Vladimer Chavchanidze Institute of Cybernetics of The Georgian Technical University

Projects received with the grant of Shota Rustaveli Scientific Foundation 2018-2023.

Appendix 4

№	Project Name	Head of Project	Project start and end years	Volume (Amount)	Status Finished/Current	Grant Code
1.	Development of a new infrared imaging method to prevent cancer recurrence after radical prostatectomy and partial nephrectomy	Besarion Partsvania	23.02.2023–23.02.2026	186 635.8 GEL	Current	FR-22-195
2.	Investigation of the effects of high frequency electromagnetic fields used in 5G technologies on some biological species	Vera Jeladze	23.02.2023–23.02.2026	240 000 GEL	Current	FR-22-2771
3.	Cholesteric Liquid Crystal Mirror-Based Hyperspectral Imaging Device for Medical Application	Gia Petriashvili	20.02.2023–20.02.2026	235 000 GEL	Current	FR-22-25543
4.	Information recording based on spatial photo-modulation of laser	Andro Chanishvili	20.02.2023–20.02.2026	238 000 GEL	Current	FR-22-3061

	generation of liquid crystal layer.					
5.	Investigation of the statistical characteristics of scattered electromagnetic waves in the terrestrial atmosphere and aplication	George Jandieri	21.03. 2021-21.03. 2024	220000 GEL	Current	FR-21-316
6.	Creation of DNA-based silver and gold nanowires and their study by spectroscopic and electron microscopic methods	Zaza Melikishvili ((leading organization is TSU and Institute of Cybernetics is a partner organization)	11.03.2020–11.03.2021	23200 GEL	Finished	NER-19--5263
7.	Synthesis of the multifunctional magnetic nanosystem with innovative technology for medical application	Shalva Kekutia	23.12.2019-13.07.2023	419 730 GEL	Current	AR-19-1211
8.	Development of high-performance calcium cobaltite thermoelectric materials through doping and nanoengineering	Nikoloz Margiani	31.07.2020-29.07.2021	249 000 GEL	Finished	CARYS-19-675
9.	Evaluation of therapeutic effect of magnetic nanoparticles	Jano Markhulia	30.07.2020–30.07.2021	249 420 GEL	Finished	CARYS-19-976

	functionalized with antitumor drug on breast cancer cells					
10.	Synthesis and research of wide-bandgap semiconductor nanomaterials for use in UV photodetectors	Aleksandre Jishiashvili	2019-2021	49 200 GEL	Finished	YS-19-087
11.	Real-time universal polarization-holographic spectroellipsometer	Barbara Kilosanidze	23.12.2019 - 23.12.2022	389 800 GEL	Finished	AR-19-1154
12.	Tuning the functional properties of Co-based thermoelectrics via doping and high-energy ball milling	Nikoloz Margiani	27.02.2019–26.02.2022	218 555 GEL	Finished	FR-18-4976
13.	Development of Bi-based HTS thin films, doped by boron-containing compounds	Giorgi Mumladze	26.09.2019 - 26.03.2020	10 500 GEL	Finished	PHDF-19-421
14.	Bi(Pb)-2223 ceramics;doping;high-energy ball milling;phase formation;superconducting properties	Armen Kuzanyan (Armenia)	13.12.2018 – 12.12.2021	209 830	Finished	DI-18-479
15.	Synthesis of bio-applicable magnetic nanofluid using plasma generation in liquid.	Vladimer Mikelashvili	10/01/2016 - 10/01/2018	58300 GEL	Finished	YS17_15

16.	Optical Information Recording Based on Photo-Modulation of Emission Property of Liquid Crystal	Andro Chanishvili	12.12.2016 – 12.12.2019	205100 GEL	Finished	FR/217162
17.	New Rewritable Optical Storage on the Basis of Spiropyran doped Liquid Crystal Bilayer Polymer Film	Gia Petriashvli	12. 12 2016 – 12.12. 2018	140 000 GEL	Finished	FR 217330

ABSTRACTS

1. **"Development of a new infrared imaging method to prevent cancer recurrence after radical prostatectomy and partial nephrectomy" (2023-2026; Head of Project -Besarion Partsvania)**

Postoperative management of prostate or kidney cancers is required after surgeries, which is mainly based on the result of the histo-morphological examination of the surgery material. If these results are not correct the patient's postoperative treatment scheme will be wrongly planned and the risk of cancer recurrence is high.

In 30-40% of patients, who were operated on radical prostatectomy develop local recurrence. The cancer recurrence is higher the greater is the degree of aggressiveness of the original tumor.

In order for the pathomorphological response to be 100% accurate, a microscopic investigation of all parts of the entire prostate should be made. However, most clinics use partial selection practices. This is not sufficient to obtain complete information about the existence of high aggressiveness tumors. This is the reason for the high percentage of cancer recurrence.

In the case of kidney cancer leaving a positive surgical margin in the kidney site remains one of the risks of cancer recurrence. For this reason, surgical kidney specimen is examined by the express diagnostic method, called 'FS diagnosis", during which surgery is suspended. FS is not characterized with high accuracy. This significantly increases the risk of cancer recurrence.

We will develop a new infrared imaging method. It will accurately determine the margins of cancerous formations in isolated specimens. The method will take only a few minutes, versus FS. The surgeon will be able to reach the negative margins and ensures that no more cancerous outgrowths remain in the kidney.

2. **"Investigation of the effects of high frequency electromagnetic fields used in 5G technologies on some biological species" (2023-2026; Head of Project - Vera Jeladze)**

5G stands for the fifth generation of wireless technology. The fifth-generation aims to increase the speed of data transmission, be more responsive, and allow for greater connectivity of devices simultaneously. The 5G networks will work within several different frequency bands. Several of these frequencies (principally below 1 GHz; UHF) have actually been or are presently used for earlier mobile communication generations. The new bands are well above the UHF ranges, having wavelengths in the centimeter (3–30 GHz) to the millimeter ranges (30–300 GHz; MMW). These latter bands have traditionally been used for radars and microwave links.The wavelengths used in 5G will be close to the body dimensions of small size biological objects, particularly insects and small birds. Because body and body parts dimensions of insects and small birds at the 5G frequencies are comparable with the wavelength, the high absorption of EMF energy and increase of the temperature in the body tissues can occur and therefore can cause harmful effects, possibly the extinction of some of them. An investigation into the impact of high-frequency nonionizing electromagnetic field (EMF) utilized in the future 5G on insects and small birds is of great importance as a very high number of 5G network components will increase the total EMF exposure in the environment.
The purpose of this proposed project is to investigate the possible hazardous impact of EMF used in 5G on insets and small birds. In the framework of this project, we are going to study the effects of 5G EMFs of different frequencies on the above-mentioned bio-objects through computer modeling. For this purpose, we will create more detailed 3D discrete models of selected insects and birds for FDTD modeling and will evaluate whole-body specific absorption rate (SAR) and temperature rise.

Since the body dimensions of insects and small birds are close to the wavelengths of 5G EMFs, therefore these EMFs will easily penetrate their brain. Therefore, we intend to investigate experimentally the effects of the mentioned EMFs on individual neurons. Results will allow us to predict the effects that these EMFs on insect behavior.

The proposed project will contribute to the harmonization of safe exposure levels, and frequencies of 5G EMFs'.
Expected outcomes: Based on the obtained results, safer frequencies, and doses of EMFs for insects and small birds will be established.

Practical value: The recommendations will be elaborated as to which EMF frequencies should be used in 5G.

3. "**Cholesteric Liquid Crystal Mirror-Based Hyperspectral Imaging Device for Medical Application´ (2023-2026; Head of Project - Gia Petriashvili)**

Multispectral and hyperspectral imaging are imaging modalities that collect more physical information than conventional color imaging, allowing detailed study of material properties. Hyperspectral imaging (HSI) systems capture spatial and spectral information and produce a hyperspectral data cube or 3D data content (2D spatial + spectral). The conventional approach to acquiring HSI data is to use a white light source, such as a halogen or mercury-xenon lamp, and band-pass filters, prisms, or gratings to select the appropriate wavelengths. The filter wheels are typically used to provide switching of filters, with the wheel generating a series of triggers that instruc t a camera when to capture each frame. It can also affect the accuracy of spectral analysis since each spectral image is captured at a different time point. Among the best materials capable of selective reflection of light are the cholesteric liquid crystals (CLCs) formed by chiral elongated organic molecules.

In this project, we present a novel, CLC polarizing mirror-based HSI device, which will allow us to obtain hyperspectral images of such biological structures, as blood vessels of the hand wrist, and palm. The principle of the operation of the proposed equipment is based on the temperature-controlled fine-tuning of the selective reflection bands of the CLC polarization mirror over the broad spectral range of the optical spectrum, including ultraviolet, visible, and near-infrared parts. The CLC-based HSI system does not rely on moving mechanical parts. Therefore, they are more compact, easily assembled, can be simply integrated with other applications, and have high potential for use in various fields.

The planned research is interdisciplinary since it combines such scientific areas as physics, biology, and medicine. Accordingly, three Doctors of Condensed Matter Physics, one Doctor of Biology, and one Resident Doctor (a qualified physician) are participating in the project.

To date, in Georgia, the HSI systems have not been widespread in clinical use. We assume that the results obtained from our project, which is related to the CLC mirror-based HSI technology, can be introduced in Georgian clinics, which will improve the quality, speed, and reliability of diagnosis and treatment of patients. Besides our HSI system can be used in such advanced and modern directions of technology as agriculture, environmental monitoring, biotechnology, remote sensing, astrophysics, food analysis, machine vision, and homeland security, which, in our opinion, will have a positive impact on the socio-political, and the technical progress in Georgia.

4. **"Information recording based on spatial photo-modulation of laser generation of liquid crystal layer" . (2023-2026; Head of Project - Andro Chanishvili)**

In this Project as a photo-modulated optical characteristic of the optical material we consider its laser emission ability. In this case the optical material in the form of a thin film acts as an active medium combined with a resonator and generating the laser emission and the recording of information is performed by spatial photo-modulation of the Q-factor of the resonator.

In the Project, as a photo-sensitive laser emitting layer, a 10…40μ-thick film of a dye doped (DD) cholesteric liquid crystal (CLC) material will be used. In our opinion, there is hardly any other material possessing both a light-controlled periodic structure and the lasing ability in such a thin layer. And the experience of our research group allows us to state that on the basis of the photosensitive DD CLC material we'll fabricate an information carrier able to generate the recorded information in the form of laser emission.

Initially, before recording, the DD CLC layer is ready to emit laser light from any point of the surface. Therefore, if it will be pumped with excitation light, the film will generate laser emission uniformly over the excited surface. As a result of exposure to recording light, the CLC undergoes the phase transition into isotropic phase and it loses the ability to generate laser emission. In other words, the recording light performs spatial modulation of Q-factor of the distributed resonator. Shortwave range light, to which one of the CLC components is sensitive, is used for recording. The reading of information can be performed by pumping the CLC layer with pulse light of midwave range. The pumping will excite lasing only from the unexposed to the recording light areas.

5. **"Investigation of the statistical characteristics of scattered electromagnetic waves in the terrestrial atmosphere and application" (2021-2024; Head of Project - George Jandieri)**

On the basis of the solution of the space-time characteristic system by the method of geometric optics using symbolic calculations, analytical and numerical simulation of the propagation of the ordinary and extraordinary radio waves in the conducting equatorial ionospheric plasma was made considering the anisotropy of plasma irregularities and non-stationary nature of propagation medium. Broadening of the spectrum and the displacement of its maximum contain velocity of a turbulent plasma flow and parameters characterizing anisotropic plasmonic structures. Statistical moments of both radio waves do not depend on the absorption sign and are valid for both active and absorptive random media. Temporal pulsations and conductivity of a turbulent ionospheric plasma have an influence on the evaluation of the spectrum-varying propagation distances travelling by these waves. The new double-humped effect in the temporal spectrum has been revealed for the ordinary wave varying anisotropy coefficient and dip angle of stretched plasmonic structures. From a theoretical point of view, the algorithms developed in this work allow effective modelling of the propagation of both radio signals in the equatorial conductive ionospheric plasma, considering the external magnetic field, electron density inhomogeneities, as well as non-stationary.

Statistical characteristics of the temporal spectrum of scattered ordinary and extraordinary electromagnetic waves in the equatorial region of the conductive terrestrial ionosphere are investigated using the stochastic transport equation for a frequency fluctuation, applying the geometrical optics approximation. The broadening of the temporal spectrum and the shift of its maximum contain the velocity of a turbulent plasma flow and the anisotropic parameters of electron density irregularities. Second-order statistical moments of electromagnetic waves do not depend on the absorption sign and are valid for both active and absorptive random media. The frequency of the turbulent pulsations and the conductivity of the ionospheric plasma have a substantial influence on the evaluation of the spectrum's varying propagation distances. A new doble-humped effect in the temporal spectrum has been revealed for the ordinary wave at different anisotropy factors and the inclination angle of elongated plasmonic structures. Numerical calculations are carried out using the experimental data. Investigations of space-time fluctuations of electromagnetic wave radiation are of essential interest for radio astronomy and atmospheric physics.

Statistical characteristics of the temporal spectrum of radio waves propagating in the equatorial terrestrial ionosphere are investigated using the WKB method and stochastic transport differential equation of the frequency fluctuations. Second-order statistical moments, broadening of this spectrum and displacement of its maximum, of both the ordinary and extraordinary electromagnetic waves are considered. The temporal power spectrum of these waves as a function of the propagation path and the nondimensional frequency parameter contains anisotropy factors and inclination angle of elongated electron density irregularities with respect to the geomagnetic lines of forces, anisotropy conductivity, and velocity of a plasma flow. These factors have an influence on the evaluation of the temporal spectrum varying propagation distances traveling by these waves in the turbulent terrestrial ionosphere. A new double-humped effect and precursors in the temporal power spectrum of the scattered extraordinary wave have been revealed. Numerical calculations are carried out using the experimental data. Investigations of space-time fluctuations of electromagnetic waves are of essential interest in developing communication systems, for radio astronomy and atmospheric physics.

The oblique radio wave incidence on a turbulent equatorial conductive collision plasma layer is considered. The "Compensation Effect" has been discovered by us. A complex refractive index of the equatorial terrestrial ionosphere has been derived for the first time. Second-order statistical moments of the spatial power spectrum (SPS) of scattered radio waves are obtained for the first time using the WKB method, taking into account the asymmetry of the problem: the inclined incidence of the wave on a plasma boundary and the asymmetry of the magneto-ionic parameters. It was established for the first time that a certain direction exists along which the inclined incidence radio wave on a plasma layer and the anisotropy parameters of a magnetoplasma compensate each other. This result will have great practical application in communication. In this case, the SPS of scattered radio waves neither widens nor is its maximum displaced. The behavior of this spectrum versus distance propagated by radio waves in the conductive equatorial ionosphere is analyzed numerically for different penetration angles and anisotropy factors of asymmetric anisotropy electron density irregularities. It was shown that the anisotropy factor of elongated plasmonic structures has a substantial influence on the "Compensation Effect" of scattered ordinary and extraordinary waves penetrating in the conductive collision ionospheric plasma the slab. Numerical calculations are carried out for the anisotropic Gaussian correla tion function applying IRI experimental data.

Inclined incidence of radio wave on a plane conductive collision ionospheric magnetized turbulent plasma layer in a homogeneous external magnetic field is considered. Stochastic differential equation for the second-order statistical moments of the spatial power spectrum is obtained in the complex geometrical optics approximation. It is finding the direction along which asymmetric factors of the task compensate each other. In this case angular power spectrum does not broadens and its maximum does not shift. Differential equations of the second order statistical moments of the phase fluctuations of scattered waves are obtain. Broadening of the spectrum and shift of its maximum are valid for an arbitrary correlation functions of electron density fluctuations. Numerical calculations are carried out using experimental data of the polar ionospheric F-layer. Numerical simulation confirmed the evaluation of the angular power spectrum with increasing propagation distance of radio wave in the turbulent polar ionospheric plasma.

We investigate propagation and multiple scattering of small amplitude radio waves propagating in the polar terrestrial ionosphere. Double-peaked shape of the spatial power spectrum is described by second order statistical moments containing complex refractive index, polarization coefficients, orientation of homogeneous external magnetic field, ionospheric conductivities, anisotropic parameters of electron density inhomogeneities, and the distances between observation points. Features of the "Double-Humped Effect" are considered analytically in absorptive statistically anisotropic magnetoactive plasma. Numerical analyses are carried out for anisotropic Gaussian cor relation function applying experimental data for polar ionospheric F-layer. The results have been obtained analytically for the first time and could find practical application in remote sensing of the terrestrial ionosphere and in communication.

6. "Creation of DNA-based silver and gold nanowires and their study by spectroscopic and electron microscopic methods" (2020–2021; (Co Head of Project - Zaza Melikishvili)

The main goal of the research is to create, to study, and to characterize the nanowires on the surface of DNA by reducing Ag(I) and Au(III) ions in the solution and on the film, also study fluorescent resonanse energy transfer in the films of DNA between intercalated in them acridine orange and ethidium bromide (AO-EB).

As a result of the research, it was found that γ-irradiation (^{137}Cs) leads to the reduction of gold ions in the absence and presence of DNA. We calculated the radiation-chemical yield $G(Au^0)$ for the reduction of Au3+ ions in the complex of DNA after 36 hours (237.6 krad) of γ-irradiation, $G(Au^0) = 0.27$, which is the amount of reduced gold atoms per 100 eV of γ-irradiation.

The interaction of DNA with AgNPs was studied spectroscopically using photoirradiation and melting. During photoirradiation of silver nanoparticles and complexes of silver nanoparticles wi th DNA, desorption of silver atoms from the surface of AgNPs (diameter 10 nm) occurs. In the case of free AgNPs, the subsequent adsorption of a silver atom on a nanoparticle leads to a change in the shape of the nanoparticle, while in the case of AgNPs–DNA complexes, the atoms are adsorbed on the DNA surface. The kinetic study of photo-desorption makes it possible to determine the desorption rate constants k_d and desorption activation energy E_d that are equal to $k_d \cong 1.6 \times 10^{-5}$ s^{-1}; $E_d \cong 85$ kJ/mol (Ag^0) for AgNPs, and $k_d \cong 2.2 \times 10^{-5}$ s^{-1}; $E_d \cong$ 84 kJ/mol (Ag^0) for AgNPs bound with DNA.

Films of DNA complexes with reduced silver and gold atoms were obtained and their resistances were measured; it was found that the film of the DNA-Au3+-AA complex is a good conductor for the given concentration ratio ($2Au^{3+}$/1P). In addition, films of DNA and intercalators, namely AO and EB, are obtained. Using the fluorescence measurements on DNA-AO and DNA-AO-EB films, energy transfer from acridine orange to ethidium bromide was registered, which is one of the important results of the project.

7. " Synthesis of the multifunctional magnetic nanosystem with innovative technology for medical application" (2019-2023; Head of Project - Shalva Kekutia)

In the synthesis of magnetic nanoscopy, great attention is paid to the sizes of nanoparticles. Sizes must be homogeneous, have a small deviation from the average size. Methods of dispersing today are partially providing an acceptable quality of the dispersion. To ensure high quality, we use the electric hydraulic effect. To ensure high quality, we apply the electrohydraulic effect. To do this, we have a device created by us that is stationary pilot equipment. Within the framework of the project, this pilot system will be the modernized with voltage, current, temperature and pressure sensors that simultaneous monitor the main parameters of the discharge through the oscilloscope. The impulse power, frequency, and other parameters will be calculated. The modernization of the existing continuous technological line, in particular, the inclusion of the electrohydraulic device, an ultrasonic reactor, and a Schlenk line, will make the synthesis process more efficient and allow obtaining highly dispersive, multifunctionalized, reproducible nanofluids with a narrow size distribution of containing nanoparticles, which represent uniqueness. Thus, multifunctional magnetic nanoparticles will be obtained by our modernized continuous technological line with further coating, loading with antitumor drugs and conjugation with targeted ligands. Some physical, chemical and pharmacokinetic parameters of biomedical application nanomaterials will be studied.

The final goal of the project - involvement the magnetic nanoparticles as nanosystem in healing therapy is one of the promising directions of modern health care. Reducing the undesirable toxic effects of chemotherapeutic drugs is the topical problem of today's medicine on healthy cells, and combined therapy with nanoparticles is expected to reduce the therapeutic dose of chemotherapy preparations and make the cure more effective. The research is aimed at developing a new method of cancer treatment.

In general, the results of the project will facilitate receiving information for future research, such as the use of optimal concentration of functionalized magnetic nanoparticles in vivo in case of acute infections in animal models. We assume that it will further strengthen the possibility of the use of functional magnetic nanoparticles for the treatment of various pathogenic bacterial diseases.

In the future, we plan to evaluate the anti-tumor effect of multifunctional magnetic nanoparticles. The goal of the research is to determine how the combination of chemotherapeutic drugs with nanoparticles is affected. In the experimental model of the combination of the drugs selected for the research, in case of successful examination and positive results, it will be possible to test on other malignant tumors of the same combination and provide practical recommendations in this direction.

8. " Development of high-performance calcium cobaltite thermoelectric materials through doping and nanoengineering" (2020-2021; Head of Project - Nikoloz Margiani)

The core concept of this Project was to explore the combined effects of boron-containing dopants and nanostructuring (high-energy ball milling) on the thermoelectric properties of layered $Ca_3Co_4O_9$ materials.

Innovative approaches of this Project will pave promising pathway toward realizing of practical applications and commercialization of thermoelectric generators for waste heat recovery, using high-performance thermoelectric materials developed by the Project team.

$(Ca,Bi)_3Co_4O_9$ materials doped with boron-containing compounds was synthesized by a solid state reaction. To compare results, undoped (reference) samples was also prepared. Fabrication process of thermoelectric materials $(Ca,Bi)_3Co_4O_9$ materials doped with boron-containing compounds will be synthesized by a solid state reaction. To compare results, undoped (reference) samples will be also prepared. Fabrication process of thermoelectric materials will be realized using the methods of (i) additional (over stoichiometric) and (ii) substitutional doping. Additonal doping of boron oxide-B_2O_3 into $(Ca,Bi)_3Co_4O_9$: the appropriate amounts of Bi_2O_3, $CaCO_3$ and Co_3O_4 reagents will be used to prepare $(Ca,Bi)_3Co_4O_9$ by the standard solid state reaction. Mixed powders will be sintered in the muffle furnace. Then, precursor powders will be divided into two groups before pressing. Various amounts of boron oxide-B_2O_3 will be introduced into the precursors as over stoichiometric.

9. " Evaluation of therapeutic effect of magnetic nanoparticles functionalized with antitumor drug on breast cancer cells" (2020-2021; Head of Project - Jano Markhulia)

The scientific research carried out within the framework of the grant project focused on the synthesis of citric acid-modified superparamagnetic iron oxide nanoparticles (CA-SPIONs) loaded with the anticancer drug doxorubicin (DOX) (DOX-CA-SPIONs) using a controlled sonochemical co-precipitation method and the in vitro cytotoxicity of the obtained magnetic nanofluids (containing unmodified or uncovered SPIONs (Bare-SPIONs), CA-SPIONs, and DOX-CA-SPIONs) on the triple-negative breast cancer (MB-468) and mouse breast cancer cell (4T1) lines. The loading of doxorubicin as an antitumor agent on the surface of the nanoparticles was carried out by electrostatic interaction. Some samples of the synthesised magnetic nanofluid were processed by electrohydraulic discharges to improve homogeneity as well as sorption properties. Physico-chemical characteristics of the obtained samples were studied using X-ray diffraction (XRD), Fourier transforms spectroscopy (FTIR), vibrating sample magnetometer (VSM), visible and ultraviolet spectroscopy, dynamic light scattering, electrophoretic light scattering (ELS), and Raman spectroscopy. To properly analyse and assess the cytotoxicity and viability of breast cancer cell lines after administering the antitumor drug DOX, as well as Bare-SPION, CA-SPION, and DOX-CA-SPION magnetic nanosystems, we used the MTT method, the optical density of which was measured on an Elisa reader at a wavelength of 570 nm. In vitro biological studies have shown that the cytotoxicity of the samples was specific and dose-dependent. In addition, the DOX-CA-SPIONs magnetic nanosystem exhibits a synergistic effect in inhibiting the growth of breast tumor cells compared to free doxorubicin. Based on the performed physico-chemical and in vitro studies, it can be said that the pathway of synthesis of iron oxide nanoparticles, its modification with citric acid, and subsequent loading with doxorubicin, according to the established optimal parameters, is an efficient, reproducible, scalable, and cost-effective strategy for the preparation of doxorubicin-functionalized magnetic nanosystems. At the same time, the synergistic effect of inhibiting the growth and proliferation of cancer cells (compared to doxorubicin) in in vitro studies, demonstrated by the combination of drug and magnetic nanosystem, opens up promising prospects for using this nanoparticle-mediated combination for targeted drug delivery and dose optimisation, which will reduce the dose-dependent side effects of doxorubicin and enhance the cytotoxic effect on cancer cells in tumor therapy. It should be noted that scientific research is interdisciplinary in nature, with the participation of physicists, chemists, and biomedical scientists. In the future, the plan of the research group participating in the grant is to expand complex research and study the antitumor therapeutic effect of multifunctional magnetic nanosystems in in vivo animal models. In addition, in order to expand interagency cooperation during the grant period, we had a connection with the biomedical segment working on nanosystems based on magnetic nanoparticles, both locally and in the Caucasus region. Interest and readiness to cooperate with several medical research institutions in Georgia were expressed in order to assess the performance of preclinical studies of magnetic nanoparticles modified with bioactive substances and functionalized with therapeutic agents, with the prospect of further joint research.

10. " Synthesis and research of wide-bandgap semiconductor nanomaterials for use in UV photodetectors" (2019-2021; Head of Project - Aleksandre Jishiashvili)

The objective of our project was the development of mew pyrolitic technology for the growth of wide band-gap (WBG) semiconductor nanomaterials. Besides, we aimed at the investigation of their properties, morphology and stricter.

The quarts reactor based technological installation was fabricated, which allowed the synthesis of WBG nanomaterials at substrate temperatures up to 700°C. The main process parameters that were optimized for specific nanomaterials were: source-substrate distance, substrate temperature, hydrazine pressure and concentration in the reactor.

Following WBG nanomaterials were synthesized during the project implementation: $CuGeO_3$, $In_2Ge_2O_7$, Ge_3N_4, ZnO, Zn_2GeO_4, In_2O_3, CuO, BN. the composition, morphology and structure of these materials were studied using such precise methods as transmission and scanning electron microscopy, X-ray diffraction, energy dispersive spectroscopy.

The test chamber with 1 kW ДРШ-type UV lamp was fabricated for the study of photodetectors. It was found that ZnO –based photodetector had the best parameters. The measurements of I-V characteristics, performed in the dark and under 9 mW/sm^2 illumination with 254 nm light source, were symmetrical to V=0 axes. This proves that the formation of Ohmic contacts between nanomaterials and gold interdigitated contacts. It was calculated that the sensitivity of our photodetectors (ratio of currents measured with, and without UV illumination) was covering three decades (2×10^2 - 3×10^{-1} mA). The reaction and recovery times were 0.51 and 0.39 s respectively. For comparison it should be mentioned, that the best Ga_2O_3 based UV photodetector these parameters are 0.45 and 0.24 s. This comparison suggests that the high quality UV detectors can be fabricated on the base of our new technology and developed nanomaterials.

11. " Real-time universal polarization-holographic spectroellipsometer" (2019-2022; Head of Project - Barbara Kilosanidze)

In this project an innovative and universal ellipsometric method has been developed based on the real time complete analysis of the polarization state of light reflected from the object surface by using only one analysing element - the integral polarization-holographic diffraction element developed by us. This element enables real time determining the all four Stokes parameters by means of the simultaneous measurement of intensities of the orders of diffraction on the element. The theoretical model of this method has developed, which established the connection between ellipsometric and optical parameters and the Stokes parameters. Ellipsometric and optical parameters were determined by using the formulas and software obtained in the project. Highly efficient and stable polarization sensitive material has obtained on which the polarization-holographic diffraction element with high diffraction efficiency has recorded. A working laboratory model of the polarization-holographic spectroellipsometer was developed and created based on the element. Test samples of different type were prepared. The laboratory model was tested on the obtained samples. The resolution, sensitivity, accuracy and speed of this model were determined. The application area of a laboratory model is determined and its universality is shown. Recommendations for the creation of an industrial prototype of the polarization-holographic spectroellipsometer are developed based on the obtained theoretical and experimental results. The proposed method has not yet been implemented in ellipsometry, and such an approach is innovative and promising; spectroellipsometer based on this method will be comparatively simple, compact and cheap.

12. " Tuning the functional properties of Co-based thermoelectrics via doping and high-energy ball milling" (2019-2022; Head of Project - Nikoloz Margiani)

The aim of the present project was to tune TE properties (Seebeck coefficient, electrical conductivity, power factor, total thermal conductivity and figure of merit) of $Ca_3Co_4O_9$ and $Bi_2M_2Co_xO_y$ (M= Ca and Sr) materials through the doping with calcium borate - $Ca(BO_2)_2$, lead borate-$Pb(BO_2)_2$, strontium borate-$Sr(BO_2)_2$, boron nitride-BN, and boron carbide-B_4C.

The proposed investigations were focused on three key objectives:

Investigation the influence of dopants on the functional properties of Co-based thermoelectric materials;Studying the effects of high-energy ball milling on the TE efficiency;

Tuning the functional properties of cobaltites by the control&optimization of the doping level, high-energy ball milling processing and thermal treatment of precursors.

Improvement of thermoelectric properties was achieved (Seebeck coefficient, electrical conductivity, power factor, total thermal conductivity and Figure of Merit) of $Ca_3Co_4O_9$ and $Bi_2M_2Co_xO_y$ (M= Ca and Sr) materials with calcium borate-$Ca(BO_2)_2$, lead borate-$Pb(BO_2)_2$, strontium borate- through $Sr(BO_2)_2$, boron nitride-BN and boron carbide-B_4C dopants. Besides:

1) It has been reliably confirmed that the use of boron-containing additives and dopants selected by the project team dramatically increases the efficiency of $Bi_2Ca_2Co_xO_y$ and $Bi_2Sr_2Co_xO_y$ thermoelectrics (improves the power factor and Figure of Merit);

2) Re-grinding, heat treatment and re-pressing the powders in the form of pellets under hydrostatic pressure, significantly increases the density of the materials and, therefore, the electrical conductivity, which is a contributing factor to the improvement of the thermoelectric conversion.

13. " Development of Bi-based HTS thin films, doped by boron-containing compounds" (2019-2020; Head of Project - Giorgi Mumladze)

Among a superconducting materials, bismuth-based $(Bi,Pb)_2Sr_2Ca_2Cu_3O_y$ compound, called Bi(Pb)-2223, is one of the most interesting for its great potential for large-scale applications in the no-loss electric power industry. After the discovery of Bi(Pb)-2223 superconductor, tremendous efforts have been undertaken to accelerate the formation of $(Bi,Pb)_2Sr_2Ca_2Cu_3O_y$ materials and improve their current carrying capacity.

Researches implemented in our lab made a great contribution in finding of the suitable boron-containing dopants. Our results have shown that high-energy ball milling of precursor powders leads to 1,5 times increase of J_c in comparison with micro-sized ones.

The project aims to prepare Bi-based HTS thin films, having enhanced HTS phase purity and high T_c value via the doping with boron-containing compounds (boron nitride - BN and boron carbide - B_4C).

DC/RF sputtering technique will let us fabricate the thin films with targets, based both on materials obtained in our lab and on the preliminary selected substrates as well.

The project has a stated goal:

Fabrication of boron compound-doped $Bi(Pb)_2Sr_2Ca_2Cu_3O_y$ thin films with best phase purity and critical current density through superconducting target samples.

We successfully implemented synthesis of working material — potential targets, which was confirmed by electro-physical measurements. The experiments carried out in Thin Films Lab (Budapest, Hungary) were particularly important. XRD measurements (Bruker 8M Discover XRD) show increase of HTS phase from 56% in reference sample up to 88% for the doped one. This is definitely a successful result. Thanks to Hungarian mentors, our targeting samples proceeded the TEM/STEM imaging and elemental mapping (Thermo Fisher Scientific); it allowed us to observe visibly the phase and elemental distribution of material, declared by the measurements. Finally, using the prepared targets and DC magnetron sputtering method, we, along with our Hungarian mentors, carried out the test deposition experiment on the SiO_2 substrate (from Hungarian colleagues). This procedure was carried out successfully. It should be noted that it was the first attempt of using the targeting material, synthesized in our lab, for film deposition.

14. " Bi(Pb)-2223 ceramics;doping;high-energy ball milling;phase formation;superconducting properties" (2018-2021; Head of Project - Armen Kuzanyan)

The first-priority aim of the Project was to create an advanced, cheap and energy efficient technology which controls the fabrication of BN, B_4C, $Pb(BO_2)_2$ and $Sr(BO_2)_2$-doped Bi(Pb)-2223 superconductors with higher Jc and enhanced formation rate compared to the conventional technology.

The proposed investigations was focused on three key objectives:

a) Clarify the fundamental mechanisms by which the boron-containing dopants alter the superconducting properties of Bi(Pb)-2223;

b) Select&optimize the doping level, particle size distribution and thermo-mechanical processing schedule, for the precursors;

c) Fabricate&test the short-length (5-10 cm) Ag-sheated Bi(Pb)-2223 superconducting wires, using the optimized precursors.

Fabrication process of Bi(Pb)-2223 superconducting bulk samples will be realized using the methods of additional and substitutional doping.

The dependence of superconducting, structural and microstructural properties on the level of doping, the conditions of materials preparation and high-energy processing was investigated. Resistivity and critical current density measurements for magnetic field values from 0 to 1 tesla were performed using the standard four-probe method. Transport Jc measurements were performed with a voltage criterion of 1 mkv/cm. Electromagnetic characterization of the obtained bulk samples was performed by magnetic acceptability analysis. A systematic study of the microstructural properties, particle sizes and elemental distribution of the synthesized materials was carried out using a scanning electron microscope (SEM) and an energy dispersive X-ray (SEM/XRD) microanalysis system. Superconducting phase content & evolution in the obtained materials, lattice parameters and crystal structures were determined based on X-ray diffraction data. Short (5-10 cm) silver-sheathed Bi(Pb)-2223 superconducting wires (tapes), were produced using the "oxide powder in a tube" (OPIT) technology. They were tested.

15. " Synthesis of bio-applicable magnetic nanofluid using plasma generation in liquid" (2016-2018; Head of Project -Vladimer Mikelashvili)

The aim of the project was to developa simple, inexpensive, and large-scale production technology of iron oxide nanoparticles of biomedical use using non-thermal plasma discharges in water (electrohydraulic discharges). The methodology was absolutely different from existing analogues, such as liquid discharge methods used for the direct production of metallic particles, metal nitrides / carbides / oxides, and so on. In addition to optimizing the technology of producing magnetic nanoparticles by chemical co-precipitation method with the necessary parameters (mixing speed, co-precipitation rate, temperature, etc.), the main parameters of electrohydraulic discharge (discharge current, voltage, etc.) have been controlled. This allowed us to manage certain degree of the most complex chemical and physical processes in the fluid (cavitation, production of H, OH, and other radicals in the discharge zone, etc.) and applied to the surface processing of nanoparticles. Thus, we have created an environment for better adsorption / stabilization and functionalization of these nanoparticles with different bioactive molecules (Dextran, polyethylene glycol, polyvinyl alcohol, citric acid, folic acid, etc.)

The physical-chemical characteristics of the samples were studied using various measurement techniques such as X-ray diffractometry, visible and Fourier transform infrared spectrometry, vibrating sample magnetometry, dynamic light scattering, Zeta potential determination, small-angle X-ray and neutron scattering. In addition, different modelling software was used to evaluate the particle size distribution and shape analysis. A biological study was conducted to study the bactericidal properties of the obtained samples on cellular structures.
During implementation of the project the prospects for the production of bioapplicable magnetis nanofluid via our the developed method were outlined, create the connections with various research institutions in Georgia and further developed the project next applied phase - In vivo study of targeted therapeutic drug delivery on tumor cells (mouse model). The topicality of the project has also attracted interest from the Central European Research Infrastructure Consortium.

16. " Optical Information Recording Based on Photo-Modulation of Emission Property of Liquid Crystal" (2016-2019; Head of Project -Andro Chanishvili)

A new principle of information recording in luminescent dye-doped cholesterol liquid crystals (CLCs) is proposed. This principle is based on the spatial modulation of emission by the action of light in the CCT layer. In known cases, information is recorded by modulating one of the following optical parameters of the material: birefringence, absorption, selective reflection, or polarization plane rotation. In the proposed case, the material acts as an active environment (generates light) and the information is recorded by photo-modulation of radiation. The magnitude of the radiated light intensity was chosen as the modulating optical parameter.

As a result of the project implementation, thin (10...40 μm) optically controlled luminescent CLC layers were obtained, in which optical information was recorded. Gratings and other images were recorded by exposure to ultraviolet light using the mask method. The recorded information is read by circularly polarized excitations by light, while the emission is non-polarized, i.e. the recorded information can be read without polarizers. In addition, the optical layer is completely dark when irradiated with light before recording (no light is emitted). After recording, when excited by light, the optical layer emits the recorded information. Thus, 1) the possibility to record optical information on the basis of spatial photo-modulation of light emission in luminescent dye doped thin CLC layers is shown; 2) a new principle of photo-control of luminescence is proposed; 3) thin CLC structures with light-controlled emission are obtained.

17. " New Rewritable Optical Storage on the Basis of Spiropyran doped Liquid Crystal Bilayer Polymer Film" (2016-2018; Head of Project -Gia Petriashvili)

In this project, we have elaborated a novel rewritable photochromic medium based on spiropyran doped liquid crystal bilayer polymer (SP-LCBP) film, which synergistically combines the capability of the photosensitive layer to reversibly generate the optical images in one step, with the optical properties of such fascinating photonic crystals as cholesteric liquid crystal. The combination of two structures allows us to formulate the optical parameters of recorded images as absorption, reflection, refraction, and colors. Due to the improved photosensitivity and optical contrast, good resistance to photo fatigue, and high spatial resolution, we suppose that our hardware will advance existing, optically rewritable, and mechanically flexible image storage prototypes. Furthermore, a proposed photochromic medium acts as a multifunctional dynamic photosensitive and cost-effective tool with real-time image recording/erasing features. The strong spatial variation in transparency, reflection, refraction, and colors between two light-induced states offers the opportunity to design the photochromic composites to form 3D microstructures, and the anaglyph 3D images can also be patterned. In addition, according to the standards in developed countries, it is possible to use the obtained results in such simple, effective, and cheap technical solutions as anti-counterfeiting and identification systems, high-frequency and ultraviolet radiation detectors, and dosimeters.