Annex 3.

Form of opening (renewal) for Project /

APPROVED

JINR DIRECTOR

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"____" _____________________ 2023 г.

PROJECT PROPOSAL FORM

Opening of a research project within the Topical plan of JINR

1. General information on the research project of the theme

1.1 Theme code (for extended projects) - *the theme code includes the opening date, the closing date is not given, as it is determined by the completion dates of the projects in the topic.*

1.2 Project code (for extended projects)

1.3 Laboratory

Flerov Laboratory of Nuclear Reactions

1.4 Scientific field

Condensed Matter Physics, Radiation and Radiobiological Research

1.5 Title of the project

Nanocomposite and functional track-etched membranes

1.6 Project leader

D. Sc. P.Y. Apel,

1.7 Project deputy leader

PhD A.N. Nechaev

2 Scientific case and project organization

2.1 Annotation

The existing and future heavy-ion accelerator facilities at FLNR JINR offer unique opportunities for interdisciplinary research, especially for material science and nanotechnology. Swift heavy ions deposit enormous energy densities along their trajectory in matter, generating high aspect ratio nanoscopic damage trails known as ion tracks. Ion-track technology utilizes special ion track properties to produce nano- and microporous materials.

Track-etched membranes (TMs) are an example of an industrial application of ion-track technology. TMs offer distinct advantages over conventional membranes due to their precisely determined structure. Their pore size, shape, and density can be varied in a controllable manner so that a membrane with the required transport and retention characteristics can be produced. Applications of “conventional” TMs can be categorized into three groups: process filtration, cell culture, and laboratory filtration. Applications of TMs in biotechnology and medicine are particularly important.

The modern trends in biology, medicine, environmental research, green energy harvesting, and other areas formulate demands for membranes with specific novel functionalities. These functionalities can be provided by tuning (setting) the geometry, morphology, and chemical properties of the TMs. The present Project will focus on the development of various functional TMs using the following approaches:

1. tuning the pore architecture;
2. composite structures;
3. hybrid structures;
4. targeted chemical and biochemical modification.

One of the Project’s goals therefore is to find out the applications of nanocomposite and functional TMs with customized pore architecture and functionality for nanotechnology, biomedicine, sensor technologies, and membrane separation processes.

Successful development of nanocomposite and functional TMs will imply the use of heavy ion beams (cyclotrons IC-100 and DC-140) followed by various UV sensibilization techniques with subsequent etching or extraction of latent tracks to obtain single- or multi-pore membranes/templates of the required structural parameters. Following analytical techniques will be utilized for the characterization of the nanocomposite and functional TMs: microscopic (SEM/EDX, AFM, TEM/SAED), spectroscopic (FT-IR, UV-vis., XPS, ICP-OES, photoluminescence), and thermal analysis (DSC, TGA).

The advancements in accelerator technology over the last decades allowed single-pore membrane fabrication, which has broadened the research in the field of Nanofluidics and ionic/molecular transport manipulation. Furthermore, various chemical etching and extraction approaches permit altering the pore geometry (cone, cylinder, funnel, and others). Another advantage of TMs is the possibility of surface modification through interactions with functional groups formed upon etching. Therefore, one of the focuses will be gaining an in-depth understanding of surface and nanoscale phenomena within the confined space of various nanopore geometries. With this fundamental knowledge, transitioning from a single- and oligo- to a multi-pore membrane will permit perfect control of the membrane properties and ensure an excellent ability to upscale from the lab findings to real applications.

Introduction of new properties into the existing membranes by surface modification using “wet-chemistry” and physical vapour deposition (PVD) methods is compulsory in developing novel membrane materials. These methods can provide sensitivity towards analytes to be detected, import bioactive molecules, and enhance ion selectivity in energy storage sources.

Investigation of ion transport in confined spaces with a high aspect ratio of functionalized nanopores will be performed to design membranes that respond to specific analytes. In the Project, the functionalization of TMs will be carried out through chemical grafting, including protein binding, and “layer-by-layer” (LBL) deposition of polyelectrolytes.

Chemical grafting of small organic molecules through catalyzed chemical reactions between carboxylic acid and amines will be performed for immobilization of polymer brushes inside track-etched nanopores. This type of functional TMs will be used for enantiomer separation. Chemical grafting of proteins on the TMs surface via adsorption, covalent bonding, and specific recognition will be involved in the nanopore technology for RNA and DNA detection and biosensing. Radiation-induced grafting as a method of introduction of functional monomers into nanoporous structure of polyvinylidenfluoride (PVDF) membranes will be elaborated for the development of electrochemical sensors of toxic metals in water.

LBL adsorption is a "bottom-up" nanofabrication method that takes advantage of self-assembling nanoparticle processes and complementary macromolecules. Applying LBL adsorption of polyelectrolytes (polyethyleneimine, polyvinylpyrrolidone, polysaccharides) in track-etched membranes can change the surface charge density, hydrophilicity, and protein binding ability. LBL will be a pre-step prior to membrane surface modification with silver and gold nanoparticles, quantum dots, nanoconjugates (for instance, silver nanoparticles-curcumin), and affinity ligands (antibodies and aptamers) for rapid and sensitive detection of dangerous virological diseases, such as roto- and coronaviruses, in very low concentrations using surface-enhanced Raman scattering (SERS) and fluorescence spectroscopy. Such types of TMs will also be used in a separation technology of exosomes and cancer cells from human blood. Modification of TMs with conjugates of silver nanoparticles and virucidal/bactericidal compounds using bifunctional crosslinking agents will allow the development of filtration materials with sterilizing properties.

Membrane surface modification with inorganic nanomaterials will enhance separation performance and offer new functions, for example photocatalytic. The PVD (thermal vacuum deposition and magnetron sputtering) is a valuable tool for incorporating inorganic nanomaterials in the form of thin layers and nanoparticles. TMs with the deposited thin layers of noble metals and alloys exhibit surface plasmon resonance and can be efficient platforms for flow biosensors. Additionally, the surface functionalization can be performed through covalent binding of aluminium or titanium oxides deposited on the top of TMs with water-soluble silanes used in the production of affinity sorbents.

The technology of nanofiber electrospinning from various casting polymer solutions on the conductive layer-coated TMs expands hybrid membrane manufacturing capabilities. Functionalizations of the spun nanofiber structures, in turn, will provide a basis for the development of various composite materials with selective complex compounds, ligands, and nanoparticles. This will allow the use of such TMs to remove colloid and ionic forms of toxic metals, including radionuclides, from drinking water. The hybrid TMs with nanofibers made from biodegradable polymers will be used as scaffolds in cellular technologies for regenerative medicine.

In conclusion, addressing the tasks of the Project will advance the scientific knowledge in Radiation Physics and Chemistry of condensed matter and promote the development of novel types of functional TMs thanks to the coordination of experts working in interdisciplinary research fields. The expected Project outcomes will include the implementation of new and elaboration of existing routes of membrane modification for the production of composite and hybrid TMs for targeted applications in Nanofluidics, sensing technologies, green energy harvesting, and biomedicine.

2.2 Scientific case (aim, relevance and scientific novelty, methods and approaches, techniques, expected results, risks)

Aim

The aim of the research is to develop functional nanocomposite track-etched membranes for various applications is nanotechnological, biomedical, sensing, and novel membrane separation processes.

Relevance and scientific novelty

TMs are a unique membrane type with a controlled pore structure and architecture [1, 2]. TMs are a vivid example of the joint scientific and technical implementation of the principles of ion track technology, radiation chemistry, the chemistry of polymers, and membrane and colloid chemistry. Commercial TMs based on polyester films are high-tech products of cross-industry application. They are used in industrial and domestic water purification processes, in producing antiviral vaccines and biological products, in systems for indicating enterobacteria and protozoa in drinking and wastewater, plasmaphereses and infusion therapy, and in microfluidic devices [1, 3]. TMs are increasingly employed in rapidly advancing and promising fields such as biotechnology and medicine. They offer efficient solutions for preventing and diagnosing epidemiological diseases and developing personalized protection against environmental hazards. However, the potential of TMs still needs to be exhausted. The next stage in the development of applications of TMs is associated with the modification of their structure and surface to solve the separation problems. The main operational parameters of TMs (permeability and selectivity) in separation and concentration processes are primarily determined by their structural parameters and surface properties, such as wetting, electrokinetic properties, and adsorption. The components of the track membrane intensification strategy are:

1. innovative materials and surface modification technologies;
2. development of solutions for the application of TMs in sensors;
3. and for diagnosing biological compounds.

Scientific research in the field of creating novel membrane materials based on TMs and ion track technologies, studying their properties, and fundamental aspects of transport phenomena in membranes are undoubtedly significant for the future. Among the priority areas in the development of membrane materials, the following types should be emphasized: “engineered,” “multifunctional,” and “nanocomposite” including “hybrid” [3, 4]. TMs are an integral and essential part of the membrane market. Thus development trends are fully applicable to them.

Currently, considerable progress has been made in implementing and studying new “engineered TMs” with controlled pore structure and architecture [4]. The possibility of obtaining such membrane materials is one of the most critical tasks of modern membrane technology and nanotechnology. They can be used in separation processes and chemical reactors, sensors, and micro- and nanofluidic devices. The development of methods for obtaining and controlling the architecture of synthesized TMs at the nanoscale will significantly expand the fields of application in the future. Ion track technologies have successfully proven that their use allows the creation of membrane structures of any desired architecture. Thus, unique properties of TMs with symmetric and asymmetric nanopores, namely electrokinetic and osmotic effects and ion selectivity in electrolyte solutions, have shown unprecedented productivity and the possibility of being used for desalination and molecule separation. One of the main directions of the Project in the frame of the development of the “engineered” TMs will be the study of permeation properties, ion selectivity, structure, and surface properties of TMs for electrodialysis; applications of TMs with both symmetric and asymmetric nanopores for electromembrane separation of ions; applications TMs with asymmetric nanopores for ultrafiltration of nanoparticles, viruses and low molecular weight substances, including enantiomers of chiral drugs. Artificial biomimetic nanochannels based on TMs, including mono- and oligo nanopore arrays, are intensely used for modelling biological membranes due to their beneficial structure and “diode-like” electrochemical properties. Many studies have shown that functional conical artificial nanochannels can be used as new sensors for detecting DNA, proteins, and other organic molecules. The rapid development of nanotechnologies and life sciences in recent decades has posed many new challenges to researchers, including those in the field of membrane science. The so-called ion channels play an immense role in the functioning of living systems.

Understanding how these nanometre channels work is crucial, as they perform a variety of specific functions. Therefore, one of the challenges both for theorists and experimentalists has been to create artificial analogues of ion channels. Because the interaction of a high-energy ion with matter is concentrated in nanometer volumes, the track etching technique has been successfully employed to produce nanopores of different geometries [1, 2]. Two approaches – chemical etching with aggressive substances and "soft" etching with solvents, e.g., water - provide the opportunity to obtain nanoporous materials with ion-selective properties with regard to aqueous solutions. Mainly, polyethylene terephthalate (PET) films were studied [5, 6]. In practical terms, thus, obtained nanopore membranes can serve two types of purposes. The first is the separation of ions via electrodialysis, and the second is the development of nanosensors based on the resistive pulse principle [4, 7]. In order to fully comprehend the practical applications of the films, a comprehensive understanding of the properties of nanometer-sized pore track membranes is necessary.

In the framework of the present Project, the following experiments are planned:

1. in-depth studies of the processes of aqueous extraction of radiolysis products from ion track in different polymers such as polyvinylidene fluoride and polyethylene naphthalate;
2. studies on ion selectivity for mono- and divalent cations of the track-extracted membranes;
3. investigation of osmotic and ion-selective properties of asymmetric track-etched nanopores;
4. studies of ion-selective properties of symmetric track-etched nanopores aimed at the separation of important ions such as Li^+.

The knowledge gained from the results of these experiments will become the basis for developing new membrane separation technologies and other applications such as sensorics.

Creating "multifunctional" membranes and predicting the interaction between the membrane surface and the substance to be separated is vital for the widespread usage of TMs in chemical technology and biotechnologies. Thus, the main objective of this part of the Project is to purposefully change the operational parameters by functionalizing TMs pore surfaces made from polyesters, polyolefins, and fluorine-containing polymers to expand their scope of application. The primary approach to solving this problem is using a chemical and physical modification of the surface of the already-made TMs. The methods employed for modifying TMs can be divided into two groups. The first group includes methods aimed at changing the chemistry of the pore space of membranes using wet chemical methods. These can be covalent bonding, adsorption, and complex formation methods, including the LBL technique. Usually, these methods are used to enhance the hydrophilicity of the surface of TMs. The second group of methods includes vacuum deposition to create a thin layer of metals, metal oxides, and nitrides on the membrane surface. The vacuum deposition methods can also apply polymer layers from a wide range of polymers, including fluorine-containing ones, to impart superhydrophobic properties to the surface. There are currently actively developing approaches for synthesizing multifunctional TMs modified with biologically active substances, nanoparticles, and bioavailable forms of their conjugates. Such membranes can have bactericidal or virucidal activity. One of the scientific questions in developing TMs with virucidal activity is: what immobilized bactericidal/virucidal agents can effectively neutralize bacterial/viral particles and their genotoxic effects? Evaluation of the effectiveness of TMs with immobilized virucidal agents for the isolation of viral pathogens and their neutralization can be based on the analysis of DNA damage levels in cell cultures.

The problem in developing multifunctional TMs with affinity properties to biologically active substances is closely related to the development of modern test systems for medical diagnostics. Creating fast, sensitive, and selective methods for detecting pathogens is one of the most critical public health tasks and guarantees national security. There is an increasing need for fast and cost-effective laboratory diagnosis of infectious diseases and identification of environmental microbiological contamination using the so-called “label-free” testing and biosensors based on fluorescence, Raman scattering, and mass spectrometry [7]. The development of rapid, sensitive, and selective methods for detecting pathogens, especially in cases requiring urgent medical care, remains a public health concern. Surface-enhanced Raman scattering (SERS) is a highly sensitive technique that allows for detecting molecules in very low concentrations. Using Raman-active tags significantly improves biosensor specificity and detection limits. A significant number of reports on the development of SERS biosensors are focused on using antibodies and aptamers that recognize the epitope of the surface of a biomolecule. Combining SERS with ultra- and microfiltration membranes capable of virus and bacteria retention can achieve high sensitivity and selectivity. An additional factor in the specificity of marker detection should be the use of bioaffinity interactions of the TM with immobilized antibodies or aptamers labeled with SERS reporters [8]. As a result, it is necessary to develop methods for obtaining membrane substrates SERS properties (SERS substrates) with desired properties required for successful bioaffinity interactions and plasmon resonance properties. It is, therefore, necessary to develop a new type of functional TMs that combines silver, gold, or their alloy nanoparticles and modulated dielectric structures based on polyester nano- and microporous support, in which the dual plasma and dielectric resonances will be implemented, and a tremendous amplification of the electromagnetic field will be achieved. Some of the works carried out at the Center for Applied Physics have already proposed a biosensor based on polyethylene terephthalate TMs coated with aptamer-conjugated silver nanoparticles for the detection of influenza A and B viruses. Upon filtration with these multifunctional TMs with aptamers-silver nanoparticle conjugates, a high detection limit for influenza A virus in blood plasma was achieved [8]. There are no analogues of this kind produced industrially in the world. In the future, experimental substantiation of hypotheses and selection of optimal technical solutions will be carried out on the model detection of diagnostically significant antigens of adenoviruses or rotaviruses. The important Project aim is the development of scientific approaches and implementation of flow sensor technology based on multifunctional TMs, which allow significantly increased selectivity of analytical identification, especially epidemiologically dangerous substances of various natures, reduce the cost of analysis due to the exclusion of numerous reagents, media, and specialized equipment, which will allow for performing analysis under field condition.

Much work has been done over the last years on fabricating hybrid membranes. The flexibility of processing and the relatively low cost of polymer membranes compared to ceramic membranes still make them very attractive for many industrial separation applications. Polymer-inorganic hybrid membranes represent an emerging field of research. Recently, hybrid membranes have been developed to improve the separation properties of polymer membranes, since they have the properties of both organic and inorganic membranes, such as good hydrophilicity, selectivity, permeability, mechanical strength, as well as thermal and chemical stability. In recent years, research has been carried out in the framework of obtaining hybrid membranes, including those based on track membranes. The creation of microfiltration hybrid membranes with selective properties in relation to particularly dangerous compounds will significantly expand the scope of TM application in water purification and quality control technologies. As part of the comprehensive development of new water treatment technologies and monitoring the safety of water supply sources, priority is given to the development of intelligent self-regulating systems. The membrane separation methods used for these purposes should be upgraded by combining them with technologies based on advanced adsorption and oxidation technologies (AOP) for disinfection and detoxification of water. Thanks to the use of new nanostructured materials based on wideband semiconductors (TiO_2, ZnO), this goal can be achieved. Traditional polymer membranes obtained from polymer solutions, unlike track membranes, can practically not be used as carriers for the production of hybrid membranes. This is due to the difficulties of using PVD and CVD methods for surface modification. Studies conducted at the Centre for Applied Physics FLNR have shown the possibility of obtaining hybrid track membranes using thermal and magnetron sputtering of metals and their oxides and nitrides. Additional functionalization of the TM surface modified with aluminium or titanium oxides can be carried out by using covalent binding methods with water-soluble silanes used in the production of affine sorbents.

The technology of electrospinning of nanofibers from various filling polymer solutions, including biopolymers, on TM with a surface coating with a conductive metal layer (Ti, Al, Ag) expands the possibilities of production of hybrid membranes. The deposited nanofiber structures, in turn, provide a basis for various composite materials with selective complex compounds, ligands, and nanoparticles [9]. Thus, hybrid membrane production is essential to fulfilling sanitary and epidemiological requirements for water quality by removing colloids and ionic forms of toxic ions, including radionuclides.

The modern world doctrine of the development of water resources states that the access of the planet's population to safe drinking water resources is one of the absolute priorities. This rather complex task has not been comprehensively resolved yet. The developed technology for obtaining functionalized and hybrid TMs should ensure the production of high-performance and selective sorption microfiltration TMs. It is planned to create a line of membranes describing the modifying agent used. This will enable TM consumers to deliberately request membranes from the manufacturer according to their specific needs. The presence on the market of multifunctional and hybrid TMs will positively impact the expansion of their use in safe infusion therapy, which requires the sorption of cytokines, viruses, and bacteria from infusion solutions of pharmaceuticals.

Methods and approaches

The scientific and methodological approaches to the creation of a new generation of structurally and chemically modified TMs with improved performance properties developed within the framework of the implementation of the JINR program and thematic plans can be a scientific basis for solving existing technological problems in the production of a new generation of TMs for nanotechnological, biotechnological and medical purposes.

The following methodological approaches available to the implementing organization will be used as the main methodological approaches for successfully fulfilling the goals and objectives of the Project, especially for so-called "engineered" or nanoporous TMs:

1. method of irradiation of polyesters films with heavy ions beams (energy 2-4 MeV/u, dE/dx 2-35 keV/nm), followed by etching or extraction of latent tracks in alkaline solutions to obtain membranes/templates of the required structural parameters by FLNR acceleration facilities (IC-100 and planning for operation DC-140);
2. method of etching latent tracks in the presence of anionic (sulfonates) and nonionic compounds (based on ethylene glycols) as surfactants to change the conditions of surface etching of ion tracks;
3. method of etching latent tracks in the presence of exposure to ultraviolet radiation as a factor to change the conditions of surface etching of ion tracks;
4. methods for studying the electrical and electrokinetic characteristics of track membranes to analyze the physicochemical state of the membrane surface and monitor the condition of the modified surface, including voltammetry and impedance spectroscopy;
5. method of calibration of nanoporous membranes with protein mixtures for the analysis of structurally selective properties such as the cut-off molecular weight of proteins, the structure of the selective membrane layer, defectiveness, hydrophilic-hydrophobic balance of the surface;

6. scanning electron microscopy methods adapted for the study of nanostructured polymer matrices;
7. methods for studying the electrical properties of nanometer channels filled with electrolyte solutions (conductivity in AC and DC modes, electrodialysis mode);
8. methods of liquid chemistry and osmotic measurement.

To complete the Project and obtain mono- and multi-pore ensembles of tracks, it is proposed to create an additional specialized line of irradiation with high-energy Kr and Xe ions at the U-400M accelerator (methodological approaches and proposed radiation protocols are available).

The proposed ion beam methodologies will facilitate the generation of fundamental scientific knowledge for developing single-, double-, and multi-porous TMs utilizing a cluster of diode-like pores in a polymer as building blocks for next-generation biomimetic membranes and medical biosensors.

The following approaches and methodology will be used for the development of multifunctional and hybrid TMs:

1. conventional track etching technology to produce membranes with various structure characteristics;
2. chemical methods for surface modification using covalent bonding and polyelectrolyte adsorption;
3. PVD methods such as thermal vacuum evaporation and magnetron sputtering of metal and alloys;
4. nanofiber electrospinning techniques of polymers, including biopolymers;
5. structure investigations using atomic force microscopy, transmission electron microscopy, and X-ray diffraction;
6. IR-, UV-VIS spectroscopy, Raman-spectroscopy, real-time optical spectroscopy;
7. Inductively coupled plasma atomic emission spectrometry for analysis of metal ions in water.

Expected results

The result of the Project is the scientific and technical groundwork for obtaining new classes of engineered, functionalized, and hybrid TMs created during both theoretical and experimental studies. Depending on this, the values of the main (scientific/scientific and technical) characteristics of the results of the work are formulated as described below.

An important expected result of the work should be laboratory methods for obtaining engineered or nano- and microstructured TMs of increased permeability with respect to aqueous solutions of substances for baro- and electromembrane processes. The experimental membrane samples obtained by this method after selective functionalization will apply to advance separation membranes, biomimetic membranes and sensors.

In brief, the main results of the Project implementation can be formulated as follows:

1) Experimental results on the feasibility of fabrication of nanocomposite, functionalized and hybrid TMs for separation, nanofluidics, medical, biochemical and sensor application:

- functionalized TMs obtained from ion-irradiated polymer foils using soft photolysis and liquid extraction of degradation products from tracks for the electro-baromembrane process;
- TMs with asymmetric nanopores modified through carbodiimide-mediated coupling method for the separation of racemic mixtures into individual enantiomers;
- chemically grafted with proteins microfiltration TMs via adsorption, covalent bonding, and specific recognition (affinity) for RNA and DNA detection and biosensing applications;

- radiation-grafted with functional monomers nanoporous PVDF membranes for selective preconcentration of toxic metals from aqueous solutions and their quantitative determination by stripping voltammetry;
- TMs functionalized through LBL assembling of silver nanoparticles and biocompatible nanoconjugates as bacteriocidic and viricidal materials;
- chemically grafted ultra- and microfiltration TMs for the protein blotting tests;
- chemically grafted TMs with improved cell adhesion for bioreactors;
- affinity ultra- and microfiltration TMs for exosome capture and separation;
- nanocomposite TMs modified with silver and gold aptamer-immobilized nanoparticles for rapid and sensitive detection of virologic diseases by means of surface-enhanced Raman scattering (SERS) and fluorescence spectroscopy;
- hybrid TMs with electrospun polymer nanofiber structures modified by selective complex compounds, ligands, and metal-organic-frameworks for selective removal of colloid and ionic forms of toxic metals from drinking water.

2) Determination of ion-selective properties of functionalized membranes obtained from ion-irradiated polymer using soft photolysis and liquid extraction degradation products from tracks. Feasibility studies of mono- and multivalent ion separation on nanoporous TMs using the electro-baromembrane process.

3) Data on the ion-selective, electrokinetic, and osmotic properties of track-etched grafted nanopores, including asymmetric nanopores, depending on the pore geometry and functional groups.

Risks

For the successful implementation of the Project and to reduce the risks the FLNR has the required scientific equipment, installations, experimental methodologies and human resources. The prerequisites for the successful completion of work and the reduction of investment risks are that the FLNR has positive results of previous fundamental and applied research. FLNR team in the subject area are world-renowned specialists and experts with publications in high impact factor scientific journals.

For the successful and low-risk implementation of the Project objectives, it is advisable to involve specialists in various fields of knowledge, especially in the field of high purity biological products technology and molecular biology. The following factors can be attributed to the severe risks of the Project:

1. deviation from the schedule of commissioning work on the DC-140 cyclotron;
2. failure and repair of crucial analytical equipment;
3. problems with ordering reagents.

References

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2.3 Estimated completion date

December 2028

2.4 Participating JINR laboratories

Frank Laboratory of Neutron Physics,
Dzhelepov Laboratory of Nuclear Problems
Laboratory of Radiobiology

2.4.1 MICC resource requirements

Computing resources	Distribution by year				
	1st year	2nd year	3rd year	4th year	5th year
Data storage (TB) - EOS - Tapes	-	-	-	-	-
Tier 1 (CPU core hours)	-	-	-	-	-
Tier 2 (CPU core hours)	-	-	-	-	-
SC Govorun (CPU core hours) - CPU - GPU	-	-	-	-	-
Clouds (CPU cores)	-	-	-	-	-

2.5. Participating countries, scientific and educational organizations

Organization	Country	City	Participants	Type of agreement
Yerevan State University	Armenia	Yerevan	A. Sargsyan, R. Aroutiounian T. Harutyunyan	Joint work
Institute of Molecular Biology	Armenia	Yerevan	H.Zakaryan	Joint work
Nalbandyan Institute of Chemical Physics	Armenia	Yerevan	O. Qamalyan	Joint work
Australian National University	Australia	Canberra	P. Kluth, S. Dutt	Joint work
Institute of Physical Organic Chemistry NASB	Belarus	Minsk	A. Bildukevich	Agreement
Francisk Skorina Gomel State University	Belarus	Gomel	A. Rogachev	Agreement
Burnasyan Federal Medical Biophysical Center of FMBA	Russia	Moscow	A. Osipov	Agreement
RUDN University Russia Moscow	Russia	Moscow	A. Lyundup	Joint work
Pirogov Russian National Research Medical University	Russia	Moscow	S. Rumyantsev	Joint work
Moscow Institute of Physics and Technology	Russia	Dolgoprudnyi	S. Leonov	Joint work
Mechnikov Research Institute of Vaccines and Sera	Russia	Moscow	A. Poddubikov	Joint work
Kurnakov Institute for Inorganic Chemistry	Russia	Moscow	A. Yaroslavtsev	Joint work
Institute of Petroleum Chemistry	Russia	Moscow	V. Volkov	Joint work
Kuban State University	Russia	Krasnodar	V. Nikonenko	Joint work
Moscow State University	Russia	Moscow	E. Zavyalova	Joint work
Institute of Solid-State Physics RAS	Russia	Chernogolovka	V. Kukushkin	Joint work
Ivanovo State University of Chemical Technology	Russia	Ivanovo	B. Gorberg	Joint work
Enikolopov Institute of Synthetic	Russia	Moscow	A.Gilman	Joint work

Polymer Materials				
Nelson Mandela University	South Africa	Gqeberha	A. Ogunlaja	Joint work
University of Kwazulu Natal	South Africa	Durban	P. Khoza	Joint work
University of Pretoria	South Africa	Pretoria	N. Nombona	Joint work
Walter Sisulu University	South Africa	Mthatha	N. Faleni	Joint work
University of Western Cape	South Africa	Cape Town	L. Petrik	Joint work

2.6. Key partners *(those collaborators whose financial, infrastructural participation is substantial for the implementation of the research program. An example is JINR's participation in the LHC experiments at CERN).*

3. Manpower

3.1. Manpower needs in the first year of implementation

№	Category of personnel	JINR staff, amount of FTE	JINR Associated Personnel, amount of FTE
1.	research scientists	12,5	0
2.	engineers	9	0
3.	specialists	2	0
4.	office workers	0	0
5.	technicians	2	0
	Total:	**25,5**	**0**

3.2. Available manpower

3.2.1. JINR staff

No.	Category of personnel	Full name	Division	Position	Amount of FTE
1.	research scientists				
1.1.		Pavel Apel	Center of Applied Physics	Head of the Center	0,5
1.2.		Alexander Nechaev	Center of Applied Physics	Deputy head of the Center (Science)	1
1.3.		Vera Shirkova	Center of Applied Physics	Head of group	1
1.4.		Andreyan Osipov	Center of Applied Physics	Leading research scientist	0,5
1.5.		Sergey Rumyantsev	Center of Applied Physics	Leading research scientist	0,5
1.6.		Alexey Lyundup	Center of Applied Physics	Senior research scientist	0,5

1.7.		Dmitriy Murashko	Center of Applied Physics	Senior research scientist	0,5
1.8.		Lyubov Kravets	Center of Applied Physics	Senior research scientist	1
1.9.		Ludmila Molokanova	Center of Applied Physics	Research scientist	1
1.10.		Olga Kristavchuk	Center of Applied Physics	Research scientist	1
1.11.		Uliana Pinaeva	Center of Applied Physics	Research scientist	1
1.12.		Irina Fadeykina	Center of Applied Physics	Research scientist	0,5
1.13.		Genrikh Serpionov	Center of Applied Physics	Research scientist	1
1.14.		Vladimir Altynov	Center of Applied Physics	Research scientist	0,5
1.15.		Arnoux Rossouw	Sector №8	Research scientist	1
1.16.		Evgeniy Andreev	Center of Applied Physics	Junior research scientist	1
2.	engineers				
2.1.		Dmitry Shchegolev	Center of Applied Physics	Deputy head of the Center (Technology)	1
2.2.		Oleg Ivanov	Center of Applied Physics	Head of group	0,5
2.3.		Oleg Orelovich	Center of Applied Physics	Head of group	0,5
2.4.		Irina Blonskaya	Center of Applied Physics	Senior engineer	1
2.5.		Nikolay Lizunov	Center of Applied Physics	Senior engineer	0,5
2.6.		Ilya Vinogradov	Center of Applied Physics	Engineer	1
2.7.		Olga Polezhaeva	Center of Applied Physics	Engineer	1
2.8.		Maria Kuvaitseva	Center of Applied Physics	Engineer	1
2.9.		Alexey Markin	Center of Applied Physics	Engineer	0,5
2.10.		Sergey Mitiukhin	Center of Applied Physics	Engineer	1
2.11.		Rozanna Ragimova	Center of Applied Physics	Engineer	1
3.	specialists				
3.1.		Natalia Kuzmina	Center of Applied Physics	Head of group	0,5
3.2.		Irina Dukach	Center of Applied Physics	Lead documentation specialist	0,5
3.3.		Elena Nesterova	Center of	Specialist	1

			Applied Physics		
4.	technicians				
4.1.		Daria Nikolskaya	Center of Applied Physics	Technician	1
4.2.		Galina Volnuhina	Center of Applied Physics	Laboratory assistant for chemical and technological research	0,2
4.3.		Oksana Donnikova	Center of Applied Physics	Laboratory assistant for chemical and technological research	0,2
4.4.		Irina Myatleva	Center of Applied Physics	Laboratory assistant for chemical and technological research	0,2
4.5.		Elena Filatova	Center of Applied Physics	Laboratory assistant for chemical and technological research	0,2
4.6.		Irina Shamshiddinova	Center of Applied Physics	Laboratory assistant for chemical and technological research	0,2
	Total:				**25,5**

3.2.2. JINR associated personnel

No.	Category of personnel	Partner organization	Amount of FTE
1.	research scientists	-	-
2.	engineers	-	-
3.	specialists	-	-
4.	technicians	-	-
	Total:	**-**	**-**

4. Financing

4.1 Total estimated cost of the project

The total cost estimate of the project (for the whole period, excluding salary).
The details are given in a separate table below.

2 275 000 $.

4.2 Extra funding sources

Expected funding from partners/customers – a total estimate.

0 $.

Project Leaders __________/__ P.Y. Apel

__________/__ A.N. Nechaev

Date of submission of the project to the Chief Scientific Secretary: _________
Date of decision of the laboratory's STC: _________ document number: _________
Year of the project start: __2024___

Proposed schedule and resource request for the Project

Expenditures, resources, funding sources			**Cost (thousands of US dollars)/ Resource requirements**	**Cost/Resources, distribution by years**				
				1st year	2nd year	3rd year	4th year	5th year
		International cooperation	100	20	20	20	20	20
		Materials	150	30	30	30	30	30
		Equipment, Third-party company services	1400	280	280	280	280	280
		Commissioning	0	0	0	0	0	0
		R&D contracts with other research organizations	250	50	50	50	50	50
		Software purchasing	75	15	15	15	15	15
		Design/construction	300	50	55	60	65	70
		Service costs (*planned in case of direct project affiliation)*	0	0	0	0	0	0
Resources required	**Standard hours**	Resources						
		– the amount of FTE,	25,5	25,5	25,5	25,5	25,5	25,5
		– accelerator/installation,	1250	250	250	250	250	250
		– reactor,…	0	0	0	0	0	0
Sources of funding	**JINR Budget**	JINR budget *(budget items)*	2275	445	450	455	460	465
	Extra funding (supplementary estimates)	Contributions by partners Funds under contracts with customers Other sources of funding	0	0	0	0	0	0

Project Leader _________/________________/

Laboratory Economist _________/________________/

APPROVAL SHEET FOR PROJECT

TITLE OF THE PROJECT

SHORT DESIGNATION OF THE PROJECT

PROJECT

THEME

NAME OF THE PROJECT

AGREED

JINR VICE-DIRECTOR
SIGNATURE NAME DATE

CHIEF SCIENTIFIC SECRETARY
SIGNATURE NAME DATE

CHIEF ENGINEER
SIGNATURE NAME DATE

LABORATORY DIRECTOR
SIGNATURE NAME DATE

CHIEF LABORATORY ENGINEER
SIGNATURE NAME DATE

LABORATORY SCIENTIFIC SECRETARY
SIGNATURE NAME DATE

THEME LEADER
SIGNATURE NAME DATE

PROJECT LEADER
SIGNATURE NAME DATE

APPROVED BY THE PAC
SIGNATURE NAME DATE