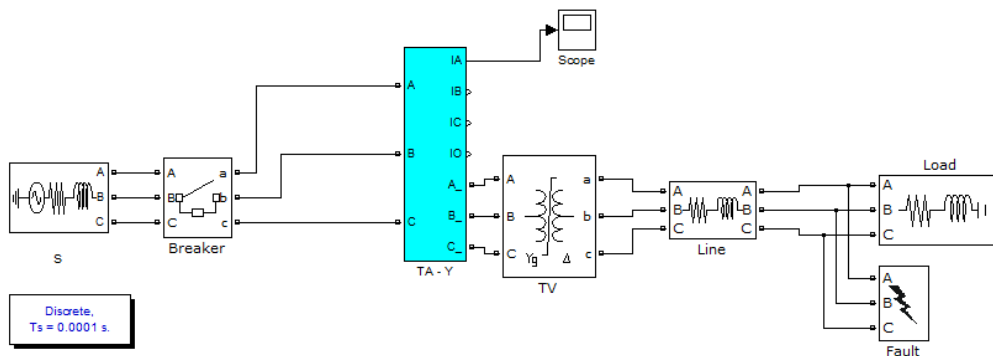


Fig. 1

10 km long 10.5 kV line is powered by a 115/10.5 kV, 16MVA transformer with the nonlinear magnetization characteristic.

As the result of calculations the distorted curve of the CT secondary current was obtained. This distorted secondary current shape is caused by the power transformer and wye-connected current transformers magnetic systems deep saturation. In the secondary current is clearly expressed the 2nd harmonic, which level decreasing with time.

Similar results were obtained during three-phase and phase-to-phase line faults simulations.

TPL-10 type current transformer case study confirmed the adequacy of the mathematical model implementation and the possibility of its usage for engineering analysis.

Features of Implementation of Microprocessor Transformer Differential Protection

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OJSC "Belektromontazhnaladka" is the leader among Belarusian companies in the development and manufacturing of microprocessor-based relay protection and automation. The system of relay protection and automation 6-110 kV substations can be completely realized on terminals which produced by "Belektromontazhnaladka."

The terminal of the differential transformer protection MR801 is one of the recent developments. Production of MR801 was organized to ensure the Belarusian power system with modern domestic product, which reduces spending for buying expensive foreign equipment.

MR801 are provided with the following function package:

- differential current stage with restraining;
- differential current stage (cut-off) without restraining;
- 3 stages of differential zero-sequence current protection;
- 8 stages of directional overcurrent protection;
- 6 stages of directional zero-sequence or negative-sequence overcurrent protection;
- 4 stages of overvoltage and 4 stages of undervoltage protections;
- 16 stages of external protections which controlling external signals;
- automatic transfer of transformers supply;
- automatic reclosure of transformer;
- monitoring and operation automatic of one transformers breaker;
- breaker failure protection;
- user-defined logic.

The MR801 terminal has 16 analog and 26 discrete inputs. Input current and voltage signals are turned into the voltage signals which pass analog filtration. Then signals are digitized by means of a 16-bit ADC. Analog second-order filters with 1 kHz frequency cut-off in MR801 are applied.

Sampling rate of 1 kHz (20 samples across period) to provide required measurement accuracy and signal processing speed are chosen. The orthogonal components of analog signals are obtained by digital processing with the Goertzel algorithm. The Goertzel algorithm is special case of fast Fourier transformation. A RMS-value is calculated in 10-millisecond cycle on the basis of 20 samples. As a result of calculations currents of transformer windings, differential current (fundamental, second and fifth harmonics), bias current, phase and line voltages data arrays can be obtained. The operation of differential, overcurrent, zero-sequence and negative-sequence overcurrent, voltage protections, automatics and user-defined logic is implemented on the basis of those data.

The differential protection with restrained operate characteristic provides reliable transformer's protection against internal faults. Differential protection has absolute selectivity and supports tripping of internal faults with no time delay. However, there are some conditions when differential current is not accompanied with internal fault:

- magnetizing inrush current (MIC) at no-load switching on of transformer. MR801 has second harmonic restrain against maloperation of the differential protections during MIC;
- current transformer (CT) saturation during the external faults. The special algorithm of offsetting from external faults accompanied with CT saturation implemented in MR801 terminal;
- overexcitation of transformer. MR801 has fifth harmonic restrain against maloperation in this case;
- tap changer operations. MR801 settings calculations take into account imbalance of differential current which occurs due tap changer operations.

The disadvantage of the differential stage with restraining is delayed operation during internal faults accompanied with CT saturation. To overcome this problem MR801 provides fast tripping stage - differential cutoff without restraining. The differential cutoff setting is chosen more than the maximum current of external fault.

The terminal of the differential transformer protection MR801 passed complex laboratory tests as well as field testing on Belarusian power system. The results of tests showed that the differential protection unit MR801 reliably identifies internal faults. In addition MR801 did not form tripping signal during the process of external short circuit with CT saturation, and also when magnetizing inrush current occurred. MR801 is successfully operated in Belarusian power system now.

The Main Economic Problems of the Energy Sector of the Republic of Belarus

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Belarus is a country with a stable and rapidly growing economy. From 2000–2012, the gross domestic product (GDP) grew at an average annual rate of 7%. Factors associated with economic growth include the government's focus on policies regarding social and economic development, external market conditions, which are favourable for export, growing domestic demand and productivity of labour. The energy sector plays a key role in the development of the national economy. The goal of Belarus' energy policy is to ensure a sustainable energy supply for consumers through improving the energy security of the country, maximising the efficient use of fuel and energy resources and the potential of the fuel and energy complex and reducing the dependence on energy resources imports in parallel with using the benefits of Belarus' geopolitical position as a transit country for energy trade between Russia and the European Union.

One of the problems which appeared due to the strict government regulation of the electricity sector is so-called "cross-subsidization". Nowadays the mechanism of energy prices does not fulfill its stabilizing function and this causes significant damage to the economy of the country.

The current energy policy has two major disadvantages: first, the need to sell electricity at rates with preferences leads to an additional economic burden on the state energy companies. Second, the policy of selling electricity at low prices stimulates excessive consumption and does not provide sufficient preconditions for energy conservation.

In order to avoid these disadvantages it is appropriate to fund the given preferences by the entire society, not the state energy companies, as this kind of help is the obligation of society.

Belarusian authorities generally understand the complexity of the situation and try to solve it.

The recent goal for the next five years stated by the Belarusian authorities is to route about €3.4 billion of investment in the energy sector. This includes €1.8 billion for the modernization of the existing power plants, €1 billion - for energy saving measures and about €0.6 billion for increasing the share of local fuels in the energy mix. The main disadvantage of the program is that it is focused on the provision of the energy-intensive economy by the electricity and heat. It should be underlined that considerable work has been done in this direction: in the past 9 years energy consumption in Belarus decreased by 40% and the gross domestic product (GDP) grew by 65%. The fuel balance structure also changed a lot. In particular, the consumption of coal today is four times lower, of fuel - 3 times lower, while the share of gas increased to 65% . At the same time in order to produce one dollar of GDP 4-5 times more energy is consumed than in Western countries. Belarus consumes approximately 2 times gas and electricity per person more than the European average.

Nowadays one of the most important issues in this direction is motivating households to save energy, which implicates the reform of the household sector. Today the households consume about 20% of all electricity and 60% of heat produced in Belarus.

Over the past year in addressing these issues has been done serious work. On 1 February 2013 the population of the Republic of Belarus pays the electricity consumed by a three-stage system based on the amount of electric energy consumption during the month. This decision was confirmed by the Council of Ministers of №63 from January 26, 2013. It is expected that this system of payment in the long term will lead to significant savings in residential electricity.

Having created an effective motivating system, state can attract inward investment into energy saving equipment and technologies that will be more beneficial for Belarus than complicated way to new energy sources.

In 2013 electricity tariffs for households were increased five times: in January, February, June, August and September. Single rate for electricity in houses equipped with electric stoves, during the year increased by 91% to €0.037 per 1 kWh. The tariff for houses not equipped with electric stoves is now stands at €0.044 per 1 kWh (increased during the year by 91%).

According to the Ministry of Finance, the profit of RUE "Minskenergo" in 2012 amounted to €2.2 million, RUE "Vitebskenergo" – to €24.8 million, RUE "Gomelenergo" - €10.5 million, RUE "Grodnoenergo" - €7.1 million, RUE "Mogilevenergo" - €2.6 million.

The increase in tariffs for electricity for households at the beginning of this year allowed the state energy companies to obtain additional profit. However, its size cannot cover the entire debt for natural gas that has accumulated on the results of the recent years. The satisfactory financial results of the state energy companies in the year 2012 first of all provided the possibility for the state energy companies to cover the shortfall that formed in 2011 from insufficient level of tariffs that did not compensate the costs. However, the state energy companies in 2013 are still in debt for natural gas that was set in 2011-2012.

Despite a significant increase in tariffs, the cost of electricity for households in 2010 - 2013 decreased from €4.1 to €2.7 cents per 1 kWh (1.5 times). What is one of the reasons for the deficit. In order to cover the losses from cross-subsidizing the state energy companies require additional funding. It should be noted that the cost of electricity for industrial users in 2006 – 2013 increased almost 2 times (from €5.2 to €10.3 cents per 1 kWh).

Regional Peculiar Features Pertaining to the Use of Renewable Energy Sources

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The current stage of development in economics presupposes constant monitoring of costs with the purpose to ensure efficient management of enterprises. According to the global tendency concerning increase of energy consumption and simultaneous increase of price for all types of energy resources it is necessary to work for reduction of energy consumption rate in total/aggregate expenses of the enterprise. First of all, reduction of energy output ratio is ensured by energy saving measures. The energy saving problem is considered as an actual one practically for all civilized countries in the world. As for the Republic of Belarus, this problem is rather important and actual because the country does not have its own reserves and deposits of mineral raw materials, and it entirely depends on suppliers. The increase in natural gas prices has recently entailed increase in expenses of gas-supply companies, price of natural gas for consumers in the Republic, tariffs in energy, and as result of it prices on the products of power-consuming enterprises of the Republic have been also increased. Therefore, one of the main tasks of the country at this moment and for the future is to solve problem pertaining to energy saving. The strategic goal of the energy saving for the period up to 2015 is to reduce energy consumption of Gross Domestic Product (GDP) of the Republic of Belarus by 50% in relation to the level of 2005 and increase ratio of local and renewable energy sources (RES) in the fuel balance.

The main types of local fossil fuels in the Republic of Belarus are peat, lignite/brown coal, oil shale. From the point of view of today's situation when the country annually recovers approximately 2 million tons of oil its oil security is estimated for the period of 35 years. Annual production of dissolved gas is about 500 million m³. It is necessary to point out the fact that in accordance with the predictive assessment of 1998 the initial total recovered oil resources constitute 355.6 million tons, 48% of the oil resources are transferred in industrial sector. The structure of the energy balance can include residues of oil processing, so-called cracking residues.

There are about 9,000 deposits with total peat reserves of nearly 5.5 billion tons on the territory of the Republic of Belarus. However, many deposits are located either on agricultural areas or in natural reserves that reduces the possibility of peat digging up to 100-130 million tons.

Earth interior of the Republic of Belarus contains about 11 billion tons of oil shale, its calorific value is within the range from 4.19 to 6.7 MJ / kg and its ash content is from 61 to 82%. According to the calculations of Belarusian scientists, replacement of natural gas with shale oil at the condensation power plants will give an effect which is equal to 6 US dollars per every generated MWh of electric power.

While estimating resource saving potential in the Republic of Belarus it is necessary to pay a special attention to the use of renewable energy sources. It is supposed that ratio of renewable energy sources (RES), local fuels and domestic energy resources in the energy balance of the Republic of Belarus will be increased up to 28% by 2012 and up to 32% by 2015, respectively. It is planned to construct 161 local stations using fuel wood by 2015. Such approach will permit to replace about 500 million m³ of natural gas. According to estimations of the UNECE experts (the organization is implementing a large-scale project on the CIS territory which is to develop renewable power generation) Belarus possesses a great potential for energy production from biomass. Today ratio of biomass in the RES balance is close to 50%. Provision is made for construction of biogas complexes using agricultural wastes production; such complexes will be also constructed in the network of housing and utilities infrastructure while using sludge deposits of sewage treatment plants and gas extracted from solid municipal waste dumps. 39 biogas complexes should be put into operation in 2012. It is expected to construct more 146 similar plants within period of 2013-2015 that will allow to replace nearly 400 thousand tons of standard oil.

The problem pertaining to reduction of dependence on supplied fuel resources is rather actually for a great number of countries, including Vietnam as well. Vietnam has various renewable energy sources such as solar energy, wind energy, small hydro energy, geothermal energy, biomass and biogas energy and ocean energy (tides, ocean waves, course etc.). The potential of renewable energy sources in Vietnam is rather significant but at the present moment the ratio of RES usage is low due to some reasons such as: low technological level, insufficiently accurate estimation of potential, absence of the stimulation component for energy saving, high self-cost of power generation using renewable energy sources, poor competitiveness in comparison with conventional energy sources.

The recent data have shown that power generation from renewable energy sources constitutes about 1.8% of total electric-power production in Vietnam.

Vietnam is a country that has a great potential for the use of solar energy. However, the terrain is complicated so there is no possibility to use this energy to the full extent. The national average index of solar energy radiation is 4-5 kWh/m² per day. Nowadays solar energy in Vietnam is used for various purposes but its main usage is to heat water. However due to climatic conditions the use of solar energy for electric-power generation is not very effective that results in high self-cost (US\$ 0.6 /kWh or 8000 Vietnam dong per 1 kWh).

Being located in the zone of the tropical monsoon climate, Vietnam is considered as a country with rather large potential of wind energy. According to the Meteorological World Organization total theoretical potential of wind energy in Vietnam is more than 100,000 MW (wind speed 7 m/s and more). The total capacity of wind power which is used at the present moment is about 30.8 MW. Today Vietnam has 42 wind power projects with a total capacity of 3.906MW and these projects are at various stages of development.

Vietnam is an agricultural country so it has a large potential of biomass energy. From the point of view of operational efficiency (ratio of the obtained capacity to potential) biomass is considered as the most used and efficient energy source in Vietnam (18.75%). Biomass energy in Vietnam can be obtained from secondary agricultural products (straw, rice hulls, bagasse etc.), domestic wastes. According to the "Plan for Development of Electric Power in Vietnam for the period of 2006-2025" the potential of biomass energy in Vietnam amounts tons early 400-600 MW including 100-150 MW of rice hulls, bagasse - 200-250 MW, wood waste - 5 MW, straw - 100-150 MW.

Main sources of raw materials for biogas production in Vietnam are animal and vegetable. The estimated potential of biogas in the country is equal to more than 3 billion m³ per year and is used mainly for cooking process.

Vietnam has a ramified river system: 90% of the rivers are small and they are suitable for development of small hydropower (0.1-30 MW). The total potential capacity of small hydropower in Vietnam is estimated at 3000 MW. About 300 MW have been put into operation up to the present moment.

The Republic of Belarus and Vietnam have one common problem in the use of renewable energy sources. It is expedient to unite efforts of researchers and practical persons with the purpose to solve these problems. This cooperation can be executed in various forms:

Development of concepts for the use of certain types of renewable energy sources;

- Development of technologies for electric-power generation from renewable energy sources;
- Development of tariff methodology for energy from renewable energy sources;
- Decoding of ecological component in energy tariff;
- Development of legislative framework for the use of renewable energy sources and energy saving.

Determination of Optimal Load Factors for Transformers of Distributive Electrical Networks

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Optimal or near optimal transformers loading of distributive power networks can be achieved with two main ways. The first one is based on the calculation of optimal load and connecting this load to the transformer. The second way implies replacement of existing transformers with new ones, having optimal nominal power. The aim of this research is to developed model to determine optimal load factor for transformers.

The minimum of relative cost of electric energy transmission C_t was used as optimal criterion:

$$C_t = \frac{S}{W}, \quad (1)$$

where

S – total cost of electrical energy transmission, \$;

W – quantity of electrical energy, transmitted to consumers, kWh.

First of all instead of original network the authors explored the network equivalent to it. This equivalent network consists of two resistors connecting in series and have the same energy losses, which lines and transformers of original network have. Optimal load factor k_c for this equivalent network can be calculated using the following equation:

$$k_c = \sqrt{\frac{pK + \Delta W_n \cdot \beta}{\Delta W_l \cdot \beta}}, \quad (2)$$

where

pK – annual operation and repair cost, \$;

ΔW_n – annual non-load energy losses, kWh

β – electric energy tariff, \$/kWh;

ΔW_l – annual load energy losses, kWh.

To use equation (2) to the single transformer isn't correct, because k_c means optimal loading of the whole network. Obviously, k_c and optimal load factor for single transformer may be different. That is why, it's necessary to calculate optimal load factor for each single transformer of the network.

Mathematical model to determine optimal load factor represents system, consisting of n equations, where n – number of transformers. After simple transformation, this system has form (3).

$$\left\{ \begin{array}{l} \left[k_1 \cdot S_1 \cdot T_1 \cdot \sum_{j_1=1}^{m_1} r_{j_1} \right] \times \frac{1}{\cos \varphi_1} = \left[k_2 \cdot S_2 \cdot T_2 \cdot \sum_{j_2=1}^{m_2} r_{j_2} \right] \times \frac{1}{\cos \varphi_2}; \\ \left[k_2 \cdot S_2 \cdot T_2 \cdot \sum_{j_2=1}^{m_2} r_{j_2} \right] \times \frac{1}{\cos \varphi_2} = \left[k_3 \cdot S_3 \cdot T_3 \cdot \sum_{j_3=1}^{m_3} r_{j_3} \right] \times \frac{1}{\cos \varphi_3}; \\ \dots \\ -E + \frac{\beta}{\cos \varphi_i} \left[2k_i \cdot S_i \cdot T_i \cdot \sum_{j_i=1}^{m_i} r_{j_i} \right] \times \sum_{i=1}^n (k_i \cdot S_i \cdot T_i \cdot \cos \varphi_i) - \beta \cdot F(k_i) + \\ 2 \cdot \frac{\beta}{\cos \varphi_i} \left[\sum_{j=1}^m r_{j_i} \cdot \sum_{i_j=1}^{n_j} k_{3i_j} \cdot S_{i_j} \cdot T_{i_j} \right] \times \sum_{i=1}^n (k_i \cdot S_i \cdot T_i \cdot \cos \varphi_i) - \beta \cdot G(k_i) = 0 \end{array} \right. \quad (3)$$

where

m – total number of lines and transformer summary;

k_i – optimal load factor of the i -th transformer;
 S_i – nominal power of the i -th transformer, kVA;
 T_i – hours of using peak power of the i -th transformer, h;
 $\cos\varphi_i$ – power factor of the i -th transformer;
 r_{ij} – equivalent resistance of network for the i -th transformer, Ohm;
 E – some constant value;
 $F(k_i), G(k_i)$ – some linear function of k_i .

The solution of system (3) allows to calculate the exact values of the optimal load factor for each transformer.

Developed mathematical model was used for optimization of real electrical network, consisting of 5 transformers. The results and comparison of two way of optimal loading are shown in table 1.

Table 1 – Results and comparison of two ways of optimal loading

Indicators	Optimal load of equivalent network	Optimal load of single transformers
Load energy losses in lines, kWh(%)	9,15(0,53)	9,17(0,52)
Load energy losses in transformers, kWh(%)	22,97(1,33)	23,98(1,36)
Non-load energy losses, kWh(%)	28,84(1,67)	28,93(1,64)
Total energy losses, kWh(%)	61,14(3,54)	62,08(3,53)
Quantity of energy, transmitted to the network, kWh	1727,07	1759,45
Relativity cost of energy transmission \$/kWh	2,311	2,303

Table 1 shows, that difference between total energy losses for two ways of optimal loading achievement is not significant. This result allows to use simplified calculations and analysis based on the equivalent networks for real networks.

Conclusions.

1. The authors developed algorithmic method to determine optimal load factors for transformers of distributive electrical networks 6-10 kV.
2. In order to rapidly identify "hot spots" of losses in real distributive networks, it is possible to carry out calculations and analysis based on networks equivalent to original.
3. Calculation of the real electrical networks with optimal load factors allow to determine the economically justified levels of electric energy losses and use them for the development of corrective actions.

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Improving the Efficiency of Biomass-Fired CHP

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Relevance of the biomass use in the energy sector significant increase in the last decade, due to the cost of traditional fossil fuels. In many countries, one of the most important decisions made in recent years in order to improve energy security, is to increase the use of local and renewable energy resources. Increase ratio of wood, peat, straw, municipal waste, sewage and waste energy to produce electricity and thermal energy are foreseen. Also the introduction of biogas, wind energy and solar thermal systems, heat pumps, construction and rehabilitation of hydropower plants.

The main purpose of this work is the development and commercialization of technologies for the creation of biomass fired combined power plant and output technology for industrial production. The use of biomass will let to create small-scale CHP with high efficiency, to achieve a system fuel economy and reduce emissions of greenhouse gases. This work can be considered as part of a comprehensive program for the development of bio-energy in Belarus (and other CIS countries) based on the use of renewable energy sources.

For the combined production of electricity and thermal energy in this context, the most appropriate use peat, wood, pellets, straw and agricultural waste as a fuel. Currently, the most used cogeneration technologies are based on water or organic fluid steam usage in various types of heat engines (reciprocating and screw machines, turbines). These technologies are well tested and fairly well understood. In the CIS countries, recently special interest to the technology of organic Rankine cycle (ORC) was shown. A characteristic feature of ORC is use a working organic fluid, which thermal and physical properties allow to obtain a higher electrical efficiency compared to the water steam. If the boiler equipment on local fuels produced in the territory of the CIS countries, the ORC turbine generator manufacturers do not. In the world there is a relatively small number ORC-manufacturers Turboden (Italy), GMK (Germany), Adoratech (Germany). It is well known that the cost of power equipment not determined its production cost, but fuel cost. So today the cost of ORC - generating unit is about 2.0 thousand euro per kW of installed capacity, and taking into account the cost of the boiler and auxiliary equipment is 4.5-6 thousand Euro per kW of installed capacity.

One of potentially promising areas for biomass use for energy purposes is the use of externally-fired gas turbine (EFGT). The structure of gas turbines similar to the open-type gas turbine. The difference is that the heat supplied to the gas turbine produced not by direct air combustion, but using a high-temperature heat exchanger. It is possible to use two options:

- for a completely closed cycle air, helium or hydrogen are used as a working fluid.
- if air is used as a working fluid, after EFGT it can be used for biomass fire instead reuse cycle. In this case, the working fluid is constantly changing, and the compressor all the time gets fresh air.

The EFGT units have two advantages. On the one hand, the utilization of waste heat from the turbine in a recuperative process increases the efficiency and, on the other, the possibility of burning "dirty" fuel.

In our opinion, units combining several technologies deserve consideration. For example, the combination of a EFGT and ORC turbine.

Our analysis of this biomass fired technology, showed the need for research on the development of technological schemes of combined technologies and equipment for Biomass fired combined power plant, which electrical efficiency can reach 25 - 40 %, and allow them to compete with traditional technologies on natural gas. These results were obtained according to the numeric experiment and show prospects of the considered energy application.

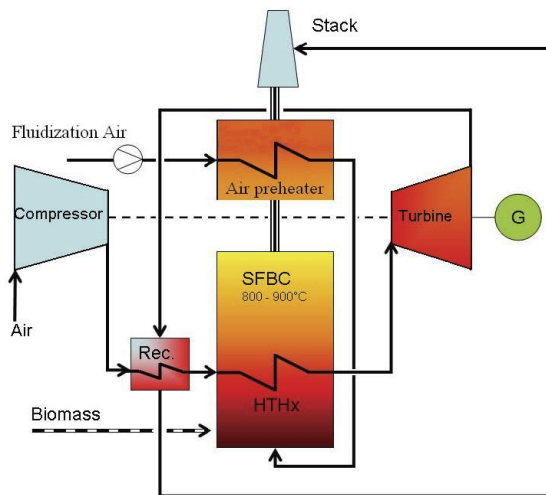


Fig. 1 – EFGT-Cycle.

In our opinion, the main problem in the creation of biomass fired EFGT-Cycle ORC unit is in the construction and manufacture of heat transfer equipment, such as high temperature heat exchangers (biomass fired exhaust gases /working fluid gas turbines).

Also subject of further investigations is working fluid selection of EFGT cycle and for this unit in particular. The working fluid must have good heat-transfer properties, low aerodynamic resistance, allow minimizing overall size of gas turbine and compressor, being capable of air substitute in case of emergency, being cheap and available.

Currently, based on nuclear reactor operating experience, there are several substances and mixtures, that could be used in EFGT technology. This working fluids and mixtures have one or several advantages as abovementioned. These are first of all helium He, air. Also argon Ar, neon Ne, krypton Kr, xenon Xe, carbon dioxide CO₂, nitrogen N₂, nitrogen oxide N₂O₄, sulfur hexafluoride SF₆ [3]. And mixtures [4] as (He+CO₂), (He+SF₆), (He+C₆F₆), (He+N₂), (He+Xe).

Conclusions

There are limited generating technologies that produce heat and power using biomass as fuel. Parts of these technologies are at research and development stage, others – commercialized.

Creation of effective biomass fired combined power plant, based on an externally-fired gas turbine help to achieve 25 - 40 % electrical efficiency that made such units attractive even in comparison with the gas fired CHP.

The potential customers for biomass fired combined power plant can be as small farms, settlements, located in energy-deficient areas and large enterprises, heading for the natural replacement of fossil fuels with renewable, environmentally friendly fuel.

New Power Efficient Industrial Technologies for Induction Heating

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In the framework of the Program for engineering modification and modernization of casting, galvanic and other power-intensive productions for 2010–2015 approved by the Enactment of the Council of Ministers of the Republic of Belarus, the Physical-Technical Institute of the National Academy of Sciences of Belarus is the head organization for scientific-technical support of the Program for modernization of industrial enterprises which use induction equipment. A part of enterprise which use heating operations in gas, electric and induction sets in heat and power consumption is more than 10%, at that, the processes with induction heating is less than 1%. Application of induction heating has a range of advantages in comparison with the conventional heating sets. This is uppermost high efficiency 90–97%, compactness of induction sets that allows installation of them into mechanical processing lines, high productivity of heating operations, and formation of thermal hardened layers on the surface of parts which ensure an increase of exploitation features and some special properties. It should be noted that induction heating is often used for forging, stamping, pressing, volumetric and surface heat treatment of metals and alloys. However, the speed of broadening of the sphere of induction heating application is restrained by a necessity to buy up-to-date equipment, to elaborate and to correct technological processes that ensure high quality of the products and a decrease of their net cost.

A second important task is elaboration of new promising technologies for induction heat treatment of different parts and blanks to replace out-of-date unprofitable technologies of furnace heating.

To solve the tasks, the R&D Centre “Induction Technologies and Heat Treatment Problems” was founded in 2011 in the Physical-Technical Institute of the National Academy of Sciences of Belarus.

The general directions of the Centre activity are as follows:

1. Elaboration and manufacture of high-frequency generators modular units with 2.4 – 60 kHz frequency and up to 1200 kW power.
2. Elaboration and manufacture of automated induction heating sets for heat treatment and heating before deformation of metals and alloys.
3. Elaboration and manufacture of additional equipment for induction heating (quenching, matching transformers, inductors).
4. Elaboration of induction heating technologies.
5. Elaboration of a control system of induction thermal equipment using up-to-date industrial controllers.
6. Certification, assemblage and adjustment of induction heating equipment.

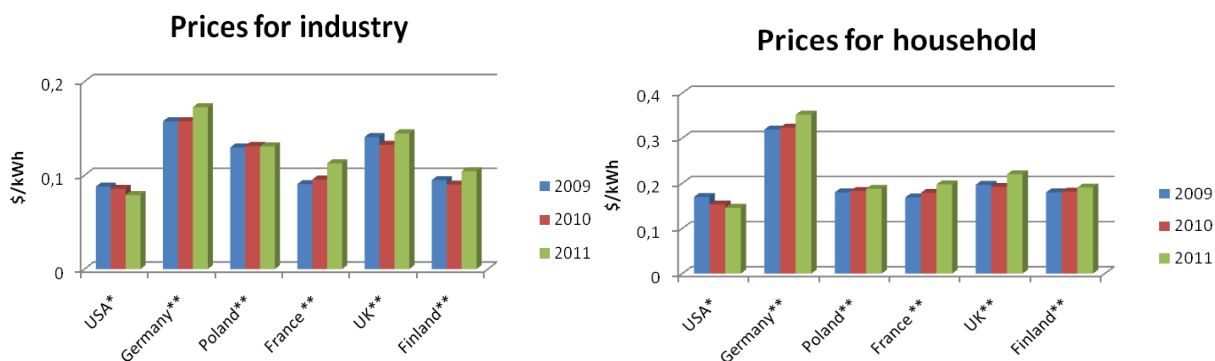
In 2012 the Institute and PLC “MAZ” have executed some works for elaboration of an energy-saving technology and a complex of automated induction equipment for heating before deformation using an upsetting machine. The complex is intended to replace the gas furnace used now in a forging shop of PLC “MAZ” to heat blanks with 40–50 mm diameter up to 1150–1250⁰C temperature with sequent deformation using the upsetting machine and manufacture of parts as brake cam and semi-axle. The technical and economic assessment has shown that replacement of gas heating with 30–40% efficiency of a furnace for induction heating with 95–97% efficiency of a complex allows 3.8 times energy saving. Besides, there is an increase of heating quality at the expense of exclusion of decarbonisation and fuming. Full automation of the heating technology and blanks feeding will allow increasing of labour productivity by no less than 20%. Recouperment of the complex is about 3 years. Starting from 2014 the technology will be used to produce about 400 000 parts per year. An induction heating complex includes: a transistorized thyristor frequency converter, a heating set with full automation, a programmed module of control system. A complex operation is shown by the functional scheme. Blanks are put on the feeding mechanism and one by one moved to the pushing mechanism, where pseudocylinders push them into an inductor for 250–300 mm depth. (3 independent heating positions). In the inductor the edge of the blank is heated up to 1200–1250⁰C, temperature control is executed using a pyrometer. After achievement of the set temperature the blanks are pushed out for the unloading mechanism to the working place of an operator of an upsetting machine for the sequent plastic deformation. The blanks are pushed out with 12–20 second speed depending on the control system settings.

Due to modernization of forging and thermal shops in the industrial enterprises of the Republic of Belarus and due to exclusion of natural gas consumption, there is a big demand for such complexes.

Fuel, Efficiency and Electricity Price

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It's common knowledge that electricity is very important for the economy of each country. This research presents the way how the electricity price and efficiency depend on the used fuel type. It's very interesting to see from figure 1 that:



* Source: www.eia.gov ; ** Source: <http://epp.eurostat.ec.europa.eu>

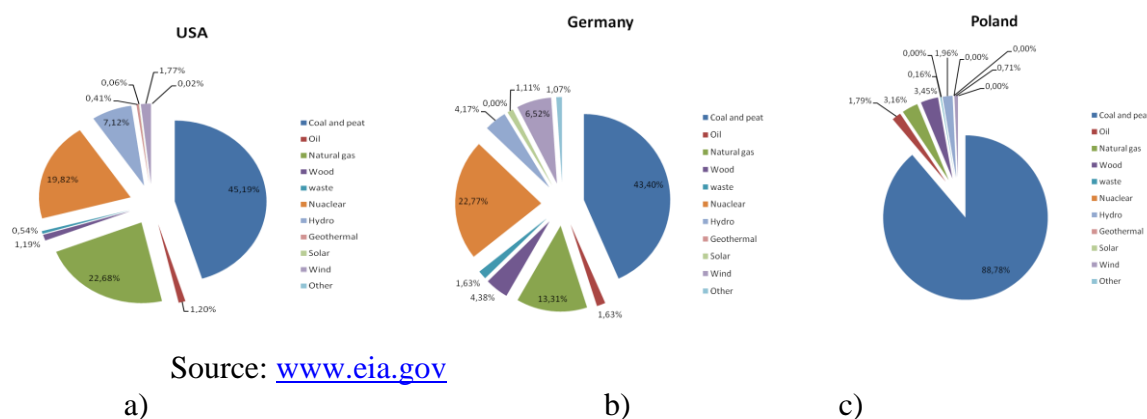
a)

b)

Figure 1. Electricity price for a) industrial and b) household consumers in 2012, 2d

1. Electricity price in the USA is 1.5-2 times lower than in Germany
2. Electricity price in the USA (for industry and household) became lower form year to year (2009-2011) and in Germany it became higher (2009-2011)
3. Electricity price in Poland was more or less similar during 2009-2011.

One of the main reasons of such difference is the fuel being used. We can see in figure 2 the diagram of the used fuel for electricity producing in 2011 for the USA; Germany and Poland.



Source: www.eia.gov

a)

b)

c)

Figure 2. Fuel consumption for electricity producing a) in the USA; b) in Germany; c) in Poland in 2011

Germany shows the tendency to “green energy”. It's very important for ecology. But it's too expensive for the end users. Poland and the USA are more conservative in the use of fossil local fuels. It helps them to have a very good and predictable electricity price.

Atheoretical research of fuel effectiveness has been carried out with the fuel of different quality(LHV and other parameters) in steam turbine as well as Brayton cycles. The conclusion is interesting – the cheapest fuel with a bad quality (for example brown coal) can have better fuel effectiveness than a good fuel (for example natural gas).



2nd Belarus-Korea Forum
"Science. Innovation. Production"



Session:

**Information
Technologies**

Parallel Processor for Pattern Recognition

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Our neuron like parallel processor has been implemented as operating sample and it consists of hardware (HW) part on FPGA and Internal software (SW), Fig1. Internal SW provides configuration of FPGA and internal control unit for control and synchronization of hardware modules. Obviously, the various HW implementations will meet the unique Internal SW.

To test, verify and evaluate the developed technical solution of processor and to demonstrate it operating we have developed the special program tool: External SW for normal computer. External computer is used as control (Host) and neuron like processor is used as coprocessor. Computer`s interface is USB, but can be PCI, Ethernet etc.

External SW consists of three levels.

Low level SW provides:

- Data exchanging between Host-computer and Coprocessor;
- API-library for development of external program applications on higher levels;
- Program emulator, which simulates the implemented HW-coprocessor and provides to test and demonstrate External SW without real HW.

Middle level SW provides:

- Programming the initial modes and tunes of coprocessor, input of processing data and display of accepted numerical results;
- Programming of modes and criteria of decision making in post-processing phase.

High level SW (it is not shown in fig.1) conducts applied programs, for instance human portrait recognition, finger prints identification, image search in big data bases and etc. Note! In similar programs of high level the classification task realized by neuron like processor occupies a predefined part in common volume of algorithms. Obviously, the final advantage will be higher when classification task needs large computing charges (it will be in cases, when classification task operates with big number of informative features and huge number of classes).

Middle and Low level SW help us to create the new versions and prototypes of analogues processors with various apparatus platforms and with given technical requirements more quickly and cheaply.

Note. Accuracy (sensitivity, specificity) of classification does not depend on HW implementation of coprocessor and its computer architecture. It is complex property and depends on math model, learning data set, learning algorithm, choice of informative features and real pattern distribution in feature space. In case we are ready to research this problem in context of considered computer architecture and whole technical problem.

The present sample has been implemented with board Spartan 6 FPGA Evaluation Kit. In FPGA chip the 8 processors has been realized. Each processor element performs the original identification model and conducts the 16 digits of input/output data with fixed point. We can provide the structure scheme of processor element, if it is necessary, but I think it is not interesting for potential customer.

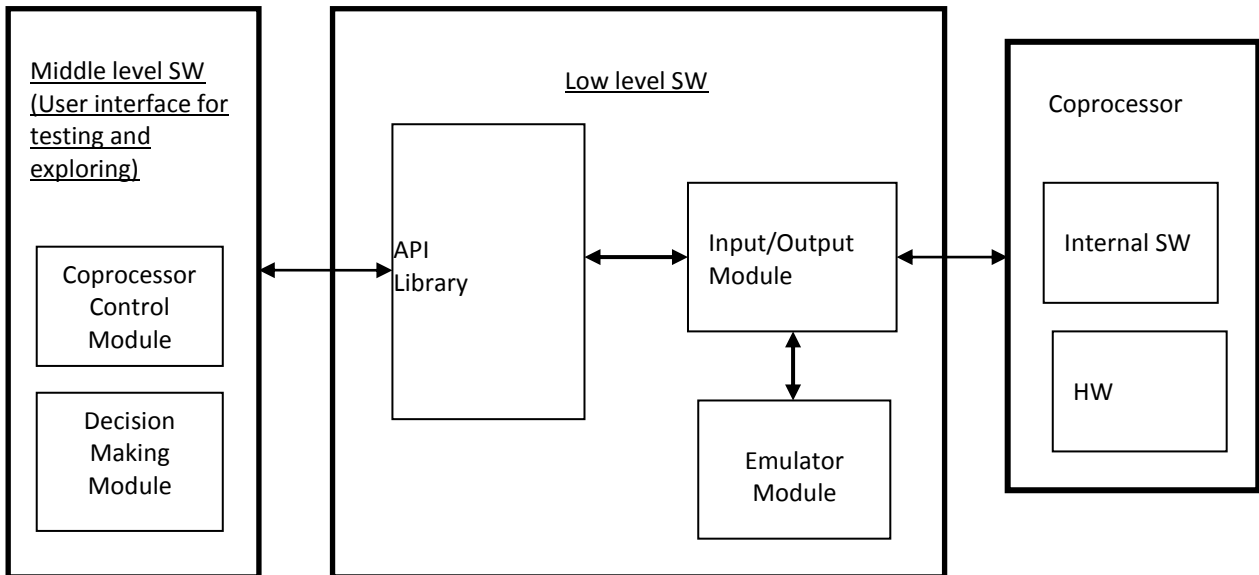


Fig.1 General scheme of evaluation system

For concrete HW solution the experimental assessments of calculation time for macro operation has been received. So, processing time of one informative feature is 50 nS. The total processing time of classification task can be calculated by expression

$$T \approx (50nk) / N_k$$

Where n – is number of informative features;

k – is number of classes;

N_k – is number of processing element in parallel processor.

We think the intellectual property and know-how are contained in technology of fast creating of HW+SW processor prototypes with defined technical requirements, limitations, with customer`s HW platform. Therefore we don`t interested in transfer our sample (SW or/and HW) in such form. To test and evaluate our technology we propose to carry out the analogues development under the specific Customer`s technical requirements. The customer might define:

- Number of informative features;
- Number of classes;
- Number of digits of input/output data;
- Computer performance (time of classification task processing);
- HW platform (DSP, FPGA, multicore CPU, GPU, cluster) with detail.

To test and evaluate the our math model Customer might give us:

- Learning data set;
- Expected efficiency (sensitivity/specificity) of classification;
- Perhaps, achieved efficiency (sensitivity/specificity) of classification with same learning data set on alternative math model (ANN, SVM and etc.) for comparison.

Then we are ready to provide fast researching with use own tools and present results to Customer without or with know-how and intellectual property transfer and take part in implementation work of our technical solutions in completed system of Customer. Furthermore, we have ideas to develop our model and computer architecture in direction of functionality enhancing. It can be subject for collaboration too.

Application of Artificial Intelligent Systems in Real-Life Tasks

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1. Artificial immune systems for malware (computer viruses) and intrusion detection

At present large majority of commercial antivirus decisions are based on signature analysis. Signature-based approach has acceptable detection rate for well known viruses and relatively low false positives. Unfortunately the ability of signature-based systems to detect new viruses is extremely poor.

Artificial Immune System (AIS) is an approach inspired by biological immune systems. It can be defined as computational system based on principles of biological immune systems. Different models of AIS exist for computer virus detection. Though there are some problems to use this approach for virus detection. As a rule AIS uses binary or real strings as detectors. In this case it is difficult to train such a detector to perform quality virus analysis. As a result such a system has high computational complexity and is not good enough to detect novel viruses. To overcome these problems we propose neural networks as detectors for AIS. The key idea is to integrate advantages of artificial immune systems and neural networks to create self-organizing system for virus (attack) detection and recognition which has ability to self-evolution. Such a system can perform recognition of novel viruses (attacks) with low false negative (positive) rates.

2. Intelligent Neural Systems in Medical Diagnostics

2.1. Detection and Prediction of Epileptic Activity

The proposed system is based on chaos theory and forecasting neural networks. The epilepsy detection is performed using calculation of largest Lyapunov's exponents. We propose neural network approach for computing largest Lyapunov exponent (that can be considered as a measure of chaos). It permits to decrease complexity and to define Lyapunov exponent using small experimental data set. The system provides perfect accuracy and permits to increase quality of treatment. This research work is developed in close collaboration with medical establishments.

2.2. Transient Ischemic Attacks Diagnostics

The proposed approach is based on integration of the NPCA neural network and multilayer perceptron. The real dataset from clinic have been used for experiments. Combination of two different neural networks (NPCA and MLP) makes it possible to produce efficient performance in terms of detection and recognition transient ischemic attacks. The main advantages of using neural network techniques are the ability to recognize "novel" transient ischemic attack (TIA) instances and quickness of work that is especially important in the real time mode. Neural network technique permits to reduce the diagnostic time and the number of misdiagnosis, as well as to assist the doctor in making a decision.

Low Power XOR Gate Decomposition

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Currently, the power consumption is one of the most important concerns of *VLSI* design [1]. Three factors mainly contribute to this trend. Firstly, without low-power design techniques, future mobile devices will have limited battery life or heavy battery pack. Secondly, power dissipation in high-speed devices leads to increase the packaging and cooling costs. Thirdly, all modern *VLSI* has built-in self testing hardware. This hardware practically don't use in normal mode operation. But during testing they use very intense. In [2] was shown that power dissipation during testing was increasing in 2-3 times. Therefore, low-power techniques are very actual problem.

Modulo two adders are widely used in a variety of digital circuits such as specialized calculators, communication circuits, error correcting circuits, pseudorandom numbers generators, signature analyzers, etc. In this work a problem low-power decomposition of *XOR* based circuits are considered.

The dominant source of power dissipation in *CMOS* circuits is dynamic power dissipation. They consist of two components: charging and discharging of the node capacitances (also referred to as the capacitive power dissipation) and short-circuit current between the supply rails during output transitions. The dynamic power dissipation is given by [3]:

$$P = \frac{1}{2} V_{dd}^2 f_{CLK} \sum_{i=1}^n C_L^i \cdot WSA_i ,$$

where V_{dd} – is the supply voltage, f_{CLK} – is the clock frequency, C_L^i – is the load capacitance at the output of gate, WSA_i – is the expected number of transitions per clock cycle (referred to as weighted switching activity, or *WSA*), n – number of nodes.

In this work next the following notation are used [3]: load capacitance of every nodes is equal; supply voltage and clock frequency is constant; gate delays are assumed to zero. Thus for power estimation it is necessary to calculate weighted switching activity for every node. Technique for calculated *WSA* was proposed in [4]. The main idea of this technique consists of different time for switching for every node. So every input switching translates onto output (fig.1).

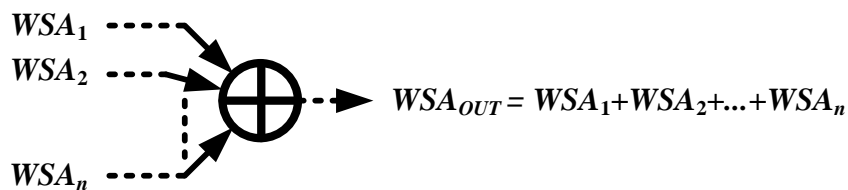


Fig.1. *WSA* Estimation of multiple-input modulo two adders

Technology decomposition is the step before technology mapping which decompose multiple-input logical elements into a network with only two-input gates (three, four, and all). In [4] was described a problem of decomposition a multi-input *XOR* gate into a tree of two-input *XOR* gates. But technology library contain different primitives such as two, tree, four, eight input gates (as example, library *AMI350HXGC* contain only two and tree input *XOR* gates [5]). In this work we consider decomposition multiple-input logical elements into a network with any input gates.

Let n is number of inputs multiple-input modulo two adders, d number of inputs gate. Number of gates (k), which is needed for making n -input logical element on d -input gates, is calculated as:

$$k = \left\lceil \frac{n-1}{d-1} \right\rceil,$$

where $\lceil x \rceil$ – is nearest integer, greatest or equal x .

As has shown in [3], exist many different variants of decomposition multi-input logical elements. This variant has equal number of gates but different switching activity. Figure 2 shown examples decomposition 11-input modulo two adders into a network with tree-input XOR gates. Both circuits have equal number of gates. But second circuit has switching activity in 1.4 time's less than first circuit.

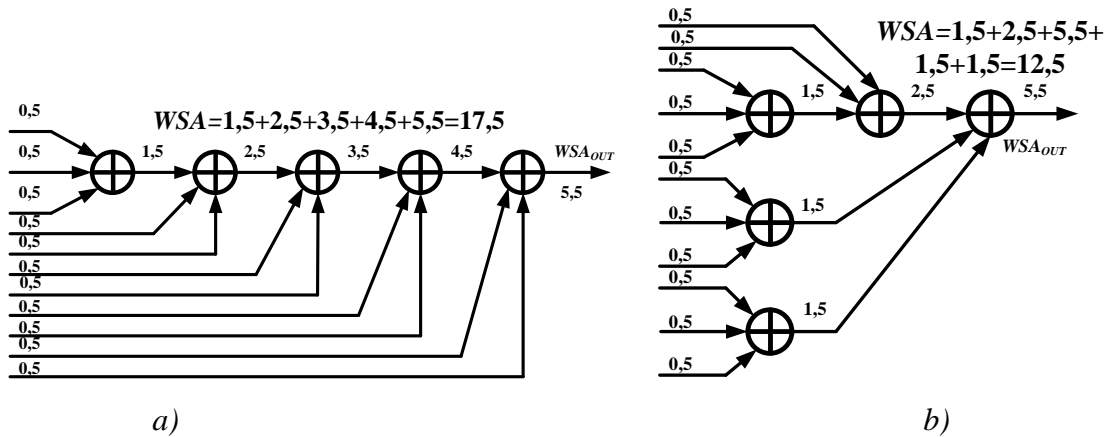


Fig.2. Decomposition of 11-input element:
a – with maximal WSA, b – with minimal WSA

For the synthesis of multi-input XOR-based circuits with minimal switching activity can be used the following recursive algorithm (assume that switching activity for any input is equal 0.5, number of inputs gate $d=3$). First calculate output switching activity $WSA_{out} = 0,5 \cdot n$ and temporary variable $WSA_d = 3 \cdot 0,5 = 1,5$. Then imagine WSA_{out} as the sum of the 3 numbers $WSA_{out} = WSA_1 + WSA_2 + WSA_3$ so that for 2 of 3 variable WSA_i ($i = \overline{1,3}$) the result of dividing WSA_i by WSA_d was integer. Moreover it is necessary following conditions $|WSA_i - WSA_j| = 0$, $|WSA_i - WSA_j| = 0,5$ or $|WSA_i - WSA_j| = 1,0$, where $i = \overline{1,3}$, $j = \overline{1,3}$, $i \neq j$. This step repeat for all nodes until $WSA_i \neq 0,5$.

The result of algorithm for $n=11$, $d=3$ was shown on fig.2, b. This algorithm easy can be modified for any gates.

This work is dealing to a problem of decomposition multiple input XOR-based circuits. Different variants of decomposition have different switching activity they characterizing power dissipation. An algorithm for synthesis of multi-input XOR-based circuits with minimal switching activity was proposed. This algorithm can be used in computer-aided environment.

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Open Semantic Technology for Intelligent Systems

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The report is devoted to the open project, aimed at creation of technology of component design of intelligent systems. The report considers basic principles of this technology, oriented on semantic representation of knowledge. One of the basic ideas of such a technology is an expansion of the contingent of developers and design time reduction via using component design principle. This technology is a main product of the open source project OSTIS (Open Semantic Technology for Intelligent Systems), which is aimed at creation of open technology, which will allow to design commercial and non-commercial intelligent systems for different purposes. At least the technology should provide such an opportunity not only to experienced IT-specialists, but for all those, who has a goal to create an high-functional intelligent system for a necessary subject domain, for example, scientist in the sphere of biology, history etc. Much attention is paid to the intelligent metasystem IMS.OSTIS, designed for complex support of intelligent systems design.

We base our investigation on the results of the researches in the field of artificial intelligence which are not only in the development of particular intellectual systems with the high intellectual opportunities but also in the development of technologies which help to create different intellectual systems quickly and easily – and this has a great practical value. It is clear that the parts of such technologies are:

- formal theory of intellectual systems (formal description of their construction)
- methods of projecting of intellectual systems
- instruments (means of automatization of projecting intellectual systems)
- information management tools(information service) of intelligent systems development;
- means of computer support of control over the collective development of intellectual systems.

Modern technologies of the projecting of intellectual systems have some imperfections like:

- technologies are not directed to the wide range of the developers and wasn't spread wide
- period of development is very long and its maintaining is difficult.
- degree of dependence of intellectual system technologies on the platforms which they are build on is very high – which provokes a lot of changes in the technologies after the start of using the new platform.
- for the effective implementation of even the existing models of knowledge representation and models solutions of difficult to formalize problems of today's computers are not well-suited, which requires the development of fundamentally new computers;
- a modern state of intelligent computer systems development is a "Tower of Babel" of variety models, methods, tools, platforms;
- there is no approach that lets us integrate scientific and practical results in the field of artificial intelligence which leads to a high level of overlapping results. In particular, the labour coefficient of the integration of different types of information presentation, problem solving schemes and different intellectual computer systems is very high.

Artificial intelligence is an interdisciplinary scientific discipline. That is why it has a great potential as the science achieve the most significant results on the science junction. But the same reason causes the main difficulties as the development of the artificial intelligence requires a great deal of mutual understanding between the researchers who has different ways of thinking, different attitude to the object, different mentalities, different directives and customs. A modern stage of artificial intelligence development has a deep need for struggling with the difficulties mentioned [1]

The most important goal of the artificial intelligence nowadays is gaining a general complex theory of intellectual systems which would have contained different types of artificial intelligence: the theory of presenting the knowledge and the theory of problem solving (also different calculus, heuristics and strategies), the theory of programs (procedural, declarative, parallel, and sequential) and the architectures of intellectual systems (detailed properly deep to the level of hardware support) and the theory of intellectual users interfaces and computer linguistics.

Today a deep semantic integration is in the centre of the development of artificial intelligence which aim is not only the theory of intellectual systems but also a general available technology of its complex development.

Our approach is aiming on the removal of disadvantages and is based on several principles. These principles were discussed in details in [2].

The proposed technologies are essential OSTIS not the principles discussed above, some of which look obvious and indisputable, and the whole coherent set of principles and their consistent as possible.

The key problems the solution of which is the basis of the proposed technology are:

- providing semantic interoperability (integrating) of various models of representation and processing of knowledge;
- creation of a general theory of abstract semantic models of intelligent systems, and not contradicting integrating a variety of approaches;
- providing maximum possible independence of intelligent systems from the variety of options and their technical implementation platforms (including from future computers, specially focused on hardware support for knowledge processing).

Table 1 - OSTIS Technology Standards [3].

sc-model of intelligent systems:			
<ul style="list-style-type: none"> ● sc-model of user interfaces; ● sc-help-system model; ● sc-model sub-project management; ● sc-model design support systems; ● sc-model subsystems for information security management 			
sc-models of problem solvers			
sc-models of of information retrieval		sc-models of knowledge Integration	
sc-models of knowledge bases			
SCK language		Unified identifiers of sc-elements	
ontology SC- language	sc- languages of purpose, questions and problems	Logical sc-language	Programming sc-languages
SCP Language			
scp-machine			
SC-code	SCg-code	SCs-code	SCn-code
Program interpreters of scp-machine			scp-computers
Internet	Local platforms		

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Software Package CellDataMiner for Processing Luminescence Microscopy Images of Cancer Cells

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A new object-oriented image analysis methodology, data mining methods, and simulation model for processing luminescence microscopy images of live cancer cells have been developed and integrated into the software package CellDataMiner. Scientific idea of the developed research methodology is in cooperation of the object-oriented image processing and data mining approaches for the analysis of biomedical experimental data. On the basis of the methodology, sets of fluorescent images are analyzed automatically and without human intervention, that greatly improves the accuracy of measurements and at the same time reduces the cost of research. Analysis mining system considers information about biological objects (nuclei, membranes, cells, etc) at the pixel level in image. Data mining methods have been applied for selection of cancer cells and diseases growth stages. The coupled object-oriented and data mining methodology enables complete automation of image processing, which greatly simplifies the analysis and interpretation of biomedical data. Simulation model is integrated for calibrating the parameters of the segmentation algorithms. CellDataMiner may have important theoretical and practical significance for the study of colonies of live cancer cells, forecasting cancer development stages and diseases.

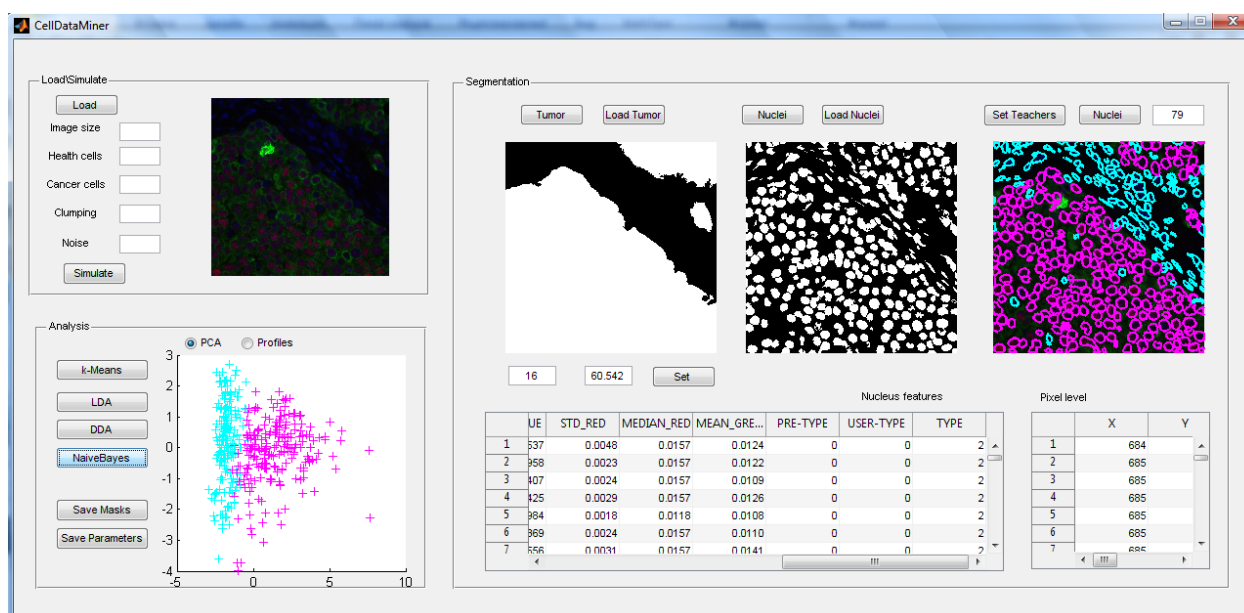


Fig 1. The main window of CellDataMiner and visualization of processing one luminescence microscopy image of cancer cells

Voice Conversion Systems with Web Interface

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Two speech processing systems have been developed for real-time and non-real-time voice conversion. Using the real-time version the user can apply conversion during voice over IP (VoIP) calls imitating identity of a specified target speaker. Non-real-time processing system converts prerecorded audio books read by a professional reader imitating voice of the user. Both systems require some speech samples of the user for training. The training procedures are similar for both systems however the user is considered as a source speaker in the first case and as a target speaker in the second. For parametric representation of speech we use a speech model based on instantaneous harmonic parameters with multicomponent sinusoidal excitation. The voice conversion itself is made using artificial neural networks (ANN) with rectified linear units.

1. Introduction

In this paper we present a voice conversion technique that has been implemented in two versions for real-time (referred to as 'CloneVoice') and non-real-time (referred to as 'CloneAudioBook') speech processing. CloneVoice is intended for VoIP communications and allows the user of the system to speak somebody else's voice. The current implementation of the system establishes VoIP to GSM connection using a voice conversion server as shown in figure 1. In order to get access to the voice conversion server a dedicated application is designed for iPhone.

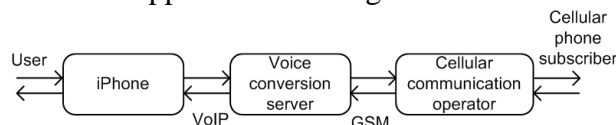


Figure 1: Schematic representation of real-time voice conversion using VoIP

CloneAudioBook is applied to prerecorded audio books which are stored in a database. The audio book chosen by the user is processed by the voice conversion server and then can be downloaded using a web interface as shown in figure 1. The aim of the conversion is to change the voice of the original reader to the voice of the user.

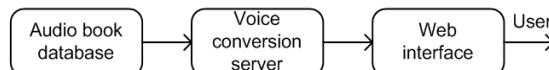


Figure 2: Schematic representation of non-real-time voice conversion for audio books

Before conversion can be performed the user is asked to utter a set of phrases which are used for training of the voice conversion function. The development of these voice conversion applications was inspired by the recent success of neural network applied to voice conversion [1] and recent advancement of contemporary speech morphing models [2].

2. Implementation

The system is divided into two main stages: training and conversion as shown in figure 3. For training parallel utterances of the source and target speakers are used. They are aligned in time and then the conversion function is trained using ANN. The conversion function matches features of the source speaker to those of target speaker. The training core is implemented in MATLAB and compiled into executables using the built-in compiler.

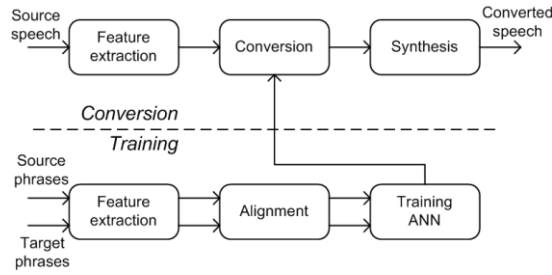


Figure 3: Schematic representation of the voice conversion system

During conversion the conversion function is applied to speech features and then the waveform of output speech is synthesized. Since the conversion stage is time critical it is implemented in C++.

For training and conversion a parametrical representation of speech is used. Instantaneous spectral envelope, pitch and excitation type (voiced, unvoiced or mixed) are extracted for each 5 ms of the signal. Unvoiced speech is modeled as a random process with a specified spectral power density. For spectral mapping we use a feed-forward ANN that consists of four layers. The ANN uses rectified linear units that implement the function $RL(x) = \max(0, x)$. The network performs mapping between the source and target envelopes and uses speakers' state vectors and to reduce oversmoothing. The state vectors are calculated using current normalized pitch values and voiced/unvoiced decisions. Weights and biases of the ANN are trained using the backpropagation algorithm.

3. Evaluation

CloneVoice and CloneAudioBook operate under different conditions considering time constrains and quality of the source speech. The input of CloneVoice is a noisy speech, recorded by iPhone in natural conditions sampled at 16 kHz, the output is sampled at 8 kHz which subsequently processed with GSM encoding/decoding scheme. The input of CloneAudioBook is a clean speech sampled at 44.1 kHz recorded in an audio recording studio and the output is sampled at 44.1 kHz as well. So it is very naturally to expect different performance of the systems regarding perceptual quality of the converted speech. We have performed some subjective evaluations which are summarized in table 1.

Table 1. Subjective evaluations of voice conversion quality (mean opinion scores)

	CloneVoice	CloneVoice (b.p. mode)	CloneAudioBook
Intelligibility	3,1	3,4	4,1
Quality	3,0	3,3	4,4
Similarity	2,9	-	3,9

Listeners were asked to rate perceptual quality of the processed speech in 1-to-5 scale (5: excellent, 4: good, 3: fair, 2: poor, 1: bad) in terms of intelligibility (how easy the words are recognized), quality (naturalness) and similarity to the target speaker. In order to evaluate the influence of the communication channel CloneVoice system has been tested in two modes: full processing mode and bypass mode where no voice conversion is applied.

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Optimal Routing Based on Service-Oriented Architecture Approach

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The optimal routing problem in a computer network consists of the determination of the optimal routing policy, i.e., the set of routes on which packets have to be transmitted in order to optimize a well-defined objective function (e.g., delay, cost, throughput etc.). Under appropriate assumptions, the optimal routing problem can be formulated as a nonlinear multi commodity flow problem [1].

A new approach architecture of optimal routing of information flows in telecommunication networks based on service-oriented and using of Quality of Service parameters proposed [2].

$$F(x) = w_i \sum_{i=1}^{m_1} \frac{L_{i\max} - L(x)}{L_{i\max} - L_{i\min}} + w_j \sum_{j=1}^{m_2} \frac{L(x) - L_{j\min}}{L_{j\max} + L_{j\min}} \quad (1)$$

Where: $L(x) \in (D(x), y(x), p(x), J(x))$

$D(x)$ – delay of the flow; $y(e) = \sum_{t=0}^{t(e)} c_t(e)x_t(e)$ for all $e \in E$,

$p(x)$ - probability of packet loss; $J(x)$ – jitter.

$$F(x) = w_D \frac{D_{\max} - D(x)}{D_{\max} - D_{\min}} + w_C \frac{y(x) - C_{\min}}{C_{\max} - C_{\min}} + w_P \frac{p_{\max} - p(x)}{p_{\max} - p_{\min}} + w_J \frac{J_{\max} - J(x)}{J_{\max} - J_{\min}} \quad (2)$$

Weights: $w_D + w_C + w_P + w_J = 1$

subject to:

$$\frac{1}{\gamma} \sum_{e \in E} f_e(s, t, e) \left[\frac{1}{y_e(s, t, e) - f_e(s, t, e)} + \mu(P_e + K_e) \right] \leq T_{\max}(s, t), \text{ for all } (s, t) \in D$$

where: $T_{\max}(s, t)$ – maximum possible delay; $1/\mu$ – the average packet length (bits/packet); λ_e – the average packet arrival rate to link e (packets/second); P_e – propagation delay on link e ; K_e – node processing delay entering link e ; γ – total traffic in the network (packets/second).

There are some ways to determine maximum possible delay. First of all, you should allocate $T_{\max}(s, t)$ empirically, for example, from performance required by any application.

For each $e \in E$ set of possible capacities are determined by the following parameters:

$t(e) = |T(e)|$ is the number of possible additional capacities for an edge e ; $C_t(e) \in Z_+$ ($1 \leq t \leq t(e)$) is the potential technologies for an edge e (it is supposed, that $C_0(e) \leq C_1(e) \leq \dots \leq C_{t(e)}(e)$); $c_t(e) = C_t(e) - C_{t-1}(e)$

For each edge $e \in E$ we enter the variables

$$x_0(e) \geq x_1(e) \geq \dots \geq x_t(e) \quad x_t(e) \in \{0, 1\}, \text{ for all } e \in E,$$

A choice of the capacity $C_\tau(e)$ ($0 \leq \tau \leq t(e)$) for an edge is equivalent to that, as

$$x_0(e) = x_1(e) \dots = x_\tau(e) = 1, \quad x_{\tau+1}(e) = \dots = x_{t(e)}(e) = 0.$$

For probability:

$$P \leq P_{\max}$$

While for Jitter:

$$\frac{1}{\gamma^2} * \frac{d\gamma}{dt} * \sum_{e \in E} f_e(s,t,e) \left[\frac{1}{y_e(s,t,e) - f_e(s,t,e)} + \mu(P_e + K_e) \right] + \frac{1}{\gamma} \sum_{e \in E} \frac{df(s,t,e)}{dt} \left[\frac{1}{y_e(s,t,e) - f_e(s,t,e)} + \mu(P_e + K_e) \right]$$

$$+ \frac{1}{\gamma} \sum_{e \in E} f_e(s,t,e) \left[\frac{dy_e(s,t,e) + df_e(s,t,e)}{(y_e(s,t,e) - f_e(s,t,e))^2 dt} + \mu \left(\frac{dP_e}{dt} + \frac{dk_e}{dt} \right) \right] \leq D_{\max}$$

In other words the General problems for QoS requirements of telecommunication networks could be formulated as the following: it's necessary to provide maximum of bandwidth and minimums of delay, jitter and packet loss ratio.

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Physical Unclonable Functions as Entropy Source to Build True Random Number Generator

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True random number sequences are widely used in many areas: cryptography, modeling, game industry, decision support systems, random sampling, art and etc [1].

In general case TRNG consists of three components: entropy source, compressing scheme and true random number register.

Basic hypothesis of this research work is that the Physical Unclonable Functions (PUF) can be high quality, unclonable, not reproducible, unpredictable entropy source with low hardware costs.

Physical unclonable functions

Physical unclonable function – function, that embodied in a physical structure, which is easy to estimate, but it is hard to describe, simulate or reproduce. Initially, the idea of using PUF belongs to R. Pappu [2]. One of the most widely used PUF definitions today was proposed by P. Tuils [3]. PUF by Tuils is physical system (device), which has inherent property – unclonability (nonrepeatability) of some its functions, properties, characteristics and parameters.

PUF is described by pairs of input and corresponding output values of parameters (signals). Such pair consists of input physical parameter (challenge) and output parameter (response) and is called challenge-response pair (CRP). In simplest case PUF can be considered as function, which converts the challenges C_i to responses R_i :

$$R_i = PUF(C_i) \quad (1)$$

PUF has two important properties: practically impossible to create a physical copy of PUF; it is impossible to create precise mathematical model of PUF that means to compute the response, if exact parameters of the challenge and other challenge-response pairs are given. This problem is connected with huge computational difficulties because physical interaction is too hard.

These properties together are called unclonability.

PUF based TRNG circuit implementation

All implemented generators have the same structure, which shown on Fig. 1.

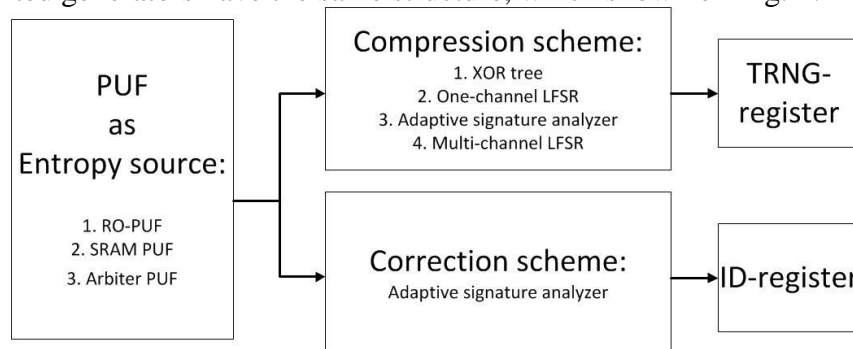


Fig. 1. Common TRNG structure.

As shown on Fig. 1 PUF may be the source of entropy and the source of stability.

There are three implementation of PUF based TRNG:

- 1) Modified Ring Oscillator PUF (RO-PUF) as entropy source, XOR tree and one-channel Linear Feedback Shift Register (LFSR) as compression scheme [4];

The ring oscillator PUF technology was used as the basis of the circuit implementation of the random number generator. The hardware circuit of the RO-PUF can be implemented with sequentially connected $2n + 1$ inverters with a negative feedback. The number of inverters should be odd. It provides the formation of the output signal in the form of a meander. Its frequency is determined by the signal propagation delay through a feedback circuit.

All RO-PUF elements together generate a bit sequence. After that sequence are compressed by n-input XOR-gate (XOR tree) and LFSR.

- 2) Combined PUF (Static Random Access Memory (SRAM) PUF when challenge = 1 and RO-PUF when challenge = 0) as entropy source, adaptive signature analyzer as compressing scheme [5];

The circuit basis is combined PUF, which can be implemented on the two inverters and multiplexer. Depending on the control signal *challenge* circuit can operate in two modes: RO-PUF (*challenge* = 0) and SRAM-PUF (*challenge* = 1).

In the SRAM-PUF mode every system start PUF emulates the memory cell behavior, which «holds» bits of information. At the same time memory cell can constantly take a logical zero (one), or to change its value from run to run.

Adaptive signature analyzer [6] was used for compressing PUF generated sequence true random number sequence.

- 3) Arbiter PUF as entropy source, multichannel LFSR as compressing scheme (see Fig. 3) [7];

Arbiter PUF can be implemented using a single pulse generator, the output pulse is applied to the component, which consists $2n$ multiplexers. Selecting signal C_i ($0 \leq i \leq n-1$) is applied to the input of each pair of multiplexers. The result of the two «chains» of multiplexers is applied to the input of D-Flip-Flop, which is an «arbiter». «Arbiter» defines, which of the signals came first. Depending on the «arbiter» decision PUF result bit can be different.

Multichannel LFSR compress several arbiter PUFs result to the true random number.

Arbiter PUF and SRAM-PUF can be used for digital device identification with adaptive signature analyzer correction scheme.

TRNG sequences testing

All generated sequences are tested on two identical FPGA Nexis-2 Spartan 3E-500 FG320 with statistical toolkit Statistica®, statistical tests packages NIST and Diehard.

Statistical tests are passed by all data packages (1000 selections of 100000 bits).

By the statistical tests result sequence is unclonable, not reproducible, unpredictable. TRNG is simple to implement and has low hardware costs.

Mentioned types of PUF also have possibility to solve digital device identification problem with the same circuit.

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Computer Aided Program of Mechanical Calculation of Flexible Conductors

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Abstract. The numerical method of mechanical calculation of overhead lines and substations flexible conductors on computer is stated. The pack of computer programs MR21 is described, the valuation of reliability of computer calculations is executed. Characteristics of developed computer programs and opportunities of last versions of set on mechanical calculation of flexible conductor are present.

The tendency of reduction of transmission lines and substation dimensions increases the requirements to accuracy of their mechanical calculation. The purpose of this calculation is the determination of tensions arising in wires and basic designs and maintenance in any point of span of requiring minimum allowable distances to various objects at all possible kinds of loads accepted when designing (ice, wind, etc.).

This calculation is executed with use of calculation model of wires represented as flexible elastic thread, that facilitates the decision of task of account of elastic and temperature lengthening of conductor in various regimes of climatic loads. The statics of flexible elastic thread is described by nonlinear differential equations of second order. Their numerical solution is proceeded by difference method with the help of computer. The system of finite difference equations is solved on a base of iterations enclosed each in other: about coordinates, tensions or lengths of conductors. If there are drops to electric apparatus one more iteration on coordinates of points their fastening to flexible bus-bars is added. These coordinates are function of tension in drop, and it in turn depends on the position of conductor.

At development of algorithm the numerous proposals and remarks of design organizations of Russia and Belarus used the early versions of set of programs are discounted. The set of computer programs MR21 working in one integrated environment is composed on a base of developed algorithms. It permits to enter the initial data, execute the calculation, view and print out the results of calculation. The main programs of set are MR1 and MR2.

MR1 represents the program of mechanical calculation of flexible conductors in various climatic regimes, based on models of conductors and insulator strings as flexible elastic thread.

MR2 is improved program of calculation, in which for acceleration of calculations in equations as tension of conductor is accepted its horizontal component H . MR2 is used for spans with small sag (ratio of sag to span length is less than $1/20$). The divergence in results of calculation of sag and horizontal displacements on MR1 and MR2 does not exceed 1.5 %.

The valuation of reliability of algorithms and programs was conducted by comparison of calculation results with data received on conventional methods of mechanical calculation based on representation of conductors by parabolas in wide range of change of initial parameters. In particular, for approach of developed algorithm to calculation model of conventional methods the drop was taken into account by vertical load, that has resulted in to divergence in calculations of sags of 2 - 4 %, horizontal displacements - up to 1 %, tensions - 0.1 - 2.8 %. The closest coincidence of results took place at large tension of conductors. At reduction of tension the divergence between them grows. It is basically explained by increase of error of approximate technique, stipulated by accepted assumption that projection of length of insulator string on coordinate axis along spans is equal to the length of string.

The comparison of results in shows that the error from not taking into account the real arrangement of drops and string depends on the quantity of drops and makes in determination of sags of 3 - 15 %, horizontal displacements - 9 - 32 %, tensions - 2 - 7%. This error is explained by different account of forces, acting from drops on substation bus-bars. For example, at use of values

of forces from drops calculated on program an error of conventional methods in determination of sags decreases to 0.5 - 3%, for horizontal displacements - to 1 - 4 % and for lengths flexible conductors - to 0.1 - 0.35 %. It confirms the reliability of results received on program.

The programs permit to determine sags in two planes and tension of flexible conductor of substations and overhead lines at their various arrangement under action of ice and wind loads. The programs take into account the difference of support heights, tensioning insulator string, spacers, as well as drops (up to three) to electric apparatus taking into account their real arrangement in substation. The programs are suitable for calculation of installation regimes with one string in span and various variants of installation of drops, as well as permit to decide the reverse task, i.e. to determine the tension of conductor for known sag.

The calculation of conductors can be executed in 12 climatic regimes. The number of initial regimes can be equal to 1 or 2. With two initial regimes the program chooses the heaviest regime of climatic loads, at which the forces from conductors on basic designs are maximum. The mentioned regime is accepted for initial one. In this regime on given tension or sag is settled an invoice of length of flexible conductor before stretching which is a base for calculation of other regimes.

By initial data it is possible to calculate installation regimes both at presence of freely hanging drops not fixed to electric apparatus and at their absence during installation.

The results of calculation represent the tables of initial data and calculation parameters: tensions, displacements and sags of conductors, loads on supports and electric apparatus, loads on conductors and insulator string. Maximal sag and horizontal displacements, as well as sags in given points in projections on horizontal and vertical axis are determined. The loads from conductors on supports, from drops on flexible bus-bars and on electric apparatus are calculated in projections on axes of coordinates.

The work with programs is simplified by built-in help, diagnostic of initial data of users, availability of catalogues of conductors and insulator string, as well as opportunity of their updating. The programs permit to draw the horizontal and vertical projection of span for each climatic regime.

The last version of program set MR21 has one integrated environment included program MR1 and MR2, files of initial data, catalogues of conductors and insulator string, files of graphic processing of information and print it out. Besides set enters the control examples of calculation, copies of files of catalogues and initial data. Lengths of drops and conductors, diagnostic of initial data on their fittings to range of allowable values are present.

The work with catalogue of conductors, i.e. entering of new types of conductors and correction of existing ones, is executed in separate menu on password to avoid of non-authorized record in it. To user the opportunity of work with new (temporary) mark of conductor without putting it in catalogue on constant storage is granted.

The version comes to users on Russian and English languages. The complemented built-in help and explanations of calculation results permit to work with set without any instruction. The uniform integrated environment indicates errors of user, as well as authors information for communications with developers on operations of set.

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